Annual Report
2009

Bridging Research, Education and Industry
The Fields Institute is a centre of mathematical activity in Canada – a place where mathematicians from educational and research institutions in Canada and abroad, and 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 by Kuwabara Payne McKenna Blumberg (KPMB) for Fields Institute activities. The Institute’s 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 life sciences, medicine, economics and 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, usually one semester in length, but shorter in the summer. 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 the Institute’s 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.

The Centre for Mathematics and Medicine serves a similar purpose to the CIM, but acting as a bridge between the mathematics community and medical researchers and practitioners. The CMM runs a seminar series and organizes several workshops and conferences. It also hosts postdoctoral fellows working at the boundary between mathematics and medicine.

The Institute is strongly committed to mathematics education and outreach. During the past couple of years, a successful Math Circle program has been developed at Fields. The free drop-in program allows high school students to explore challenging new areas of mathematics and prepare for academic competitions.

Major funding is provided by the Ontario Ministry of Training, Colleges, and Universities and the federal Natural Sciences and Engineering Research Council (NSERC). The Institute’s 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 thirteen affiliate universities: Nipissing University, Queen’s University, the Royal Military College of Canada, the University of Guelph, the University of Houston, the University of Manitoba, the University of Maryland, the University of Ontario Institute of Technology, Ryerson University, the University of Saskatchewan, the University of Windsor, Trent University, and Wilfrid Laurier University.

The Corporate Affiliate Members of the Fields Institute are: Algorithmics, General Motors, QWeMA Group Inc., R2 Financial Technologies Inc., and Sigma Analysis and Management.
FIRST OF ALL I BELIEVE IT TO BE HIGHLY APPROPRIATE TO pass comment on the leadership provided by the Institute’s Directorate during the past academic year. June 2008 marked Barbara Keyfitz’s completion of a highly productive four years as Director. Her successor, Ed Bierstone, had been identified and contracted, but he would not be available for Fields until July 2009. What were we to do, we asked ourselves in the spring of 2008? Improvise was the answer.

The bridge over that twelve month gap worked marvelously well. Barbara was able to continue for an additional six months, although it meant juggling a difficult travel schedule. Juris Steprans handled the responsibilities with aplomb during the remaining six months as Acting Director, supported by Matthias Neufang who stepped up to the plate as Acting Deputy Director. It is fair to say, and I believe Ed will agree with me, that the Institute didn’t miss a beat during this unorthodox time, and I would like to thank all those involved in handling this transition. Its successful outcome is a testament to the leadership skills and professional commitment of the mathematical community in this country.

During the past year increased financial support from the provincial and federal agencies that support the Institute came into play, enabling the Institute to enrich its programming and to encourage the development of mathematics and of mathematicians on the campuses of member universities through the introduction of new post-doctoral programmes. We believe both these initiatives, described in detail in the Director’s report, will advance mathematical research across the province, and we thank the provincial government for their encouragement.

Good governance is scarcely ever recognized. It is only bad governance that ends up in the press. Our Board of Directors continues to work well together, all its members contributing with wisdom and energy. Rotation of membership on the Board is a healthy practice, but it does mean that every year the Board loses the services of individuals who have helped build and develop the Institute. On behalf of the Institute I would like to thank Tom Coleman, Feridun Hamdullahpur, Bradd Hart and Matthias Neufang for all they have done for Fields.

John R. Gardner, Chair
Message from the Director

It is a true honour to become Director of this wonderful institution. I recognize that it is also a great responsibility and a big challenge – my predecessors have set the bar very high.

During the earlier part of my career, I was fortunate to spend several happy and productive years at great mathematics institutes in the US, France and Brazil. Each of my visits had a profound effect on the direction of my work and the development of my career. It is exciting to be again in this kind of mathematics research environment at the Fields Institute. I am looking forward to contributing to the bright future of the Institute; particularly to our impact on the many young mathematicians who will participate in our programs during the next few years.

I am indebted to Barbara for the care and generous guidance she has offered me over the past year, and especially for having left the Fields Institute in such great shape, both scientifically and financially. The vision that Barbara brought to the Fields Institute during her four and a half years as Director is in the spirit of the Message of our first Director, Jerry Marsden, in his last Annual Report in 1994: “One of my pet interests is the interdisciplinary nature of mathematics, especially its interactions with the other sciences – engineering, physics, chemistry, economics, biology, etc. I hope that the Institute is off to a good and healthy start in this direction and that this unique aspect of the Institute will continue.”

I am also grateful to be able to rely on the experience and insight of Juris during the coming year. He and Matthias deserve an enormous amount of credit for serving as Acting Director and Deputy Director in the last six months. It is a very tough job to step into an important position for a short time, with so many responsibilities and so little time to learn. I very much appreciate the wisdom and aplomb with which Juris and Matthias have guided the Institute.

I will not try to give a summary of Fields Institute activities for the 2008-2009 year in this Message. I was on sabbatical from my position at the University of Toronto during that time, and tried to keep a little distance from the Fields Institute administratively. But I was fortunate to be able to participate in activities in both the Fall and Winter/Spring Thematic Programs, so I can well appreciate the very high scientific level of these programs and the Institute’s focus...
on areas of mathematics that are of great promise for future development.

The Institute was brimming with activity during both of these programs. The Fall Program on Arithmetic and Hyperbolic Geometry (organized by John Bland, Caterina Consani, Steve Kudla, Min Ru, Paul Vojta and Pit-Mann Wong) was probably the first time that we have had so many distinguished visitors in residence for the entire term. Credit is due to the organizers and also to our increased funding from the Ontario Ministry of Training, Colleges and Universities (MTCU) and from NSERC, as well as to generous support from the NSF, the Clay Institute (for support of our Clay Senior Scholar, Henri Gillet) and the University of Toronto for support of the Dean's Distinguished Visitor, Yum-Tong Siu. I attended Siu’s course on Transcendental Techniques in Complex Geometry, and encouraged my students at Toronto also to seize this once-in-a-lifetime opportunity. Siu illuminated the idea of a multiplier ideal sheaf and gave a panoramic view of the role of multiplier ideals in algebraic geometry and several complex variables, from the d-bar Neumann problem to his own recent proof of finite generation of the canonical ring.

During the Winter/Spring term, I had the pleasure of giving one module of a graduate course on Resolution of Singularities to a large and engaged audience, as part of the Program on o-minimal Structures and Real Analytic Geometry, organized by David Marker, Chris Miller, Jean-Philippe Rolin, Patrick Speissegger and Carol Wood. The way that Patrick structured the program was particularly effective. It began in January with a week-long Winter School in O-minimal Geometry, to bring the many students to a level where they could actively participate in the diverse and intense graduate courses offered during the first half of the six-month program. The level of activity was maintained until the closing workshop at the end of June, by an imaginative series of (no less than eight!) mini-workshops, each bringing a half-dozen core participants together with other visitors for two to three days of lectures and discussion focused on a particular problem or solution.

These remarks describe only a few of the Fields Institute’s activities that I personally took part in during the 2008-2009 year. Please look at the following pages for a full picture of our programs, including our distinguished lecture series (the Coxeter Lectures and the Distinguished Lectures in Mathematics and in Statistical Science), our wide-ranging workshops (many of which take place with the Institute’s support at our partner universities), weekly seminar series, Nathan and Beatrice Keyfitz lectures in Mathematics and Social Sciences, and our programs on commercial and industrial mathematics. The 2008 interdisciplinary Summer Program on Mathematical and Quantitative Oncology (organized by Siv Sivaloganathan, Lourdes Estrada, Mohammad Kohandel, Irwin Pressman and Hongmei Zhu) showcased our Centre for Mathematical Medicine and the Fields Institute’s increasing involvement in mathematical biology as one of the frontiers of twenty-first century applied mathematics.

The success of all of our programs depends on our partner institutions, not only as important sources of revenue, but also for the people who help organize our programs and provide ideas on our policies and planning. I am grateful to our seven Principal Sponsoring Universities, to our thirteen Affiliate Universities in Canada and the US, and to our Commercial and Industrial Partners. The Fields Institute is committed to providing value in return. During the past year, we appointed our first Fields Ontario Postdoctoral Fellows (thanks to our increased MTCU funding), dramatically increasing our support of postdocs at our Principal Sponsoring Universities. The program will support eight postdocs per year when it reaches its steady state. I am interested in exploring new ways that we can benefit our partners (in particular, in ways that we can broaden our involvement in the training of students).

During the past year, I attended the meetings of the Fields Institute’s Board of Directors and Scientific Advisory Panel as an invited observer, so I can already appreciate the scientific, educational and administrative leadership of our many friends who serve on these important committees. No less do I appreciate the Institute’s administrative staff, some of whom I have had the pleasure of knowing for many years, for their hard work and the support they provide, and for their dedication to making the Fields Institute a welcoming community.

Our mandate at the Fields Institute includes both research in the mathematical sciences and the development of research potential. These things depend on the communication of ideas. I think that the growth of mathematical institutes worldwide has above all changed the ways that
mathematics is communicated. We create opportunities by bringing people who are interested in mathematics together – researchers, students, educators, and scientific and industrial users. We try to bring mathematicians together with a receptive community. By bringing people together to learn from each other and to work in cooperation, we help generate ideas and enthusiasm.

Edward Bierstone, Director
Thematic Program on Mathematical and Quantitative Oncology
July–August 2008

Organizing Committee: S. Sivaloganathan, Chair (Waterloo & CMM), L. Estrada (VICBC), M. Kohandel (Waterloo), I. Pressman (Carleton), H.M. Zhu (York)

Scientific Advisory Committee: A. Friedman (MBI), T. Hudson (OICR), P. Maini (Oxford), M. Milosevic (PMH), V. Quaranta (VICBC), S. Sivaloganathan (Waterloo), J. Tuszyński (Cross Cancer Institute), G. Webb (Vanderbilt)

PROGRAM DESCRIPTION

Roger Bacon once said that “… nothing magnificent in the sciences can be known without mathematics... if we ought to come to certitude without doubt and to truth without error in the other sciences, it is necessary that we place the foundations of knowledge in mathematics.” Throughout the history of mathematics, the interaction with the sciences has posed the challenges which have led to the development of new mathematical methods and techniques which in turn, have contributed to dramatic advances in all the sciences. It appears that in the twenty-first century, we are on the brink of reaping the rewards of the rapidly developing synergy between mathematics and the biomedical sciences. Nowhere is this more apparent than in the nascent field of mathematical oncology, where the interaction of these disciplines heralds the possibility of the eradication of a disease that has been the scourge of humanity from time immemorial. Cancer is one of the most devastating diseases in the industrialized nations and according to the World Health Organization, it is poised to surpass cardiovascular disease as a world-wide killer. Thus, for this reason alone, the fight against cancer would appear to be of major importance and a worthwhile endeavour, both from the societal viewpoint of improving public health and from a socio-economic viewpoint (to avoid a significant drain on economic resources). In addition, as pointed out by several eminent researchers, one of the great scientific revolutions of this century will undoubtedly be brought about by the mathematization of the Life Sciences and Medicine.

More and more mathematicians are becoming involved in mathematical oncology and contributing to a deeper understanding of the complexities and mechanisms of cancer. However, as is abundantly clear, this is a far from an easy task and numerous fundamental conceptual issues remain to be elucidated and resolved. What is the right framework in which to study cancer? What are the critical biological mechanisms and corresponding scales? Is the study of cancer a multi-scale problem? These were the types of basic questions that formed the backdrop to the inaugural summer thematic program on “Mathematical & Quantitative Oncology” that was held July-August, 2008 at the Fields Institute. The program was coordinated by the Centre for Mathematical Medicine (CMM) but was a multi-institutional and international venture, involving the Ontario Institute for Cancer Research (OICR) and the Vanderbilt Integrative Cancer Biology Center (VICBC). The opening workshop on “Growth and Control of Tumours” (July 2-4, 2008) brought together cancer biologists, clinical researchers and mathematical scientists to address a broad range of topics from recent developments in the cancer stem cell hypothesis, to advances in the development of targeted drug therapies and novel drug delivery systems, as well as the optimization of combination therapies. The talks were an excellent balance between theory and experiment and had an underlying unifying theme in that they addressed specific aspects of the multi-scale, multi-factorial nature of cancer. The workshop also set the stage for the highly interdisciplinary nature, and balance of theory and experiment, that characterized the rest of the thematic program.

Events rapidly gathered momentum with numerous short and long term researchers visiting in July, culminating in the highly successful Society for Mathematical Biology Conference (SMB2008) held July 30-August 2. The meeting brought together 330 mathematical and biomedical scientists. The conference opened with the inspiring plenary talk on “mechanochemistry and motility” delivered by L. Mahadevan of Harvard University. This led to the various mini-symposia and contributed talks that comprised the bulk of the four day conference. The sessions spanned a broad range of topics in mathematical biology, although cancer remained a major theme of each. Seven other plenary speakers, T. Secomb (Arizona), H. Levine (UC San Diego), M. Knothe-Tate (Case Western), N. Komarova (Irvine), Y. Zhou (Xi’an Jiaotong University, China), M. Lewis (Alberta) and M. Golubitsky (MBI, Ohio) gave distinct perspectives on their particular areas of research in mathematical biology.

SMB2008 elided smoothly into the CMM/VICBC 4th workshop and summer school “Current Challenges in Oncology: Through the mathematical looking glass” which ran from August 2-6. This was based on the exemplary hands-on workshops pioneered by VICBC over the previous three
The Coxeter lectures. He presented three highly engaging and accessible talks in a style perfectly suited to the mixed audience of biomedical and mathematical scientists. Nowak covered three directions in his research (in which he has made seminal contributions): the evolutionary dynamics of cancer, discrete models of evolution, and the evolution of cooperation.

Nowak expounded masterfully on evolutionary dynamics, the mathematical study and description of evolution. Why is this an important field? Nowak commented that the renowned geneticist T. Dobzhansky had once stated that “nothing in biology makes sense except in the light of evolution.” It is Nowak’s contention that ideas in evolutionary biology are crying out for a mathematical description, since evolutionary biology is based on very simple and very precise fundamental principles – namely, selection and mutation. A mathematical description of these simple concepts has contributed to more precision and a deeper understanding in evolutionary biology. Clearly one of the major applications of the mathematical models developed, is in the study of cancer progression.

years. This workshop brought the Vanderbilt efforts to a new level. We were fortunate in managing to assemble an excellent collection of faculty (thanks to the tireless efforts of Lourdes Estrada as well as over 70 graduate students and postdocs. The students were divided into four groups, each under the mentorship of several faculty (mathematical, biological and clinical) and were actively engaged in current problems of interest to basic scientists and clinicians in oncology. The Fields Institute was a constant hive of activity over this period, with many participants working through the night in a contagiously enthusiastic and stimulating atmosphere. This was fortified by the ever-flowing supply of coffee and tea from the Fields Institute (the staple of every successful mathematical institute!) The workshop was a resounding success by all accounts, and extremely successful in exposing and engaging a new generation of researchers to a new paradigm of biomedical research.

The ultimate aim is to generate a critical mass of young researchers, well-versed in both mathematics and oncology, to whom the torch will be passed. Energized by the workshop, many of the participants remained for the Coxeter lectures.
Two graduate level courses “An Introduction to Mathematical Oncology” and “Medical Image Processing” were very successfully run over the two months attracting significant student attendance. The notes on the former will be published as a Fields Institute research monograph in 2009.

The thematic program concluded with the final workshop on “Quantitative Cancer Modelling: Mathematical Models, Imaging and Bioinformatics” held August 25-27 at Fields, which again brought together a diverse group of researchers. The topics ranged from the application of time reversal signal processing and robust optimization techniques in radiotherapy, through machine learning for automatic cell classification (with reference to digital pathology), to model-based reconstructive elasticity imaging and magnetic resonance elastography, as well as model selection and network reconstruction for high throughput biological data.

In summary, the workshops and conferences and the thematic program as a whole provided a focused, stimulating (if demanding) two month period where many collaborations were forged and new research directions set. In many respects, it exceeded our expectations and represents the “coming of age” of CMM. It is also the dawning of a new era of collaborative, inclusive interdisciplinary research and we look forward to future collaborations with VICBC and OICR and indeed with other mathematical bioscience institutes and centres. In his Opus Majus, Roger Bacon comments that “The strongest arguments prove nothing so long as conclusions are not verified by experience... Experimental science is the queen of all sciences and the goal of all speculation.” On reflection, the program very successfully brought together the experimental sciences (cancer biology, clinical oncology) and the mathematical sciences to move the field forward under a new paradigm and under the new banner of “integrative mathematical oncology.”

Siv Sivaloganathan

GRADUATE COURSES

Introduction to Mathematical Oncology
Instructors: M. Kohandel, S. Sivaloganathan (Waterloo)

This course involves biology and clinical aspects of cancer, and also presents an overview of recent mathematical models developed to examine different stages of cancer growth and therapeutic strategies. It is basically designed as a course for graduate students (not for credit) who are interested in working in the area of cancer modeling and related treatment strategies.

Medical Image Processing
Instructors: C. Drapaca (Waterloo), C. Studholme (Alberta), H. Zhu (York)

Tumors, and in particular cancer, can be difficult to detect, diagnose and treat. Digital imaging techniques, computer aided diagnosis, image-guided surgery and drug treatment can improve the accuracy and efficiency of tumors detection, diagnosis and treatment. Therefore computer assisted techniques have become a valuable component in today’s clinical research and practices. This graduate course on image processing and treatment planning is a collection of feature lecture series, focusing on IMRT inverse treatment planning, CT, MR image reconstruction and various means of analyzing and processing images including image co-registration, level sets, and time-frequency analysis, etc.

WORKSHOPS

Workshop on Growth and Control of Tumors: Theory and Experiment
July 2–4, 2008

Organizing Committee: M. Kohandel (Waterloo), P. Maini (Oxford), S. Sivaloganathan (Waterloo), K. Swanson (Washington)

Cancer is a class of diseases characterised by the three traits of uncontrolled growth, invasion and metastasis. Once diagnosed, the standard treatment is some combination of surgery, chemotherapy and radiotherapy. With more recent research developments, treatments are becoming more specific for different types of cancer. There have been significant advances in the development of targeted drug therapies that hone in on detectable molecular abnormalities (thus minimizing damage to normal cells), development of novel drug delivery systems, optimization of combination therapies and in numerous other directions. Hand in hand with the significant advances in experimental cancer biology and clinical oncology, the last decade has witnessed an increasing interaction between oncology and the mathematical sciences. This has resulted in an interdisciplinary field of research nowadays referred to as “mathematical oncology”. This synergistic interaction between oncology and mathematics heralds an era (in the not-too-distant future) where mathematical oncology will become an integral part of the study of cancer. This workshop brings together cancer biologists, clinical researchers and mathematical scientists, to provide stimulus and impetus to this interdisciplinary approach which will, no doubt, be central to the conquest of cancer.
Thematic Programs

Speakers:

Davide Ambrosi (Torino)
Adhesion forces in T24 cell migration

Robyn Araujo (George Mason University)
Combination Therapies: Insights from Mathematical Modeling

Khalid Boushaba (Iowa State)
A mathematical model for cell signaling and endothelial migration in a living zebra fish embryos

Lloyd Demetrius (Harvard)
Cancer in Mice and Men: a comparison

James Glazier (Indiana)
Simple Modeling of Avascular and Vascular Tumors Using the GGH Model and CompuCell3D

Richard Hill (Ontario Cancer Institute)
Cancer stem cells in tumours

David Hodgson (Princess Margaret Hospital)
Learning from the Fat Man: Modeling Radiation-related Second Cancer Risk for Clinical Use

Yi Jiang (Los Alamos)
Multiscale modeling for tumor angiogenesis

Philip Jones (Cambridge Cancer Centre)
The self assembling stem cell niche: a new model of epidermal homeostasis

Rama Khokha (Ontario Cancer Institute)
Functional and Biological Variables in Metastasis

Mike Milosevic (Princess Margaret Hospital)
Angiogenesis, Interstitial Fluid Dynamics and Hypoxia in Tumors

Lance Munn (Harvard)
Multi-scale analyses of tumor physiology and blood vessel dynamics

Leonard M. Sander (Michigan)
Micromechanics of collagen-gels and invasion by glioma cells

Shiladitya Sengupta (MIT)
Spatiotemporal targeting of tumor parenchyma and stroma by hybrid nanoparticles

Jack Tuszynski (Cross Cancer Institute)
MD and QMMM modeling successfully predict binding and effectiveness of novel colchicine derivatives against multiple cancer cell lines

Zhihui Wang (Harvard-MIT)
Multiscale Lung Cancer Modeling

Glenn F. Webb (Vanderbilt)
Models of Tumor Growth in vitro

VICBC Summer School on Integrative Cancer Biology:
Current Challenges in Oncology, through the Mathematical Looking Glass
August 2–6, 2008

Organizing Committee: A. Anderson, P. Crooke, L. Matrisian, L. Estrada, G. Webb and V. Quaranta (Vanderbilt), M. Kohandel and S. Sivaloganathan (Waterloo)

Workshop on Quantitative Cancer Modelling:
Mathematical Models, Imaging and Bioinformatics
August 25–27, 2008

Organizing Committee: Hongmei Zhu (York), Corina Drapaca (Pennsylvania State), Mike Milosovic (University Health Network), Siv Sivaloganathan (Waterloo)

Speakers:

Amir Asaf (York)
Application of Time Reversal Signal Processing in Radiotherapy

Bernhard Bodmann (Houston)
Machine learning for automated classification in cell microscopy

Jeff Collins (Medipattern Corporation)
B-CAD Toward Consistent Detection and Diagnosis in Breast Cancer Sonography

Xin Gao (York)
Model Selection and Network Construction For High-Throughput Biological Data

David Jaffray (Princess Margaret Hospital)
Title not available

Eva Lee (Georgia Tech)
Robust Optimization to Accommodate Effects of Systematic Treatment Uncertainties in Intensity-Modulated Radiation Therapy

Hengguang Li (Pennsylvania State)
Preliminary Results in MRE: a Finite Element Approach
Thematic Programs

Roderick Melnik (WLU)
Studying Properties of RNA Nanostructures and Their Potential Applications

Ross Mitchell (Calgary)
Virtual Biopsies: Non-invasive Molecular Diagnosis of Cancer

Alessandro Oliaro (Torino)
Time-Frequency Representations and Applications to Signal Analysis

Nataliya Portman (Waterloo)
Estimation of growth parameters of the Drosophila’s wing disc development from a sequence of micrographs using the Growth as Random Diffeomorphisms Model

Abbas Samani (UWO)
Fast Finite Element Technique for Real-time Biomedical Applications

Colin Studholme (UC San Francisco)
In utero mapping of brain tissue growth patterns from clinical MRI of developing human fetuses: An emerging field of image analysis research

Eli Van Houten (Canterbury)
Model Based Reconstructive Elasticity Imaging: Finding a Best Fit Between Imaging Goals and Computational Methods

Yuriy Zinchenko (Calgary)
Multiple gEUD-type constraints for radiotherapy optimization

SEMINARS

Mathematical/Quantitative Oncology
Co-ordinators: M. Kohandel (Waterloo), P. Maini (Oxford), K. Swanson (Washington)

This seminar addressed a broad number of issues in oncology. Amongst them, the development of models that incorporate the effects of various processes on drug delivery to tumour sites and that help identify treatment protocols and regimens that result in the most effective drug concentrations and residence time in the target tissue areas. Another focal point was the development of mathematical models linking the effective drug concentration in tumour cells with molecular targets (in a time and concentration dependent manner) which are needed to improve our
understanding of drug-target interaction. Another focus area of potentially enormous practical interest was the modelling and optimisation of chemotherapy and radiotherapy protocols. Mathematical models are required to improve understanding of the dynamic interplay between various processes and to translate these to clinical applications. Several other areas of focus included mathematically driven experimental oncology, evolutionary models of carcinogenesis as well as organ models (brain, breast, prostate, ovarian, colorectal cancers). Specific topics addressed during this focus period include:

1) *Integration of multiscalar/multilevel Data*
Core group: P. Maini (Oxford), A. Anderson (Dundee), H. Byrne (Nottingham), V. Quaranta (Vanderbilt), G. Webb (Vanderbilt)

2) *Multiphase and mechanical aspects of tumour biology*
Core group: M. Chaplain (Dundee), H. Byrne (Nottingham), A. Stephanou (Grenoble), T. Roose (Oxford), L. Preziosi (Torino), Z. Agur (IMBM)

**Bioinformatics**
Co-ordinators: M. Li (Waterloo), I. Jurisica (OCI)

The “molecular revolution” of the last two decades, spurred on particularly from the impetus provided by the genome projects, has inundated the field with an over abundance of data but done little to remedy the paucity of relevant mathematical models and techniques. Recent advances in computational statistics have heralded the possibility of vast improvements in the quality of statistical analyses. Coupled with this, the problems in analysing the flood of molecular genetic sequences and structures has raised a range of challenging biomathematical topics. These draw on a variety of sub-branches including stochastic processes, probabilistic modelling, statistical data analysis, neural networks, genetic algorithms and expert systems. This theme encompasses several areas including the analysis of gene expression data, regulatory networks and computational proteomics as well as other emerging areas. Specific topics addressed during this focus period included:

1) *Protein structure prediction and refinement*
Core group: D. Baker (Washington), B. Berger (MIT), M. Li (Waterloo), J. Skolnick (Georgia Tech), J. Xu (Toyota Institute, Chicago), Y. Zhang (Kansas), J. Tuszynski (Cross Cancer Inst., Alberta).

2) *New algorithms to annotate genes and other functionally active parts of the genome*
Core group: A. Condon (UBC), H. Hoos (UBC), M. Li (Waterloo), C. Sahinalp (Simon Fraser), L. Stacho (Simon Fraser), K. Zhang (UWO)

3) *Modelling and analysis in the discovery and characterisation of genes that influence susceptibility to various cancers*
Core group: M. Corey (Toronto), G. Darlington (Guelph), J. Graham (Simon Fraser), C. Greenwood (Toronto), K. Morgan (McGill), B. Smith (Dalhouse), D. Tritchler (Toronto), S. Bull (Mt. Sinai).

**Medical Imaging and Related Treatment Modalities**
Co-ordinators: C. Drapaca (Pennsylvania State), H. M. Zhu (York), M. Milosevic (PMH)

Modern technology coupled with the mathematical sciences holds the very real promise of providing quantitative imaging information about structures and phenomena, hitherto thought to be inaccessible to imaging. There is also potential to build up information based on the synthesis and fusion of multiple imaging modalities. Thus this theme was focused on a number of topics including new computational techniques and algorithms for 3D imaging as well as inverse problems, magnetic resonance elastography, tomography, PDEs and conformal maps. Specific topics addressed during this focus period included:

1) *Precision in radiation therapy - accounting for organ/tissue motion and Computational challenges in radiation oncology*
Core group: K. Brock (PMH), T. Chan (MIT), J. Deasy (Washington, St. Louis), E. Lee (Georgia Tech), D. Jaffray (PMH), L. Xing (Stanford), M. Milosevic (PMH)

2) *Determination of the mechanical properties of tumours and abnormal tissue using magnetic resonance elastography (MRE)*
Core group: C. Drapaca (Mayo), I. Sack (Berlin), C. MacGowan (Sick Kids), A. Samani (UWO), C. Lugnibuhl (Sunnybrook), D.B. Plewes (Toronto), A. Manduca (Mayo), E. Van Houten (Dartmouth), R. Muthupillai (Houston), J. Sciaretta (Toronto)

Irwin Pressman
The correspondence between results in arithmetic geometry and its relative, diophantine approximation, and hyperbolic geometry with its close relative, Nevanlinna theory, is quite extensive. A correspondence was originally noted by C. Osgood in 1981 and further developed by P. Vojta starting in 1983. This correspondence proceeds roughly as follows. A non-constant holomorphic curve \( f : \mathbb{C} \rightarrow X \) in a complex projective variety \( X \) corresponds to an infinite set of \( k \)-rational points on a projective variety \( X \) over a number field \( k \). One can think of the restriction of \( f \) to the disc \(|z| < r\) as corresponding to a single rational point. Under this correspondence, the metrical behavior of \( f \) on the boundary \(|z| = r\) can be compared with the metrical behavior of a rational point at archimedean places of the number field, and if \( D \) is a divisor on \( X \) then the analytic divisor \( f^*D \) on \(|z| < r\) can be compared with a similarly obtained divisor on \( \text{Spec } O_k \), where \( O_k \) is the ring of integers of \( k \). If one makes this analogy, then Nevanlinna's characteristic function \( T_f(r) \) corresponds to the height of the rational point, and statements of theorems and conjectures in Nevanlinna theory translate over to statements of theorems and conjectures in diophantine approximation. The proofs of the foundational theorems, however, are quite different and at this time cannot be translated.

The analogy has spawned a different proof of the Mordell conjecture, which in turn led to proofs of conjectures of S. Lang on rational points on closed subvarieties of abelian varieties.
Thematic Programs

varieties and on integral points on their open subvarieties, as well as counterparts for semiabelian varieties.

This analogy calls to mind a much older analogy in number theory, in which the ring \( \mathbb{Z} \) and certain of its extensions are replaced by polynomial rings \( F[t] \) over a field \( F \), and certain of its extensions. This leads to finite extensions of the field \( F(t) \), which also arise as fields of rational functions on projective curves \( B \) over \( F \). Projective varieties \( X \) over \( F(t) \) extend to projective varieties \( X \) over \( F \) with a flat morphism to the base curve \( B \). One can then apply standard methods of algebraic geometry (such as intersection theory) to \( X \) to obtain Diophantine results on \( X \). This methodology does not immediately carry over to the study of schemes over \( \text{Spec} \, \mathbb{O}_k \), however, since the latter is not a complete curve. This limitation is largely overcome by Arakelov theory, which adds structure at archimedean places of \( k \) to replace much of what is lost by replacing \( B \) with \( \text{Spec} \, \mathbb{O}_k \).

Arakelov theory has become a key tool in arithmetic geometry. In addition, complex manifolds and related objects play a key role in the theory – in fact some of its tools (such as secondary Chern classes) were originally developed for Nevanlinna theory.

This thematic program brought together the leading experts in the three areas of arithmetic geometry, hyperbolic geometry, and Arakelov theory. This was a welcome development, since there had not been an extended program in the fields for many years.

One unique aspect of this program was how it interwove the arithmetic and hyperbolic sides of the program. Long-term residents came from both fields: M. McQuillan, P. Vojta, P. Corvaja, C. Gasbarri, and H. Gillet from the arithmetic side; J. Noguchi, Y.-T. Siu, Pit-Mann Wong, S. Lu, and Min Ru from the hyperbolic side. The October workshop on arithmetic geometry and Arakelov theory was matched by the November workshop on hyperbolic geometry; the mini-workshop on \( p \)-adic dynamics paired with a mini-workshop on complex dynamics; and the Coxeter Lecture Series by S. Zhang emphasized arithmetic, whereas the Distinguished Lecture Series by Y.-T. Siu had more analytic flavour. Courses on Arakelov theory, on Nevanlinna theory and diophantine approximation, and on jet spaces ran throughout the semester.

Among the topics prevalent in the first workshop were recent results using Schmidt’s celebrated Subspace Theorem, on approximation to hyperplanes in projective space, which has been adapted to give results on more general divisors on arbitrary varieties. Other talks concerned work on extending the Lefshetz theorems to Arakelov theory, and an integral-points version of the Brauer-Manin obstruction to the Hasse principle.

One of the interesting aspects of the second workshop was that it reflected the growing interactions with other areas of current interest, such as random polynomials and random matrices. Topics ranged from classical Nevanlinna theory and hyperbolic geometry to the Torelli theorem over finite fields to problems on bounded symmetric domains arising from questions in arithmetic geometry.

Both workshops featured panel discussions on possible future trends in their respective areas, leading in each case to lively discussions on topics such as whether “Griffiths’ conjecture” is true (i.e., whether the Second Main Theorem extends in the same form to higher dimensions).

Dynamical systems, in which one studies behavior of measures or points under iterations of a map from a variety to itself, have been a growing area both in complex analysis and arithmetic geometry. In reflection of this, the program included two instructional mini-workshops to emphasize the importance of this circle of ideas to the main topics of the program. Attendees were able to see directly the parallel methods and results in these mostly separate areas.

Henri Gillet was in residence for the semester as Clay Mathematics Institute Senior Scholar. In his course on Arakelov Theory, he explained how the intersection theory on arithmetic surfaces introduced by Arakelov and Faltings can be generalized to arithmetic varieties \( X \) of arbitrary dimension. His treatment featured a number of recent developments, including the use of the Deligne pairing in the case of surfaces, the use of cycle complexes constructed using Milnor K-theory, following Rost, and the use of Burgos’ approach to Green currents using relative real Deligne cohomology. These techniques, together with a judicious use of de Jong’s alterations, make it possible to carry over the Fulton-MacPherson method of deformation to the normal bundle to the arithmetic situation. This gives a very satisfying and elegant definition of the functorial ring structure on the arithmetic Chow groups \( CH^*(X)_q \). Along the way to the proof of this fundamental result, Gillet’s lively and lucid lectures provided a wealth of background material and many valuable insights and explanations.

Yum-Tong Siu was in residence throughout the program as Dean’s Distinguished Visiting Professor at the University of Toronto, and gave a very enlightening and entertaining course on transcendental techniques in complex geometry. One of his themes in the course can be summed up by the
following analogy: in both arithmetic geometry and hyperbolic geometry, metrics play a central role; in arithmetic geometry, one tries to concentrate the curvature at points, while in complex geometry, one tries to spread the curvature out over the entire space. Through this analogy, Siu suggested ways to think about the correspondence between the two areas.

In this course, Siu began with the definitions of complex manifolds, line bundles, metrics, connections and curvatures and rapidly progressed to surveying modern uses of multiplier ideal sheaves in complex analysis and algebraic geometry. The course emphasized the historical development, providing the basic understanding of how and in what manner new techniques and theories were developed. In the spirit of the program, his topics ranged from Bombieri’s proof of the Gelfond-Schneider theorem in arithmetic to an effective version of the Fujita conjecture, which is proved using analysis. He ended the course by outlining his proof of finite generation of the canonical ring, exhibiting the power of multiplier ideal sheaves.

Overall, the program was a beehive of activity, with two workshops, four graduate courses (on Arakelov theory, on number theory and Nevanlinna theory, on complex geometry, and on jet spaces), two “mini-workshops” on complex and $p$-adic dynamics, an affiliated weekend workshop held in Montreal, and lecture series by S. Zhang and Y.-T. Siu. Accordingly, it should have a lasting impact on the field.

Paul Vojta

GRADUATE COURSES

Introduction to Arakelov Geometry
Instructor: Henri Gillet (UIC)

The course follows a review of the “non-arithmetic” theory, with a study of Arakelov’s intersection theory on arithmetic surfaces as developed in Faltings. We develop arithmetic intersection theory for varieties of arbitrary dimension. The main results include the relationship between arithmetic intersection theory, heights and height pairings, the arithmetic Bezout theorem, the arithmetic Hilbert-Samuel formula, and the arithmetic Riemann-Roch theorem. The course continues with the $K$-theory of Hermitian vector bundles for general arithmetic varieties and the characteristic classes for this bundles, the determinant of cohomology and Quillen metrics, and the arithmetic Grothendieck-Riemann-Roch theorem. Some applications to problems in number theory will be discussed.

Course on Nevanlinna Theory and Diophantine Approximation
Instructor: Min Ru (Houston)

Diophantine approximation is a tool to study rational points on algebraic varieties defined over a number field. On the other hand, Nevanlinna theory studies holomorphic curves in complex algebraic varieties, especially it studies how well a holomorphic curve intersects divisors in a complex algebraic variety. It has been observed by Osgood, Vojta and others that there is a striking correspondence between statements in Nevanlinna theory and in Diophantine approximation. The mini-course covers: Roth’s theorem and Schmidt’s subspace theorem; Diophantine equations and approximation; the theory of global and local heights; Faltings’ theorem on abelian varieties; the classical theory of Nevanlinna on meromorphic functions; The Ahlfors-Cartan theory of holomorphic curves; holomorphic curves in Abelian varieties; the complex hyperbolicities and the general case of Lang’s conjecture.

Course on Jet Spaces Mini Course in Complex Geometry
Instructor: Pit-Mann Wong (Notre Dame)

This is an outline of a mini-course in complex geometry, with six chapters.


3. A brief introduction to Complex Finsler Geometry and Intrinsic Metrics. Intrinsic metrics, mainly the Kobayashi and the Caratheodory metric, will be introduced. Positive currents and Lelong numbers. A Finsler characterization of ample bundles and big bundles will be given.
The thematic programs spurred more work in Nevanlinna theory. The thematic program at the Fields Institute examined the interplay between these two areas, as well as with Arakelov theory (a key tool in diophantine geometry which relies heavily on tools from several complex variables).

Workshop on Arithmetic Geometry: Diophantine Approximation and Arakelov Theory October 20–24, 2008

Organizing Committee: Caterina Consani (Johns Hopkins), Henri Gillet (Co-Chair, UIC), Yuri Manin (Northwestern), Paul Vojta (Co-Chair, UC Berkeley), Umberto Zannier (SNS Pisa)

This was the first workshop held in conjunction with the six-month long Thematic Program on Arithmetic Geometry, Hyperbolic Geometry and Related Topics held at Fields from July to December, 2008. This workshop brought together researchers in diophantine approximation and Arakelov theory, in roughly equal numbers, so as to enhance collaboration between the two fields.

Talks on number theory included a talk by J.-L. Colliot-Thélène, in which he described a version for integral points of the Brauer-Manin obstruction to the Hasse principle, and showed how it related to classical work on representations by quadratic forms. Many talks touched on Schmidt’s subspace theorem; for example, P. Corvaja and Y. Yasufuku spoke on recent adaptations of the theorem to more general varieties, and J.-H. Evertse described recent work on finding sharper bounds on the number of exceptional subspaces.

Talks related to Arakelov theory included a talk by Jean-Benoit Bost on Lefschetz theorems on arithmetic schemes. The classical Lefschetz theorems relate the geometry and topology of a projective variety to a hyperplane section of it. Bost described analogs in Arakelov theory of these results. In the case of surfaces the results combine diophantine approximation techniques with the Hodge index theorem of Faltings and Hriljac. In dimensions greater than two, the Lefschetz theorems are still work in progress. Bost also mentioned the subject of dimensions of objects over “the field with one element” F1. In a thought-provoking talk on joint work with Alain Connes, Caterina Consani discussed some new ideas on the geometry over F1. Appropriately enough for a talk at Fields, Coxeter groups play a key role in their work.

In other talks on Arakelov theory, José Burgos gave explicit computations of the heights of toric varieties in terms of the...
geometry of the associated polytopes, and Amnon Besser reviewed the question of $p$-adic analogs of Arakelov theory, and in particular of $p$-adic metrics on line bundles.

The workshop also featured a panel discussion on future directions in diophantine geometry and Arakelov theory. Panelists J.-B. Bost, H. Gillet, M. McQuillan, P. Vojta, and S. Zhang each gave short presentations on what they felt to be the key problems and areas going forward, and advice for people new to the field. Some themes emerged, such as an increasing emphasis on logic (following Hrushovksy) and a suggestion that people look to Shimura varieties to find a rich source of examples. The discussion was a success – to the point of running past its allotted time.

Paul Vojta

Speakers:
Amnon Besser (Ben-Gurion)
On the $p$-adic analogue of hermitian line bundles
Enrico Bombieri (Institute for Advanced Study)
Roots of polynomial in subgroups of $F_p^*$ and applications to congruences
Jean-Benoît Bost (Paris XI – Orsay)
Lefschetz theorems on arithmetic schemes
Jose Ignacio Burgos (Barcelona)
The height of toric subvarieties
Antoine Chambert-Loir (IRMAR)
Rationality of formal functions on arithmetic schemes
J.-L. Colliot-Thélène (CNRS)
Integral Brauer-Manin obstruction for homogeneous spaces
Caterina Consani (Johns Hopkins)
On the notion of geometry over $F_1$
Pietro Corvaja (Udine)
Integral points, divisibility between values of polynomials and entire curves on surfaces
Jan-Hendrik Evertse (Leiden)
On the Quantitative Subspace Theorem
Kalman Gyory (Debrecen)
S-unit equations in number fields: effective results, generalizations, applications, abc conjecture
Eugene Ha (Johns Hopkins)
On vector bundles and the adele-class space
Philipp Habegger (ETH Zurich)
Height Upper Bounds on Abelian Varieties and Algebraic Tori
Noriko Hirata-Kohno (Nihon)
Unit equations having few solutions
Minhyong Kim (University College London)
Selmer varieties
Klaus Kunneman (Regensburg)
Line bundles with connections on projective varieties over function fields and number fields
Aaron Levin (Scuola)
Runge’s method and the effective computation of integral points
Gael Remond (Institut Fourier)
Heights of Jacobians and rational points
Christophe Soule (CNRS)
Linear projections and successive minima
Lucien Szpiro (CUNY)
Algebraic Dynamics
Yu Yasufuku (CUNY)
On Vojta’s Conjecture
Shou-Wu Zhang (Columbia)
Gross-Schoen cycles, dualising sheaves, and tautological classes

Mini-workshop on $p$-adic Dynamics
October 27–28, 2008
Organizer: Joseph Silverman (Brown)

Sandwiched between a weeklong conference on arithmetic geometry and a week-long conference on complex dynamics, this workshop provided a nice bridge between these two seemingly disparate subjects. The three speakers were Rob Benedetto, Robert Rumely and Joseph Silverman.

The workshop started with an introductory lecture by Rob Benedetto in which he gave a tutorial on $p$-adic numbers, $Q_p$ and $C_p$ and $p$-adic analysis. This lecture was designed for people unfamiliar with $p$-adic numbers and $p$-adic fields and covered $p$-adic (non-archimedean) absolute values, the field of $p$-adic rationals $Q_p$ and its algebraic $p$-adic field $C_p$.

This was followed by six talks, three on Monday and three on Tuesday, allowing plenty of time for participants, who were drawn from diverse fields, to discuss the subject with one another. There were many fruitful discussions during the breaks and at dinner on Monday evening, attended by approximately 20 people.

Here is a brief description of the talks, which as a whole were designed to give non-experts an entry into this relatively new and exciting field.
### Thematic Programs

**Joe Silverman** (Brown)

*Families of dynamical systems and their associated moduli spaces*

The first part of this talk discussed the construction of parameter and moduli spaces associated to families of rational functions, including the use of multiplier systems, an explicit description of the moduli space of rational maps of degree two, and a sampling of open questions concerning such spaces. The second part focused on the dynamical modular curves that classify quadratic polynomials having a specified periodic point structure, analogous to classical elliptic modular curves.

**Bob Rumely** (Georgia)

*Non-archimedean potential theory and dynamical applications*

This talk described the Laplacian on the Berkovich projective line and used it to construct the “canonical measure” associated to a rational function of degree at least 2, which is analogous to the classical invariant measure constructed by Brolin, Lyubich, and Freire-Lopes-Mané. It also included a discussion of equidistribution theorems relative to this measure and used them to derive structural information about the Berkovich-Julia set.

**Joe Silverman** (Brown)

*A survey of (global) arithmetic dynamics*

Arithmetic dynamics is the study of dynamical systems from a viewpoint derived from the classical theory of Diophantine equations and arithmetic geometry. This talk explained this correspondence and described various results and conjectures, in particular those related to rationality of periodic points and integrality of wandering points. Additional topics included dynamical canonical heights, dynamical analogues of theorems of Faltings and Raynaud, and reduction modulo \( p \) theory.

**Rob Benedetto** (Amherst College)

*Introduction to \( p \)-adic dynamics*

This talk was an introduction to \( p \)-adic dynamics, including a discussion of periodic points, (attracting, repelling, indifferent), the \( p \)-adic Fatou and Julia sets, disk-components and analytic components, wandering domains, and additional topics.

**Bob Rumely** (Georgia)

*Berkovich space and dynamics on Berkovich space*

This talk started with a description of the Berkovich projective line over a complete, algebraically closed non-archimedean field, and the way that a rational function acts on the Berkovich projective line. It then compared the dynamics of a rational function on the classical projective line over the complex numbers and on the Berkovich projective line, focusing on the theory of periodic points and Fatou-Julia theory.

**Rob Benedetto** (Amherst College)

*Applications of \( p \)-adic dynamics*

This talk focused on applications of \( p \)-adic dynamics, including strong (non-uniform) bounds for global periodic points.

**Bob Rumely** (Georgia)

*Non-archimedean potential theory and dynamical applications*

This talk described the Laplacian on the Berkovich projective line and used it to construct the “canonical measure” associated to a rational function of degree at least 2, which is analogous to the classical invariant measure constructed by Brolin, Lyubich, and Freire-Lopes-Mané. It also included a discussion of equidistribution theorems relative to this measure and used them to derive structural information about the Berkovich-Julia set.

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**Joe Silverman**

**AFFILIATED ACTIVITY**

**Workshop on Arithmetic and Hyperbolic Geometry**

November 8–9, 2008

Held at UQAM, Montreal

Organizing Committee: A. Granville (Montreal), S. Lu (Montreal) P. Russell (McGill), N. Yui (Queen’s)

Scientific Committee: H. Gillet (UIC), K.-F. Liu (UCLA), M. McQuillan (Glasgow), J. Noguchi (Tokyo), M. Ru (Houston), Y.T. Siu (Harvard), P. Vojta (UC Berkeley), P.-M. Wong (Notre Dame)

One of the aims of this workshop was to bring together people who may be interested in the program at the Fields Institute but are unable to attend the part that may be of
Henri DeThelin discussed some applications of Oseledec-Pesin theory to meromorphic mappings. He began by introducing the dynamical notions of topological and metric entropy, Lyapunov exponents, and Pesin charts. Then he showed how, if one begins with a meromorphic mapping and a reasonably nice invariant measure, then one can establish some interesting relationships among entropy, dynamical degrees, and Lyapunov exponents of the mapping.

Jeffrey Diller

Speakers:
Nessim Sibony (Paris Sud)
Equidistribution problems in holomorphic dynamics

Mattias Jonsson (Michigan)
Superattracting fixed points

Henri De Thelin (Paris Sud)
Dynamics of meromorphic maps on compact Kahler manifolds

Jeff Diller (Notre Dame)
Holomorphic maps and entropy: Background and guiding principles

Eric Bedford (Indiana)
Dynamics of polynomial diffeomorphisms

Mini-workshop on Complex Dynamics
November 10–14, 2008

Organizers: Jeff Diller (Notre Dame), Eric Bedford (Indiana)

The complex dynamics workshop at the Fields Institute took place over five mornings from November 9-14. During that time five speakers, each giving two or three lectures, discussed various aspects of the dynamics of holomorphic and meromorphic mappings on compact complex manifolds. The overall aim was to introduce the field to complex geometers with little previous exposure to dynamics.

Eric Bedford presented some of his work with Kim concerning the construction of dynamically non-trivial automorphisms on rational surfaces. He showed how one can sometimes begin with a family of mappings that are merely birational and then use a blowing up procedure to eliminate indeterminacy behavior for certain maps in the family and thereby arrive at honest automorphisms.

Nessim Sibony devoted his lectures to various types of equidistribution problems, the general problem being to describe the asymptotic behavior of preimages of an analytic variety under iterates of a holomorphic mapping. In his final lecture, he introduced the notion of a ‘superpotential’, which is a new tool developed by he and Dinh for coping with varieties (or more generally, positive closed currents) with codimension larger than one.

Jeff Diller discussed the connection between the ergodic theory of a meromorphic surface mapping and its induced pullback action on cohomology groups. He discussed how the pullback action can be used to detect certain special types of mappings, and he showed how one can use the leading eigenvector for the pullback to construct natural invariant currents with special geometric structure, which can then be intersected to create invariant measures.

Mattias Jonsson discussed his work with Favre concerning the problem of ‘degree growth’ of polynomial maps on $\mathbb{C}^2$. In particular, he introduced two related geometric tools that are essential for this work: the space of valuations centered at a point, and intersection theory on the Riemann-Zariski space. These tools are in some sense dual to each other, and both can be regarded as ways of encoding and completing the set of all possible blowups at a point, along a line, or on the entire space.

Workshop on Complex Hyperbolic Geometry and Related Topics
November 17–21, 2008

Organizing Committee: Jean-Pierre Demailly (Grenoble I), Junjiro Noguchi (Tokyo), Min Ru (Houston), Bernard Shiffman (Chair, Johns Hopkins), Yum-Tong Siu (Harvard), Paul Vojta (UC Berkeley)

The theme of this workshop was the analytic approach to hyperbolic and arithmetic geometry and related topics on the distribution of values of holomorphic mappings. By way of background, S. Kobayashi introduced in 1967 the concept of hyperbolicity of complex manifolds, which can be considered as an aspect of value distribution theory. A connection between diophantine approximation and value distribution theory was proposed by Paul Vojta in 1983 in his thesis. Talks at the workshop were given by leading researchers who have made advances in value distribution theory of holomorphic curves: Eremenko, McQuillan, Noguchi, Siu, Winkelmann, and others. Two postdoctoral researchers gave talks on new results in exciting directions: Robert Berman used Bergman kernels and an argument connected to arithmetic volume in Arakelov
theory to show how the zeros of sections of high powers of big line bundles are distributed; Masaki Tsukamoto gave estimates for the mean dimension, as defined by Gromov, of Brody curves.

Kobayashi hyperbolicity for a compact manifold is equivalent to the non-existence of entire holomorphic curves in the manifold, which is a type of Second Main Theorem on the value distribution of holomorphic curves. The first day of the workshop began with a discussion of the Second Main Theorem. Yum-Tong Siu concluded the first day by reviewing his method of proof of the Kobayashi conjecture on the hyperbolicity of generic hypersurfaces of large degree and suggesting approaches to a simpler proof.

The second day was devoted to a variation of the value distribution theme: the deviation from the mean of the distributions of zeros of random holomorphic sections. The third day included various aspects of Nevanlinna theory: e.g., over function fields, for non-archimedean fields, and for entire curves in semi-abelian varieties. Talks on holomorphic mappings between balls and between bounded symmetric domains were given on the fourth day. Returning to the theme of the first day, Eremenko concluded the workshop with an effective bound for maps from the disk to the Kobayashi-hyperbolic complement of $2n + 1$ hyperplanes in projective space.

A panel discussion on Future trends and outstanding problems in complex hyperbolic geometry and Diophantine problems over function fields was organized by Paul Vojta, who participated in a lively discussion with the other panelists Michael McQuillan, Junjiro Noguchi, Nessim Sibony, and Yum-Tong Siu. McQuillan, Noguchi, and Vojta reviewed the progress on the longstanding conjectures of Kobayashi, Green-Griffiths, and Lang on holomorphic curves in projective varieties. In particular, McQuillan discussed Duval’s characterization of Brody hyperbolicity in terms of an isoperimetric inequality. Sibony discussed some new related questions concerning holomorphic foliations on projective space.

The formal part of the workshop included 24 talks and a panel discussion. Although the schedule was rather full during the day, animated discussions continued into the evening in the open hallways of the Fields Institute. The workshop covered a range of areas with intriguing interconnections and was quite successful; around 90 mathematicians attended over the course of the workshop.

Bernard Shiffman

Speakers:
Yoshihiro Aihara (Numazu College of Technology)
Deficiencies of holomorphic curves for hypersurfaces and linear systems

Atsushi Atsuji (Keio)
Diffusions and Nevanlinna theory

Robert Berman (Grenoble I)
From volumes of line bundles to equidistribution

Thomas Bloom (Toronto)
Large Deviations for VanDerMonde determinants

Frederic Campana (Nancy)
Special Orbifolds and Birational Classification: Hyperbolic and Arithmetic Aspects

William Cherry (North Texas)
Algebraic degeneracy of non-Archimedean analytic maps omitting divisors

Gerd Dethloff (Brest)
A Second Main Theorem for Moving Hypersurface Targets

Julien Duval (Paris-Sud)
On Nevanlinna second main theorem

Alex Eremenko (Purdue)
Landau’s theorem for holomorphic curves in projective space

Vincent Guedj (Aix-Marseille)
Monge-Ampere equations in big cohomology classes

Shanyu Ji (Houston)
Application of the Moving Frame Theory to Holomorphic Mappings between Balls

Yu Kawakami (Kyushu)
Value distribution of the hyperbolic Gauss map

Steven Lu (UQAM)
Algebraic hyperbolicity for varieties with maximal albanese dimension

Ngaiming Mok (Hong Kong)
Holomorphic isometries with respect to the Bergman metric

Junjiro Noguchi (Tokyo)
Some Second Main Theorems and applications

Nessim Sibony (Paris-Sud)
Super-Potentials on Compact Kahler Manifolds and dynamics of Automorphisms

Yun-Tong Siu (Harvard)
Hyperbolicity of generic hypersurfaces of high degree
Yuri Tschinkel (Courant)
A Torelli theorem over finite fields

Hajime Tsuji (Sophia)
Global generation of the direct images of pluricanonical systems

Masaki Tsukamoto (Kyoto)
Deformation of Brody curves and mean dimension

Julie Wang (Academia Sinica)
An effective Schmidt’s subspace theorem for projective varieties over function fields

Jorg Winkelmann (Lehrstuhl Mathematik VII)
Entire curves in surfaces with large irregularity

Steve Zelditch (Johns Hopkins)
How probable is a given configuration of zeros?
Thematic Program on o-minimal Structures and Real Analytic Geometry January–June 2009

Organizing Committee: David Marker (UIUC), Chris Miller (Ohio State), Jean-Philippe Rolin (Bourgogne), Patrick Speissegger (McMaster), Carol Wood (Wesleyan)

Scientific Committee: Edward Bierstone (Toronto), Lou van den Dries (UIUC), Robert Moussu (Bourgogne), Alex Wilkie (Oxford)

PROGRAM DESCRIPTION

We set out to organize our program with a clear focus: that of constructing o-minimal structures from classes of functions that arise from dynamical systems. By “construction”, we mean the method of establishing the o-minimality for such a structure, which usually relies on a description of its definable sets reminiscent of the concept of “constructibility” used in algebraic geometry.

Many of the classes of functions considered for the construction of o-minimal structures are quasi-analytic, that is, each function in such a class is uniquely determined by its asymptotic expansion (usually at 0 or at infinity). The functions in the quasi-analytic classes considered in the past all admit power series as asymptotic expansions. One of the goals of our program was to extend the construction techniques to quasi-analytic classes whose asymptotic series are so-called generalized series, that is, series whose monomials are not restricted to real powers of the identity function, but may be logarithmic-exponential terms or similar. Such classes are prominent in both Ecalle’s and Ilyashenko’s solution of Dulac’s problem – which states that a real analytic vector field in the Euclidean plane has finitely many limit cycles – and they arise as solutions of Dirichlet’s problem on certain subanalytic domains.

The motivation for establishing o-minimality for such structures is to have access to model-theoretic tools, such as the model-theoretic compactness theorem, in order to obtain uniform finiteness results. For example, the second part of Hilbert’s 16th problem (abbreviated simply as “H16” below) states that for a polynomial vector field X in the Euclidean plane, there is a natural number N depending only on the degree of X such that X has at most N limit cycles. While Dulac’s problem was solved independently by Ecalle and Ilyashenko in the 1990s, H16 remains wide open.

Roussarie’s finite cyclicity conjecture (FCC for short) reduces H16 to establishing the existence of uniform bounds on the number of limit cycles for certain analytic families of vector fields obtained as small perturbations of a single vector field. Recent work of Kaiser, Rolin and myself shows that the approach of establishing o-minimality does give uniform finiteness results for certain non-generic perturbative families. By extending current construction methods for o-minimal structures to quasi-analytic classes whose asymptotic series are generalized power series, we hope to extend this uniform finiteness result to certain generic perturbative families of vector fields. I therefore choose the example of H16 as a guiding line to describe our program activities.

While constructing o-minimal structures appears to be a very narrowly focussed topic, the methods for doing so draw on diverse areas of mathematics, most notably on analysis, differential topology, differential algebra, valuation theory and resolution of singularities. Moreover, as we are motivated by functions arising from various problems in dynamical systems such as H16, the study of the already existing large body of work on these problems is essential to our pursuit.

We were able to bring together both leading specialists and junior mathematicians representing many of these areas in mathematics. To establish some necessary common background, we started off with an introductory workshop organized by Matthias Aschenbrenner. Aimed especially at our junior participants, this workshop was run in the manner of the Arizona Winter Schools. Introducing the very basics of the focus of our program, the lecturers of this workshop were Deirdre Haskell (model theory), Sergei Starchenko (o-minimality), Krzysztof Kurdyka (real analytic geometry) and Sergei Yakovenko (planar real analytic vector fields).

The three graduate courses were a cornerstone of our program, functioning both as initiators of discussions and disseminators of some of the core mathematics. The first course covered o-minimality and much of what is known about constructing o-minimal structures. It was taught by three of the program organizers: Chris Miller (o-minimality and Hardy fields), Jean-Philippe Rolin (construction of o-minimal structures from quasi-analytic classes) and myself (pfaffian closure). The second course focused on quasi-analytic classes arising from dynamical systems, such as Ramis and Sibuya’s multisummable functions or Ecalle’s resurgent functions. The lecturers were Fernando Sanz, Jean-Philippe Rolin and myself (multisummability),
As is natural when bringing such a diverse group of mathematicians together, participants were working on many other projects than those at the focus of the program as a whole. The mini-workshops also served as a platform for presenting such work to other participants. For example, Ayhan Gunaydin and Chris Miller organized a mini-workshop on expansions of the real field by multiplicative groups. Following this mini-workshop, one of our junior participants, Philipp Hieronymi, made a significant breakthrough on the topic. Mario Edmundo, Artur Piekosz and Luca Prelli held a mini-workshop on cohomology and sheaves in o-minimal (and other model-theoretic) settings. Finally, Gareth Owen Jones organized a mini-workshop around the question of just how constructive some of the known constructions of o-minimal structures really are. The latter question is particularly interesting in the case of the exponential real field itself, where Macintyre and Wilkie have previously shown that it is intricately tied to Schanuel’s conjecture.

We ended the program with a regular week-long workshop organized by Fernando Sanz and myself and entitled “Finiteness problems in dynamical systems”. Besides giving some of the program participants a venue for presenting their recent work, we also invited non-participants to present work in areas tangentially related to the focus of our program. Our hope in doing so was that the work presented in this final workshop, together with the experience gathered during the program, might inspire some junior participants to establish new connections between model theory and dynamical systems.

Patrick Speissegger

GRADUATE COURSES

Three semester-long graduate courses took a more detailed look at the topics of the programme and served both students looking for a research problem and established researchers hoping to learn more about a particular subject. We taught the three courses in parallel; each course in turn split into three modules. Each of the modules was four weeks long, with three hours of lectures per week. The courses are:

Topics in o-minimality
Module 1: o-minimality and Hardy fields (C. Miller)
Module 2: Construction of o-minimal structures from quasianalytic classes (J.-P. Rolin)
Module 3: Pfaffian closure (P. Speissegger)
Thematic Programs

Multisummability and Quasianalyticity
Module 1: Basic multisummability (R. Schäfke)
Module 2: Resurgent functions (D. Sauzin)
Module 3: Non-oscillatory trajectories (F. Sanz)

Resolution of Singularities
Module 1: Resolution of singularities for functions (E. Bierstone)
Module 2: Resolution of singularities for foliations (Felipe Cano)
Module 3: Resolution of singularities of real analytic vector fields (D. Panazzolo)

WORKSHOPS

Winter School in o-minimal Geometry
January 12–6, 2009
Organizer: Matthias Aschenbrenner (UCLA)

The thematic program on O-minimal Structures and Real Analytic Geometry at the Fields Institute kicked off with this school in O-Minimal Geometry. It was modeled on the very successful Arizona Winter School in Number Theory, held annually since 1998 at the University of Arizona. The concept is simple but effective: a number of leading researchers give intensive tutorials, over the course of a week, targeted at graduate students who are beginning thesis research in the topic of the tutorials or in neighboring fields. In order to give the students the opportunity to adequately prepare beforehand, the lecturers are asked to provide, a few weeks ahead of the workshop, a preliminary version of their lecture notes and a list of projects. These projects may be anything from a collection of exercises on the material covered in the course, filling in proofs, etc., up to small “research” questions. During the week of the workshop, the graduate students work on these problems in small groups, and the meeting culminates with presentations by the students on their results.

O-minimality is a desirable property of structures on the field of real numbers \( \mathbb{R} \). Here, a structure \( \mathbb{R} \) on \( \mathbb{R} \) is simply a sequence of distinguished collections of subsets of the Euclidean spaces \( \mathbb{R}, \mathbb{R}^2, \ldots, \mathbb{R}^n, \ldots \) (one class for every \( n \), containing at least all real algebraic subsets of \( \mathbb{R}^n \)), subject to being closed under natural operations on sets: complement and (finite) intersection and union, Cartesian products and linear projections. The distinguished subsets in a structure \( \mathbb{R} \) on \( \mathbb{R} \) are also referred to as definable sets with respect to \( \mathbb{R} \). (The terminology of structures and definability was coined in mathematical logic. It is often a routine matter to check that a geometric construction of finitary nature, when applied to sets definable in a given structure \( \mathbb{R} \), again produces sets definable in \( \mathbb{R} \). For example, the interior and the closure of a definable set are also definable. In this way, every structure on \( \mathbb{R} \) gives rise to a self-contained “geometric universe”.

A structure on \( \mathbb{R} \) is called o-minimal (abbreviating order-minimal) if the definable subsets of the line \( \mathbb{R} \) are exactly the subsets of \( \mathbb{R} \) with only finitely many connected components. The definition of o-minimality is given only in terms of subsets of \( \mathbb{R} \), but yields the kind of finiteness properties of definable subsets of higher-dimensional Euclidean spaces \( \mathbb{R}^n \) familiar in semialgebraic and subanalytic geometry. For example, every definable set in an o-minimal structure \( \mathbb{R} \) on \( \mathbb{R} \) has only finitely many connected components, each itself definable in \( \mathbb{R} \); dimension theory for definable sets in \( \mathbb{R} \) is extremely well-behaved (e.g., phenomena like space-filling curves are absent), etc. This leads to the development of a kind of “tame topology” based on o-minimal structures.

An archetypical example of an o-minimal structure on \( \mathbb{R} \) is the class of semialgebraic sets, i.e., finite unions of solution sets of (finitely many) real polynomial equations and inequalities. The theory of o-minimal structures, although originating in model theory (a subfield of mathematical logic), can therefore be seen as a natural generalization of real algebraic geometry. In the last twenty years, many more examples of o-minimal structures on \( \mathbb{R} \) have been constructed, strictly extending the collection of semialgebraic sets and containing various classes of functions (or, to be precise, their graphs) relevant for analysis, including basic functions such as the real exponential function and the Riemann zeta function. Many of these constructions involve differential geometric techniques, resolution of singularities, and tools from model theory and algebra. (In a manner similar to the way commutative algebra supports algebraic geometry, o-minimal geometry has an associated underpinning in algebra, mainly comprising relevant parts of the theory of ordered fields, valuation theory, and differential algebra.) The theory of o-minimal structures has even had applications to subjects as varied as Lie theory, economics, neural networks, and more recently, diophantine geometry.

As should be apparent from the above, carrying out research successfully in o-minimal geometry requires knowledge of many different areas of mathematics. This made it desirable to provide the graduate students (and interested senior researchers) who were planning to par-
Since the invention of the concept by Van den Dries, the development of o-minimality has been strongly influenced by real analytic geometry and, conversely, model-theoretic methods through the o-minimal point of view have led to new insights into real analytic geometry. Many recent developments in the intersection of o-minimality and real analytic geometry use resolution of singularities in crucial ways. There is good reason to believe that extending resolution algorithms to certain classes of functions involving exponential scales may help shed new light on various interesting problems in real analytic geometry. Examples of particular interest to us are the classes of multisummable and of resurgent functions.

All these topics were extensively covered in several of the activities of the Program: the Graduate Courses, the Miniworkshops dedicated to specific themes and the permanent Geometry and Model Theory Seminar. The workshop that closed the Program was intended as a kind of conclusion of the whole Semester where speakers had the opportunity to present their results under the light of the new ideas, work projects or advances achieved during the activities of the Program.

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Workshop on Finiteness Problems in Dynamical Systems
June 22–26, 2009

Organized by: Fernando Sanz (Valladolid) and Patrick Speissegger (McMaster)

This workshop was the final activity of the Thematic Program on o-minimal Structures and Real Analytic Geometry, which took place at the Fields Institute from January to June 2009.

The main focus of the Program was to establish the o-minimality of certain expansions of the real field that arise naturally in problems about dynamical systems and differential equations in the real analytic setting. The main example guiding many activities of the Program was the expansion generated by the Dulac transition maps studied by Ilyashenko and Ecalle in his proof of Dulac’s problem. Others examples come from pfaffian sets, non-oscillating trajectories of vector fields and associated Hardy fields, limit cycles of planar vector fields, abelian integrals, diffeomorphisms, normalizations and formal solutions as well as transseries.
Thematic Programs

Speakers:
Andreas Fischer (Dresden)
*Extension of Lipschitz functions*

Andrei Gabrielov (Purdue)
*Limits of compact sets in tame geometry*

Tobias Kaiser (Regensburg)
*O-minimality of certain Dulac transition maps*

Krzysztof Kurdyka (Savoie)
*Gradient vector fields*

Olivier Le Gal (Rennes 1)
*O-minimality of non-oscillating solutions of ODEs*

Jean-Marie Lion (Rennes 1)
*Pfaffian sets*

David Marín Pérez (Barcelona)
*Time period map for hyperbolic singularities*

Chris Miller (Ohio)
*Model theory of spiralling solutions of planar vector fields*

Dmitry Novikov (Weizmann Institute)
*Finiteness of Abelian Integrals*

Daniel Panazzolo (Sao Paulo)
*Resolution of singularities of vector fields*

Adam Parusinski (Angers)
*Gradient vector fields*

Christiane Rousseau (Montreal)
*Normal forms of saddle-nodes and hyperbolic singularities*

Tere Seara (Barcelona)
*Resurgence theory of the MacMillan map*

Masahiro Shiota (Nagoya)
*Haupvermutung in o-minimal structures*

Lou van den Dries (UIUC)
*Model theory of the field of transseries*

Joris van der Hoeven (Paris-Sud)
*Computability with transseries*

Yosef Yomdin (Weizmann Institute)
*Composition of moments and center-focus problem*

Alex Wilkie (Manchester)
*o-minimal complex geometry*
The Operator Algebras Thematic Program began in 1996, after a two-year major program in the same subject, and has continued since then. In the fall of 2007, there was a second major Fields Institute program in the subject, and this continued at a substantial level of activity also in the spring of 2008. (For instance, Eberhard Kirchberg (Berlin) was in residence from January to March 2008, as well as during the preceding five months, as an Elliott Distinguished Visitor.)

During the 2008-09 year, eight postdoctoral fellows participated in the program, for varying periods (of from one to twelve months): Alin Ciuperca, Ivan Dynov, Benoît Jacob, Trieu Le, Leonel Robert, Luis Santiago, Maria Grazia Viola, and Khye Loong Anthony Yew. Also, seventeen students participated in the program: six PhD. students, Alan Lai, Greg Maloney, Fernando Mortari, Henning Petzka, Barry Rowe, and Aaron Tikuisis; seven M.Sc. students, Nadish de Silva, Jordan Bell, Nemanja Kosovalic, Steve Lowdon, David Reiss, Brian Skinner, and Kevin Teh; and four undergraduate research assistants, Arthur Huang, Dan Lin, John Yang, and Qiao Zhou.

A regular working seminar was held, usually meeting on Tuesday and Thursday afternoons for two to four hours, and concerned with various aspects of the theory of operator algebras and related subjects – including structure and classification theory for C*-algebras, noncommutative geometry, dynamical systems, free probability, random matrices, quantum field theory, and statistical physics. All of the students and postdoctoral fellows associated with the program reported on their work in this seminar, many speaking more than once.

The following fifteen mathematicians participated in the program for shorter periods (varying from one day to one month), and almost all of them spoke at least once in the Operator Algebra Seminar: Teodor Banica (Toulouse), Ilijas Farah (York), Julien Giol (Texas A&M), Eugene Ha (Johns Hopkins), Nigel Higson (Pennsylvania State), Dan Kucerovsky (UNB), Hanfeng Li (SUNY Buffalo), Snigdhayan Mahanta (Johns Hopkins), Rob Martin (UC Berkeley), Ping Wong Ng (University of Louisiana, Lafayette), John Quigg (Arizona State), Bahram Rangipour (UNB), Shoichiro Sakai (Sendai), Andrew Toms (York), and Makoto Yamashita (Tokyo).

As an offshoot of the program, a group of twenty-one high school students was supervised during weekly meetings under the auspices of the University Toronto Arts and Science Mentorship Program. This was carried out by the following nine graduate students and postdoctoral fellows: Ioannis Anapolitanos, Catalina Anghel, Aaron Chow, Karene Chu, Benoît Jacob, Greg Maloney (coordinator), Jesse McKeown, Barry Rowe, and Daniel Rowe.

George Elliott
Lectures and Special Events

Royal Canadian Institute for the Advancement of Science Fall Mathematics Lecture

Margaret Wright (Courant Institute)
Coping with Impossible Problems – With a Smile
November 9, 2008

In early November, Fields again co-sponsored an RCI Science on Sundays lecture on the University of Toronto campus. This fall’s speaker was Margaret Wright, a past-president of the Society for Industrial and Applied Mathematics, who spent much of her career at AT&T Bell Labs and is now Silver Professor of Computer Science and Mathematics, and chair of the Computer Science Department, at New York University. Margaret is a renowned mathematical scientist whose field is optimization. In addition to her distinguished career in research and service, Margaret is famous for her catchy talk titles – “The ferment in optimization” and “What can we say after we say we’re sorry, or adventures in optimization” are two recent examples. When you attract a large audience with a title like “Coping with impossible problems”, you had better be prepared to deliver the goods, and the RCI talk did just that, telling an important story with enthusiasm and humour.

In her lecture, Margaret gave a good sense of what is meant by the term “optimization”, and also of how mathematics contributes to solving real-world problems that involve optimization. Her lecture was enlivened with many references to Sherlock Holmes – especially to his famous statement, “When you have eliminated the impossible, whatever remains, however improbable, must be the truth”.

The abstract goals of optimization can be stated very simply: find the best solution to an equation or inequality; prove that it is the best; and estimate how long it will take to find that solution. This doesn’t sound very exciting. But Margaret illustrated her theme with two examples that were nothing short of astounding. The first was a problem presented to her when she was a young researcher working at Stanford University. It involved an engineering problem of recalibrating the Stanford Linear Accelerator (SLAC), a task that needed to be done once a year, and was performed by “knobbers” who turned a set of knobs located along the two-mile beam until the beam was perfectly straight. It was done by trial-and-error and took about six weeks, after which the accelerator was ready to run experiments.

The mathematics, and physics, of the situation was clear enough: the knobs controlled magnets that affected the beam in a predictable way. But the problem was still “impossible” in the sense that the controls were located at fixed points which could not be adjusted, and the way that each control changed the beam had to be inferred from data caught by monitoring the system. There were a large number of constraints, and the problem was nonlinear. Wright and colleagues adapted a new kind of algorithm, Sequential Quadratic Programming, or SQP, to solve this problem. They were able to reduce the time it took to calibrate the beam to a single eight-hour shift. As Margaret joked, this might have put some “knobbers” out of work, but the scientists were grateful to have their very expensive machine available for productive work for a much longer time.

The second example involved designing indoor wireless communication systems, a project that surfaced during Margaret’s career at Bell Labs. The problem is to design an optimal placement of transmitters in a building to assure complete coverage of the space by radio waves. Unlike the SLAC problem, this one featured imperfect knowledge of the physics, and a shortage of data with which to monitor progress towards an optimum. The mathematical key to this problem was a fast ray tracing algorithm that provided a (sufficiently good) approximation to the way radio waves propagate in real office buildings. “Impossible” was turned into “possible” by recognizing that the scale of the problem was human-sized working spaces. Following this insight, the optimization technique was what is called a direct search algorithm, a method suited to functions that are non-smooth and noisy. In this example, the optimization strategy resulted in a program called “WISE”, which is still in use, and produced an improvement of about 6% (over the engineering design) in typical buildings. Even though that does not sound dramatic, it was very important to the customers. The analysis also produced some insights into the way coverage worked – a byproduct of approaching practical problems with theory, as many applied mathematicians are aware.

One feature of both examples was the requirement that the mathematical group establish the trust of their clients. Like many of Margaret’s other comments about the climate of applied research, her perception of the need to convince suspicious clients and co-workers that mathematics can do more than just provide verification of answers that “every-
one knows already” struck a chord with those of us who are keen on interdisciplinary collaboration.

In her concluding remarks, Margaret Wright returned to the theme of the joy of collaboration and teamwork. The success stories of her lecture were a vivid example, and her enthusiastic delivery served to dispel the image of an isolated, unsmiling mathematician.

Barbara Lee Keyfitz

**Florin Diacu, (Victoria)**
*Before Tragedy Strikes*
March 1, 2009

Mai Khao Beach, Phuket, December 26, 2004. Tilly Smith and her parents are enjoying their time on the seaside. But to Tilly, something seems different on that day: the sea has receded much more than usual, the water is bubbly and stings the skin, and there is a strange smell, that of oil and rotten eggs... Tilly instantly recalls a school project on which she had worked just a few weeks before - the title was: *Tsunamis*. Immediately she alerts her parents that these are the signs of a tsunami and that they have to run!

The Smith family survived one of the most horrific natural catastrophes that has ever struck civilization, their lives saved by a science project and a little girl who remembered it: if science ever had an application to real life, it was on that day at Mai Khao Beach.

Florin Diacu of the University of Victoria is an internationally renowned mathematician, and a specialist in disasters. During his lecture in Toronto at the Royal Canadian Institute for the Advancement of Science on March 1, 2009, he took the audience on a captivating tour through the forces of nature and the mathematical tools to make predictions - “Before Tragedy Strikes.” The 2004 tsunami was one such catastrophe, which tragically came without warning. It was one in a list of “mega-disasters” analyzed in Florin Diacu’s recent book of the same title: earthquakes, volcanic eruptions, hurricanes, rapid climate change, collisions with asteroids or comets, pandemics, and, now more than ever, stock market crashes... which somehow made the audience wonder if they will really get home safe after the talk.

As the lecture illustrated, the mathematics behind disasters involve a wide array of disciplines. With tools at our disposal ranging from mathematical physics and biology to chaos theory, and dynamical systems to probability, statistics and mathematical finance, virtually no disaster escapes from being modelled mathematically.

On February 4, 1975, a 7.3 magnitude earthquake destroyed 90% of Haicheng, China; but since it had been accurately predicted, the city had been evacuated to a large extent. The number of victims, which would otherwise have been in the order of 150,000, was only 2,000. However, every model surely comes with a certain price of inaccuracy, and every prediction, probabilistic in nature, with uncertainty. Improving the models is at the basis of the dialogue between the scientist and the mathematician, and reading the signs becomes essential for both – as it was for Tilly.

Matthias Neufang
Lectures and Special Events

On November 25, Fields welcomed Henri Gillet of the University of Illinois at Chicago to speak as part of the thematic program in Arithmetic Geometry, Hyperbolic Geometry and Related topics. Not surprisingly, the intriguing title attracted a large number of well-seasoned mathematicians to the lecture, in addition to the undergraduates for whom it was designed. Gillet began by boldly stating that

$$\infty! = 1 \cdot 2 \cdot 3 \ldots \cdot n \ldots = \sqrt{2\pi}$$

and

$$1 + 1 + 1 + \ldots + 1 + \ldots = -\frac{1}{2}.$$  

The general question then is: how can one assign a (finite and useful) value to a divergent product or divergent sum? Since any product of positive numbers can be converted into a sum by taking the logarithm, Gillet concentrated on answering this question for infinite series.

In our first course in calculus, we learn that an infinite series

$$a_0 + a_1 + \ldots + a_n + \ldots$$

can be assigned a sum as the limit of the sequence of partial sums

$$s_0 = a_0, \ s_1 = a_0 + a_1, \ldots, \ s_k = a_0 + a_1 + \ldots + a_k, \ldots$$

if the limit exists, of course. But in the 18th century, the distinction between convergent and divergent series was not at all clear – it was only to be clarified later in the 19th century. For example as illustrious a mathematician as a Bernoulli brother reasoned that since the partial sums of

$$1 - 1 + 1 - 1 + \ldots$$

are 1, 0, 1, 0, … the sum of the series is ½, or at least should be. This answer is consistent with another 18th century argument: since the geometric series

$$1 + r + r^2 + \ldots = \frac{1}{1-r}$$

if \( |r| < 1 \), substituting \( r = -1 \) gives

$$1 - 1 + 1 - 1 + \ldots = \frac{1}{2}$$

as before. The fact that both methods gave the same answer must have been pretty convincing!

The first method also led to concluding that the series

$$1 + 0 + (-1) + 1 + 0 + (-1) + \ldots = \frac{1}{2}$$

(as we will later see) since the partial sums are 1, 1, 0, 1, 1, 0, …

Gillet then returned to the general question of how to sum a series \( a_0 + a_1 + \ldots + a_n + \ldots \) which is possibly divergent according to the modern point of view. There are some reasonable conditions to require:

1. If the series converges, its sum should be \( \sum_{n=0}^{\infty} a_n \) in the usual sense.
2. If \( a_0 + a_1 + \ldots + a_n + \ldots \) and \( b_0 + b_1 + \ldots + b_n + \ldots \) are summable in the new sense, then so is \( (a_0 + b_0) + (a_1 + b_1) + \ldots \) and

\[
(a_0 + b_0) + (a_1 + b_1) + \ldots = (a_0 + a_1 + \ldots) + (b_0 + b_1 + \ldots)
\]
3. \( a_0 + (a_1 + \ldots + a_n + \ldots) = a_0 + a_1 + \ldots + a_n + \ldots \)

One possible approach if a series has an infinite sum in the usual sense, is to subtract \( \infty \) from it in some consistent way to obtain a finite sum. This is similar to the “renormalization” process in physics.

Gillet then discussed two other approaches: Abel and Cesàro summability. The series \( a_0 + a_1x + \ldots + a_nx^n + \ldots \) is Abel summable if, first of all \( a_0 + a_1x + \ldots + a_nx^n + \ldots \) converges for \( |x| < 1 \), and secondly the limit \( a \) of \( a_0 + a_1x + \ldots + a_nx^n + \ldots \) exists as \( x \to 1^- \). And then of course its sum is defined to be \( a \). The series is Cesàro summable if the sequence \( (s_0 + s_1 + \ldots + s_n)/(n + 1) \) of averages of the partial sums of the series converges, and then again the sum is defined to be the limit.

Both of these methods satisfy the properties (1), (2) and (3) above and furthermore if a series is Cesàro summable, it is Abel summable (with the same sum). For example the series

$$1 + 0 + (-1) + 1 + 0 + (-1) + \ldots$$

considered earlier is easily seen to have Cesàro (and Abel) sum \( \frac{1}{2} \) since the averages of the partial sums are

$$1, 1, \frac{2}{3}, \frac{3}{4}, \frac{4}{5}, \frac{5}{6}, \ldots$$

One can think of a more general approach similar to Abel summation, namely: find a function involving \( a_0, a_1, \ldots, a_n, \ldots \) and then define the sum \( a_0 + a_1 + \ldots + a_n + \ldots \) to be given by some particular value of the function. For example one can use the Riemann zeta function to evaluate

$$1 + 2^k + 3^k + \ldots \ (k \text{ a nonnegative integer})$$

in this way: the zeta function is defined to be

$$\zeta(s) = 1 + 1/2^s + 1/3^s + \ldots$$
and is easily seen to be convergent for \( s > 1 \) – or \( \text{Re} \ s > 1 \) if one considers \( s \) as a complex variable – as one must for this method to be applied. In fact \( \zeta'(s) \) is then an analytic function for \( \text{Re} \ s > 1 \), and can be analytically continued to a meromorphic function in the complex plane, holomorphic everywhere except for a pole at \( s = 1 \). If this is done, one can define \( 1 + 2^s + 3^s + \ldots \) (for \( k \geq 1 \)) to be \( \zeta(-k) \), which is known to be \( -B_{k+1}/(k+1) \) where \( B_k \) is the \( k \)th Bernoulli number defined by

\[
x/(e^x - 1) = \sum_{n=0}^{\infty} B_n x^n/n! .
\]

Thus

\[1 + 2 + 3 + \ldots = \zeta(-1) = -B_2/2 = -1/12 ,\]

and

\[1 + 1 + 1 + \ldots = \zeta(0) = -B_1 = -1/2 ,\]

a result known to Euler – which he worked out in a manner similar to this example, in spite of the fact that the Riemann zeta function had not yet been defined!

At this point, Gillet returned to the problem in the title, a definition (or determination?) of \( \infty! \). He first introduced the “alternating” version of the zeta function:

\[L(s) = 1 - 1/2^s + 1/3^s - 1/4^s + \ldots .\]

and then applied the “Euler transformation”, giving

\[L(s) = \frac{1}{2} \left( 1 + (1 - 1/2^s) - (1/2^s - 1/3^s) + (1/3^s - 1/4^s) - \ldots \right)\]

which implies that

\[L(0) = \frac{1}{2} .\]

(One can show that \( L(s) \) actually converges for \( s > -1 \)).

Simple algebraic manipulation shows that

\[\zeta(s) - L(s) = 2^{1-s} \zeta(s) \]

so

\[\zeta(s) = \frac{1}{1-2^s} L(s) ,\]

and then a little freshman calculus that the derivative

\[\zeta'(0) = -(2 \log 2) L(0) - L'(0) = -\log 2 - L'(0) \]

and, since the derivative of \( 1/n^s \) at \( s = 0 \) is \( -\log n \),

\[L'(0) = \frac{1}{2} \left( \log 2 - (-\log 2 + \log 3) + (-\log 3 + \log 4) - \ldots \right) = \frac{1}{2} \left( \log 2 + \log (2/3) + \log(4/3) + \log(4/5) + \log(6/5) + \ldots \right) = \frac{1}{2} \log \left( 2 \cdot \frac{2}{3} \cdot \frac{4}{5} \cdot \frac{6}{5} \ldots \right) = \frac{1}{2} \log \frac{\pi}{2} ,\]

since \( \frac{\pi}{2} = \frac{2}{1} \cdot \frac{2}{3} \cdot \frac{4}{5} \cdot \frac{6}{5} \ldots \) by the “classical” Wallis product for \( \pi/2 \).

But

\[\zeta'(s) = \sum_{n=1}^{\infty} (-\log n)/n^s ,\]

so formally

\[\zeta'(0) = \sum_{n=1}^{\infty} (-\log n) = -\log(\infty!) = -\log 2 - L'(0) = \frac{1}{2} \log \frac{\pi}{2} ,\]

and therefore

\[\log(\infty!) = \log \sqrt{2\pi} ,\]

so

\[\infty! = \exp(\log \sqrt{2\pi}) = \sqrt{2\pi} .\]

QED!!

Carl Riehm

THE 2009 MATHEMATICAL SCIENCES FELLOWS OF THE ROYAL SOCIETY OF CANADA

Pengfei Guan (McGill), Agnes M. Herzberg (Queen’s), Eckhard Meinrenken (Toronto)

March 16, 2009

The Canadian mathematical community collectively may delight in a circumstance that is quite embarrassing to the organizers of the Fields Institute’s annual Symposium for the New Fellows of the Royal Society: This year there were too many honorees to fit into the traditional half-day format of three talks and a reception. Perhaps the event will have to be renamed “A Sampling …”

This year’s symposium took place on March 16 at Fields. The organizers noted that at least seven new fellows are close enough to mathematics that the Fields community would like to hear from them. Indeed, Stuart Kauffman, of the Institute for Biocomplexity and Informatics, University of Calgary, honoured as a “founder of the science of Biological Complexity”, has given a colloquium at the Centre for Mathematical Medicine in the past year.

At this point, Gillet returned to the problem in the title, a definition (or determination?) of \( \infty! \). He first introduced the “alternating” version of the zeta function:
Raymond Laflamme, Institute for Quantum Computing, University of Waterloo, an organizer of the upcoming program on Quantum Information at Fields in Summer 2009, will give his FRSC colloquium during the summer program. George Habashi, Department of Mechanical Engineering, McGill University, “widely recognized for the formulation, modeling and application of finite element methods to Computational Fluid Dynamics (CFD)”, was lauded in the introduction to the symposium. And Fields congratulates Ivar Ekeland, taking a well-earned sabbatical from his five-year position as Director of PIMS to renew his research in France, and hopes to welcome him here when he is back on this continent.

The three inductees who were able to speak at our March meeting were Pengfei Guan, Agnes Hertzberg, and Eckhard Meinrenken. All three gave fascinating, and very different, talks.

Pengfei Guan, of the Department of Mathematics and Statistics, McGill University, is a good friend of many at Fields – a legacy of his time at McMaster University. His Royal Society citation recognizes him as “the leading researcher of his generation in the study of fully non-linear elliptic partial differential equations, a deep and central area of mathematics which has very important applications in geometry and in mathematical physics”. In his talk, titled, Geometric nonlinear partial differential equations, Pengfei showed how geometric and analytic ideas intertwine in the study of fully nonlinear elliptic and parabolic PDE. Beginning with a proof of the isoperimetric inequality in the plane, using curvature, he then stepped back to consider the development of isoperimetric estimates, beginning with the work of Alexandrov and Fenchel. The key tool, Harnack estimates, went through two stages of development: first, for quasilinear equations, in the celebrated work of Di Gorgi and Nash, and then for fully nonlinear equations by Safanov and Krylov. Harnack estimates are pointwise estimates that compare the maximum to the minimum of a harmonic function in a subdomain of a larger domain. In the end, he confessed, it all comes down to the maximum principle. But, as Guan’s talk – and his work – show, it’s amazing what one can do with a good idea, a grasp of geometry, and immense technical skill.

Agnes Herzberg, of the Department of Mathematics, Queen’s University, was the second speaker. Her Royal Society citation is worth quoting in full: “Recognized globally for her pioneering contributions to statistics, Agnes M. Herzberg founded, shaped and nurtured the international Conference on Statistics, Science and Public Policy held at Herstmonceux Castle, England. In this unique context, she assembles an unusual mix of scientists, politicians, civil servants and journalists from several countries who annually address significant policy issues. The outcomes of these invaluable conferences have demonstrably furthered knowledge, trust and co-operation across the divides of government, science and public policy.” Agnes’ introductory remarks gave a striking picture of the world situation that led her to set up these unique meetings. First, her father, Gerhard Herzberg, received the Nobel Prize just as the Senate moved to dismantle the NRC. She looked at a world in “serious trouble” and noted that once science has been destroyed it is hard to get it back. She considered the impact (on all of us) of having the government attempt to run science. One of her sentences, “The high value of publically funded scientific research needs to be understood by the public”, could stand as an epigram for much that we do. Thus Agnes, having set up one meeting, was inspired to turn it into an annual affair, with a changing group of participants and an evolving set of themes, but always featuring a mix of scientists and policymakers. (And, according to David Andrews, a long-term collaborator on the project, always featuring good company and outstanding entertainment in the unique English castle that belongs to Queen’s University.)

The final speaker of the afternoon was Eckhard Meinrenken, Mathematics Department, University of Toronto. Eckhard, lauded for his achievements in symplectic geometry, has been involved in a number of programs and seminar series at Fields. His results have connections with topics in theoretical physics, such as conformal field theory and the theory of D-branes in string theory. He chose, however, in his charming presentation, to give what he called a “small-picture talk”, a proof of a remarkable theorem. The statement is that if G is a simply connected Lie group with a bi-invariant pseudo-Riemannian metric, then the conjugacy classes of G carry distinguished invariant volume forms. And the proof? It was carried out by actually constructing the volume form. The point was that the standard candidates would not work – they were degenerate, or not closed – and an old idea, “pure spinors”, came to the rescue. Many in the audience would have shared the wonder in Lisa Jeffrey’s question at the end, “How did you think of this?” Following the talks there was a well-attended reception and a dinner for the honorees. Fields congratulates them again, and all the other new Fellows.

Barbara Keyfitz
Kumar Murty completed his undergraduate degree in mathematics at Carleton University. While a student at Carleton, he wrote his first mathematical paper, coauthored with his brother Ram and later published in the Canadian Mathematical Bulletin. In this paper the Murty brothers extended Niven's proof of the irrationality of $\pi$ to prove a general result from which they deduced the irrationality of $\log r$ for every positive rational number $r$ not equal to 1, as well as of $\exp r$, $\sin r$, $\cos r$, $\cosh r$, $\sinh r$ for every nonzero rational number $r$. Also in his honors project Murty improved the bound known at the time for Linnik’s constant, an important number connected with the least prime in an arithmetic progression. Murty then went to Harvard University, where he completed his PhD. in 1982 under the direction of John Tate with a thesis on algebraic cycles on abelian varieties. After postdoctoral studies, Murty joined the faculty of the Department of Mathematics at the University of Toronto, where he is professor and currently department chair.

With over seventy research publications in leading mathematics research journals, he is also the author, coauthor or editor of a number of books, as well as editor of the Journal of the Ramanujan Mathematical Society. His research, focusing on important topics in analytic number theory such as the non-vanishing of Dirichlet $L$-functions, zeros and poles of Artin $L$-functions, the Chebotarev density theorem, modular forms, and abelian varieties, has been very influential in the development of the subject. More recently his research has moved in the direction of the applications of various aspects of number theory, such as abelian varieties, modular forms, computational number theory, elliptic curves over finite fields and the number theory sieve, to information technology, particularly to the theory and implementation of encryption methods. In this connection he is Director of GANITA (Laboratory for Geometry, Algebra, Number Theory for their Information Technology Applications), a research laboratory in Mississauga, Ontario.

The main topic of his two talks at Carleton University was the mathematics of information technology. In his public speech on Thursday, March 19, 2009, he addressed some basic problems of information technology, reviewing the mathematical techniques behind these problems, and then talking about what the future might hold for the interaction between mathematics and information technology. The audience consisted of people from many different fields such as mathematics, statistics, engineering, computer science, and the natural sciences. The colloquium room was packed with many people standing up. His second talk on Friday, March 20, was on discrete logarithms, exponential sums and data integrity. He outlined a new approach to data integrity, and showed how tools from mathematics, particularly analytic number theory, could be used to tackle the problems in data integrity.

Saban Alaca and Kenneth S. Williams

Rabbi Chaim Michael Dov Weissmandl is best known for his efforts to save the Jews of Slovakia from extermination during the Holocaust by bribing diplomats. As a student, though, he copied large portions of the Torah onto ten character by ten character grids and observed that the word “torah” can be found spelled in Genesis by starting with the first letter, a “t”, and skipping the 50th letter of the text, 100th letter of the text and continuing until the word “torah” is spelled. It takes little imagination to realize that the notion of an *Equidistant Letter Sequence* (ELS) implicit in Weissmandl’s observation can be generalized to

Saban Alaca and Kenneth S. Williams

Nathan and Beatrice Keyfitz Lecture Series on Mathematics and Society

Maya Bar-Hillel (Hebrew University)
The Bible Code: Riddle and Solution
March 31, 2009

Rabbi Chaim Michael Dov Weissmandl is best known for his efforts to save the Jews of Slovakia from extermination during the Holocaust by bribing diplomats. As a student, though, he copied large portions of the Torah onto ten character by ten character grids and observed that the word “torah” can be found spelled in Genesis by starting with the first letter, a “t”, and skipping the 50th letter of the text, 100th letter of the text and continuing until the word “torah” is spelled. It takes little imagination to realize that the notion of an *Equidistant Letter Sequence* (ELS) implicit in Weissmandl’s observation can be generalized to
not stated explicitly in the *Statistical Science* article, the conclusion to be drawn from it is that the book of *Genesis* contains information about the events that took place after it was written. Incredible as this may seem, the other conclusion, that there is a flaw in the statistical analysis, is also difficulty to believe. *Statistical Science* is a very respected journal drawing on the resources of distinguished referees. The Rips, Rosenberg and Witztum article, for example, was refereed by no less that Persi Diaconis as well as others, and was under review for an extended period of time. How is it possible that a flawed article, an article claiming prognostication of the future, could pass all the tests to which one would expect it to be subjected by the editorial board of *Statistical Science*?

The answer to this riddle provides an instructive glimpse into the sociology and methodology of statistical research. It has already been mentioned that Rips, not being a statistician, had devised his own method for calculating the likelihood of the observed ELS pairs of names of rabbis and dates of their deaths. The method was too complicated to expect any referee to subject it to a mathematical analysis. Diaconis’ approach was to ask Rips, Rosenberg and Witztum to repeat their experiment with a different collection of names of rabbis and dates of their deaths. This they did and were able to report similar results, thus lending even more weight to the assertion that the future is predicted in *Genesis*.

In spite of this though, the argumentation of Rips, Rosenberg and Witztum was indeed flawed and the explanation of what is behind the Bible codes was finally given by Dror Bar-Natan, Brendan McKay, Gil Kalai and Maya Bar-Hillel in an article that appeared in *Statistical Science* in 1999. The key to solving the puzzle is in understanding both the mathematics and the Biblical Hebrew in which the codes are claimed to appear. It turns out that both names and dates in the Bible take on various forms. In her talk, Maya Bar-Hillel provided the following example: In Canada “July 1”, “The first of July”, “Canada Day” all designate the same date. The fact that a similar lack of uniqueness can be observed in *Genesis* is at the heart of understanding the source of the Bible Code results.

The ambiguity in describing a person or date leads requires one to decide on which version of a name or date to use when searching for close pairs of ELSs. Not all forms of a date are equally likely to be used, so it would not be reasonable to use all possible variants and it is equally unreasonable to choose just one variant, at least this is the line of argument used by Rips, Rosenberg and Witztum.
As was shown by Bar-Natan, McKay, Kalai and Bar-Hillel, however, the outcome of a search for closely related ELSs varies greatly depending on how the group of allowable variants is chosen.

An early argument used in the debate on the Bible Codes was that, if the phenomenon reported by Rips, Rosenberg and Witztum was simply due to chance, then it should be equally easy to find the same closely related pairs of names of rabbis and dates of their deaths in War and Peace as it is in Genesis. To the delight of Bible Code defenders, the early experiments with War and Peace were inconsistent with this. By tweaking the choice of alternate ways of writing dates and name though, Bar-Natan, McKay, Kalai and Bar-Hillel were able to reproduce exactly the same phenomenon in War and Peace as found in Genesis.

Maya Bar-Hillel’s lecture provided a precise description of her work on the Bible Code, but was also filled with interesting examples and anecdotes about the key people involved. Nor did she shy away from coming to conclusions about the ethics of some of these key people. Was the work of Rips, Rosenberg and Witztum merely an example of poor methodology, or was the choice of alternate names and dates leading to their fantastic conclusions the result of deliberate deception? Bar-Hillel believes that some form of data manipulation had to have been involved.

The heart of the talk though, was a clear and compelling description of the analysis of the reasoning behind the Bible Code claims. The audience’s questions at the end of the talk provided a good indication that she had succeeded in conveying her message.

Juris Steprāns

COXETER LECTURE SERIES

Martin Nowak (Harvard)
August 6–8, 2008

Somatic Evolution of Cancer
Aug 6, 2008

Evolution of Cooperation
Aug 7, 2008

Prevolutionary Dynamics (the origin of life)
Aug 8, 2008

The Fields Institute was honoured to have Martin Nowak deliver the Coxeter lectures. He presented three engaging and accessible talks in a style perfectly suited to mathematical biologists: filled with functions, facts and fun. In this series, Nowak covered three areas in his field: the evolutionary dynamics of cancer, discrete models of evolution, and the evolution of cooperation.

Evolutionary dynamics is the mathematical study and description of evolution. Why is this an important field? The geneticist Theodosius Dobzhansky once stated that “nothing in biology makes sense except in the light of evolution”. According to Nowak, “It is more and more recognized that ideas in evolutionary biology want to have a mathematical description, because evolutionary biology is based on very simple and very precise fundamental principles, namely selection and mutation.” A mathematical description of these simple concepts has lead to many advances in the understanding of population dynamics, not only in populations of individuals, but in populations of cells within an individual. One of the major applications of these models is the study of the progression of cancer.

Cancer arises because of genetic mutations. Every time a cell divides in the body, there is a risk of cancer since cell division can lead to mutation. Fortunately, cells have measures that protect the genome. One of these is the diploid nature of healthy cells; there are two copies of each chromosome in the nucleus. If one of the chromosomes is corrupted by mutation, there is still a functional copy to take over. Some cancer cells, however, have been found to be aneuploid, meaning there is an abnormal number of certain chromosomes. This is a consequence of chromosomal instability (CIN). A mutation to a CIN gene results in an increased rate of losing or damaging chromosomes. In fact, in colon cancers, it has been found that 85% of the cancerous cells have CIN. This leads to the following question: is chromosomal instability a consequence of cancer, or a driving force?

The first major mutation in the onset of colon cancer is to APC, a tumour suppressor gene. Without chromosomal instability, the APC gene requires two point mutations (one in each copy of the chromosome) to become inactivated. With a mutation to a CIN gene, there is an increased rate of loss of heterozygosity (LOH), resulting in a fast inactivation of APC with only a single point mutation. The rates of mutation are measured, so by examining all possible pathways, the probabilities that APC is inactivated with a CIN mutation and without a CIN mutation at time t can be computed. The two probabilities can then be compared to determine which pathway is more likely. The same process can be applied to inactivation of multiple tumour suppressor genes.
There is also a possibility that mutation to a CIN gene has a cost; such a mutation may cause lethal damage to the cell. In this case, after a single mutation to the APC gene, the cell is not very likely to enter the inactivated state, but will instead undergo apoptosis (cell death). By comparing the various paths in the model, Nowak has come to the following conclusions:

1. In a pathway where only one tumour suppressor gene needs to be eliminated, having only one or few neutral (no cost) CIN genes is enough to ensure CIN initiates the tumour formation.

2. If the CIN genes have a dramatic cost, then in pathways where two tumour suppressor genes need to be inactivated, it is enough to have one or few costly CIN genes to ensure CIN initiates tumour formation.

By studying the possible mutation dynamics, one can gain insight into the sequence of mutations that occur in the progression of cancer. In the case of the colon, it is reasonable to claim that chromosomal instability is a driving force for cancer, rather than a late-stage consequence.

There is an important distinction regarding evolution that Nowak made sure to re-iterate: it is not cells or people or species that evolve, but populations. In the case of cancer, a population of cells evolves. In society, populations of individuals evolve. Evolution cannot occur without a group of interacting individuals forming a population. When one studies the evolution of these populations, one has the choice of adopting a continuous model (assuming large population sizes) or a discrete one (finite populations). The continuous forms are often easier to analyze, but do not allow for stochasticity to strongly influence the results. To study small populations, a discrete model must be used.

One of the oldest models for the evolution of a finite population is the Moran process. In this process, one begins with a given initial population of size $N$. For each event, one individual from the population is selected to reproduce and another is selected to die based on relative fitnesses. The first is duplicated, while the second is removed from the population. At each time step, the population size remains constant. If a population begins with $N-1$ type $B$ individuals and one $A$ individual, one can ask what the probability is that $A$ will take over. This is known as the fixation probability, and can be calculated given the relative fitness $r$ of $A$:

$$p = \frac{1 - \frac{1}{N}}{1 - \frac{1}{r}}$$

If both $A$ and $B$ have the same fitness ($r = 1$), then the previous expression simplifies to $p = 1/N$, as expected. This analysis treats fitness as constant. A better model would treat an individual’s fitness as a function of frequency. Consider the following payoff matrix:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>B</td>
<td>c</td>
<td>d</td>
</tr>
</tbody>
</table>

If a player $A$ meets a player $A$, then its fitness is $a$. If a player $A$ meets a player $B$, its fitness is $b$. The overall fitness (or payoff) of an $A$ player then becomes $F_A(x) = ax + b(1-x)$, where $x$ is the probability of meeting an $A$ player. Similarly, the fitness of a player $B$ becomes $F_B(x) = cx + d(1-x)$. With a finite population size with $i$ players of type $A$, the payoffs are the following:

$$F_A(i) = a \left( \frac{i-1}{N-1} \right) + b \left( \frac{N-i}{N-1} \right)$$

$$F_B(i) = c \left( \frac{i}{N-1} \right) + d \left( \frac{N-i-1}{N-1} \right)$$

In these finite populations, the intensity of the selection matters. For weak selection, the selection forces can be defined as follows:

$$f_A(i) = 1 + w \cdot F_A(i)$$

$$f_B(i) = 1 + w \cdot F_B(i)$$

where $w << 1$ is the selection strength. For the case of weak selection, the fixation probability of $A$ taking over $B$ can be computed:

$$p = \left( 1 + \sum_{i=1}^{N-1} \prod_{j=1}^{i} \frac{f_A(j)}{f_B(j)} \right)^{-1}$$

If the fixation probability satisfies $p > 1/N$, then $A$ is favoured over $B$. This condition is equivalent to $a + 2b > c + 2d$, which is also known as the one-third rule. One needs only to check the fitness values at frequency $x = 1/3$ to determine who will take over the population. More complex models can be built on this framework involving graphs of interacting individuals, where individuals form the vertices of the graph, and connections indicate interactions between them. In such cases, the graph induces a transformation of the payoff matrix. The same analysis is performed to find the dominant species.
The previous discussion touches evolutionary game theory. An interesting topic in this area, one that Nowak finds to be ‘quite beautiful’, is the evolution of cooperation. Evolution is driven by mutation and selection for reproduction. Selection is based on an individual’s relative fitness, which begs the question: why would evolution design individuals to cooperate amongst each other, increasing the fitness of others (its competitors)? This evolution of cooperation cannot be explained by natural selection alone.

Consider the following version of the prisoner’s dilemma: There are two players, A and B. If either player chooses to cooperate, it will cost him c, and the other will receive benefit b. The two players cannot communicate with each other before the game is played. Should player A cooperate or defect?

<table>
<thead>
<tr>
<th></th>
<th>B cooperates</th>
<th>B defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>A cooperates</td>
<td>b - c</td>
<td>-c</td>
</tr>
<tr>
<td>A defects</td>
<td>b</td>
<td>0</td>
</tr>
</tbody>
</table>

If player B chooses to cooperate, then A should defect since \( b > b - c \). If player B chooses to defect, then A should still defect since \( 0 > -c \). Therefore, A should always choose to defect. With this sort of rational reasoning, both A and B will choose to defect. However, if they both had cooperated, both would have obtained the reward \( b - c \) (assumed \( > 0 \)). In this way, natural selection chooses defection and destroys cooperation. However, evolution seems to design individuals that cooperate, so there must be other underlying mechanisms.

The five major mechanisms that allow for the evolution of cooperation are as follows: kin selection, direct reciprocity, indirect reciprocity, graph selection, and group selection.

Kin selection can best be described by a quote from the late British evolutionary biologist J. Haldane: “I will jump into the river to save two brothers or eight cousins.” A number \( r \) can be defined describing the level of relatedness, and an individual will choose to cooperate if this relatedness is greater than the cost to benefit ratio: \( r > c/b \).

The idea of direct reciprocity is the following: If I help you now, you will be more likely to help me in the future. The more likely you are to interact with the person, the more likely it is you will receive some benefit down the road. Here, cooperation will occur if \( w > c/b \), where \( w \) is related to the probability of interacting again.

Indirect reciprocity is very similar to the direct form, but is based on reputation. If I help you now, someone will help me later. Social experiments have confirmed that people help those who help others, and don’t help those who don’t. This is a product of social intelligence and communication. As Nowak accurately states, “Gossip spreads”. Here, an individual will cooperate if \( q > c/b \), where \( q \) is the probability of knowing someone’s reputation.

Often in populations, individuals form a social network and interact with several others. These interactions can be mapped out on a graph, where the individuals form the vertices and the interactions form the line segments connecting them. Here, an individual receives the benefits of all cooperators connected to him, but has a cost for each neighbour. In these graphs, selection favours cooperation only if \( b/c > k \), where \( k \) is the average number of neighbours. This is graph selection.

The last mechanism that can give rise to cooperation is group selection. This mechanism considers competition with other groups of individuals. A group of individuals who cooperate is more likely to out-compete other groups that do not. Here, cooperation is favoured if \( b/c > 1 + n/m \), where \( n \) is the group size and \( m \) is the number of other groups.

Luckily, we as a species have evolved with this ability to cooperate. One of the recurring lessons in this Thematic Program on Mathematical and Quantitative Oncology is that in order to progress, both mathematicians and doctors (or biologists) need to cooperate with each other. Vito Quaranta (Vanderbilt University) recently quipped, “Talking to mathematicians is easy, it’s listening to them that is hard.” In this Coxeter Lecture Series, Martin Nowak attempted to bridge the gap, approaching the topic of evolutionary dynamics from both perspectives. He began the series with the following joke to illustrate the conflict between the two fields:

There’s a shepherd standing in a field with a flock of sheep. A man comes up to the shepherd and asks, “If I can guess exactly how many sheep you have, can I have one of them?” The shepherd accepts, believing it impossible to guess the exact number. The man answers instantly: “83 sheep.” The shepherd is completely amazed by this correct guess, and lets the man choose whichever sheep he wants. The man makes his choice and is about to leave when the shepherd stops him, “Wait! If I can guess your profession, can I get my animal back?” “Okay”, says the man. “You’re a mathematical biologist, now give me back my dog!”

A mathematician can use these evolutionary models to make all sorts of predictions. However, without the biologists to guide them, they can see a sheep in a dog. Similarly,
biologists can obtain tremendous amounts of data, but without the proper mathematical tools and expertise in analysis, they can come to false conclusions and be left with mounds of useless information. Only when both fields learn to communicate, will we see major advances in both medical and mathematical sciences.

Antonio Sanchez

Shou-Wu Zhang, (Columbia)

*Periods, Heights, L-values*

September 29–October 1, 2008

Usually number theorists do not work with transcendental numbers – working with objects over \( \mathbb{C} \) is considered to be part of geometry. Important exceptions (other than transcendence theory itself, of course) occur as values of \( L \)-functions at specific points (“special values”), as heights in Arakelov theory, and as periods (integrals of differential forms over generators of the fundamental group) – hence the title of the lectures.

Zhang’s lectures focused primarily on special values of \( L \)-functions and on periods, but also described some relations of these values with heights.

The lectures began by highlighting two transcendental numbers in particular. The first, \( \pi \), has been known since antiquity. Numerous exact expressions for this quantity have been discovered over the past 600 years or so, but for the purposes of these lectures the expression

\[
\pi = \int_{-1}^{1} \frac{dx}{\sqrt{1-x^2}}
\]

played a central role, as did the number

\[
\Omega = \int_{-1}^{1} \frac{dx}{\sqrt{1-x^2}}
\]

defined by a very similar-looking integral.

The number \( \pi \) occurs in many special values of the Riemann zeta function

\[
\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s} , \quad \text{Re} \ s > 1 .
\]

At age 28, Euler showed that \( \zeta(2) = \pi^2/6 \), and at age 30 he found the Euler product expansion

\[
\zeta(s) = \prod_{p \text{ prime}} \left(1 - \frac{1}{p^s}\right)
\]

bringing the arithmetic of primes into the picture. Later, Riemann showed that the function

\[
\Lambda(s) = \pi^{-s/2} \Gamma(s/2) \zeta(s) \text{ has an analytic continuation to the whole s-plane and satisfies } \Lambda(s) = \Lambda(1-s). \text{ Thus } \zeta(s) \text{ extends to a holomorphic function on the whole complex plane, except for a simple pole at } s = 1 .
\]

This allows one to discuss values of \( \zeta(s) \) for \( \text{Re} \ s \geq 1 \). In addition to the (rational) Bernoulli numbers \( B_n = -n \zeta(1-n) \) \( (n \geq 0) \), it was observed by Colmez that

\[
\frac{\zeta''(0)}{\zeta'(0)} = \log 2\pi = \log \left| \oint \frac{dz}{z} \right| .
\]

This relates the zeta function to a period of the algebraic group \( \mathbb{G}_m = \mathbb{C}^* \); i.e., the integral of the differential form \( dz/z \) over a generator of its fundamental group.

The integral \( \Omega \) is also (half of a) period. Let \( E \) be the elliptic curve \( y^2 = 1 - x^4 \). Viewing it as a double cover of the complex plane (by dropping the \( y \) coordinate), the inverse image of the real interval \([-1,1]\) is a loop in \( E \), and this integral becomes half of the period obtained by integrating the form \( dx/y \) over this loop.

This elliptic curve also has an Euler product associated to it:

\[
L(E,s) = \prod_{p \text{ prime}} L_p(E,s) , \quad \text{Re} \ s > \frac{3}{2} ,
\]

where at primes \( p \) of good reduction

\[
L_p(E,s) = (1 - a_p p^{-s} + p^{1-2s})^{-1}
\]

and \( a_p = p + 1 - |E(F_p)| \). Then the far-reaching conjecture of Birch and Swinnerton-Dyer suggests that \( L(E,1) \) should be a certain nonzero rational multiple of \( \Omega \).

More generally, if \( E \) is an elliptic curve over a number field \( k \), then its set \( E(k) \) of rational points over \( k \) has the structure of a finitely-generated abelian group, and if \( r \) is the rank of this group, then the Birch and Swinnerton-Dyer conjecture asserts that \( L(E/k, s) \) has a zero of order \( r \) at \( s = 1 \), and the
leading coefficient of its power series is a certain nonzero rational multiple of a factor coming from periods of $E$ over the archimedean places of $k$, and a factor coming from heights of a generating set of $E(k)$.

At present, the assertion regarding the ranks is known when $k = \mathbb{Q}$ and $L(E,s)$ has a zero of order $\leq 1$ at $s = 1$; this is a combination of results of Gross and Zagier in 1983; Kolyvagin in 1990; and Wiles, Breuil, Conrad, Diamond, and Taylor in 1999.

The 1999 result is the assertion that all elliptic curves over $\mathbb{Q}$ are modular: there is an $N$ for which the modular curve $X_0(N)$ admits a non-constant morphism to $E$.

Zhang’s third lecture centred on recent efforts to extend the Birch and Swinnerton-Dyer conjecture to more general situations.

First, let $Y = X_1 \times X_2 \times X_3$ be the product of three curves over a number field $k$ and let $CH^2(Y)^0$ denote the kernel of the rational map $CH^2(Y) \to H^2(Y)$ from the Chow group of codimension-$i$ cycles on $Y$ modulo rational equivalence to cohomology. As a generalization of the Birch and Swinnerton-Dyer conjecture, the Beilinson-Bloch conjecture asserts that the rank of $CH^2(X)^0$ is finite, and equals the order of vanishing of the $L$-function $L(s, H^{2i-1}(Y)(n))$ at $s = i + 1$.

Specializing this to $i = 2$, let $X$ be a smooth projective curve over a number field $k$, and fix $e \in X(k)$. There is a Gross-Schoen cycle $\Delta_e \in CH^2(X^3)^0$ defined by

$$\Delta_e = \{(x,x,e): x \in X\} - \{(x,e,x): x \in X\} - \{(e,x,x): x \in X\} + \{(x,e,e): x \in X\} + \{(e,e,e): x \in X\}.$$

Now assume that $X$ is a Shimura curve, and choose cusp forms $f_1, f_2, f_3$ of weight 2. These define algebra homomorphisms $T \to C$, where $T$ denotes the Hecke algebra, and $T^3$ acts on $CH^2(X^3)^0$ by letting each copy of $T$ act on one factor of $X^3$. This gives a cycle $\Delta_{f_1 \cdot f_2 \cdot f_3}$ that is closely related to $\Delta_e$, and after extending it to a cycle in Arakelov theory, its height $\Delta_{f_1 \cdot f_2 \cdot f_3} \cdot \Delta_{f_1 \cdot f_2 \cdot f_3}$ is a number which the Gross-Kudla conjecture asserts is related to $L'(2f_1 \times f_2 \times f_3)$ in much the same way as the Birch and Swinnerton-Dyer conjecture relates the derivative $L'(E,1)$ to the height of a generating rational point when the rank of that elliptic curve equals 1.

As an application of this conjecture, Zhang then showed how a generalization of Grothendieck’s “standard conjectures” due to Gillet and Soulé overlaps with the Riemann hypothesis for $L(s, f_1 \times f_2 \times f_3)$.

As these lectures showed, some of Euler’s ideas have come very far, but still have a long way to go.

Paul Vojta

DISTINGUISHED LECTURE SERIES

Yum-Tong Siu, (Harvard)

Multiplier Ideal Sheaves - an Interface Between Analysis and Algebraic Geometry

November 12–14, 2008

Yum-Tong Siu, William Elwood Byerly Professor of Mathematics at Harvard, has been a dominant figure in geometric complex analysis for over a quarter of a century. His theme in this set of lectures was multiplier ideal sheaves as an interface between analysis and algebraic geometry.

Multiplier ideal sheaves identify the location and the extent of failure of estimates in partial differential equations and describe the degeneracy from instability in geometric analysis. They have been applied to solving a number of outstanding conjectures in algebraic geometry and also opened up a new avenue of applying algebraic geometric methods to solvability and regularity problems of partial differential equations.

Siu discussed how the idea of multiplier ideal sheaves arose historically from two different perspectives, explained their use in complex analysis and algebraic geometry, and indicated many open questions where the use of multiplier ideal sheaves may yet provide the key ingredient to their solution.

To see how multiplier ideal sheaves arose from the perspective of failure of estimates in partial differential equations, we look at the regularity question of the $\overline{\partial}$-Neumann problem.
Consider the $\bar{\partial}$-equation $\partial u / \partial z^j = f_j$ on a domain $D$ in $\mathbb{C}^n$ for the unknown function $u$ when the given functions $f_1, \ldots, f_n$ satisfy the compatibility condition $\partial f_j / \partial z^i = \partial f_i / \partial z^j$.

For the $\bar{\partial}$-equation on a weakly pseudoconvex domain (which is the complex analog of a weakly convex domain), Joseph J. Kohn posed the regularity question of the $\bar{\partial}$-Neumann problem which asks whether $u$ is smooth up to the boundary when $f$ is assumed smooth up to the boundary. A sufficient condition for the regularity is that a certain estimate known as the subelliptic estimate holds for the test functions for the weak solution of the equation. When the subelliptic estimate is not yet known to hold, we multiply the test function first by a function known as a multiplier before doing the estimation in order to make sure that the estimate holds for the product. The sheaf of germs of such multipliers is the multiplier ideal sheaf. The zero-set and the vanishing order of the multiplier ideal sheaf identify the local position and the extent of the failure of estimates. The multiplier ideal sheaf corresponds to iteration of many levels of micro-local analysis. Unlike micro-local analysis which treats all the directions the same way, the multiplier ideal sheaf technique distinguishes certain directions and jet directions.

The second perspective of the multiplier ideal sheaves is related to the notion of stability. When a differential equation is solved by using the continuity method or by using an evolution equation such as the heat equation, the most crucial part of the problem is the convergence of the limit or the closedness question. In order to get the convergence of some subsequence in the norm under consideration, according to the technique of Ascoli-Arzela, we try to get a uniform bound in some stronger norm. For example, in order to get the $L^2$ convergence for some subsequence, we can use a uniform bound of the $L^2$ norm for derivatives up to the first order. The $L^2$ norm for first-order derivatives scales differently from the $L^2$ norm without derivatives. To use ever smaller coordinate charts with varying scaling to normalize the stronger norm, such as the $L^2$ norm for derivatives up to the first order, is the same as estimating the stronger norm after inserting a multiplier to account for the varying scaling. In the limit the base manifold jumps to a new structure defined by the multiplier ideal sheaf and becomes unstable. In this perspective the multiplier ideal sheaf is known as the destabilizing subsheaf. The work of Alan Nadel on the problem of the existence of Kähler-Einstein metrics on Fano manifolds and the work of Donaldson and Uhlenbeck-Yau on the relation between Hermitian-Einstein metrics for vector bundles and their stability are used as examples to illustrate this perspective of the multiplier ideal sheaves.

The technique of multiplier ideal sheaves has been applied to obtain effective results in algebraic geometry, such as the Fujita conjecture, the effective Matsusaka big theorem, and the effective Nullstellensatz. Both the Fujita conjecture and the effective Matsusaka big theorem are effective versions of Kodaira’s embedding theorem, which states that for a positive line bundle $L$ on a compact complex algebraic manifold $X$, global holomorphic sections of $mL$ over $X$ can distinguish points and give local coordinates when $m$ is noneffectively sufficiently large. The Fujita conjecture states that when the complex dimension of $X$ is $n$, at every point $P$ of $X$ there is a global holomorphic section of $mL + K_X$ which is nonzero at $P$ for $m \geq n+1$. Moreover, global holomorphic sections of $mL + K_X$ over $X$ can distinguish points and give local coordinates for $m \geq n + 2$. The effective Matsusaka big theorem gives an explicit bound $m_0$ depending on the Chern numbers $L^n$ and $L^{n-1}K_X$ such that global holomorphic sections of $mL$ over $X$ can distinguish points and give local coordinates for $m \geq m_0$. The effective Nullstellensatz is the effective version of the Hilbert Nullstellensatz.

For the other direction the method of multiplier ideal sheaves makes it possible to apply algebraic geometric methods to regularity problems in partial differential equations as illustrated by the algorithm which Kohn introduces to generate multipliers for the regularity question of the $\bar{\partial}$-Neumann problem. In his algorithm new multipliers can be constructed by applying some process of differentiation to known multipliers so that, under some geometric condition involving a uniform bound for the order contact between the boundary of the domain and local complex-analytic curves, the subelliptic estimate can be shown to hold by generating the constant function 1 as a multiplier from the algorithm. The relation between the estimate and the geometric condition of the boundary comes from the idea that the directions of failure of estimates given by the multiplier ideal sheaves cannot be integrable in the sense of Frobenius.

Finally, it should be mentioned that the techniques of multiplier ideal sheaves are central to Siu’s recent work on the deformational invariance of the plurigenera and the finite generation of the pluricanonical ring.

Siu’s beautifully constructed lectures gave a very nice overview of how the techniques of multiplier ideal sheaves
provide a unifying framework in which to understand many problems which arise in analysis and geometry, and how the structure of the sheaf inherits structure coming from the original situation. The multiplier ideal sheaf effectively captures the geometry of the degeneracies/singularities and even encodes the microlocal nature of the problem.

John Bland

Jean-Christophe Yoccoz, (Collège de France)
Uniformly hyperbolic SL(2,R) cocycles
May 25–27, 2009

In this series of three one-hour lectures, Jean-Christophe Yoccoz motivated and proved several basic results in a new direction in dynamics, largely developed by him, Artur Avila, and Jairo Bochi in a paper posted to the arXiv (http://arxiv.org/abs/0808.0133). For $X$ a compact metric space, $f : X \to X$ a homeomorphism, and $\pi : E \to X$ a vector bundle on $X$, a linear cocycle over $f$ is a vector bundle map over $f$ which is linear and depends continuously on $x \in X$. The familiar example is the tangent bundle and the familiar example is the tangent bundle and the tangent map over a $C^1$ diffeomorphism of a manifold. In this setting, a linear cocycle $F : E \to E$ is uniformly hyperbolic if and only if there exists a continuous splitting of $E_x = F^{-1}(x)$ into a stable manifold $E_x^s$ and an unstable manifold $E_x^u$ on which $F^n$ is contracting, respectively expanding, uniformly with respect to $x$. In order to recognize uniformly hyperbolic cocycles, Yoccoz generalizes the Alekseev cone criterion: A linear cocycle is uniformly hyperbolic if to every $x \in X$ one can associate an open cone $C(x)$ of directions in $E_x$ so that $F_x(C(x)) \subseteq C(f(x))$. In order to establish basic principles, we specialize to the trivial vector bundle $E = X \times \mathbb{R}^2$ with the map $F(x, v) = (f(x), A(x)v)$ where $A : X \to \text{SL}(2, \mathbb{R})$ is continuous.

Iterates must be computed along orbits: For $n \geq 0$, $F^n(x, v) = (f^n(x), A^{(n)}(x)v)$, where $A^{(n)}(x) = A(f^{n-1}(x)) \cdots A(f(x))A(x)$, and similarly for $n < 0$. In this case, the space of directions in $\mathbb{R}^2$ is the projective space $\mathbb{P}(\mathbb{R}) \cong S^1$, and the cocycle $F$ is called uniformly hyperbolic just in case the norm of $A^{(n)}$ grows exponentially in $n$.

Yoccoz digresses to motivate why one should study $\text{SL}(2, \mathbb{R})$ cocycles in particular at all. For example, they arise in the study of Schrödinger operators with quasiperiodic potential.

Given a continuous potential $V$ from the $d$-dimensional torus $T^d$ to $\mathbb{R}$, one can introduce an operator $H = H_{V, \omega, \theta} : L^2 \to L^2$ defined by $(Hu)(n) = u_{n+1} + u_{n-1} + V(\theta + n\alpha)u_n$.

The analysis of the spectrum of such an operator reduces to analyzing a particular matrix $A_{\lambda, V}(\theta) \in \text{SL}(2, \mathbb{R})$: $\lambda$ is in the spectrum of $\mathcal{H}$ if and only if the cocycle over $\theta \to \theta + \alpha$ defined by $A_{\lambda, V}$ is uniformly hyperbolic. Yoccoz suggests that rather than study cocycles over quasiperiodic dynamics, one study the cocycles arising from a chaotic dynamical system. To that end, let $\mathcal{A}$ be a finite alphabet of $N$ letters, $\Sigma = \mathcal{A}^Z$, and $\sigma : \Sigma \to \Sigma$ the full shift map $(\sigma(x))_n = x_{n+1}$.

We specialize to the cocycles $F$ over $\sigma$ where $A(x)$ depends only upon the coordinate $x_0$ of $x \in \Sigma$. This amounts to choosing matrices $A_1, \ldots, A_N \in \text{SL}(2, \mathbb{R})$ and $F_x$ is multiplication by $A_i$ when $x_0$ is the $i$th element of $\mathcal{A}$. So, the space of parameter of cocycles is canonically isomorphic to $\text{SL}(2, \mathbb{R})^N \cong \text{SL}(2, \mathbb{R})^N$ and the operator $A^{(n)}(x)$ is a product of some of $A_1, \ldots, A_N$.

Uniform hyperbolicity in this setting means that we can form product words any way we like in the alphabet $A_1, \ldots, A_N$ and the norms of the products will grow exponentially with the length of the word.

The locus $\mathcal{H}$ of parameters in $\text{SL}(2, \mathbb{R})^N$ for which the corresponding cocycle is uniformly hyperbolic is an open subset of the parameter space. In analogy with other studies of dynamical systems (holomorphic dynamics comes to mind), we are interested in questions about the components of this locus, the boundaries of the components, and the boundary of the locus itself. One can ask the following questions given an alphabet $\mathcal{A}$.

1. Are the boundaries of components of pairwise $\mathcal{H}$ disjoint?
2. Is the union of the boundaries of the components of $\mathcal{H}$ equal to the boundary of $\mathcal{H}$?
3. The elliptic locus $\mathcal{E}$ is the set of parameters for which there is a periodic point in $\Sigma$ corresponding to an elliptic matrix (i.e., matrices which fix no direction). This is an open set whose closure is the complement of $\mathcal{H}$. Is the closure of $\mathcal{H}$ equal to the complement of $\mathcal{E}$?
4. Are the components of \( H \) bounded modulo conjugacy? (That is, is there a bounded subset of each component \( H \) of \( H \) which meets every conjugacy class of elements of \( H \)?)

In Lecture I, Yoccoz provided motivation and context, defined the tools, and stated some of the theorems partially answering the above questions. In brief, the answers are “yes” for the full 2-shift, and largely open for the 3-shift and higher, and largely open for subshifts of finite type, even for alphabets of two symbols. In lectures II and III, Yoccoz presented proofs of some examples of typical lemmas and theorems in this setting, and described more fully the profound, yet simple, tools employed.

As the major tool, Yoccoz introduced the previously mentioned generalization of the cone criterion: a multicone \( M \) is a nonempty open subset of \( \mathbb{P}^1(\mathbb{R}) \) with finitely many components having pairwise disjoint closures. A multicone with one component is an ordinary cone. The theorem connecting multicones to hyperbolicity is the following.

**Theorem 1.** The cocycle \( A_1, \ldots, A_N \) over \( (\Sigma, \sigma) \) is uniformly hyperbolic if there exists a multicone \( M \) such that for all \( i \in \mathcal{A} \), \( A_iM \) is compactly contained in \( M \). (The definition and theorem can be extended to subshifts by taking into account allowed transitions.) One might hope to recognize uniform hyperbolicity only by looking at the dense set of periodic points in \( \Sigma \). This is partially true, but there is a more subtle obstruction to hyperbolicity than periodic orbits with non-hyperbolic associated cocycles. Yoccoz is able to characterize the only ways out of hyperbolicity, and proved the following theorem in Lecture III, though only for the case of a full shift (sparing us notational complexity).

**Theorem 2.** Fix any subshift of finite type \( (\Sigma, \sigma) \), and let \( \mathcal{H} \) be the associated locus of uniform hyperbolicity. Suppose \( (A_1, \ldots, A_N) \) belongs to the boundary of component \( H \) of \( \mathcal{H} \). Then at least one of the following holds:

1. There is a \( k \)-periodic point \( x \) such that \( A(k)(x) \) is not hyperbolic (in fact is \( \pm \text{id} \) or parabolic, i.e., fixing exactly one direction), or
2. there is a heteroclinic connection.

I will omit the complex, yet natural, definition of a heteroclinic connection, and refer the reader to the paper. All in all, Yoccoz provided a challenging and illuminating series of lectures that excited the curiosity of many in the audience, among them the writer and his student.

*John Mayer*

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**DISTINGUISHED LECTURE SERIES IN STATISTICAL SCIENCES**

**David Spiegelhalter** (Cambridge)

*Analysing Uncertainty and Visualising Uncertainty*

May 27–28, 2009

Spiegelhalter is a Fellow of the Royal Society of London and was recently appointed to an unusual academic post: he is the Winton Professor for the Public Understanding of Risk in the Statistical Laboratory at the University of Cambridge. He is also a senior scientist in the Biostatistics Unit of the Medical Research Council. As the Winton Professor, he leads a collaborative team that engages with the public, with schools, with academic colleagues in many disciplines, and with the press. In the week or two before his visit to Toronto he published an article in *The Times* on the swine flu epidemic, gave as well radio interviews on forecasting football results for the Premiership weekend and comments on the MRC publication of a report from the “Million Women Study” concerning the risk of cancer associated with moderate alcohol intake.

His first talk described the Winton program’s efforts at improving the public understanding of the quantitative aspects of risk and uncertainty, efforts which include educational lectures and workshops at schools and universities, engagement with the media and with people who want to communicate risk, inter-disciplinary research, and the website [www.understandinguncertainty.org](http://www.understandinguncertainty.org). In his talk, he considered four types of uncertainty, with increasing levels of complexity. Uncertainty about specific future events can be analysed using probabilistic models – the...
topic chosen to illustrate this was the 6/49 Lottery. Graphical presentations of lottery results help people to understand that the patterns that occur in random events follow quite predictable laws. Uncertainty about quantities in a model is typically presented as an estimate of standard error or interval of plausible values for an estimated effect of interest, but this source of uncertainty may be dominated by other sources, including a range of systematic biases. Several of these biases were illustrated in the context of meta-analysis, or “study of studies”. Spiegelhalter also described the models he used for the football league predictions mentioned above. Pleasingly, he scored 9/10 correct predictions for the Premiership weekend in May, beating the BBC’s expert, who scored 7/10! The third type of uncertainty, about the structure of the ‘best’ model, was discussed in the context of Bayesian inference and Bayesian model selection and illustrated with data from the IPCC’s projections on the impacts of carbon dioxide emissions on global surface warming. Finally he discussed the hardest aspect of uncertainty, which derives from both recognized and unrecognized inadequacies of our best models. This aspect is especially important in tackling some of the biggest problems we face today – climate change being a very prominent example.

The second talk, on “Visualising Uncertainty”, discussed the problems of conveying to a broad audience the ideas developed in the first talk. The same quantitative information can be conveyed in a number of ways: for example the World Cancer Research Fund report in 2007 stated that an intake of 50g of processed meat per day increased the risk of colon cancer by 20%. Since the lifetime risk is approximately 5%, this intake would raise the risk to 6%; the absolute risk increase is 1%. Another view of the same data is that 100 similar people eating 50g of processed meat each day would lead to one additional case of colon cancer. Each of these interpretations can be obtained and visualized on the Understanding Uncertainty website. There are many other aspects of communicating and visualizing risk and uncertainty, and a good deal of psychology and cognitive science comes into the discussion as well. One proposal that is gaining in popularity is to convey risk using the “micro-mort”: a one-in-a-million chance of dying. On this scale you can travel 200 miles in a car per micromart, but just 20 miles on a bicycle, and considerably fewer on a motorcycle. Spiegelhalter illustrated a variety of graphical displays that convey uncertainty in innovative ways including fan charts, density strips and funnel plots. One of the most inspiring is the set of dynamic scatter plots available on Hans Rosling’s site www.gapminder.org.

Spiegelhalter’s talks, to a crowded seminar room, engaged and enlightened the audience, and left us all with much to think about, often about topics that we thought we had understood well. His work on the public understanding of risk is very important for a reasoned public discussion of complex issues.

Nancy Reid

FIELDS INSTITUTE ANNUAL GENERAL MEETING LECTURE

Matheus Grasselli (McMaster)

After the Storm: Current Perspectives in Financial Mathematics

Held at the Fields Institute

June 25, 2009

Each year, the occasion of the Fields Institute annual general meeting allows a general audience to delve into the mathematics of the institute’s thematic programs. This year, Matheus Grasselli, one of the organizers of the upcoming 2010 thematic program Quantitative Finance: Foundations and Applications, gave the audience a fascinating and witty overview of the current financial crisis, as well as a preview of the activities to take place in 2010 during this program.

Matheus Grasselli described the role of mathematics in the vast expansion of the financial sector, since the groundbreaking work of Black, Scholes, and Merton on the rational pricing of options. He explained the evolution of the 2007 meltdown in housing prices, its impact on mortgage backed securities and CDS’s (credit default swaps), as well as on complex products incorporating credit risk, such as CDO’s (collateralized debt obligations). The collapse of the credit market impacted first general borrowing and then the equity markets as a whole, which remained severely depressed at the time of the Fields meeting. In describing the progress of this crisis, he fastened blame securely on those who misused these derivative instruments, or who ignored known uncertainties about model parameters, in the pursuit of excessive returns.

Turning back to mathematics, he discussed the progress in the field that arose from earlier thematic programs in mathematical finance at other institutes, as well as the role of the Fields quantitative finance seminar in stimulating the financial community in Toronto. In describing a number of emerging issues (including some brought to light by the current downturn), he showed why the field of quantitative finance is ripe for another concentrated thematic semester, this time at the Fields Institute.
Lectures and Special Events

That semester will see many of the field’s top researchers in attendance at Fields for various periods. A number of truly distinguished lecture series will take place, as well as four academic conferences, plus a number of shorter industrial-academic forums. The semester will conclude with the biannual congress of the Bachelier Society, the premier international event in mathematical finance. Matheus Grasselli’s wide-ranging talk itself concluded with the audience eagerly anticipating what looks to be an outstanding thematic program.

Tom Salisbury
The second week of the summer school had the same format, consisting of three series of five lectures by Kannan Soundararajan, Francesco Amoroso and Andrew Granville. Soundararajan gave a series of lectures on L-functions. He discussed probabilistic models, the distribution of values, and moments of L-functions. In his final lecture Soundararajan presented exciting new work on weak sub-convexity for L-functions. In a complementary series of lectures Granville gave a comprehensive overview of the theory of sums of multiplicative functions. He discussed many advances obtained jointly with Soundararajan, including their recently introduced notion of pretentiousness. Amoroso’s lectures first dealt with Lehmer’s problem which asks for a lower bound for the Mahler measure of non-zero algebraic numbers which are not roots of unity. Then, going to higher dimensions, he defined the height of an algebraic sub-variety of an algebraic torus and proved several fascinating results, mostly due to him and Sinnou David, concerning generalizations of Lehmer’s problem in this setting.

The conference took place in the pleasant setting of Ottawa. The student accommodations were well-situated next to the lecture rooms and library. In addition, they were near many famous landmarks of Ottawa including Parliament Hill and the Museum of Civilization. All of this created a motivating and congenial environment. As the courses were finished each day at 3:20 pm, the students had the opportunity to review the lectures of the day, ask questions, and hold discussions with the lecturers. During the two weeks of school the interactions among participants increased both academically and socially. In the evenings and weekends there were a number of organized and spontaneous activities. Some of these included the Canada Day festivities on Parliament Hill, biking in Gatineau park, and organized soccer matches. There were also a luncheon and two suppers organized for the whole group.

The organizers of this conference were very happy with the large number of participants and by their enthusiasm and eagerness to learn. In addition, we were pleasantly surprised by the diverse representation from 14 countries. We believe that this summer school was inspiring and helpful for the participants’ research and will lead to further advances in the fields of analytic number theory and Diophantine approximation.
The following day, Nantel Bergeron (York) introduced some surprising and interesting ways of looking at permutation groups and Edward Barbeau (Toronto) spoke of his experience going from undergraduate student to professor in mathematics and challenged the audience with a few math puzzles. Barbara Keyfitz (Fields) provided insights on how partial differential equations feature in the workings of traffic lights. In the closing lecture of the conference Alexander Holroyd (UBC) explained and showed some beautiful examples of cellular automata.

Its continuity being ensured by the CMS Student Committee, the CUMC is one of the main events of undergraduate mathematics in Canada and this year was no different, as students got to learn some new mathematics and talk to their peers as well as experienced professors from all over Canada. The conference will be held at Carleton University next year.

CUMC 2008 was supported by the CMS, the Fields Institute, CAIMS, AARMS, PIMS, SSC, the MITACS Student Advisory Committee, and the University of Toronto.

Iva Halacheva

Invited Speakers:
- Dror Bar-Natan (Toronto) 
  Solving Rubik’s Cube
- Edward Barbeau (Toronto) 
  From student to retired professor: perspectives on a half-century of mathematics
- Nantel Bergeron (York) 
  Le Monde des permutations
- Alexander Holroyd (UBC) 
  Is seeing believing? Cellular automata in theory and experiment
- Barbara Keyfitz (Fields) 
  Analysis and modeling with nonlinear partial differential equations; or how I became resigned to waiting at traffic lights

Student Speakers:
- Faisal Alfaisal 
  The invariant subspace problem
- Devon Armstrong 
  Optimization of the Czochralski method for InSb crystal growth
- Taylor Barrett 
  Total Positivity of Matrices
General Scientific Activities

Michael Barriault  
*Numerical Methods for Boundary Condition Problems*

Gary Bazdell  
*Introduction to design theory*

Rosalie Bélanger-Rioux  
*Spectrum and expansion of biregular graphs*

Farzin Berekat  
*Equality of Ribbon Schur Q-Functions*

Victor Bomers  
*Probabilistic inference on ChIPsequencing: A statistical approach to modelling genomewide maps of chromatin states*

Joe Boutilier  
*Chemometrics applications to the multivariate calibration of overlapped 1H NMR spectra of complex mixtures*

Leila Bridgeman  
*Why Airplanes Fly: A Brief Introduction to Fluid Dynamics*

Pietro-Luciano Buono  
*Graduate Studies in Modelling and Computational Science at UOIT*

Natalie Campbell  
*Sign Pattern Analysis and Classification*

Philippe Carphin  
*Escher-Droste*

Richard Cerezo  
*Models and Bifurcations*

Gregory Chambers  
*Dividing a Cake without Envy*

Vincent Chan  
*Equivalents of the Axiom of Choice*

Oliver Cheng  
*Mathematics of Juggling*

Paul Cheng and Tom Du  
*Mathematics of Voting*

Christopher Chlebovec  
*Sums of Cantor Sets*

Alexandra Chouldechova  
*Lies and Statistics*

Michael Christoff  
*Algebraic Topology and Distributed Computing*

Peter Crooks  
*A complex-analytic approach to proving the fundamental theorem of algebra*

Iain Crump  
*Graph Convexities and Elimination Orderings*

Michelle Cylwa and Laura Hurajit  
*Transient Probabilities for M/M/1/c queue via path counting (Queueing theory)*

Bradley Dart  
*Loops, Rings, and Other Things*

Colin Decker  
*Polynomial Approximation*

Kael Dixon  
*An introduction to differential forms and integration*

Arron Dos Remedios  
*Online Algorithms for Multi-Unit Auctions with Unknown Supply*

Julia Evans  
*A foray into algebraic graph theory*

Wei Fan  
*Summation*

Jérôme Fortier  
*Contemplating Incompleteness*

Maxime Fortier Bourque  
*Higher-order pseudospectra*

Parker Glynn-Adey  
*Numeration Systems*

William Gollinger  
*When is a 3-sphere not a 3-sphere?*

Gurleen Grewal  
*A game theoretic perspective on peer-to-peer systems: Incentives and payoffs*

AJ Guillon  
*Pi Calculus*

Ezra Hahn  
*Farey Sequences and Ford Circles*

Iva Halacheva  
*Reidemeister’s theorem and more on knots*

Charlotte Haley  
*The Stirling Numbers of the second kind, Multinomial Coefficients, and a Generalized Pascal’s Triangle*

Brad Hannigan-Daley  
*Generalized abstract nonsense*
Paul Hanz
*Optimal Design of a Biolistic Gene-Particle Delivery System*

Doki Hwang and Matthew Gregson
*The Sky is Falling*

Steven Karp
*Forbidden Configurations*

Olivier Lafleur
*An interesting decomposition of GL(2,Q)*

Stacey Lamont
*Graph Reconstruction*

Alex Lang
*Introduction to the untyped lambda calculus*

Alexander Leithead
*Bases of the Weyl Module*

Janet Li
*Fractals and Dimension*

Chester Lipka
*An introduction to matroids and Rota’s conjecture*

Julie Mallet-Paret
*Kasiski and Friedman attacks as a means to decode Vigenere ciphers*

Kathryn Mann
*An Introduction to Cut and Paste Topology*

Justin Harry Martel
*Some transcendental Sums (or how you know a number)*

Terri May
*The strong metric dimension of distancehereditarygraphs*

Shilan Mistry
*Hausdorff Measure*

Jonathan Moscovici
*Doughnut Go In There: Symmetry Groups and Dehn Fillings*

Sina Motamedi
*Incompleteness – why Godel is misunderstood*

Nikita Nikolaev
*On the Equation of Continuity and the Dynamics of Continuous Media*

Robert Parkinson
*Introduction to Morse Theory*

Mark Pavlovski
*P-ordering and its Connection to Integer Valued Polynomials*

Michael Pawliuk
*Amenable groups and Folner nets*

Louis-Xavier Proulx
*En route vers le chaos*

Benoit Pouliot
*Méthode de redimensionnement d’images*

Oren Rippel
*An Introduction to Fluid Mechanics*

Annie Raymond
*Small Chystal Rank of Fractional Polytopes*

Alissa Razy
*Toto, I have a feeling we’re not in Kansas anymore: Understanding Tornadoes*

Carol Ross
*An Introduction to Metric Geometry and Length Structures*

Christian Roy
*Attack of the Tyranotorus : An overview of torus-based cryptography*

Veronica Sabelnykova
*Predicting the mutation of Influenza A virus*

Chandrika Sadanand
*Group theory and Rubik’s cubes*

Yuval Sanders
*An introduction to quantum entaglement*

Malcom Sharpe
*Good integral solutions to feasible network flow problems*

Alexandre St-Onge
*Euclidean and Hyperbolic Geometries*

Phoebe Su
*Mathematics and Metaphysics*

Yi Su
*Random Graph Theory*

Michael Szestopalow
*Pairwise Independene and the Max Cut Problem*

Brett Teeple
*Differential Galois theory applied to mathematical physics*

Jenna Tichon
*Random Graphs and the Probabilistic Method*

Jeffrey Tsang
*Evolved Art, Planetary Motion and Dynamical Systems*
General Scientific Activities

Graeme Turner
*A glance at Invariant Rings of Permutation Groups*

Polina Vinogradova
*Groups Acting on Trees*

Yu Wang
*On a simple intrinsic proof of Gauss-Bonnet theorem*

Yehua Wei
*The Steiner Tree Problem in Graphs*

Margaret Wong
*How to Count with Burnside’s Lemma*

Katherine Woodard
*Fibonacci Numbers and the Binet Formula*

Malik Younsi
*Banach algebras and the exponential spectrum*

Meeting of the Canadian Number Theory Association
July 13–18, 2008
Held at the University of Waterloo

Organizers: Kevin Hare, Wentang Kuo, Yu-Ru Liu, David McKinnon, Michael Rubinstein and Cameron Stewart (Waterloo)

The biennial meeting of the CNTA has become one of the largest conferences in number theory in the world, and is regularly attended from all over the globe. The tenth meeting attracted over 200 attendees from outside Waterloo, and was well attended by local mathematicians, graduate students, and even several undergraduates.

The purpose of CNTA meetings is to bring together a wide variety of leading number theorists, junior researchers, and graduate students to discuss all areas of number theory. The tenth meeting had talks in computational number theory, random matrix theory, arithmetic geometry, the arithmetic of modular forms, diophantine geometry and equations, transcendence theory and diophantine approximation, the circle method, rational points on algebraic varieties, and $L$-functions, as well as connections between number theory and mathematical logic, dynamical systems, and cryptography.

In fact, CNTA X featured eight plenary lectures, forty invited lectures, and over sixty contributed talks in the space of a week. The talks covered the breadth of number theory from computing moments of $L$-functions to rational points on algebraic surfaces to Iwasawa theory to transcendence theory and beyond – virtually every branch of number theory is represented at CNTA meetings, including applications such as cryptography. In 2008, there was a school for graduate students on analytic number theory and diophantine approximation in Ottawa that took place during the two weeks immediately preceding the CNTA meeting, and there were a significant number of participants who took part in both events.

In addition, the Ribenboim Prize is awarded at CNTA meetings for distinguished research in number theory by a mathematician who has strong ties to Canada. In 2008, Paulo Ribenboim himself presented the Ribenboim Prize to Adrian Iovita of Concordia University, who gave his prize lecture on $p$-adic Hodge theory.

David McKinnon

Speakers: (as listed on program itinerary)
Peter Hilton (Binghamton)
*Breaking highgrade German ciphers in WWII*

Henri Darmon (McGill)
*Rational points on elliptic curves and algebraic cycles*

Andrew Granville (Montreal)
*Pretentiousness in analytic number theory. Zeros of $p$-adic Forms*

Roger Heath-Brown (Oxford)
*Zeros of $p$-adic Forms*

Ram Murty (Queen’s)
*L-series and Transcendence*
Bjorn Poonen (MIT)  
*Undecidability in number theory*

Carl Pomerance (Dartmouth)  
*Counting fields*

Alice Silverberg (UC Irvine)  
*Title not available*

Trevor D. Wooley (Bristol)  
*Meeting and beating the limits of the circle method for systems of cubic diophantine equations*

Jean-Paul Allouche (CNRS)  
*A set of binary sequences, unimodal functions, beta-expansions and Diophantine approximation*

Francesco Amoroso (Caen)  
*Some remarks on relative Lehmer*

A. Baragar (University of Nevada Las Vegas)  
*Vector heights on K3 surfaces*

Valentin Blomer (Toronto)  
*Sums of Hecke eigenvalues over quadratic polynomials*

Andrew Booker (Bristol)  
*Computing automorphic forms*

Tim Browning (Bristol)  
*Rational points on cubic hypersurfaces*

Jörg Brüdern (Stuttgart)  
*Approximations to Weyl sums*

Yann Bugeaud (Strasbourg)  
*Diophantine approximation and Cantor sets*

Imin Chen (Simon Fraser)  
*On the equation $x^2 - 2 x^6 = y^n$.*

B. Conrey (American Institute of Mathematics)  
*Title not available*

Chantal David (Concordia)  
*Frobenius Fields and Frobenius Rings of Elliptic Curves*

Christophe Delaunay (Lyon 1)  
*Remarks on the discretisation process*

Jan-Hendrik Evertse (Leiden)  
*Approximation of complex algebraic numbers by algebraic numbers of bounded degree*

J. Ellenberg (Madison)  
*Title not available*

David W. Farmer (American Institute of Mathematics)  
*Some calculations involving higher-rank $L$-functions*
interactive seminars run by PhD students on the topics of cancer and chronic care, high-level healthcare applications and hybrid simulation models. Hybrid simulation models based on system dynamics and discrete event approaches drew a lot of questions and discussion. These models seem to be promising in merging operational and strategic optimization decisions in one model package. The participants had the opportunity to continue the discussions on the day’s presentations and network with colleagues at a dinner hosted by Michael Carter (Toronto).

The second day of the workshop started with an inspiring presentation by Murray Côté (Colorado) on feasibility models for healthcare resource planning. Côté’s tutorial was made possible by the videoconferencing facilities available at the Fields Institute, as Côté was forced to join from the safety of his home in Denver following an emergency aircraft landing on his way to Toronto. This presentation was followed by another set of PhD student led interactive sessions on the applications of operations research in disease planning, patient and wait list management. The presentation on developing quantitative measurement approaches to prioritize surgical wait lists aptly demonstrated the difficulty of quantitatively assessing the urgency of patients by involving the audience in a mock wait list decision process.

At the end of the two-day workshop, the participants relaxed at a Blue Jays game. Due to the success of this event, ORAHS is already planning the next workshop to be held in Leuven, Belgium in the summer of 2009.

The event was sponsored by the Centre for Research in Healthcare Engineering, Fields Institute, MITACS, European Operational Research Societies (EURO), SAS Institute, Cancer Care Ontario, Courtyard Group, Hay Group, Siemens and the Canadian Operational Research Society.

Mike Carter

Speakers:
Kirandeep Chahal (Brunel)
_A symbiosis between system dynamics and discrete event simulation in healthcare_

Murray Côté (Colorado)
_A feasibility model for healthcare resource planning:_
_Applications and potential future research opportunities_

David Hutton (Stanford)
_Cost effectiveness of Hepatitis-B catch-up vaccination among children and adolescents in China_

Nina Snaith (Bristol)
_Recent applications of random matrix theory in number theory_

Hugh Williams (Calgary)
_A Cubic Extension of the Lucas Functions_

Jing Yu (National Tsing Hua University)
_A Tale of Two Motives: Gamma and Zeta in positive characteristic_

Jiu-Kang Yu (Purdue)
_A dyadic exercise in the construction of supercuspidal representations and types_

ORAHS PhD Workshop
July 24–25, 2008
Held at the Fields Institute

Organizers: Dionne Aleman, Ali Vahit Esensoy and Daphne Sniekers (Toronto)

This two-day workshop was organized as a precursor to the Operational Research Applied to Health Services (ORAHS) 34th annual conference held at the University of Toronto. ORAHS is a special interest group of the Association of European Operational Research Societies (EURO), and aims to provide a network for researchers involved in the application of systematic and quantitative analysis in support of planning and management in the health services sector. Operational research methods can help the health services sector, which is in need of quantitative tools to help guide decisions in an environment of the growing demands on the healthcare system, emerging technologies and shifting policy positions.

The goal of this event was to provide an intimate forum for current and recently graduated PhD students to showcase and discuss their research. The workshop was composed of tutorials and seminars focusing on operational research and healthcare topics run by prominent researchers in these fields. There were 38 researchers from North America and Europe who participated in the event.

The first day of the event started with a tutorial by Steven Schechter (UBC) on Medical Decision Making using mathematical models. The tutorial introduced various modeling techniques that help physicians and patients determine the best course of treatment, including decision trees, Markov models, and Monte Carlo simulations with examples on applying these techniques to decisions regarding liver transplantation and HIV treatment. This was followed by
The 2008 Society for Mathematical Biology Conference held July 30 – August 2 brought together 330 mathematicians, scientists, statisticians and computer scientists (and of course an entire spectrum of hybrids of these) in Toronto, a city as diverse as the backgrounds of the meeting’s participants. Those able to arrive early on July 29th enjoyed a pre-conference reception at Fields. Early the next morning was the official Conference commencement at the Medical Sciences building at the University of Toronto.

Following introductory remarks, the first plenary talk (Mechanochemistry and motility) was delivered by L. Mahadevan. This inspiring lecture served as a springboard into the various mini-symposia and contributed talk sessions that made up the bulk of the three-and-a-half day conference. The sessions focused on a broad range of topics in mathematical biology. Other plenary speakers included Timothy Secomb, Herb Levine, Natalia Komarova, Yicang Zhou, Mark Lewis and Martin Golubitsky. These speakers discussed varied and distinct topics but were consistently excellent. Between talks, guests were able to socialize and share ideas over coffee, tea and pastries.

On Thursday, a new SMB tradition began as the first Lee Segel Prizes were awarded. These prizes, to be awarded biennially, recognize what are determined to be the best articles appearing in the Bulletin of Mathematical Biology over the previous two years. The inaugural Lee Segel Prizes went to Emma Y. Jin in the student category for her work Combinatorics of RNA structures with pseudoknots (with Jing Qin and Christian M. Reidys) and to Tomas de-Camino-Beck for A new method for calculating net reproductive rate from graph reduction with applications to the control of invasive species. Since Tomas was unable to attend, his work was presented by collaborator Mark Lewis. Emma Jin also gave an exceptional presentation on the research that earned her the prize. Following these talks, conference attendees retreated to a lovely reception at Massey College. The setting was further enhanced by the ideal weather, which shocked locals by continuing to cooperate for (almost) the entire conference.

With Friday came the annual poster viewing, as over 70 students and post-docs competed for glory (and more tangible prizes) in an event that truly foreshadowed the Olympic Games. While all posters were interesting and appreciated, the top honours went to Luay Almassalha of the University of Michigan in the graduate student category (Understanding the formation of the Arabidopsis root epidermis through an intimate collaboration between modeling and experiment) and Richard Brown of the University of Canterbury (NZ).
(A meta-population model for the growth of nassella tussock) for best poster by a postdoctoral fellow. To recognize the significant contribution of undergraduate researchers to this year’s event, the organizers also awarded a top undergraduate poster prize to Jacob Barker and Naomi Pollica of the University of Vermont (A statistical approach to population studies of Chagas Disease). Congratulations to the winners, as well as to all who participated!

Friday was made even more memorable by the presentation of the first annual Torcom Chorbajian Lecture, given by Melissa Knothe Tate (Engineering an ecosystem: taking cues from Nature’s paradigm to build tissue in the lab). This lecture series was established to pay tribute to the continuing service of Torcom Chorbajian, who was a founding member of the SMB and has served as its treasurer for over 30 years. His generosity of time and spirit cannot be overstated. The Torcom Reception followed the lecture and the time went quickly, but not as quickly as the free liquor, as the conference attendees prepared for the banquet. The banquet was a lively affair that culminated with the after-dinner speech, wherein Vito Quaranta humbly pondered the sometimes-obscure relationship between mathematicians and biologists.

Saturday morning contained the last of the talks of the 2008 SMB Conference. Some lucky guests were able to experience the (relatively) nearby Niagara Falls following the conclusion of the meeting, before once again dispersing until next year’s conference in Vancouver. Many people deserve thanks for helping to facilitate this year’s meeting, but perhaps none more so than the chair of the local organizing committee, Siv Sivaloganathan. So, thanks to Siv and the rest of the organizing committee, the executives of the SMB, the staff of the Fields Institute, and of course to all of the attendees for the success of this year’s meeting in Toronto! We look forward to next year’s meeting in Vancouver!

Colin Turner

Plenary Speakers: (as listed in program itinerary)
L. Mahadevan (Harvard)
Mechanochemistry and motility
T. Secomb (Arizona)
Growth and structural adaptation of blood vessels in normal and tumor tissues
Herb Levine (UC San Diego)
Models of Eukaryotic Chemotaxis: How cells use stochastic
N. Komarova (UC Irvine)
Stochastic modeling of cancer

Y. Zhou (Xi’an Jiaotong University, China)
Discrete TB Transmission Model with Age and Infection Age Structures
M. Lewis (Alberta)
Dynamics of emerging wildlife diseases
M. Knothe Tate (Case Western)
Engineering an Ecosystem: Taking Cues from Nature’s Paradigm to Build Tissue in the Lab and the Body
M. Golubitsky (Houston)
Coupled Systems in Neuroscience

Workshop on Effective Use of High Performance Workstations in Scientific Computing
August 4–6, 2008
Held at the Fields Institute

Organizers: W.H. Enright, C.C. Christara, and K.R. Jackson (Toronto)

This workshop was and focused on bridging the gap between developers of numerical software, and scientists and engineers who use numerical software in their modeling and simulations. It also provided an overview of how modern workstations have incorporated multicore processors and high resolution graphics which have made simulations easier and more reliable. Several of the talks reported on “case studies” of recent simulations, while others described how current state-of-the-art hardware and software make reliable simulations easier to implement and interpret.

The use of computer simulations and mathematical modeling has become an essential component of research in areas such as computational biology, computational medicine and computational finance. The workshop brought together developers of numerical software and users in different application areas to explore the challenges and implications that are involved in developing, implementing and distributing effective numerical software that is accessible to a wide range of user communities.

Fields staff

Speakers: (as listed in program itinerary)
Wayne Enright (Toronto)
Developing Easy to use ODE Software: The associated Cost/Reliability Trade offs
Darren Schmidt (National Instruments)
Real-Time Big Physics Applications In National Instruments LabVIEW
Stuart Kauffman’s Public Lecture Reinventing the Sacred: Science, Faith and Complexity, took place at the SIAM Conference on the Life Sciences, August 5, at the Montreal Hyatt. The evening was an unqualified success. He engaged an audience of 250, of which more than 100 were non-conference, in a serious discussion of the limits of reductionism. The crowd was rapt as he spoke in a slow deliberate fashion, without slides or notes, for 90 minutes on themes, metaphors and analogies that he has developed in three earlier books as preparation for his proposal:

As reductionism can not be the whole truth, we can not “mathematicize” the class of Darwinian pre-adaptations and therefore much about our immediate future (what he deems our adjacent possible) remains, and will always remain, a mystery. As this mystery has historically been a well-spring of creativity let us agree to call this mystery sacred.

His talk closed with a vibrant question and answer period where audience members struggled to discern argument from assertion and skeptics sought to expose the semantic sleight of hand that “must” underlie any proposal that “explains” religion. Kauffman skillfully navigated this period by alternately correcting misunderstandings and humbly admitting that his conclusion was no more than a proposal. This session catalyzed a wide ranging discussion during the adjacent reception, where Stu engaged many small groups while enjoying the refreshments.

Advance press for his lecture appeared in three places in the Saturday, August 2 issue of The Gazette, Montreal’s English language newspaper. In particular, Stu’s talk and a link was listed in both the Religion column and the Literary column and was the subject of a two-page article by Graeme Morton titled His god is a reverence for nature’s creativity. The latter can be found at www.canada.com/montrealgazette/news/weekendlife/story.html?id=61770306-1e85-41ae-a8eb-bb650e6d964&p=1
Regarding public response to his lecture, I point to the careful review of a non-conferee Colin Cordner. See his August 12 entry Reinventing the Sacred, by Kauffman at http://coord.livejournal.com/tag/everything^2

For an insider’s view I recommend Carson Chow’s blog, sciencehouse.blogspot.com

Carson is a longtime SIAM Life Science member and an organizer of one our previous meetings. He surveys our 2008 meeting in his August 9 entry and then further develops his response to Kauffman in his entries of August 16 and 21.

In summary, Kauffman’s Public lecture to a broad audience succeeded on every possible front. It attracted a significant audience and sparked a healthy, serious and ongoing discussion regarding science and religion and the perceived limits of mathematics. Fields Institute support was crucial to this success.

Steve Cox

Workshop on Approximate Behavioral Equivalences
August 18, 2008
University of Toronto
Organizer: Franck van Breugel (York)

The Workshop on Approximate Behavioural Equivalences (ABE 08) took place at the University of Toronto in Toronto, Canada, on August 18, 2008. The workshop was affiliated with the 19th International Conference on Concurrency Theory (CONCUR 08).

Traditionally, equivalence relations have been used to capture whether concurrent systems behave the same. Behavioural equivalences, such as bisimilarity and trace equivalence, play a central role in concurrency theory. Such an equivalence relation answers the fundamental question “Do (states of) systems behave the same?” This question is not only of theoretical interest, but also has practical implications in areas such as compiler optimization and program analysis. For systems that contain quantitative information, like time or probability, such a discrete notion (systems are either equivalent or they are not) does not make much sense. Minor changes in the quantitative data may cause equivalent systems to become behaviourally different and vice versa. Since the quantitative information is usually an approximation, in such a case a behavioural equivalence contains very little information, if any at all.

Instead of equivalence relations, several related notions have been proposed to capture the behavioural similarity
of systems with quantitative features. For example, pseudometric spaces and uniform spaces have been exploited to capture behavioural similarity in a quantitative way. Behavioural equivalences can also be quantified by using an appropriate norm of a linear operator on a Hilbert space. A family of equivalence relations (one for each nonnegative real number) can also be exploited to generalize an equivalence to a quantitative setting.

In 1990, Giacalone, Jou and Smolka proposed pseudometrics as a generalization of equivalence relations to model systems with quantitative features. Their initial proposal had some limitations and for almost a decade, no further progress was made. Around the turn of the century, a number of research groups revisited the work of Giacalone et al. Since then, numerous generalizations of equivalences have been proposed.

In the last few years, quantitative generalizations of equivalence relations have been developed for a variety of systems with quantitative features. Furthermore, several algorithms have been developed and implemented to approximate these quantitative notions. These notions and their approximation algorithms have been exploited in several areas, ranging from system biology to model fusion.

A bibliography on approximate behavioural equivalences can be found at the workshop’s website www.cse.yorku.ca/abe08.

The purpose of this workshop was to bring together researchers and students interested in approximate behavioural equivalences.

ABE 08 was attended by roughly 20 participants. The speakers provided an overview of their work and presented their view on the future of approximate behavioural equivalences. The talks ranged from a historical overview of approximate behavioural equivalences to applications of approximate behavioural equivalences in areas such as model-based development, biochemical processes, and quantum processes.

The social program of ABE 08 consisted of a lunch at Burwash Hall of the University of Toronto and a reception at the Fields Institute.

ABE 08 received financial support from the Fields Institute, the Department of Computer Science of the University of Toronto, and the Department of Computer Science and Engineering of York University.

Franck van Breugel

Speakers: (as listed on program itinerary)
Franck van Breugel (York) and Scott Smolka (Stony Brook)
Approximate Behavioral Equivalences: A Historical Perspective
Shiva Nejati (Toronto)
On the Use of Approximate Equivalences in Model-Based Development
Prakash Panangaden (McGill)
Approximating Labelled Markov Processes
David Thorsley (Washington)
Approximating Stochastic Biochemical Processes
Vishwanath Raman (UC Santa Cruz)
Game Refinement Relations and Metrics
Mingsheng Ying (Tsinghua)
Approximate Bisimilarity between Quantum Processes
Herbert Wiklicky (Imperial College)
Behavioural Equivalences: Abstraction, Approximation and Estimation
Salem Derisavi (IBM)
Symbolic Methods for Equivalence Computation in Partition Refinement Algorithms

MOPTA 2008 - Modelling and Optimization Theory and Applications
August 18–20, 2008
Held at the University of Guelph

Organizers: Monica G. Cojocaru (Guelph), Anna Lawniczak (Guelph), Ed Thommes (Guelph), Miguel Anjos (Waterloo)

MOPTA is a series of conferences launched in 2001 at McMaster University, that has since been hosted by universities in Southwestern Ontario. MOPTA 2008 was organized by the Department of Mathematics & Statistics of the University of Guelph in collaboration with The College of Physical and Engineering Sciences at Guelph, The Fields Institute, MITACS and the Department of Management Sciences of the University of Waterloo.

The 2008 edition of the conference consisted of 8 invited lectures by internationally acclaimed researchers, two parallel sessions with multiple morning and afternoon presentations, a poster session for the graduate and postdoctoral participants, as well as participating talks from researchers in from Ontario, Canada and universities abroad, all taking place over three days. The event is traditionally entirely dedicated to communicating the
newest research in the areas of optimization and its many applications, to encourage dissemination of knowledge and collaborative research among its participants, and to offer an opportunity to younger researchers (graduate students and postdoctoral fellows) to expose their work to the mathematical community. This edition was no exception, the current schedule also featuring a celebration of one of the biggest names in the Canadian optimization community, Henry Wolkowicz from the University of Waterloo. In addition, the conference featured the submission of new research papers for a special edition of the journal Mathematical Programming B.

The number of participants was approximately 90, and was balanced between well-known researchers in the area and young researchers, including graduate students and postdoctoral fellows. A poster session also hosted a competition with an award being given to the best presented novel research. It is our hope that this conference proved to be yet another step towards exciting future research projects among Canadian researchers, both young and experienced, and their international counterparts in the area of optimization and its applications.

Monica G. Cojocaru

Plenary Speakers:
Florian Jarre (Dusseldorf)
Old and New Approaches for Linear Conic Minimization Problems

Don Jones (General Motors)
Large-Scale Multidisciplinary Mass Optimization in the Auto Industry

Joaquim Judice (University of Coimbra)
The Eigenvalue Complementarity Problem

Jean Lasserre (LAAS-CNRS)
Moments, Sums of Squares and Semidefinite Programming

Chris Paige (McGill)
Orthonormal Completion of an Array of Unit Length Vectors

Panos Pardalos (Florida)
Global Optimization Applications in Biomedicine

Georgia Perakis (MIT)
Loss of Efficiency Due to Oligopolistic Competition in a Market for Differentiated Products.

Yves Smeers (Catholic University of Louvain)
Optimization and Equilibrium Models for Capacity Expansion in the Reformed Electricity Industry


August 19–22, 2008
York University

Organizers: Franck van Breugel (York) and Marsha Chechik (Toronto)

The 19th International Conference on Concurrency Theory (CONCUR 2008) took place at the University of Toronto in Toronto, Canada, August 19-22, 2008. CONCUR 2008 was co-located with the 27th Annual ACM SIGACT-SIGOPS Symposium on the Principles of Distributed Computing (PODC 2008), and the two conferences shared two invited speakers, some social events, and a symposium celebrating the lifelong research contributions of Nancy Lynch.

The purpose of the CONCUR conferences is to bring together researchers, developers, and students in order to advance the theory of concurrency, and promote its applications. Interest in this topic is continuously growing, as a consequence of the importance and ubiquity of concurrent systems and their applications, and of the scientific relevance of their foundations. Topics include:

- basic models of concurrency (such as abstract machines, domain theoretic models, game theoretic models, process algebras, and Petri nets),
- logics for concurrency (such as modal logics, temporal logics and resource logics),
- models of specialized systems (such as biology-inspired systems, circuits, hybrid systems, mobile systems, multi-core processors, probabilistic systems, real-time systems, synchronous systems, and web services),
- verification and analysis techniques for concurrent systems (such as abstract interpretation, atomicity checking, model-checking, race detection, run-time verification, state-space exploration, static analysis, synthesis, testing, theorem proving and type systems), and
- related programming models (such as distributed or object-oriented).

CONCUR 2008 received 125 submitted papers (120 regular papers and 5 tool papers). Of those submitted papers, 35 papers (33 regular papers and 2 tool papers) were accepted for presentation at the conference. During the reviewing process, at least three reviews were collected for each paper. In total, 416 reviews were collected.

The final versions of the accepted papers and the abstracts of the invited talks appeared in the proceedings of
CONCUR 2008. These proceedings were published by Springer-Verlag in their Lecture Notes in Computer Science series as volume 5201. Of the accepted papers, seven have been selected for a special issue of CONCUR 2008. This special issue will appear in the Journal of Information and Computation.

The best paper award was given to Petr Jancar, Martin Kot and Zdenek Sawa for their paper entitled Normed BPA vs. Normed BPP Revisited. The best student paper award was given to Martin Abadi, Tim Harris and Katherine Moore (student) for their paper entitled A Model of Dynamic Separation for Transactional Memory.

CONCUR 2008 was attended by 102 participants, including 23 students. The social program of CONCUR 2008 included a reception at the Fields Institute, lunches at Knox College and Brennan Hall of the University of Toronto, and a banquet at Centre Island.

CONCUR 2008 had five satellite workshops:
- Workshop on Approximate Behavioural Equivalences (ABE 08);
- 15th International Workshop on Expressiveness in Concurrency (EXPRESS’08);
- Workshop on Formal Methods for Wireless Systems (FMWS 2008);
- 10th International Workshop on Verification of Infinite-State Systems (INFINITY 2008);
- 6th International Workshop on Security Issues in Concurrency (SecCo 08).

CONCUR 2008 received support from ACM’s SIGACT and SIGOPS, the Fields Institute, IBM, Microsoft, SAP, the Department of Computer Science of the University of Toronto, and the Department of Computer Science and Engineering, the Faculty of Science and Engineering and Office of the VP Academic of York University.

The symposium “Nancy Lynch Celebration: Sixty and Beyond” included the following talks:

Michael Fischer (Yale)
Evolution of Distributed Computing Theory: From concurrency to networks and beyond

Seth Gilbert (EPFL)
On Robustness, Fault-Tolerance and Wireless Networks

Maurice Herlihy (Brown)
The Future of Distributed Computing: Renaissance or Reformation?
his focus has included Seifert manifolds, singularities, reflection groups and invariant theory, braids, hyperplane arrangements, and hypergeometric integrals. Together with Hiroaki Terao and Louis Solomon, Peter Orlik pioneered the study of hyperplane arrangements and established many foundational results. Their work has attracted the interest of many mathematicians, equally from topological, combinatorial, and algebraic perspectives. (Today, a MathSciNet search for “hyperplane arrangement” or “arrangement of hyperplanes” turns up 551 papers.)

The conference featured twenty invited lectures by mathematicians with expertise in hyperplane arrangements and related areas. The speakers (listed below) included two former students of Peter Orlik (Falk, Randell), a number of young mathematicians (Brav, Delucchi, Kamnitzer), and an established researcher who has recently begun work in the theory of arrangements (Roos). Approximately 35 mathematicians attended the meeting, including a number of young researchers and graduate students, from Canada, the U.S., Europe, and Japan. The conference provided several participants, including de Concini and Roos, with their first opportunity to meet Peter Orlik in person. The organizers were happy to see that there were lively informal discussions taking place at all times, involving in particular the graduate students and postdocs.

The lectures, and attendant discussion, served to uncover a number of new connections between the theory of arrangements and other areas. The study of fundamental groups of smooth algebraic varieties discussed by Matei builds on work of D. Cohen, Falk, and Randell in the context of arrangements; the lecture of Roos used algebraic tools new to arrangement theory to exhibit arrangements with surprising homological properties; the lectures of Delucchi and Salvetti complemented each other in describing some recent success in using discrete Morse theory in the study of local systems on complements of complex arrangements. This last subject has become a focal point of arrangement theory in recent years, and was featured in a number of other lectures (including those of Randell and Suciu). Other themes in evidence at the meeting included tropical geometry (Feichtner), braid group actions on derived categories (in the lectures of Brav and Kamnitzer), as well as buildings, moment-angle complexes, and related topological objects (in the lectures of F. Cohen and Davis).

Graham Denham

Invited Speakers:
Alejandro Adem (UBC)
Simplicial spaces of homomorphisms
Chris Brav (Queen’s)
The projective McKay correspondence
Fredrick R. Cohen (Rochester)
On generalized moment-angle complexes, their properties, and applications
Mike Davis (Ohio)
Compactly supported cohomology of buildings
Corrado de Concini (Rome)
Vector partition functions and index of transversally elliptic operators
Emanuele Delucchi (Binghamton)
Combinatorics of minimal models for hyperplane arrangements
Igor Dolgachev (Michigan)
Moduli spaces of hyperplane arrangements
Michael Falk (Northern Arizona)
On vanishing products in Orlik-Solomon algebras
Eva-Maria Feichtner (Bremen)
Arrangements and tropical geometry
Joel Kamnitzer (Toronto)
Braid group actions on derived categories of coherent sheaves with applications to knot homology
Toshitake Kohno (Tokyo)
Bar complex of Orlik-Solomon algebra and rational universal holonomy maps
Daniel Matei (IMAR)
Fundamental groups of smooth algebraic varieties
Richard Randell (Iowa)
Homotopy and local system homology for arrangements
Jan-Erik Roos (Stockholm)
Complex hyperplane arrangements having unexpected homological properties
Mario Salvetti (Pisa)
A method for local system cohomology of a hyperplane complement
Hal Schenck (Illinois)
The Orlik-Terao algebra and 2-formality
Alexander Suciu (Northeastern)
Spectral sequences and homology with local coefficients
General Scientific Activities

Hiroaki Terao (Hokkaido)
Totally free arrangements of hyperplanes

Masahiko Yoshinaga (Kobe)
Periods and computational complexity of real numbers

Thomas Zaslavsky (Binghamton)
Topological hyperplane arrangements

Workshop on Nonlinear Wave Dynamics
August 20–22, 2008
Held at Carleton University
Organizers: David Amundsen and Lucy Campbell (Carleton)

Nonlinear wave interactions lie at the heart of numerous physical phenomena and the mathematical modelling of these systems has driven the development of a broad field of mathematical research. The study of nonlinear wave equations has led to the development of numerous mathematical techniques including aspects of scattering theory, asymptotic expansions, perturbation theory, as well as advances in numerical simulation methods for wave propagation.

This three-day workshop brought together researchers with expertise both in the numerical and analytic aspects of nonlinear wave problems and provided the opportunity for students and other researchers to share in the latest developments in these areas and foster new collaborations and avenues of research. In total there were approximately 30 participants including 17 students. The workshop comprised 4 short courses each consisting of 3 hours of lectures, as well as 7 contributed talks by students and postdoctoral fellows. The 4 invited lecturers were Triantaphyllos Akylas, Simon Clarke, Gordon Swaters and Jianke Yang. While each spoke on a distinct topic, they complemented one another very effectively, providing participants with a broad overview of leading edge research in nonlinear waves.

Triantaphyllos Akylas gave an extensive review and discussion of internal gravity waves in continuously stratified fluids, starting with an overview of their significance in the atmosphere and oceans. He focused one of his lectures on recent advances in understanding the propagation and nonlinear interactions of finite-amplitude beam-like disturbances that result from localized forcing and propagate in specific directions depending on the driving frequency. Another lecture dealt with the reflection of internal wave beams induced by tidal flow over bottom topography and the local generation of solitary waves in the ocean thermocline. A nonlinear model was presented and the results compared with field observations.

Simon Clarke’s lectures dealt with the problem of large-amplitude waves forced by the flow of a two layer fluid of finite depth past topography, such as would arise in exchange flows in geophysical fluid dynamics. His particular focus was on the case of long waves for which the wave dynamics are governed by the forced Camassa–Choi (CC) equations, which under certain limiting conditions lead to the two-layer shallow water equations and the
forced extended Korteweg–de Vries equation. He discussed asymptotic and numerical procedures that allow one to analyze and solve these equations and give insight into the evolution of the waves.

Gordon Swaters spoke on direct perturbation theory for modulated solitary waves. These waves typically arise in problems where the underlying dynamics is linear to leading order but nonlinearity also plays a non-negligible role at higher order. In some cases the solutions may also be modulated by dispersion or other physical processes such as dissipation or spatially and temporally varying environments. A thorough discussion of the theory and asymptotic solution procedures was presented, with a focus on the Korteweg-de Vries and nonlinear Schrödinger families of equations among others.

Jianke Yang gave a series of lectures on numerical methods for nonlinear wave equations. He described numerical methods for various aspects of nonlinear wave computations such as evolution simulation, computation of solitary wave solutions, and computation of linear-stability spectra of solitary waves. The methods discussed included the classical methods such as the pseudo-spectral, split-step and integrating factor methods, as well as recent advances such as the accelerated imaginary-time evolution method, the squared-operator iteration method and the Petviashvili method. The common features of these methods are their high accuracy, high speed, general applicability, and more importantly, easy implementation.

The contributed talks covered a broad range of topics including numerical simulations and analyses of internal gravity waves, studies of the nonlinear Schrödinger equations in various contexts, and group-theoretical methods applied to hydrodynamic systems.

Overall it was a very lively and informative series of lectures, keeping the participants enthusiastically engaged throughout. Despite the busy schedule of lectures, participants were also able to get out and enjoy the beautiful summer 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, a suitable spot for experimental observation of nonlinear waves! The second day ended with a leisurely walk along the shores of Dow's Lake from the Carleton campus to a nearby restaurant followed by an expedition downtown led by some of the local student participants.

David Amundsen

**Speakers:**
- Triantaphyllos R. Akylas (MIT)
- Simon Clarke (Monash)
- Walid Abou-Salem (Toronto)
- Heather A. Clark (Colgate) and Bruce R. Sutherland (Alberta)
- Gordon E. Swaters (Alberta)
- Jianke Yang (Vermont)
- Guenbo Hwang (Buffalo) and Gino Biondini (Buffalo)
- Alexander J. Hariton (Montreal)
- Lidia Nikitina (Carleton) and Lucy Campbell (Carleton)
- Danhua Wang (Indiana) and Gino Biondini (Buffalo)

**Conference for Canadian Queueing Theorists and Practitioners**
August 28–30, 2008
Held at Carleton University
Organizers: Minyi Huang and Yiqiang Zhao (Carleton)

The 10th annual Canqueue conference was sponsored jointly by the Fields Institute and MITACS, and the Laboratory for Research in Statistics and Probability at the School of Mathematics and Statistics of Carleton University. The goal of the conference is to promote research in, and applications of, queueing theory. The conference brought together more than 35 participants, including researchers, students and post-doctoral students from Canada and abroad.
The event was very successful in bringing together scientists, researchers, engineers, and students in the field, providing a forum for exchange of research ideas and discussion of work-in-progress, by researchers from mathematics, industrial engineering, management, electrical engineering, and the industrial world.

The three days of the conference featured two one-hour tutorials, two plenary talks, and twenty thirty-minute invited talks, covering a wide range of topics on queueing networks and related areas, including priority queues, retrial queues, parallel queues, resequencing queues, computing systems, matrix-analytic methods, asymptotic analysis, and management of research processes, among others.

The two tutorials were targeted at graduate students while their speakers made an effort to ensure that the topics were of interest to a general audience. In the first tutorial, A. S. Alfa introduced vacation queues in discrete time via a matrix-analytic approach. The second tutorial was given by D. McDonald. He described the method of large deviations for obtaining exact asymptotics in queueing networks.

The plenary talks were given by D. Mitra, and B. Zwart. Mitra presented new stochastic models for control and optimization of industrial research management. These models were created from a queueing system point of view of research management processes. Concrete examples were used to illustrate the related concepts and new research directions were pointed out. Zwart focused on queueing models associated with customer contact centers such as telephone call centers. He developed new bounds for the Erlang loss and delay formulae, and showed their applications to square root staffing problems.

Minyui Huang

Speakers:
Debasis Mitra (Bell Labs)
Stochastic Models for Control and Optimization of Industrial Research Management

Qi-Ming He (Dalhousie)
Stability Conditions of a Preemptive Repeat Priority MMAP[N]/PH[N]/S Queue with Customer Transfers

Nuwan Balasuriya (Manitoba)
Performance Measures of MAP/PH/1 Priority Feedback Queues

Hui Li (Mount Saint Vincent)
Exact Tail Asymptotics in a Priority Queue

Baris Balcioglu (Toronto)
On Priority Queues with Impatient Customers

Femi Adelani (Manitoba)
Optimal Token Buffer Size in A Pair Formation with Priorities

Doug Down (McMaster)
On Accommodating Customer Flexibility in Service Systems

Issam Al-Azzoni (McMaster)
Linear Programming Based Affinity Scheduling for Heterogeneous Computing Systems

Myron Hlynka (Windsor)
Transition Matrices, Fibonacci Numbers and Queues

Guichang Zhang (Saskatchewan)
The Analysis of Retrial Queues with Losses

Percy H. Brill (Windsor)
A Series for M/G/1 Queues

Bart Zwart (Georgia Tech)
Bounds and Expansions for the Erlang B and C formulae with applications to square root staffing

Peter Rabinovitch (Alcatel-Lucent)
A Problem in Resequencing Buffer Sizing

Jun Li (Carleton)
Resequencing Analysis of Stop-and-Wait ARQ over Parallel Markov Channels

Barbara H. Margolius (Cleveland)
How to find the matrix (function) R of matrix analytic methods for the time-inhomogeneous periodic Quasi-Birth Death Process in continuous time

Telex Ngatched (Manitoba)
A Modified Binary Communication Channel with Memory Based on a Finite Queue Abstract

Ramon Alanis (Alberta)
A Birth-Death Model for the Performance of an EMS System with Re-positioning

Fernanda Campello (Alberta)
Stating Requirements based on Infinite Server Models

Winfried Grassmann (Saskatchewan)
Computational Probability: the past, the present and the future

Jiashan Tang (Nanjing)
Performance Analysis of Joining the Shortest Queue Model among a Large Number of Queues
Hanjun Zhang (Xiangtan)
*Quasi-Stationary Distributions and Domain of Attraction Problem*

Alireza Chavoushi (Dalhousie)
*Analyzing the Behaviour of Queues with Costumer Interjection*

**Biomathematics and Statistics Symposium**
September 3, 2008
Held at the University of Guelph

Organizers: Paul McNicholas and Allan Willms (Guelph)

This symposium brought together researchers from a variety of disciplines, including epidemiology, biology, mathematics, statistics and information technology. Sixty-one registered participants from universities all over Southern Ontario and one or two from further afield, over half of which were graduate students, took part in the symposium.

Opening remarks were made by the Chair of the Mathematics and Statistics Department at the University of Guelph, Brian Allen, and by co-organizer Paul McNicholas. The first talk was the Gordon C. Ashton Biometric Lecture, named after the first practicing statistician at the University of Guelph. An outstanding statistician delivers the Ashton Lectures periodically and this is the second time that the lecture was tied in with the symposium. Ashton was at McGill University for a time and, in a fitting coincidence, the 2008 Ashton Lecture was delivered by James Hanley from McGill. This lecture was well received by all and especially so by graduate students who enjoyed Hanley’s entertaining style of delivery. In the second session of the morning, faculty members from Queen's University, McMaster University and the University of Guelph delivered presentations on interesting problems in biostatistics.

After lunch, graduate students from Oxford, Carleton, Guelph and Waterloo delivered presentations. These students were selected from a strong field of applicants and they each received a travel award from the Fields Institute. This was the first time that there was a graduate student session at the symposium and it will not be the last time. A number of students gave very good feedback on the session and on the opportunities that they had to network with students from other universities.

On that networking theme, the three coffee breaks and the luncheon provided excellent networking opportunities for faculty and students alike. One attendee commented that he “never knew there were so many people working in biometrics at Guelph” and this is indicative of the benefit to the University of hosting such events. In addition, a few attendees commented on how well the event had been organized.

The final session of the day was a biomathematics session, where two professors from the University of Waterloo delivered very interesting presentations. The event was rounded off by closing comments from co-organizer Allan Willms, who thanked speakers, attendees and the Fields Institute for what was a very successful symposium.

Paul McNicholas

Speakers: (as listed in program itinerary)

James Hanley (McGill)
*A new way to fit smooth-in-time hazard functions, a Cox regression / ANCOVA paradox, and statistical analyses for an unusual clinical trial design.*

Bingshu Chen (Queen’s)
*Competing Risks Analysis of Correlated Failure Time Data.*

Peter Kim (Guelph) and Michael Pierrynowski (Guelph)
*Statistical Estimation of Curvature and Torsion with Application to Biomechanics*

Angelo Canty (McMaster)
*Model-based Bootstrapping for M-estimators*

Majid Bani-Yaghoub (Carleton)
*Numerical study of neuronal differentiation influenced by Retinoic Acid and Notch interaction*

Hedia Fgaier (Guelph)
*Mathematical modeling and analysis of probiotic bacteria*

Shilan Mistry (Oxford)
*Detrended fluctuation analysis of compositional time series.*

Shahedul Ahsan Khan (Waterloo)
*An Extension of Bent-Cable Regression for Longitudinal Data*

Sivabal Sivaloganathan (Waterloo)
*Mathematical modelling of hydrocephalus and the possible role of transcapillary filtration*

Brian Ingalls (Waterloo)
*Parameter estimation in molecular systems biology*
First Canadian Hopf Algebra Conference
September 3–6, 2008
Held at the University of New Brunswick

Organizers: Alain Connes (Vanderbilt/Collège de France), Piotr M. Hajac (Polish Academy of Science), Dan Kucerovsky (New Brunswick), Henri Moscovici (Ohio State), and Bahram Rangipour (New Brunswick)

The theme of this conference, associated with the Centre for Noncommutative Geometry and Topology at the University of New Brunswick, was the role of Hopf algebras in noncommutative geometry. It attracted top researchers in the field from all over the globe. Speakers were from Alabama, Colorado, France, Hungary, Italy, Pennsylvania, Poland, and the UK – local researchers also participated in the conference as audience and/or speakers. The conference achieved its goal which was to promote the new area of mathematics which emphasizes the use of Hopf algebras in Noncommutative Geometry.

The conference was designed to let the participants interact with each other. At the end of each day before dinner there was a free discussion session led by one of the experts, in which new research was initiated.

The first day was started by Tomasz Brzezinski, who is a known specialist in Hopf algebras and corings from the UK. He lectured on Contramodule coefficients for Hopf-cyclic homology, introducing new coefficients for Hopf cyclic cohomology. The next speaker was Gabriella Bohm. Bohm is one of the mathematicians in noncommutative geometry (NCG) who uses category theory as a primary tool. She talked about A categorical approach to Hopf cyclic (co)homology. Her new perspective, joint with D. Stefan, on Hopf cyclic cohomology, has solved a longstanding problem in NCG – the definition of Hopf cyclic cohomology for Hopf algebras over noncommutative rings with coefficients in SAYD modules. The last talk of the first day was given by B. Rangipour. He is one of the founders of Hopf cyclic cohomology with coefficients. He talked about Characteristic maps in Hopf cyclic cohomology via the Weil complex. He presented a new way to construct Hopf cyclic classes from a finite complex which is quasi isomorphic with the truncated Weil complex. The first day ended with a free discussion about the the applications of Hopf cyclic theory with coefficients.

Ulrich Kraehmer, the first speaker of the second day, talked about Duality and products in algebraic (co)homology theories. His observations unify many unrelated dualities under the umbrella of Hopf x-algebras. Kraehmer is known for his computation of the twisted cyclic cohomology of certain quantum groups. The second speaker of the day was Tomasz Maszczyk. He talked on A characteristic map without an invariant trace. One of the most fundamental tools in geometry and also in NCG is characteristic maps. These maps usually build on an invariant trace. His result could be used in places that the algebra, the coordinate algebra of the noncommutative space, in question lacks an invariant trace. Teodor Banica finished the day’s lectures with Liberation of orthogonal Lie groups. Roughly speaking, he showed a one-to-one correspondence between classical groups and free quantum groups. Banica is known for his research on
Speakers:  
T. Brzezinski (Swansea)  
Contramodule coefficients for Hopf-cyclic homology  
G. Bohm (Swansea)  
A categorical approach to Hopf cyclic (co)homology  
B. Rangipour (UNB)  
Characteristic map in Hopf cyclic cohomology via Weil complex  
U. Kraehmer (Glasgow)  
Duality and products in algebraic (co)homology theories  
T. Maszczyk (Warsaw)  
A characteristic map without an invariant trace  
T. Banica (Paul Sabatier)  
Liberation of orthogonal Lie groups  
A. Dean (Lakehead)  
Classification of C*-dynamical systems  
P. M. Hajac (Warsaw)  
The Chern-Galois character and Ehresmann cyclic homology  
A. Gorokhovsky (Colorado)  
Secondary Characteristic Classes and Cyclic Cohomology of Hopf Algebras  
C. Ingalls (New Brunswick)  
Noncommutative Coordinate rings of stacks  
Y. Sommerhauser (South Alabama)  
Frobenius-Schur indicators and congruence subgroups  
M. Beattie (Mount Allison)  
Generalized Quantum doubles with projection  
P. Baum (Pennsylvania State)  
Peter-Weyl algebra and free actions of compact quantum groups

The third day began with Andrew Dean’s talk on Classification of C*-dynamical systems. Dean is a well-known Canadian mathematician working on C*-algebras. The next speaker was Giovanni Landi, who is well known for his fundamental research, joint with Alain Connes, on the noncommutative geometric structure of quantum groups. He talked about Monopoles and instantons on quantum projective space.

The first speaker in the afternoon was Piotr M. Hajac, who is known for his fundamental work on Hopf Galois theory, an active area of research in NCG. He spoke about The Chern-Galois character and Ehresmann cyclic homology. The last talk of the day, Secondary characteristic classes and cyclic cohomology of Hopf algebras, was given by Alexander Gorokhovsky, who is well known for his work on characteristic classes in noncommutative geometry and also on deformation of gerbes on manifolds. This day ended with a free discussion on the coefficients of Hopf cyclic theory.

Colin Ingalls, a Canadian mathematician working on noncommutative algebraic geometry, started the last day of the workshop by giving a talk on Noncommutative coordinate rings of stacks. He presented his studies on semigroupoid schemes and showed a correspondence between Deligne-Mumford stacks and equivalence classes of hereditary orders on smooth curves. The next speaker was York Sommerhauser, who talked about Frobenius-Schur indicators and congruence subgroups. He presented his recent studies on Frobenius-Schur indicators for certain Hopf algebras.

He is known for his deep research on Yetter-Drinfeld Hopf algebras. The afternoon was started by Margaret Beattie who spoke on Generalized quantum doubles with projection. She gave a very interesting lecture on the quantum double and its generalization. Beattie is known for her research on pointed Hopf algebras and classification of finite dimensional Hopf algebras. The final speaker of the workshop was Paul Baum. He lectured impressively on Peter-Weyl algebra and free actions of compact quantum groups. Baum is known for his many achievements in mathematics but he is famous for his eponymous conjecture, joint with with Alain Connes, concerning the bijectivity of the assembly map. The workshop ended with an open discussion on algebraic and non-algebraic formulations of cyclic theory, followed by a conference dinner at a local restaurant.

Dan Kucerovsky
Conference on Non-linear Phenomena in Mathematical Physics: Dedicated to Cathleen Synge Morawetz on her 85th birthday
September 18–20, 2008

Organizing Committee: Jim Colliander (Toronto), Susan Friedlander (USC), Irene M. Gamba (Chair, Austin), Fern Hunt (NIST), Barbara L. Keyfitz (Fields Institute), Walter Strauss (Brown)

This past September the Fields Institute was proud to host a conference on non-linear analysis, Non-linear Phenomena in Mathematical Physics: Dedicated to Cathleen Synge Morawetz on her 85th birthday. The conference was co-sponsored by the Association for Women in Mathematics (AWM) and, departing slightly from the structure of most AWM events, featured both women and men speakers. In fact, slightly to the embarrassment of AWM, men outnumbered women among the attendees. Making the best of it, the organizers observed that the influence of Cathleen Morawetz (former President of the American Mathematical Society, winner of the U. S. Presidential Medal of Science, Fellow of the Royal Society of Canada) has been so profound that “we couldn’t keep the men out.”

This scientific meeting focused on the legacy of Cathleen Morawetz and the impact that her scientific work on transonic flow and the non-linear wave equation has had in recent progress on different aspects of analysis for non-linear wave, kinetic and quantum transport problems associated to mathematical physics. These are areas where the elements of continuum, statistical and stochastic mechanics, and their interplay, have counterparts in the theory of existence, uniqueness and stability of the associated systems of equations and geometric constraints.

The conference, with a stellar group of organizers, including Jim Colliander, Susan Friedlander, Fern Hunt and Walter Strauss, some of whom were also speakers, was a central event for the applied and computational analysis community. The focus was on Partial Differential Equations. There were 20 speakers (including two Abel prize winners, Peter Lax and Ragu Varadhan), 10 poster presentations, about 70 junior and senior participants and, of course, the participation of Cathleen Synge Morawetz.

It was a happy occasion, not only to celebrate Morawetz’s paramount contributions to the theory of non-linear equations in gas dynamics, and their impact in the current trends of nonlinear phenomena in mathematical physics,
but also to serve as an awareness session of current women's contribution to mathematics. Of the twenty speakers, seven were women, and many among them showed how their research has been inspired by or carried the legacy of Morawetz’s work.

At a gala banquet, held at the Faculty Club of the University of Toronto, Cathleen Morawetz's friends and family toasted her achievements as a researcher, colleague, wife and mother, and stateswoman of the world mathematical community. And we saluted Constance Reid, whose letter to AWM President Cathy Kessel suggesting that the time was ripe for such a conference, started the whole affair. Not for the first, and, we hope, not for the last time, Cathleen enjoyed the banquet like the true Irishwoman she is – and showed up bright and early the next morning for the culminating set of talks.

The participants also enjoyed a set of posters of women mathematicians (including Cathleen Morawetz and several of the speakers) designed and composed by Fields’ Manager of Scientific Programs Alison Conway and displayed around the atrium.

The conference was sponsored and partially funded by the Fields Institute and the Association for Women in Mathematics, through a generous grant from the Department of Energy.

Irene Gamba and Barbara Keyfitz

Speakers:
Walter Strauss (Brown)
Two Problems: Nonlinear Wave Scattering and Plasma Stability

Claude Bardos (Paris VI)
Remarks on Navier Stokes and Euler Equation

Costas Dafermos (Brown)
Hyperbolic Conservation Laws with Weak Dissipation

Sylvia Serfaty (Courant)
From the Ginzburg-Landau energy to vortex lattice problems

Louis Nirenberg (Courant)
Some remarks on nonlinear second order elliptic equations

Gigliola Staffilani (MIT)
Kato’s smoothing effect for solutions to the Â capillary water-wave problem.

Peter Lax (Courant)
Spectral Representation and Translation Representation

Yan Guo (Brown)
Boltzmann equation in bounded domains

Irene M. Gamba (Austin)
Sharp estimates for the Boltzmann Equation

Gui-Qiang Chen (Northwestern)
Shock Reflection-Diffraction Phenomena, Transonic Flow, and Free Boundary Problems

Horng-Tzer Yau (Harvard)
Lower bounds on the blow-up rate of the axisymmetric Navier-Stokes equations

Susan Friedlander (USC)
Energy Conservation and Onsager's Conjecture for the Euler Equations

Tom Hou, (California Institute of Technology)
On the stabilizing effect of convection in 3D incompressible flows

S.R.S Varadhan (Courant)
Large deviations for Random walks in a Random Environment

Izabella Laba (UBC)
Arithmetic progressions in sets of fractional dimension

Manoussos Grillakis (Maryland)
Correlation Estimates and Applications to Schroedinger Equations

Jalal Shatah (Courant)
The Method of Space-time Resonances

Lia Bronsard (McMaster)
On the mixed state in anisotropic superconductors

Kevin Payne (Milan)
Weak well-posedness of the Dirichlet problem for equations of mixed elliptic-hyperbolic type

Ottawa-Carleton Algebra Week
September 13–21, 2008
Held at Carleton University and the University of Ottawa

Organizers: Erhard Neher (Ottawa) and Benjamin Steinberg (Carleton)

The Algebra Week kicked off with a day dedicated to the representation theory of finite dimensional algebras. The main speakers were Osamu Iyama, Bernhard Keller and Claus Ringel. The day opened with a lecture by Iyama on n-cluster tilting and n-APR tilting. He touched on Auslander’s notion of representation dimension, bringing
General Scientific Activities

us up-to-date on the most recent results on the subject. His lecture was followed by Bernhard Keller who spoke on quiver mutation and derived equivalence. A high point of his lecture was the java applet he had created with animated quiver mutations. The final talk of the first day was by Claus Ringel who gave a dynamic presentation on the structure of length categories.

Our two mini-courses aimed at graduate students began on Monday, along with a colloquium talk by Ringel at Carleton. Ringel’s riveting lecture focused on a class of algebras of representation dimension at most 3 called torsion-less finite algebras; these are algebras with only finitely many isomorphism classes of indecomposable modules that embed in projective modules.

The mini-course at Carleton was taught by Osamu Iyama. His crisp lectures on Auslander-Reiten theory were a boon to the graduate students attending the talks. He gave both the functorial construction of almost split sequences, as well as the construction via Auslander-Reiten duality. Dlab suggested that Iyama’s notes presented an excellent viewpoint, worthy of being made generally available.

Equally well presented and attended was the mini-course at the University of Ottawa on PI-algebras, given by Vesselin Drensky from Monday to Thursday. The taped lectures as well as Efim Zelmanov’s fascinating colloquium on Asymptotic properties of finite groups and finite dimensional algebras can be viewed at www.fields.utoronto.ca/programs/scientific/08-09/algebraweek/. In his lecture Zelmanov discussed limits of finite groups and finite dimensional algebras and their connections with number theory, low dimensional topology and combinatorics. This included, for example, topics such as the Burnside problem, Milnor’s problem on growth of groups, expander graphs and Kazhdan’s property (T), the structure of the Golod-Shafarevich groups, the Fontaine-Mazur conjecture on Galois groups of number fields, the Virtual Positive Betti-Number Conjecture by Thurston and Waldhausen, and his recent work with Petrogradsky and Shestakov on algebras with polynomial growth. It was an amazing view of diverse and fundamental problems, yet all connected by the concept of growth.

The colloquium was part of a 3-day conference (Friday-Sunday) celebrating our colleague Michel Racine at the occasion of his retirement. The topics of the conference were of course those close to Michel’s mathematical interests: nonassociative algebras. We were fortunate that the world’s leading experts in these areas came to Ottawa to take part in this conference. Allison and Faulkner talked on structurable algebras, Loos and Petersson on composition algebras, Anquela McCrimmon and Zelmanov again on Jordan (super) structures, Shestakov on Malcev algebras and Drensky on nilpotent derivations of polynomial algebras, a topic closely related to the Jacobian conjecture (for the record, he did NOT announce a solution of the conjecture) and Hilbert’s 14th problem.

Of course, part of the celebration was a big retirement party, graciously organized by Michel’s friend Henri Wong in his cottage, to which everybody was invited. It was a great party, even if at the end the bus couldn’t make it up a steep hill and all participants had to walk up the hill in the darkness of the night – an event, which will not easily be forgotten.

Erhard Neher

Speakers:
Bruce Allison (Alberta/Victoria)  
Some 3x3 matrix algebras and cubic structures in Lie theory
Jose Anquela (Oviedo)  
More on Minimal Ideals of Jordan Systems
V. Drensky (Bulgarian Academy of Science)  
Locally Nilpotent Derivations of Polynomial and Free Associative Algebras
John R. Faulkner (Charlottesville)  
Structurable superalgebras of classical type
Osamu Iyama Paris  
n-cluster tilting and n-APR tilting
Bernhard Keller (Paris)  
Quiver mutation and derived equivalence
Ottmar Loos (Innsbruck)  
The scheme of quaternionic algebras
Kevin McCrimmon (Charlottesville)  
Odd automorphism dreams
Holger P. Petersson (Fernuniversität Hagen)  
Composition algebras over local fields revisited
Claus Michael Ringel (Bielefeld)  
The structure of length categories
The torsionless modules for an artin algebras
Ivan Shestakov (Sao Paulo)  
The Chevalley and Kostant theorems for Malcev algebras
Paul Smith (Washington)
An equivalence of categories involving the graded Weyl algebra and an algebraic quotient stack

Efim Zelmanov (UC San Diego)
Jordan Superalgebras
Asymptotic properties of finite groups and finite dimensional algebras

Conference on Infinite Dimensional Dynamical Systems
September 24–28, 2008
Held at York University
Organizers: John Mallet-Paret (Brown), Jianhong Wu (York), Yingfei Yi (Georgia Tech), Huaiiping Zhu (York)

Infinite dimensional dynamical systems are generated by equations describing the evolution in time of systems whose status must be depicted in infinite dimensional phase spaces. Studying the long-term behaviour of such systems is important in our understanding of their spatio-temporal pattern formation and global continuation, and has been among the major sources of motivation and applications of new development of nonlinear analysis and other mathematical theories. Theories of infinite dimensional dynamical systems have also found an increasing number of important applications in the physical and life sciences.

This conference was designed to bring together researchers working in different areas of the subject to celebrate past achievements, to discuss recent progress and to stimulate and develop future collaborations. The very successful conference of over 80 participants from all over the world was held at York University, Sept. 24-28, 2008, thanks to generous support by the Fields Institute, PIMS and York University.

The forty-eight invited lectures covered a wide range of topics and addressed both the common features and distinctions in those infinite dimensional dynamical systems generated by parabolic partial differential equations, hyperbolic partial differential equations, solitary equations, lattice differential equations, delay differential equations, and stochastic differential equations.

The conference started with a talk by Barbara Keyfitz discussing the difficulties in conservation laws from the point of view of infinite dimensional dynamical systems. After some discussion about the essential difference between conservation laws and other infinite dimensional systems that behave somewhat like finite-dimensional dynamical systems, Keyfitz reviewed some of her collaborative work, providing critical tools for the understanding of the dynamics of multi-dimensional systems. Her talk was followed by lectures of Susan Friedlander, Michael Jolly and Genevieve Raugel on Onsager’s conjecture, on global attractors and on long-term behaviours of high dimensional Navier-Stokes equations.

Invariant manifolds and their approximations continue to be a major concept and to provide technical tools in the study of infinite dimensional systems, as was clearly illustrated at the conference. Peter Bates presented his work on using invariant manifold theory to reveal the global dynamics of boundary spike states for the generalized Allen-Cahn equation, and Chongchun Zeng described the unstable manifolds and $L^2$-nonlinear instability of the Euler equation. Alexandre N. Carvalho discussed perturbation of attractors, while Yuncheng You talked about the existence of global attractors of cubic autocatalytic reaction-diffusion systems. Through the presentations of Weishi Liu and Ken Palmer, singular perturbation techniques were shown to be effective tools in the investigation of the impact of turning points on global dynamics and homoclinic orbits.

A conference in this subject normally has many talks dedicated to the dynamics of parabolic equations, and this conference was no exception. Peter Polacik talked about parabolic Liouville theorems and their applications; Hiroshi Matano showed how a braid-group method can be used in the blow-up problem in nonlinear heat equations; and James Muldowney described the Bendixson conditions for differential equations in Banach spaces and used them to rule out periodic motions in certain parabolic equations. There were talks about “beyond” classical diffusion. For example, Chris Cosner considered conditional dispersal in ecological models, and Stephen Gourley presented a novel nonlocal reaction-diffusion model for cellular adhesion. Travelling waves and their connections to global dynamics as well as their applications to biological invasion, disease propagation and combustion were the central subject of a number of talks – by Wenzhang Huang, Xing Liang, Xiaobiao Lin, Stephen Schecter, Wenxian Shen and Xiaoqiang Zhao.

Delay differential equations, another prototype of infinite dimensional dynamical systems, received the attention they deserved in the conference. Stefan Siegmund presented his work on a general qualitative theory for equations with random delay, based on the recent work of Zeng Lian and Kening Lu on generalized multiplicative ergodic theorem of Oseledec in Banach spaces. Delay differential equations with state-dependent delay were covered by a few featured
Global Scientific Activities

talks: Hans-Otto Walther provided a brief account of his recent work on algebraic-delay differential systems in the temporal order of reactions, Roger Nussbaum and Tibor Krisztin presented their results on the global structure of solutions, introducing several major technical tools developed for this important class of dynamical systems.

Global attractivity of solutions of differential equations, both retarded or neutral types, with infinite delay and monotonicity were discussed in the talks by Carmen Núñez and Rafael Obaya. Yuming Chen gave a rather complete description of the global attractor of a delayed differential system with monotone feedback, and Bernhard Lani-Wayda showed, for a scalar equation, how disk-like global attractors change when the nonlinearity changes to non-monotone shapes. Two other speakers, Sue Ann Campbell and Connell McCluskey, added further to the strong Canadian representation in the subject area: Campbell considered a model for regenerative chatter in a drilling process and some perturbation techniques to obtain the delayed induced Canards, and McCluskey illustrated how the classical Lyapunov functional method coupled with some local analysis can yield the global asymptotic stability of a biologically meaningful equilibrium for a disease model with distributed delay. The interface between spatial diffusion and time delay were addressed by the talks of Sérgio Oliva and Xingfu Zou.

Horst Thieme’s talk concerned the classical but difficult issue of differentiability of convolution operators in solving an abstract linear inhomogeneous evolution equation, where the linear part gives rise to an integrated semigroup. Semilinear equations involving integrated semigroups and a non-densely defined Cauchy problem were then discussed in back-to-back presentations by Pierre Magal and Shigui Ruan, focusing on the centre manifold theorem and applications to structured population models.

Martin Golubitsky talked about feed-forward networks near Hopf bifurcation and illustrated how the theoretical work finds applications to auditory receptor cells on the basilar membrane in the cochlea. Pattern formation due to the interaction of symmetric coupling and feedback was addressed by Yuan Yuan, and the realization of critical eigenvalues for linear delay-differential equations with multiple delays and with a certain symmetry was discussed by Pietro-Luciano Buono.

There were a couple of talks about data and databases, by and for nonlinear dynamical systems: Arno Berger spoke about *Digits and dynamics: from finite data to infinite dimensions* while Konstantin Mischaikow discussed *Building a database for global dynamics of parameterized nonlinear systems*.

The conference concluded with a talk by Walter Craig that provided an authoritative update of some remarkable progress on infinite dimensional Hamiltonian systems. Hamiltonian systems were also discussed by Yingfei Yi.

This conference was dedicated to George Sell of the University of Minnesota on the occasion of his 70th birthday. Sell was honored by an invitation to deliver a public lecture *An evolution in evolutionary equations*. His lecture and the reception following the lecture were sponsored by MITACS.

Sell described some of the historical developments of the theory of infinite dimensional dynamical systems during the last 50 years, with particular focus on the theory of the dynamics of solutions of partial differential equations, and specially on the applications of the theory of the Navier-Stokes equations in fluid flows. A number of colleagues from Minnesota delivered their best wishes to Sell, along with their lectures, including: Marta Lewicka on Derivation of shell theories from 3d nonlinear elasticity and Arnd Scheel, about *How robust are Liesegang patterns?*

A special feature presentation was jointly given by John Mallet-Paret and Gerry Sell consisting of some personal anecdotes of Sell’s mathematics and life, providing an excellent view of the evolution of evolution equations and the dynamics of the study of dynamical systems by a legendary figure with infinite energy.

Jianhong Wu

Speakers:
Peter Bates (Michigan)
*Approximately Invariant Manifolds and Global Dynamics of Spike States*

Arno Berger (Alberta)
*Digits and dynamics: from finite data to infinite dimensions*

Pietro-Luciano Buono (OUI)
*Realization of critical eigenvalues for linear scalar and symmetric delay-differential equations.*

Sue Ann Campbell (Waterloo)
*Delay Induced Canards*

Alexandre N. Carvalho (São Paulo)
*Continuity of attractors and of its characterization*

Yuming Chen (WLU)
*The global attractor of a delayed differential system*
Chris Cosner (Miami)
Beyond diffusion: conditional dispersal in ecological models

Walter Craig (McMaster)
Lagrangian and resonant tori for Hamiltonian PDEs

Susan Friedlander (USC)
Kolmogorov’s Turbulence, Onsager’s Conjecture and a Dyadic Model for the Fluid Equations.

Hongjun Gao (Nanjing Normal University)
Random Attractor for the 3D viscous stochastic primitive equations with additive noise.

Martin Golubitsky (Ohio State)
Feed-forward networks near Hopf bifurcation

Stephen Gourley (Surrey)
A Nonlocal Reaction-Diffusion Model for Cellular Adhesion

Jack K. Hale (Georgia Tech)
Perturbing Periodic Orbits in Infinite Dimensions

Wenzhang Huang (Alabama Huntsville)
The Minimum Wave Speed of Traveling Waves for a Competition Model

Michael Jolly (Indiana)
Estimates on enstrophy, palinstrophy, and invariant measures for 2-D turbulence

Barbara Keyfitz (Fields)
The Trouble with Conservation Laws

Tibor Krisztin (Szeged)
Morse decomposition for differential equations with state-dependent delay

Bernhard Lani-Wayda (Giessen)
Attractors for delay equations with monotone and non-monotone feedback.

Marta Lewicka (Minnesota)
Derivation of shell theories from 3d nonlinear elasticity.

Xing Liang (University of Science and Technology of China)
A variational problem associated with the minimal speed of travelling waves for spatially periodic reaction-diffusion equations.

Xiao-Biao Lin (North Carolina)
Traveling Wave Solutions of a Model of Liquid/Vapor Phase Transition

Weishi Liu (Kansas)
Effects of some turning points on global dynamics

Michael C. Mackey (McGill)
Temporal Dynamics in the Tryptophan and Lactose Operons

Pierre Magal (Le Havre)
Semilinear Non-densely Defined Cauchy Problems: Center Manifold Theorem and Applications

Hiroshi Matano (Tokyo)
A braïd-group method for blow-up in nonlinear heat equations.

Connell McCluskey (WLU)
A Global Result for a Disease Model with Infinite Delay

Konstantin Mischaikow (Rutgers)
Building a Database for Global Dynamics of Parameterized Nonlinear Systems

James Muldowney (Alberta)
Bendixson conditions for differential equations in Banach Spaces

Roger Nussbaum (Rutgers)
Nonlinear Differential-Delay Equations with State Dependent Time Lag(s)

Carmen Núñez (Valladolid)
Global attractivity in monotone concave differential equations with infinite delay

Rafael Obaya (Valladolid)
Exponential ordering for scalar neutral functional differential equations with infinite delay.

Sérgio Oliva (São Paulo)
Analytical Methods for Approximation Schemes in Partial Functional Differential Equations

Ken Palmer (National Taiwan University)
Homoclinic Orbits in Singly Perturbed Systems

Wenzhang Huang (Alabama Huntsville)
The Minimum Wave Speed of Traveling Waves for a Competition Model

Michael Jolly (Indiana)
Estimates on enstrophy, palinstrophy, and invariant measures for 2-D turbulence

Barbara Keyfitz (Fields)
The Trouble with Conservation Laws

Tibor Krisztin (Szeged)
Morse decomposition for differential equations with state-dependent delay

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Attractors for delay equations with monotone and non-monotone feedback.

Marta Lewicka (Minnesota)
Derivation of shell theories from 3d nonlinear elasticity.

Xing Liang (University of Science and Technology of China)
A variational problem associated with the minimal speed of travelling waves for spatially periodic reaction-diffusion equations.

Xiao-Biao Lin (North Carolina)
Traveling Wave Solutions of a Model of Liquid/Vapor Phase Transition

Weishi Liu (Kansas)
Effects of some turning points on global dynamics

Genevieve Raugel (Paris de Sud)
Dynamics of some equations in fluid mechanics

Shigui Ruan (Miami)
Center Manifolds for Semilinear Equations with Non-dense Domain and Applications on Hopf Bifurcation in Age Structured Models

Arnd Scheel (Minnesota)
How robust are Liesegang patterns?
General Scientific Activities

Wenxian Shen (Auburn)  
*Spreading and Generalized Propagating Speeds of KPP Models in Time Varying Environments*

Stefan Siegmund (Dresden University of Technology)  
*Differential Equations with Random Delay*

Hal Smith (Arizona State)  
*Persistence Theory for Semidynamical Systems*

Horst R. Thieme (Arizona State)  
*Differentiability of convolutions*

Stephen Schecter (North Carolina)  
*Stability of fronts in gasless combustion*

Arnd Scheel (Minnesota)  
*How robust are Liesegang patterns?*

Hans-Otto Walther (Giessen)  
*Algebraic-delay differential systems, state-dependent delay, and temporal order of reactions*

Gail S. K. Wolkowicz (McMaster)  
*Comparison of Predator-Prey Models with Discrete Time Delay*

Yuan Yuan (Memorial)  
*Pattern Formation in a Ring Network with Delay*

Chongchun Zeng (Georgia Tech)  
*Unstable manifolds and L2 nonlinear instability of the Euler equation*

Yuncheng You (South Florida)  
*Global Dynamics of Cubic Autocatalytic Reaction-Diffusion Systems*

Xiaqiang Zhao (Memorial)  
*Spatial Dynamics of Abstract Monostable Evolution Systems With Applications*

Xingfu Zou (UWO)  
*Impact of map dynamics on the dynamics of the associated delay reaction diffusion equation with Neumann condition*

International Workshop on Quantum Critical Phenomena, Statics and Dynamics  
September 25–27, 2008

Organizing committee: S. Julian (Toronto), Yong-Baek Kim (Toronto), Catherine Kallin (McMaster), Tom Deveraux (Stanford), Phil Stamp (UBC)

In late September a three-day international workshop on the physics of Quantum Critical Phenomena was held at the Fields Institute. Nearly 40 participants from Canada, the US, and Europe took part.

The idea of quantum critical phenomena began in the mid-1970’s as a description of phase transitions at zero temperature. It has since grown to describe a whole program of classification of the low-energy properties of systems in condensed matter physics, quantum optics, and even in more speculative discussions of quantum computation. Nevertheless the touchstone of the field still remains the properties of a few experimental systems.

The Toronto workshop brought together experts and active researchers in the general field of quantum phase transitions, to discuss the issue of static and dynamical properties at and near a quantum critical point. The meeting focused on several important new aspects: (i) The dynamics of quantum phase transitions, as one sweeps an external parameter at a given rate through the critical point. This problem has been widely discussed for both condensed matter and quantum optical systems, as well as for adiabatic quantum computation. (ii) The way in which decoherence from the interaction with a ‘spin bath’ environment influences a quantum phase transition. There is now extensive debate about this for rare earth and transition metal spins interacting via dipolar interactions, with the physics being relevant to both Condensed Matter Physics and some proposed quantum computation schemes. (iii) Hidden order and the hidden Quantum Phase Transition: Under what conditions will a continuous transition not be pre-empted by a first order transition? (iv) Applications to so-called strongly-correlated electron systems, notably quantum liquids featuring competition between magnetic and superconducting ordering, and frustrated spin systems, including spin liquids, and quantum spin glasses.

The meeting began on the afternoon of Thursday, 25 September with a session on the developing connections between Quantum Phase Transitions and Quantum Information and Computation. Stefan Haas gave an introductory talk which was very beneficial for those participants who have been more focused on Quantum Criticality in condensed matter systems; this was followed by Gerald Milburn and Peter Young who talked about quantum Jahn-Teller bifurcation in circuit QED, and size dependence of the minimum gap in the quantum Adiabatic Algorithm, respectively.

In the evening session on Thursday, Piers Coleman gave an overview of quantum criticality as a central paradigm in condensed matter physics, followed by Thomas Vojta (Mis-
souri University of Technology) who summarized his recent work on Quantum Criticality in disordered systems.

On Friday morning the subject turned to the strange quantum critical behavior associated with the spin-glass state in LiHoF and its doped counterparts, with contributions from Gabriel Aeppli and Jan Kycia followed by theoretical talks by Moshe Schechter, Michel Gingras.

In the afternoon there was a session on quantum criticality in the cuprate superconductors, with experimental talks by Louis Taillefer and Tanya Cuk followed by presentations on developing theories in this area by T. Senthil and Sung-Sik Lee. There were then two more talks on quantum critical superconductor/insulator and superconductor/metal transitions, by Nayana Shah and Adrian del Maestro. This was followed by a banquet that moved rather early to a number of bars so that the first of the US Presidential Debates could be watched.

The final day of the conference was devoted mostly to high-powered theory, with presentations by D. Belitz on the amazingly complex behaviour associated with first-order quantum phase transitions; L. Balents on a theory of quantum criticality in orbitally degenerate FeS$_2$S$_4$; Matthew Fisher on a so-called critical quantum spin liquid on a triangular zig-zag strip with ring exchange; and S. Sachdev (whose book on quantum criticality is one of the definitive works in this field) on dynamics and transport of the Z$_2$ spin liquid. Nikolai Prokof'ev attempted, under fire from a number of members of the audience, to establish there is no such thing as deconfined criticality, that is, a quantum phase transition at which fluctuating degrees of freedom such as domain walls can dominate the fluctuations of the order parameter. The final talk was by Andrew Mackenzie, on the Thermodynamics of the formation of a new phase at the quantum critical point in Sr$_3$Ru$_2$O$_7$.

The meeting was quite informal, and the venue contributed significantly to the success of the new meeting. The new connections were made between apparently unrelated areas of research. Although this field contains a number of major unsolved problems, new ideas continue to be generated at a terrific rate. There is however a clear need for more model experimental systems.

The principal sponsor of the meeting was the Pacific Institutes of Theoretical Physics but significant contributions also came from the Canadian Institute for Advanced Research, the University of Toronto Department of Physics and the Fields Institute.

Stephen Julian

Speakers:
Stephan Haas (USC)
Information Theoretical Measures of Quantum Phase Transitions
Gerard Milburn (Queensland)
Quantum Jahn-Teller bifurcation in circuit QED
Peter Young (UC Santa Cruz)
Size dependence of minimum gap in the Quantum Adiabatic Algorithm
Jingfu Zhang (Waterloo)
Direct observation of quantum criticality in Ising spin chains
Piers Coleman (Rutgers)
Quantum Phase Transitions: frontier challenges in condensed matter physics
Thomas Vojta (Missouri)
Effects of Dissipation on quantum critical points with disorder
Bill Atkinson (Trent)
Electodynamic response of coexisting amorphous magnetic and superconducting phases
Jan Kycia (Waterloo)
LiHoF experiment and review
Gabriel Aeppli (University College London)
The road between solid state ion trap and quantum critical ferromagnet
Moshe Schechter (UBC)
Dilute anisotropic dipolar systems as random field Ising ferromagnets
Michel Gingras (Waterloo)
Random Field and Spin Glass Physics in LiHoYF4 and Assessment of the (Dy,Ho)(OH)$_3$ Materials as new Transverse Field Ising Systems
Louis Taillefer (Sherbrooke)
Quantum critical behaviour in cuprates
Tanja Cuk (Stanford)
A pressure-tuned electronic transition in lightly doped Bi2212
Senthil Todadri (MIT)
Critical Fermi surfaces and non-fermi-liquid metals
Sung-Sik Lee (McMaster)
Stability of the U(1) spin liquid with spinon Fermi surface in 2+1 dimensions
Nayana Shah (Illinois)
Quantum phase transitions in low dimensional superconductors
Adrian del Maestro (UBC)
*Infinite randomness and the superconductor-metal transition*

Dietrich Belitz (Oregon)
*First order versus second order transitions in quantum magnets*

Leon Balents (UC Santa Barbara)
*Quantum criticality in orbitally degenerate insulator FeSc$_2$S$_4$*

Matthew Fisher (UC Santa Barbara)
*Critical quantum spin liquid on the triangular zigzag strip with ring exchange*

Subir Sachdev (Harvard)
*Dynamics and transport of the $Z_2$ spin liquid*

Nikolai Prokofev (Amherst)
*Search for Deconfined Criticality: SU(2) Dejavu*

Andrew Mackenzie (St Andrews)
*Thermodynamics of phase formation in Sr$_2$Ru$_2$O$_7$*

2nd Annual Pure and Applied Mathematics Graduate Student Conference
October 24–26, 2008
Held at McMaster University

On October 24-26, 2008, graduate students from across Canada and the United States gathered at McMaster University in Hamilton, Ontario for the 2nd Annual Pure and Applied Mathematics Graduate Student Conference. Fifty-three students from 16 universities, some just beginning their graduate work and others nearly finished, arrived to participate in this student organized event.

The conference opened with a plenary talk Heat Rises: Energy transport in Rayleigh-Bénard convection by Charles Doering after which the main focus of the event began with the first session of student talks. Over the course of the weekend, forty-seven students presented their research on such diverse topics as Projective completions of affine varieties and a Bezout-type theorem (Pinaki Mondal) to Schramm-Loewner Evolution (Matthew Folz). “Overall, I was impressed by the quality of the talks,” said co-organizer Laurel Miller-Sims. “I think events such as these provide an important opportunity for graduate students to present their research to an audience of their peers.” In addition, participants were brought together for talks by Megumi Harada and Matt Davison.

Over the weekend, students had a multitude of opportunities to mingle, socialize and network. “It can be lonely when you are the only graduate student in your field of research in your university,” said co-organizer, Jonathan Gustafsson, in his opening remarks. “I hope you have the chance to meet others in your fields of research.” Perhaps the highlight of the event was the well-attended student social at the Acclamation Bar and Grill in downtown Hamilton.
General Scientific Activities

Participating students came from McMaster, Toronto, York, Guelph, Waterloo, Western Ontario, Queen’s, Ottawa, Montreal, Brown, Carnegie Mellon, Chicago, Memorial, Regina, Simon Fraser and British Columbia. The 2nd Annual Pure and Applied Mathematics Graduate Student Conference was generously supported by the Fields Institute, AARMS, MITACS, CAIMS and the CMS as well as the School of Graduate Studies and the Faculty of Science at McMaster University.

Laurel Miller-Sims

Plenary Speakers:
Matt Davison (UWO)
Adventures in Industrial Mathematics
Charles Doering (Michigan)
Heat Rises: Energy transport in Rayleigh-Benard convection
Megumi Harada (McMaster)
A glimpse of symplectic geometry, via lots of pictures

Weekend Workshops on Algebraic Varieties with Special Emphasis on Calabi-Yau Varieties and Mirror Symmetry
November 1–2, 2008, March 7–8, 2009
Organizers: Noriko Yui (Queen’s) and James D. Lewis (Alberta)

This series of weekend workshops, inaugurated in 2003 by James D. Lewis, Stefan Müller-Stach and Noriko Yui, has entered its sixth year. Each of the 2008-2009 workshops attracted 25 to 30 participants. The subjects covered in the workshops ranged widely from arithmetic/algebraic geometry and noncommutative geometry, to mathematical physics – in particular, to string theory.

These workshops have generated a lot of interest in both the mathematics and physics communities and, perhaps due to their informal nature, have attracted a significant number of young researchers. Besides local (Canadian) participants, many of the participants came from various parts of the United States, as well as Europe and some Asian countries. Several supervisors supported their doctoral students’ participation in the workshops, some coming from as far away as Japan to take part.

With generous financial help from the Fields Institute, the workshop is now able to pick up the local expenses for young participants who have no support from other sources.

The workshops are organized under the guiding principle that the participants and speakers should include researchers from the following groups:

- Researchers working on the leading edge of the subject.
- The next generation of promising younger researchers, including graduate students and postdoctoral fellows.
- Leading experts in closely related areas where fruitful interactions are thought to be likely.

The pedagogical aspects of the workshops are emphasized in the choice of topics so that every participant can benefit from them through the talks and informal discussions. The workshops provide a forum for young participants to get first hand opportunities to discuss their problems and results with mid-career and senior researchers. This formula has worked very well for these workshops.

The Fall Workshop of the 2009-2010 academic year is planned for October 31-November 1, 2009, and the Spring Weekend Workshop for a weekend in March 2010.

Noriko Yui

Speakers at November workshop:
Steven Lu (UQAM)
On the structure of algebraic varieties and holomorphic curves (the case of nef-K)
Tatyana Foth (UWO)
Varieties of complex Lie algebras
Andrey Todorov (UC Santa Cruz)
Holomorphic metrics, flat connections on the moduli space of Hodge structures and proof of the global Torelli Theorem for polarized CY manifolds
Matthew Ballard (Pennsylvania State)
Understanding derived categories of sheaves on singular projective varieties
Chris Brav (Toronto)
Tilting in derived categories
Fernando Gouvêa (Colby College/Queen’s)
Rigid Calabi – Yau threefolds over Q are modular
James Lewis (Alberta)
Biextensions associated to algebraic cycles I
Andrey Novoseltsev (Alberta)
Closed form expressions for Hodge numbers of Calabi-Yau complete intersections
Ying Zong (Toronto)
Hypersymmetric abelian varieties
Su-Jeong Kang (Alberta)
The general Hodge conjecture and Calabi-Yau varieties
General Scientific Activities

Noriko Yui (Queen’s)
*On the modularity of certain K3 surfaces with non-symplectic group actions*

Speakers at March workshop:
Steven Lu (UQAM)
*Picard theorems for holomorphic curves in varieties with maximal Albanese dimension and the resolution of a conjecture of Lang*

Ling Long (Iowa)
*Modularity of Galois representations attached to an elliptic modular surface*

Bill Hoffman (Louisiana)
*Infinitesimal structure of Chow groups*

David Ploog (Toronto)
*Understanding derived categories of sheaves on singular projective varieties*

Doug Haessig (Rochester)
*Mirror symmetry and quotients of zeta functions*

Sheldon Joyner (UWO)
*Zeta functions as iterated integrals*

Noriko Yui (Queen’s)
*Certain K3 surfaces with non-symplectic group actions and their modularity*

Yasuhiro Goto (Hokkaido University of Education)
*On the L-series of some Calabi-Yau threefolds over the rationals*

Gregory Pearlstein (Michigan)
*The zero locus of an admissible normal function*

James Lewis (Alberta)
*An Archimedean height pairing on the equivalence relation defining Bloch’s higher Chow groups*

Ying Zong (Toronto)
*CM-liftings of abelian varieties*

Snigdhayan Mahanta (Johns Hopkins)
*Geometries over $F_1$*

Conference on Women in Numbers
November 2–7, 2008
Held at the Banff International Research Station

Organizers: Kristin Lauter (Microsoft), Rachel Pries (Colorado State), Renate Scheidler (Calgary)

The idea for this conference was conceived a few years back by the organizers when they noticed the dearth of prominent female number theorists at a conference they were attending. The main goal of this workshop was to increase the representation and visibility of women in number theory, thereby enhancing gender diversity in the field. This was to be done by introducing female graduate students to potential advisers, collaborators, and thesis problems, and, as a more long-term objective, by increasing the participation of women in research activities in number theory and related applications.

Against the snowy backdrop of the Canadian Rockies, from the early morning talks to the late night working sessions, the atmosphere was joyful and warm. About 15 faculty, 16 junior faculty and postdocs, and 10 graduate students participated in the workshop.

The junior participants were divided into eight research groups, and distinguished female number theorists were chosen as group leaders. They selected and prepared projects in advance as well as providing materials and references for background reading to the students ahead of time. At the conference, they gave lectures, and directed the research efforts of their respective groups, mentoring students and younger researchers.

Many group members are currently writing joint research articles based on their research project in WIN.

As a result of this workshop, some of the participants will set up a network by establishing a wiki for Women in Numbers. This will include hosting a web page with information on female number theorists from different categories (active researchers, graduate and post-doctoral students, educators). The web page will link to the web pages of participants when possible, and will include an e-mail mailing list for discussion topics. There will also be a list and links to (male and female) advisers, collaborators, and co-organizers of conferences to try to increase the connectivity and inclusiveness of the community.

The organizers and participants are determined to continue working toward the goals of the workshop. Two of the next steps are publishing a top-quality conference proceedings volume, and organizing future follow-up and spin-off conferences, some of which will include both men and women in particular areas of number theory.

Following the standard process of BIRS workshops, participation in this meeting was by invitation only. Since the primary purpose was to highlight the activities of female researchers and bring together junior and senior female number theorist, only women were invited. The group leaders were chosen from established researchers in Canada,
the Unites States, and South Korea. An open application process advertised for graduate students.

Thanks to our sponsors there were sufficient funds to provide travel support to graduate students, postdocs, unfunded young faculty, and the project leaders.

Sponsors: The Fields Institute, PIMS, Microsoft Research, the University of Calgary, and the United States National Security Agency.

Shabnam Akhtari
Speakers: (as listed on program itinerary)
Stephanie Treneer (Western Washington)
Modular Forms I
Ling Long (Iowa)
Modular Forms II
Chantal David (Concordia)
Frobenius Distribution and L-functions
Alina Cojocaru (Chicago)
Koblitz's Conjecture on Average
Audrey Terras (UC San Diego)
Zeta Functions of Graphs I
Winnie Li (Pennsylvania State)
Zeta Functions of Graphs II
Kirsten Eisentraeger (Pennsylvania State)
Computation of pairings on hyperelliptic curves I
Edlyn Teske (Waterloo)
Computation of pairings on hyperelliptic curves II
Katherine Stevenson (Northridge)
Towers of Galois covers in characteristic p I
Rachel Pries (Colorado State)
Towers of Galois covers in characteristic p II
Renate Scheidler (Calgary)
Class groups of function fields
Yoonjin Lee (Ehwa Womans University)
Class groups of function fields II
Helen Grundman (Bryn Mawr)
Computations on Hilbert Modular Surfaces I
Kristin Lauter (Microsoft)
Computations on Hilbert Modular Surfaces II
Mirela Ciperiani (Columbia)
Galois representations I
June Hui Zhu (Buffalo)
Galois representations II
General Scientific Activities

IFID/MITACS Conference on Financial Engineering for Actuarial Mathematics
November 9–10, 2008

Organizers: Huaxiong Huang (York), Sebastian Jaimungal (Toronto), Moshe Milevsky (York), Kristen Moore (Michigan), David Promislow (York), Tom Salisbury (York)

With the baby-boomer generation planning for retirement and with an aging population worldwide, managing income in retirement has become a key question for the finance and insurance industries, as well as for individuals. At the same time, many corporations have stepped away from the standard defined benefit pensions traditionally offered to employees. As a result, individuals increasingly have to manage the risks associated with sustaining retirement income. To deal with this, new products, some substantially more sophisticated than traditional annuities, have been designed and marketed to retirees. Many of them blend features from both finance and insurance. Managing them and analyzing them demands novel and innovative tools and often a combination of expertise in several areas such as finance, actuarial science, probability theory, differential equations and numerical methods.

The fundamental problem is that life insurance and financial economics approach have quite different points of view, and use quite distinct approaches. The perfect hedging paradigm does not apply in actuarial science, where risk is retained and managed without dynamic hedging. Traditional life insurance products used to provide little exposure to equity returns. What has changed is that in recent years there has been rapid innovation of various equity-linked insurance and annuity products. These products are very attractive because they not only provide the potential of positive gains in the equity markets, but they also provide protection from market downturns - the recent propagation of the effects of the sub-prime mortgages in the US is a prime example of such events. The complex embedded options in these equity-linked contracts coupled with their inherent mortality risk make them notoriously difficult to model, value, hedge and assess for risk. However, it is exactly this interplay between the upside potential and downside protection that makes them interesting and useful for retirement planning.

This conference brought together researchers from both the insurance and finance sides of the subject. Over two days, nearly 50 participants heard four keynote talks, as well as six other invited talks (some by new researchers in the field). Some of these talks addressed the blending of mortality and equity risk, such as the keynote lecture by Ragnar Norberg of the London School of Economics. Others, such as the keynote lectures of Shege Peng (of Shandong University), and Sid Browne (formerly of Columbia, but at the...
These talks were followed by 20 minute presentations by students and postdoctoral fellows Bernd Schulze, Elisa Ross, Daniel Pellicer and Feng Xie.

Asia Ivic Weiss
Speakers:
Karoly Bezdek (Calgary)
Partial covering by planks - a new variant of Tarski’s plank problem
Robert Connelly (Cornell)
Global Rigidity
Antoine Deza (McMaster)
Polytopes and Arrangements: Diameter and Curvature
Daniel Pellicer (UNAM)
Combinatorial structure of the chiral polyhedra in Euclidean 3-space
Elissa Ross (York)
Periodic Rigidity
Bernd Schulze (York)
Symmetry as a sufficient condition for a finite flex
Feng Xie (McMaster)
Hyperplane Arrangements with Large Average Diameter

Connecting Women in Mathematics Across Canada 2008
December 4–5, 2008
Held at the University of Ottawa
Organizers: Lucy Campbell (Carleton), Gerda de Vries (Alberta), Ariane Masuda (Ottawa), Monica Nevins (Ottawa), and Ping Zhou (St. Francis Xavier)

The 4th “CWiMAC” workshop, organized by the CMS Committee for Women in Mathematics, was held just prior to the CMS Winter Meeting. This was a great organizational move as it encouraged the workshop participants to attend both meetings. The purpose of the CWiMAC workshops is to support the career development of junior female academics in the Canadian mathematics community, and CWiMAC 2008 succeeded in fulfilling its purpose.

The opening talk by Margaret-Ann Armour, Connecting more women to mathematics through Project Catalyst was a thought-provoking start to the workshop. During the talk, Armour pointed out that there are few women mathematics faculty and talked about her Project Catalyst initiative to help change that.
Following her talk there was a dinner at which the attendees had the chance to network. There were women from all stages of their careers at the meeting, from entry-level graduate student to full professor, and the dinner provided an opportunity to learn from mathematicians at varied stages in their careers. Prior to the dinner, graduate students were assigned an informal mentor, and many conversed with their mentors during dinner. The dinner speaker, Larissa Vingilis-Jaremko from the Canadian Association for Girls in Science (CASIS), spoke about CASIS, following which many ideas were generated about incorporating mathematics into CASIS activities.

The second day began with a featured talk by Gerda de Vries, Mathematicians must speak: The DOs and DON’Ts of giving effective mathematical presentations, which provided advice highly relevant to anyone pursuing a mathematical career. Following de Vries’ presentation, there was a featured talk by Malgorzata Dubiel who spoke about finding a balance between teaching and research – an issue with which all mathematicians (including many graduate students, who are often teaching assistants) struggle.

The morning talks were followed by a poster session, at which students who were presenting a poster had the opportunity to feature their research and practice mathematical communication. All students were encouraged to present their research either as a poster or as a twenty minute talk; the talks were held in the late afternoon.

Lunch on the second day was accompanied by an innovative presentation by Wendy MacCaull, in which she challenged us to find new and unexpected funding and research opportunities by partnering with industry. MacCaull’s talk demonstrated that the sky is the limit when it comes to what mathematics can do.

The most interactive presentation of the workshop was a panel discussion, moderated by Lucy Campbell and featuring panelists Margaret Beattie, Lucia Moura, Mateja Sajna, and Rebecca Tyson. After the panelists explained how they ended up in mathematics, the attendees had the opportunity to ask questions and raise issues.

All in all, the one and a half day workshop, although short, explored a spectrum of issues relating to women pursuing a mathematical career and was immensely beneficial to the attendees. For this writer, a second time attendee of CWiMAC, it was a significant and positive event that enriched the overall graduate student experience.

Financial support was received from the Canadian Mathematical Society and the Fields Institute. For a full list of participants, abstracts, and further information, visit the workshop’s webpage at [www.cms.math.ca/Events/cwimac2008/](http://www.cms.math.ca/Events/cwimac2008/)

Monica Nevins

Speakers:
Margaret-Ann Armour (Alberta)
Connecting More Women to Mathematics Through Project Catalyst

Gerda de Vries (Alberta)
Mathematicians Must Speak: The DOs and DON’Ts of Giving Effective Mathematical Presentations
Malgorzata Dubiel (Simon Fraser)
Teaching and Research: Finding a Balance

Wendy MacCaull (St. Francis Xavier)
New Directions in Applying for Mathematical Research Funding

Elaine Beltaos (Alberta)
Algebra and Conformal Field Theory

Rebecca Hammond (Acadia)
Modeling Mites in Apple Trees

Hong Yue (Concordia)
A John-Nirenberg Type Inequality

Caroline Lambert (Montreal)
Classification of linear differential systems

Asia Matthews (Queen’s)
Post-secondary mathematics instruction: the change in enrollment and the lack of change in teaching methods

Workshop on Computational Methods for Hyperbolic Problems
April 20–22, 2009
Held at the University of Waterloo
Organizer: Lilia Krivodonova (Waterloo)

Forty speakers and participants from across Canada and the United States attended this workshop. There were contributions from world-renowned researchers in the field of scientific computing as well as from many young scientists and graduate students. The format of the workshop consisted of an hour long keynote lecture to begin each day, followed by five forty-five minute presentations. This allowed enough time for highly detailed presenta-
tions which facilitated many interesting discussions and exchange of opinions between participants during the talks and between sessions.

The workshop began with a keynote presentation by Marsha Berger. Her talk described current state of the art approaches to embedded boundary grid methods for compressible flow simulations in complex geometries. Included in the discussion were details of her research on maintaining accuracy and stability on cut cells. She also showed very interesting visualizations of large scale simulations of space shuttle flight worked on in collaboration with NASA.

The first morning session also included talks by Clinton Groth who spoke on continuum and non-equilibrium flows and Carl Ollivier-Gouch who discussed unstructured finite-volume schemes for computational aerodynamics. The afternoon session consisted of presentations on computations of internal waves by Marek Stastna and flame propagation by Smadar Karni. The final talk of the day was given by Martin Berzins on positivity preserving (W)ENO schemes. The first day was brought to a close by a poster session which featured work by graduate students.

The second keynote lecture marked the beginning of the second day of the workshop. Chi-Wang Shu presented fascinating new results on error analysis for discontinuous Galerkin methods. Two other talks on discontinuous Galerkin methods were given by Lilia Krivodonova and, on the final day, by Timothy Warburton. Other talks of the second day were presented by Barbara Keyfitz on stability of shock waves, Marc Laforest on a stochastic numerical scheme for the Boltzmann equation, Allen Tesdall on shock reflection, and lastly, Jae-Hun Jung on spectral collocation methods for problems with singular sources.

The last day of the workshop featured the final keynote lecture by Timothy Barth (NASA Ames) who talked on error estimation and presented complex three dimensional simulations of rotating helicopter blades. The final three talks were focused on solving hyperbolic equations on surfaces by Steve Ruuth stationary flows by Hans De Sterck and employing the reservoir technique by Emmanuel Lorin.

Lilia Krivodonova

Speakers:
Marsha Berger (NYU)
Status Report on Embedded Boundary Grids
Clinton Groth (Toronto)
Numerical Solution of Continuum and Non-Equilibrium Flows Using Hyperbolic and Physically-Realizable Descrip-

G e n e r a l  S c i e n t i f i c  A c t i v i t i e s

Carl Ollivier-Gooch (UBC)
High-Order Accurate Unstructured Mesh Finite-Volume Schemes for Computational Aerodynamics
Marek Stastna (Waterloo)
Application of hyperbolic system methods to dispersive, non-linear internal waves and porous media acoustics
Smadar Karni (Michigan)
A Hybrid Scheme for the Baer-Nunziato Two-Phase Flow Model
Chi-Wang Shu (Brown)
Superconvergence and Time Evolution of Discontinuous Galerkin Finite Element Solutions
Barbara Keyfitz (Ohio)
Linear and Nonlinear Stability of Shocks
Marc Laforest (Montreal)
An adaptive version of the Illner-Rjasanow stochastic scheme for the Boltzmann equation
Lilia Krivodonova (Waterloo)
A space and time adaptive discontinuous Galerkin method
Allen Tesdall (CUNY)
A two-phase Stefan problem for the unsteady transonic small disturbance equations
Jae-Hun Jung (SUNY Buffalo)
Spectral collocation methods for hyperbolic equations with singular sources
Timothy Barth (NASA Ames)
Error Representation for Time Dependent Compressible Flow Calculations
Timothy Warburton (Rice)
Advances in Wave Propagation with the Discontinuous Galerkin Method
Steve Ruuth (Simon Fraser)
A Simple Technique for Solving Partial Differential Equations on Surfaces
Hans De Sterck (Waterloo)
Efficient solution of stationary Euler flows with critical points and shocks
Emmanuel Lorin (UOIT)
About the reservoir technique for hyperbolic conservation laws
Workshop on Fire Spotting  
April 23–24, 2009  
Held at the University of Toronto  

Organizers: David Stanford (UWO), Rob Mcalpine (Ontario MNR), Mike Wotton (Toronto)

This workshop brought together the leading engineering scientists and forest fire modellers working with the fire spotting phenomenon, and applied mathematicians and statisticians with interests in developing models of it, in order to provide students the opportunity to become aware of the state of the art.

Mathematical and statistical interest in the modelling of forest fire behaviour has increased recently, and this development is timely because of increased fire risks due to climate change and increases in population at the wildland-urban interface. In this context, fire - spotting behaviour has not received adequate attention until now. Large-scale forest fires often generate powerful up-drafts which carry firebrands into the atmosphere; the firebrands are then transported to regions remote from the original fire.

Such spot-fires increase the rate of spread of fires and enable fires to spread across natural and artificial firebreaks such as rivers and roads. Thus, spot-fires are a particularly dangerous aspect of the forest fire management problem, as was evident in the fire storms experienced by the state of Victoria in Australia in February of this year.

The main objective of the proposed workshop was to bring together the key stakeholders noted above to work towards the development of good approaches to handle this problem. In many cases, we discovered that standard assumptions for one region were not at all realistic for others. A key case in point pertained to discussions as to what constituted medium versus long range fire spotting. In the context of Northern Ontario, medium range spotting might be considered as distances between 500 metres and 1.5 km, with long range spotting being on the order of 5 km. In the Australian context, however, we learned that it is not uncommon for Eucalypt embers to travel 20 km.

Other topics discussed were as wide ranging as data acquisition plans with forest managers who are set to acquire a substantial set of spot-fire behaviour data in late 2009, and a review of vertical and horizontal winds given by engineers on the current state of wind tunnel experiments. Issues related to data structures were also discussed.

The key outcome was the recognition from both ends of the spectrum (practitioners and academics) to identify a series of key questions they most need to answer in order to carry their research to the next level. Those conducting upcoming data gathering experiments will then be better able to track the variables of interest to academics developing the relevant mathematical models of fire spotting. Conversely, academics need to know the phenomena of greatest concern to forest scientists in order to focus their modelling efforts on them.

David Stanford

Speakers:
Mike Wotton (Toronto)  
*Canadian FBP system - current and future treatment of spotting*

Brett Butler (USDA Forest Service)  
*US models of spot fire and their applications*

Cordy Tymstra (Promotheus)  
*Prometheus and spot fires*

Derek Onn Cho (Melbourne)  
*Phoenix project - realistic spotting model development*

Jim Gould (Canadian Forest Service)  
*Spot fire models and research in Australia*

Chelene Krezek (Canadian Forest Service)  
*IR Camera research into Fire Behavior in Canada*

Rodney Linn (Los Alamos National Laboratory)  
*Title not available*

Dave Stanford (UWO)  
*What distribution do spotting distances follow?*

Greggory Kopp (UWO)  
*Wind Tunnel Modelling*

Thomas Hillen (Alberta) and Jon Martin (Alberta)  
*Mathematical modelling of spotting*

Hao Yu (UWO)  
*Parallel spatial grid computing*

Workshop on the Philosophy of Quantum Field Theory  
April 24–26, 2009  
Held at the University of Western Ontario  
Organizer: Wayne Myrvold (UWO)

While philosophers have devoted a great deal of attention to quantum mechanics ever since its inception, it is only recently that a significant amount of attention has been focused on quantum field theory. The talks shed light on
many different facets of quantum field theory, but most fit into three broad themes:

1. the relationship between quantum field theory and other physical theories, such as non-relativistic quantum mechanics and classical (i.e., non-quantum) spacetime theories,
2. the implications of different formulations of the theory (e.g., the Lagrangian formulation found in most introductory textbooks and the mathematically rigorous algebraic axiomatic formulation), and
3. whether quantum field theory describes a reality that contains entities that are particle-like in some respects.

One of the main aims of philosophy of science is to clarify the mathematical and conceptual structure of scientific theories. The talks and subsequent discussions made it clear that the mathematical structure of the theory plays a particularly important role in the foundations of quantum field theory. A recurrent issue was how to draw out the implications of the mathematical formalism. In part, this is due to the fact that fields are associated with an infinite number of degrees of freedom, which permits more complex mathematical representations to be employed; the complexity of the mathematical representation complicates the job of interpreting the theory. The fact that there exist both informal and mathematically rigorous variants of the theory is also a contributing factor. The question of which variant of quantum field theory is most appropriate for the purposes of interpretation and foundational analysis was the subject of a lively debate.

This workshop brought together leading researchers from North America and the United Kingdom. The speakers were David Baker, Gordon Belot, Steve Weinstein, Hilary Greaves, Jon Bain, Laura Ruetsche David Wallace, Doreen Fraser, Nick Huggett and Gordon Fleming. Many others present participated in the discussions, including a contingent of graduate students and also a number of professors, from the University of Western Ontario and elsewhere. It was particularly appropriate that this workshop was held at the University of Western Ontario since Southwestern Ontario is now home to a concentration of philosophers of quantum field theory. The meeting also provided an opportunity for junior scholars, including graduate students, to interact with senior scholars in the field. One of the highlights was the panel discussion at the end of each day, which featured both debates and shared insights. Discussions that began in the conference room continued informally over meals. Video recordings of the workshop papers and discussions will soon be posted online to make them available to a wider audience, and there are plans in progress to publish selected workshop papers in Studies in the History and Philosophy of Modern Physics, a leading journal in this area.

Thanks to the Fields Institute for support that enabled graduate students to participate in this workshop.

Christopher Smeenk

Speakers:
David Baker (Michigan)
Broken Symmetry and Spacetime
Gordon Belot (Michigan)
The Wave-Function for Primitive Ontologists
Steve Weinstein (Waterloo)
Decoherence and the emergence of classicality
Hilary Greaves (Oxford)
Towards a Geometrical Understanding of the CPT Theorem
Jon Bain (NYU)
Intertheoretic Implications of Non-Relativistic Quantum Field Theories
Laura Ruetsche (Michigan)
Why be normal?
David Wallace (Oxford)
Taking particle physics seriously: a critique of the algebraic approach to the foundations of QFT
Doreen Fraser (Waterloo)
Interpreting Quantum Field Theories: The Significance of Variant Formulations (Part II)
Nick Huggett (Chicago)
Are Quarticles Discernible?
Gordon Fleming (Pennsylvania State)
Observations on Unstable Quantons, Hyperplane Dependence and Quantum Fields

Prairie Research Network in the Mathematical Sciences
April 29–May 1, 2009
Held at the University of Saskatchewan

Organizers: Jaydeep Chipalkatti (Manitoba), Steve Kirkland (Regina), Chenkuan Li (Brandon), Ray Spiteri (Saskatchewan), Anna Stokke (Winnipeg)

The third Annual Meeting of the PNRMS attracted approximately 120 registrants, primarily from Saskatchewan and Manitoba. The meeting showcased the rich diversity of the
mathematical research across the prairies in four themes: pure mathematics, applied mathematics and theoretical physics, probability and statistics, and computational and industrial mathematics.

The Pure Mathematics theme included a plenary address by Yuri Bahturin and 17 contributed talks by senior faculty, new faculty, and graduate students in a broad range of areas of pure mathematics, including analysis (operator algebras and real and complex analysis) topology and algebraic geometry, and algebra and representation theory. The diversity of the speakers was particularly impressive: of the 17 contributed talks, four were by graduate students, one by a postdoctoral fellow, six by new faculty members, and five by women.

The Applied Mathematics and Mathematical Physics theme also had a strongly multidisciplinary character, reflecting the current global trends in science and mathematics research. The plenary address by A.M. Zagoskin emphasized the mathematical and scientific challenges in quantum engineering and quantum computing. This relatively new research area has attracted a lot of interest, in no small part because it is perceived as a portent of the inevitable changes that it will bring to the practice of applied mathematics. The quantum trend was maintained also in many of the 18 contributed talks. A number of participants also presented results in other areas of modern applied mathematics, ranging from the theory and applications of partial differential equations, Hamiltonian mechanics, and wavelets to mathematical modelling in biology, geoscience, and nanotechnology.

The Probability and Statistics theme began with the illuminating opening plenary talk by Paul Gustafson on the limits of inferences from “lousy data”. This was followed by 15 contributed talks spread over two days. The first day focused on Statistics and featured graduate student and faculty speakers from Saskatchewan, Manitoba, Alberta, and Ontario. The morning of the second day focused on topics in Markov Chain theory and applied probability with postdoctoral and faculty speakers from Saskatchewan and Ontario. The afternoon of the second day focused on Monte Carlo and statistical mechanics with talks by graduate students and faculty from Saskatchewan and Manitoba.

The Computational and Industrial Mathematics theme was focused around a two-day workshop on programming for the Cell Broadband Engine (CBE) computer chip. The workshop leader was Michael Perrone, Manager of IBM’s Multicore computing division based at the T.J. Watson Research Center, who also delivered a plenary lecture on the looming paradigm shift in computing and software design to multi-core computer architectures. The 15 participants in the workshop ranged from senior undergraduates to faculty members. This workshop was the first in Canada to allow participants local access to Cell hardware.

Overall, the organizers felt the meeting was very successful. The sessions covered a broad range of research topics and were all well attended and well received. Moreover the palpable grass-roots support of the PNRMS inspired new interactions within the Prairie Universities and beyond. Most notably, for the first time at a PNRMS meeting there was a significant involvement of applied mathematicians and statisticians. Melody Gharamani, who spoke at this meeting, hopes to build on this success in her role as an organizer for the next PNRMS annual meeting which will be held at the University of Manitoba.
Workshop on Smooth Structures in Logic, Category Theory and Physics
May 1–3, 2009
Held at the University of Ottawa
Organizers: P. Scott, R. Blute, P. Hofstra, M. Warren (Ottawa)

The purpose of this meeting was to bring together researchers studying mathematical structures arising from or related to notions of smooth spaces. Our hope was that a variety of different approaches such as logic, category theory, algebraic topology, and differential geometry would be represented. In this respect the workshop was a definite success, with a total of 40 registered attendees, among them 15 graduate students and two postdocs.

One of the challenges of the area of smooth structures is to find an appropriate setting in which to organize the objects of study. One problem is that the natural category of smooth manifolds is not cartesian closed. This has led a number of researchers from widely varying backgrounds (e.g. differential geometry, analysis, category theory, logic, physics, etc.) to develop various “convenient” settings for smooth analysis, with better structural properties. The purpose of the conference was to survey these different approaches, to investigate their differences and similarities, and to further the interaction of the different research areas involved. To achieve this goal, there were tutorials and invited talks surveying the different approaches to smoothness, allowing the participants to gain a comprehensive perspective on recent developments.

The invited speakers were John Baez, Kristine Bauer, Thomas Ehrhard, Anders Kock, Gonzalo Reyes and Andrew Stacey. Baez posed and then suggested several answers to the question “Why smooth spaces?” Bauer gave two tutorial talks in which she presented an introduction to the Goodwillie-Weiss functor calculus, wherein one studies “polynomial” approximations of functors by analogy with differential calculus. Ehrhard described a model of differential linear logic arising from linearly topologized vector spaces. Kock gave two tutorials on the topic of Kaehler differentials in the setting of synthetic differential geometry. In his talk, Reyes considered several questions, such as existence of solutions of differential equations, in specific models of synthetic differential geometry. Finally, Stacey presented a comparison of several of the proposed abstract approaches to categories of smooth spaces.

III was held in Toronto in 2005 and was co-sponsored by CMS and Fields.]

Two major aspects of the Forum set it somewhat apart from comparable meetings, first that it centred around the work of 13 working groups which had been collaborating already for many months before the actual meeting, and second, that the meeting brought together a wide range of folks engaged in mathematics education. In particular it is rare that so many teachers from across the country are able to come together to share ideas and talk with university folk, and with publishers and government officials in panels and working group encounters. We mention this in that all the comments received from participants, the most “wonder-full” were the comments from teachers particularly from far away – “I can’t believe I’m here!”

We had three plenary speakers, Rina Zazkis a professor of Mathematics Education at SFU (joint speaker with the Changing the Culture conference), Steve Rasmussen of Key Curriculum Press and Hugh Burkhardt of the Shell Centre in Nottingham. The soul of the meeting was perhaps provided by the panel discussions. Two of these were Reaction Panels of teachers and researchers which followed each of the second two talks. In addition, the opening panel featured a number of teachers from across Canada discussing the questions: What did I need then? What do I need now? The working groups spanned many areas including assessment at all levels, problem-solving, on-line learning, school-university interface, text-book design (which included a number of publishers), indigenous knowledge, statistics, spatial reasoning and (or course?) philosophy.

The success of the meeting persuaded us that the Forum must continue, and though new co-organizers have yet to be chosen, a 4-year cycle seems to be favoured with much the same format as we had this year.

Peter Taylor and Malgorzata Dubiel

Plenary Speakers:
Hugh Burkhardt (Nottingham)
Making School Mathematics Functional: A Stool Needs Three Legs

Steven Rasmussen (Key Curriculum Press)
The Vantage Point of a Publisher: One View of Curriculum Development

Rina Zazkis (Simon Fraser)
Reconsidering Basic Mathematical Assumptions in Teacher Education
In addition to the invited speakers, there were several additional talks given at the workshop: Richard Blute gave a tutorial on differential structures from the perspective of categorical logic – focussing in particular on linear logic and differential categories. Robin Cockett discussed further axiomatic structure relating differential categories to abstract Kähler differentials. Alexander Hoffnung described the setting of diffeological spaces as a candidate for a reasonable abstract notion of smooth space. Dorette Pronk discussed the equivariant homotopy theory for smooth orbifolds; and Konrad Waldorf detailed the use of smooth functors for higher-dimensional parallel transport.

In conclusion, we believe that the workshop was a success in achieving its aims. By bringing together researchers from several different “fields” who are nonetheless studying similar structures, it has helped the attendees to cultivate a better appreciation and understanding of the various approaches to smoothness. Consequently, we anticipate that the interaction between researchers attending the workshop – in particular several collaborative projects arose – will lead to new results in and greater understanding of this exciting area of mathematical research.

Phil Scott

Speakers:
John Baez (UC Riverside)
Why Smooth Spaces?

Kristine Bauer (Calgary)
Introduction to functor calculus

Rick Blute (Ottawa)
From Linear Logic to Differential Categories

Robin Cockett (Calgary)
Introduction to Cartesian Differential Categories

Thomas Ehrhard (PPS Paris)
Differential Linear Logic and Computation

Alexander Hoffnung (UC Riverside)
From Smooth Spaces to Smooth Categories

Anders Kock (Aarhus)
Kähler differentials for Fermat theories
Synthetic meaning of Kähler differentials.

Dorette Pronk (Dalhousie)
Equivariant Homotopy Theory for Smooth Orbifolds

Gonzalo Reyes (Montreal)
Analysis in Smooth Toposes: Knowledge and Conjecture

Andrew Stacey (NTNU Norway)
Comparative Smootheology

Konrad Waldorf (UC Berkeley)
Smooth Functors for higher-dimensional Parallel Transport

Conference on Nonparametric Methods for Measurement Error Models
May 2–5, 2009
Held at Carleton University

Organizers: A.K.Md.Ehsanes Saleh and M.Ould Haye (Carleton)

Although the topic is a century old, challenging problems remain and not many scholars deal with the nonparametric approach. The conference was a great success in many ways. It attracted many experts in the field from all around the world, including four women. We also invited, with Fields support, two graduate students (one woman and one man) from the University of Toronto and York University to participate. Scholars from the Czech Republic, the UK, Sweden, Australia, Malaysia, the USA and of course Canada, participated. There were 22 presentations altogether. They were very satisfied with the funding, housing and entertainment arrangements and the banquet in the tradition of the Carleton statistics group. We are grateful to the Fields Institute for providing funding for this conference.

E. Saleh

Speakers: (as listed in program itinerary)
Jana Jureckova (Charles University)
Rank Tests in Partially Linear Models with Measurement Errors

P.K. Sen (North Carolina)
The Theil-Sen Estimator In A Measurement Error Model

J. N. K. Rao (Carleton)
Small area estimation under nested error regression models with measurement errors in the covariates

Aurore Delaigle (Bristol)
Prediction in Measurement Error Models

Jan Picek (Liberac)
Rank Score Tests in Measurement Error Models

Boris Levit (Queen’s)
Minimax Revisited or Asymptopia in the Age of Personal Computer
Discrete and Computational Geometry is a field where one studies the interplay between geometric properties of discrete structures and the computational problems related to these discrete structures. The field has applications to all areas that touch geometric computing. Application areas are as diverse as protein-folding, wireless networks, facility location, statistical analysis or robot motion planning to name a few. Abstracting and studying the geometry problems that underlie important applications of computing leads not only to new mathematical results, but also to improvements in these application areas. Therein lies the benefits of studying this interplay.

The goal of the workshop was to bring together top researchers in the field, both from Canada and abroad, to Carleton in order to foster collaboration as well as expose graduate students to the latest techniques and important problems in this growing field. To achieve this goal, we had 14 experts each give an invited presentation. In their presentations, the speakers gave a fairly comprehensive overview of a specific subarea, taking the time to elucidate the main ideas and techniques within the subarea. This was followed by the proposal of a number of open problems. The objective that the speakers were asked to keep in mind was to give sufficient detail and background such that graduate students in the area could start working on the open problems. To this end, each invited presentation was immediately followed by a discussion forum where participants attempted to solve the proposed open problems.

Moreover, all of the workshop participants that came from out of town stayed at the conference center, which lead to continued discussions in the evenings in a more relaxed setting. We felt that this format would help graduate students learn and understand some of the latest techniques in our field and also give them a chance to actively participate in research discussions. It was also an opportunity for graduate students to see firsthand how research is done.

We are pleased to report that this approach was a resounding success. During the course of the workshop, the participants were able to solve two of the proposed open problems. One of these solutions has already been accepted for publication and presentation at the upcoming Canadian Conference on Computational Geometry (P. Bose, J. Cardinal, Silvelyn Zwanzig (Uppsala)
On R-Estimation in Errors-In-Variables Model
Y.Ma (Texas A & M )
Score-Type Tests in Semi-Parametric Measurement Error Models with Applications to Testing Lack of Fit
John Staudenmayer (Massachusetts)
Density Estimation In The Presence Of Heteroskedastic Measurement Error
Abdul Ghapor Husain (Malay)
The Complex Linear Functional Relationship Model and Detection of Outliers
Jan Kalina (Charles University)
Locally Most Powerful Tests Based on Sequential Ranks
Liquin Wang (Manitoba)
Identifiability and Estimation of Nonlinear Semi-Parametric Models with Measurement Errors
Ivan Mizera (Alberta)
Density Estimation Via Penalised Maximum Entropy
Mayer Alvo (Ottawa)
Nonparametric Tests of Hypothesis for Umbrella Alternatives
H.M. Kim (Calgary)
Bias in the Estimation of Exposure Effects with Group-Base Exposure Assessment
Rafal Kulik (Ottawa)
Regression in Random Design with Heteroscedastic Dependent Errors
Yuliya V. Martsynyuk (Carleton)
Invariance Principles and Functional Asymptotic Confidence Intervals for the Slope in Linear Structural and Functional Errors in Variables Models
Natalia Steponova (Carleton)
Estimation and Detection of Multivariate Functions
S.E. Ahmed (Windsor)
Penalized Estimation in Partially Linear Models
Sanjoy Sinha (Carleton)
Robust Analysis of General Linear Models with Missing Responses

Workshop on Discrete and Computational Geometry
May 4–8, 2009
Held at Carleton University
Organizers: Prosenjit Bose, Anil Maheshwari, and Michiel Smid (Carleton)
General Scientific Activities


We are still in the process of writing the article describing the solution to the second open problem that was successfully resolved. Furthermore, significant progress was made on two other open problems, and an online discussion forum was created for the workshop participants to continue research on these two problems. Finally, three other online discussion forums were created to continue discussions on some open problems where minor progress was made. These discussion forums are quite active and demonstrate that the workshop was indeed successful in fostering and continuing to foster collaboration among the graduate students, postdocs and researchers.

*Jit Bose*

Speakers:
- Glencora Borradaile (Waterloo)
- Prosenjit Bose (Carleton)
- Sebastien Collette (Brussels)
- Mirela Damian (Villanova)
- Erik Demaine (MIT)
- Stephane Durocher (Manitoba)
- Mohammad Farshi (Yazd)
- Matthew Katz (Ben-Gurion)
- Stefan Langerman (FNRS)
- Anna Lubiw (Waterloo)
- Belen Palop (Valladolid)
- Yurai Rodriguez (Queen’s)
- Michiel Smid (Carleton)

Approximating Geometric Network Design Problems
Plane Geometric Spanners
Proximity Graphs and their Properties
Geometric Spanners for Wireless Networks
Folding Graphs
Bounding the Locality of Distributed Routing Algorithms
Semi-Separated Pair Decomposition with Applications
Perfect Graphs and their Applications to Geometric Covering
Detours in Point Sets and Polygons
Morphing Geometric Graphs
Transportation Networks
On the Complexity of Geometric Recoloring
Geometric Spanner Networks

Graduate Student Research Day
May 5, 2009

The graduate student research day included three Special Invited Lectures and a panel discussion towards the end of the day. The rest of the day was occupied by graduate student presentations. The event was be hosted by the Department of Statistics at U of T with the involvement of the division of biostatistics, Dalla Lana School of Public Health.

*Fields staff*

Speakers: (talk titles not available)
- David Andrews (Toronto)
- Andreas Buja (Wharton)
- Jeffrey Rosenthal (Toronto)
- Ross Upshur (Toronto)

Workshop on Connections in Geometry and Physics
May 8–10, 2009

Held at Perimeter Institute

Organizers: Marco Gualtieri (Toronto), Ruxandra Moraru (Waterloo), Spiro Karigiannis (Waterloo), McKenzie Wang (McMaster)

A workshop entitled *Connections in Geometry and Physics* was held at the Perimeter Institute for Theoretical Physics from May 8-10, 2009. It was sponsored jointly by the Fields Institute, the Perimeter Institute, the faculty of mathematics at the University of Waterloo, and NSERC. The intent of the organizers (Marco Gualtieri, Spiro Karigiannis, Ruxandra Moraru, and McKenzie Wang) was to hold a yearly, regional meeting focusing on the interface between mathematics and physics, and we are pleased to report that the first meeting attracted well over 60 researchers and graduate students from across Canada as well as a number of international participants, forcing us to use the larger lecture theatre at the Perimeter Institute. A programme of the lectures given during the workshop, as well as full audio/video recordings, is available from the Perimeter Institute webpage dedicated to the event.

As the exchange between geometry and physics has been particularly fertile over the past several years, the meeting involved a quite broad array of topics which, somewhat unintentionally, meshed to a high degree with speakers citing each others’ transparencies with alarming frequency. Indeed, the diverse topics included the following: we had updates on results related to Mirror symmetry (Auroux and Brav) from both the symplectic and complex points of view, recent discoveries in geometric flows including...
the Ricci flow as well as the Lagrangian mean curvature flow (Chau and Weinkove), not to mention the discovery of new Kahler-Ricci Solitons as described by Dancer. We heard about novel constructions of special Riemannian metrics (Apostolov, Gambioli and Sparks) by a wide variety of methods, as well as a review of our fundamental understanding of the geometric analysis of Kerr geometry (Kamran) as well as Monge-Ampere equations in Sasakian geometry (Guan). There was a remarkable description of new algebraic-topological invariants of embedded codimension-2 submanifolds (such as knotted circles in Euclidean space) by Godin, which was very inspiring - an amazing feat considering that it hinged on the intricacies of spectral sequences. We reviewed the importance of the Tau function in the study of isomonodromic integrable systems (Harnad), were treated to a surprisingly classical geometric introduction to notoriously non-geometric objects in non-commutative algebraic geometry (Ingalls) and we struggled to think 2-categorically in order to reach understanding of higher quantum field theory (Morton). Using methods of geometric analysis and topological field theory, we were shown recent breakthroughs in symplectic topology (Hu and Ziltener), and were treated to a fascinating description of combinatorial results on box-stacking which were relevant to the fundamental behaviour of Calabi-Yau manifolds (Young). Finally we were awed by a tour-de-force of string theory applied to the solution of long-standing puzzles in geometric representation theory (Gukov).

Despite this diverse group of talks, there was a high degree of interaction between the participants, irrespective of specialization. This multitude of topics was of particular benefit to the large number of graduate students in attendance, both from the Ontario universities as well as from other parts of Canada. In fact, there was even participation from undergraduates, who managed somehow to avoid shell-shock and gained inspiration from the talks, and in some cases embarked on summer projects to understand some of the topics discussed. The facilities of the Perimeter Institute created an intense working environment, where meals and coffee breaks became short sub-seminars and extended question periods. The conference was also carefully designed to include cardiovascular exercise, as the coffee was placed in the Black Hole Bistro, on the top floor. We hope to repeat and improve the conference in its future incarnations.

Marco Gualtieri
General Scientific Activities

4th Workshop on Theory of Quantum Computation, Communication, and Cryptography (TQC 2009)
May 11–13, 2009
Institute for Quantum Computing, University of Waterloo
Organizers: Sarah Croke (Perimeter Institute), Dmitri Maslov, Michele Mosca, Simone Severini and Tzu-Chieh Wei (Waterloo)

The 4th Workshop on Theory of Quantum Computation, Communication, and Cryptography (TQC 2009) was held from May 11-13, 2009 at the Institute for Quantum Computing (IQC). TQC 2009 focused on theoretical aspects of Quantum Information Processing. This is the first time the workshop has been hosted by an institution outside of Japan. With over 100 in attendance, participants came from Africa, Asia, Australia, Europe and North and South America.

The list of invited speakers included Masato Koashi, John Preskill, Miklos Santha, Graeme Smith and Stephanie Wehner.

The invited talks included surveys on quantum walks and fault-tolerance, giving the participants a wide perspective of two important areas. There were also 14 contributed talks on recent research developments in areas including quantum algorithms, quantum error correction, quantum cryptography and quantum entanglement. A selection of the papers presented will be published in the official post-proceedings in the Lecture Notes in Computer Science by Springer.

A rump session and poster session gave the participants the opportunity to informally present a short summary of recent research developments. The participants also had chance to interact during the breaks and on-site lunches, as well as during a reception at the Perimeter Institute and during the banquet at the University Club.

More information regarding the TQC 2009 Workshop is available at www.iqc.ca/tqc2009.

Anne Broadbent
Invited Speakers: (as listed in program itinerary)
Miklos Santha (Paris-Sud)
Quantum walk based search algorithms
Stephanie Wehner (California Institute of Technology)
Unconditional security from noisy quantum storage
John Preskill (California Institute of Technology)
Fault-tolerant quantum computation vs. realistic noise

Graeme Smith (IBM Watson)
Rocket Channels
Masato Koashi (Osaka)
Quantitative relations among different aspects of quantum correlations

Fields Cryptography Retrospective Meeting
May 11–15, 2009
Organizing Committee: John Friedlander (Toronto), Kristin Lauter (Microsoft), Igor Shparlinski (Macquarie) and Hugh Williams (Calgary)

The Fields Cryptography Retrospective Meeting held in May at the Fields Institute in Toronto, was a follow-up workshop related to and built upon the success of the Thematic Program on Cryptography held at the Fields Institute in 2006. The purpose of this year’s meeting was to survey the foremost achievements in the area (partially inspired by the success of the Thematic Program) and also to outline new directions for further investigation. Participants of this year’s workshop included mathematicians and theoretic and practical cryptographers.

This program was designed to engage the cryptographic and mathematical communities in Canada and abroad to increase awareness of recent developments in these fields and to initiate a greater degree of collaboration in attacking the important problems, particularly on the boundaries. Developments in certain areas of mathematics (for example, number theory, combinatorics, algebraic geometry) and in cryptography are both numerous and rapid; however, it is often the case that lack of contacts and communication between cryptographers and mathematicians presents obstacles in achieving significant advances on both sides. The focus of the meeting was to overcome these obstacles and foster new links between both areas.

The specific areas of concentration were:

• algebraic curves and cryptography
• computational challenges arising in algorithmic number theory and cryptography
• lattice-based cryptography
• new cryptographic protocols

The workshop provided researchers with an opportunity to meet with the participants and speakers which led to discussions on a variety of cryptographic subjects.

One of the main problems in computer security is “accessibility”, by definition “the prevention of the denial access”
Can an encrypted protocol prevent there being any denial of access--that is, can periodicity be limited and its identity embedded so that its description is given (precisely) in terms that reference or specify its coefficients—not merely the sum of these, and is there a direct 1:1 mapping? A first order operator differentiates, that is, by random sampling a divisor is determined. Periodicity then functions as a base generator for the curve. Embedding this, as such, as access information can ensure that specific entry points are enabled with periodicity identities only, identities that can be exchanged as encrypted material.

In several of the ECC Workshop presentations the foremost problem is “elliptic curve generation.” Whether electronic and other telecommunications data transmission refers to discrete or continuous digital media, encryption along the lines of ECC increasingly requires that there be a well-formed elliptic curve or other spatial geometry. The fact that carrier information has, in fact, something that can be described in terms of an elliptic curve is extremely interesting. The Workshop represented a significant move toward bringing this kind of encryption into an open, public domain and, also, mainly that its problems are ones of basic and applied research—the domain being one of either corporate or university ownership. The general point found in the Workshop is that upon the Elliptical Curve derivation from data therein embedded there is significant information; this can be exploited by encryption algorithms transforming the raw data (“root coefficients”) into information. “Elliptic Curve Architecture” (ECA) appeared in light of the Workshop’s content as a framework for retrospection and reflection on past efforts and these to date. Just what such an ECA looks like in terms of functional and decision-making logic programming algorithms is an important problem the Workshop posed.

The presentations indicated that there is room for, or that some kind of space can be made for, root coefficients—algorithms for their derivation, specification in terms of fully-described sets, or, at least, semi-algebraic objects, number-valued geometric curve “points” or binary bits. Also, it was shown that coefficients have a functional part: their allowance as divisors in prime calculations and projection operations (e.g. differential equations and as pseudo-differential operators). In sum, the demonstrations indicated that perhaps root coefficients pose the problem of elliptic curve architecture, this having questions for an “elliptic curve calculus” as well as some kind of EC quantum state description entailing typing of various data that in the EC computation. That any of this is “Encryption Code” was not obvious, however.

One example is IP and secure data entry points in wireless networking. Can an interval phase point or juncture be secure? Clearly there has been consideration of this and perhaps the solution already found or created in the specification of root coefficients and functional programming algorithms allowing these exponents or information bits, as embedded objects, to function as a transformational basis for the generation of finite, complex-real projection spaces—for example, embedding the coefficients as information in vector incidence matrices (boundaries) that is projected.

The solutions presented appear to be in two methodological areas:

1a) (Diffie-Hellman) elliptic curve discrete logarithms with, for example, Katharine Strange’s “elliptic divisibility sequence” (EDS); logarithms include polynomial (compositional) analysis; and,

1b) embedded intelligence; this was described by, for example Edlyn Teske, in her group’s solution: “curve pairing” for the prime extraction problem and, especially in terms of decision-making oracle programming along with hidden number sequence (HNS) as Adi Akavia presented.

Three specific presentations exemplify the cryptography architecture problem and bring out questions:

Andrew Sutherland, in his presentation, Powered by Volcanoes: Three New Algorithms described algorithms for EC generation by way of “isogenous volcanoes.” In computing coefficients over (Hilbert) class polynomials. The recourse to matrix multiplication, specifically Complex Multiplication (CM) in the algorithms, implies both the generality: efficiency (root coefficients), and, the engineering solution of the ECC generation. The question refers to “finding” the coefficients: in asymptotic varieties and elliptic functions involving some kind of bifurcation or, at least, source data being “split” in its projection, the coefficients’ specification is an acute problem.

2) Francois Morain’s presentation, Advances on the CM Method for Elliptic Curves was an explained complex multiplication. Understanding this is crucial in appreciating its encryption value in cryptography. The presentation also bridged concerns from Andrew Sutherland’s CM method suggesting an intelligent decision-making module or integrated component can be designed in an ECC algorithm. One of his concerns is prime extraction to build the curve. His forthcoming SAGE algorithm is much anticipated in answer to questions that are similar to those raised in (1) specific to encryption whereby “a [decision-making] cipher algorithm transforms plain text into readable functions.”
3) Adi Akavia’s presentation, *Bit Security, Significant Fourier Coefficients and the Hidden Number Problem* (HNP) struggles with and overcomes the standard problem of differential equations and time-frequency analysis. The latter, as it is known in signal processing (DSP) is concerned mainly with “sampling” and continuous data sampling only. Nonetheless, why could the same methods as presented at the Workshop not be used to analyse data in terms of making it “discrete” or discretized instead of continuous. For example, the data could be described in terms of “finite space” periodic data, this analysed in terms of dynamics differential operators and projections across Hilbert-like or other projective space? Such an analysis was not clear in the presentation. However, obviously and as described next, the oracle as presented enables the program to overcome transformational, generative dynamics. Still, assuming the FFT and oracle provided code, bit security programming of the curve’s generation – as well, information encryption – was not presented (possibly, not worked out).

Also, the decision-making she described in terms of the HNP is good. The oracle implies there is formally-specified quanta. This in terms of periodic and aperiodic as well as quasi-periodic information is quite simple actually: it is embedded intelligence – and its encryption could be elegant. It is an availability constraint that could be encrypted in data bus protocol, specifically protocol designed with the incorporation of ECC concerns in the Elliptic Curve, complex analytics of dynamical systems.

While the Workshop did not address the “encryption” problem of an adequate encryption-related programming language, clearly there was considerable reflection on root coefficients and the description of these in terms of the form of a mathematical object with a specific value being a well-formed model for a transform basis whereby an elliptic curve could be generated. That these can be optimized, digitally, in electronic data transmission as, for example, entry point access IP (protocol) was an essential concern of the Workshop.

Several suggestions for avenues for future research also emerged. Several examples are provided below:

Kristin Lauter, Reinier Broker and Andrew Sutherland had an opportunity to work on their project *Computing modular polynomials with the Chinese Remainder Theorem*.

Andrew Sutherland had several discussions with Francois Morain regarding class invariants that may be suitable for use with the CRT method for constructing Hilbert class polynomials, a topic with practical application to the construction of pairing-friendly elliptic curves for use in cryptography.

Rainer Steinwandt made many new acquaintances and had a number of discussions with Atefeh Mashatan on her work on message recognition protocols, and hopefully these discussions will prepare the ground for a future joint research paper. He met with Sanjit Chatterjee, who presented results in which he is very much interested, and he hopes they can be used as starting point for follow-up research in the area of key establishment.

Reinier Broker’s discussions with Matthew Greenberg, which he hopes will lead to a joint project using Shimura curves to efficiently compute isogenies between abelian surfaces, has application to the construction of pairing friendly abelian surfaces that can be used in cryptography.

Kenny Patterson states the meeting: “gave me an important opportunity to put my recent research in front of a group of world experts and obtain feedback on it. My recent work relies on the existence of certain types of groups, called trapdoor discrete logarithm (TDL) groups, to obtain efficient constructions of certain cryptographic primitives. The known constructions of these groups rely heavily on number theoretic objects of certain types: for example, elliptic curves over an extension of GF(2) having a Weil descent to the Jacobian of a moderate genus curve over an intermediate field. At the Fields Institute meeting, I was able to discuss the cryptographic implications of such objects with mathematicians who are expert in the area of curves over finite fields, and to discuss potential methods for constructing new classes of TDL groups. In particular, I benefited from conversations with Edlyn Teske and Andrew Sutherland on these topics. From the invited and contributed talks, I also obtained an update on the state-of-the-art in the mathematical aspects of cryptography, a topic of huge importance for the continued development of the field. In this respect, I obtained great insights into the latest advances in implementation of elliptic curve cryptography from the talk by Dan Bernstein and into mathematical aspects of pairing-based cryptography from the talk by Edlyn Teske.”

Kristin Lauter talked with Igor Shparlinski about some of his ideas on expander graphs and hash functions and met Alina Ostafe in connection with this work. She also talked with Tanja Lange and Dan Bernstein about optimizations of pairings and various other crypto implementation issues, and had a discussion with Renate Scheidler and made more plans for the proceedings volume for WIN that is being published by Fields.
In all of the above the Workshop illustrated both its retrospective and forward looking aspects; it was considered a great success by both the speakers and the participants.

regime; and (3) the renewed kernel method, which is an efficient method for tail asymptotics for both probability distributions and combinatorics enumeration problems, that raised many interesting questions and very vivid discussions.

George Yin’s short course covered stochastic approximation, two-time scale stochastic systems and switching diffusions. Stochastic approximation is a powerful tool for many optimization problems when noisy data is obtained instead of exact data. George Yin introduced the basic theory of stochastic approximation, and gave emphasis on weak convergence properties of the algorithms. Various applications were described, including stock liquidation and time-varying parameter tracking. He next introduced two-time scale systems, and examined stochastic control and filtering problems for such systems. The application of two-time scale modelling to manufacturing was also introduced. The last part of this course studied switching diffusions and their asymptotic behaviour, a class of processes that has close connections with the previous two-time scale systems. Throughout this course weak convergence analysis was systematically developed, where the related martingale problems, as an analytical tool, play a central role.

The last course of the Summer School had two parts. Conrado Martinez focused on analytic combinatorics, and specially on the symbolic method for combinatorial structures and their asymptotic estimation via singularity analysis and the saddle point method. Hsien-Kuei Hwang continued the course with focus on the probability distributions of parameters arising from analysis of algorithms. These parameters all satisfy linear recursions of a certain form which can either be analyzed by recursion, or by studying the differential equations satisfied by the generating functions. One important aspect of Hwang’s course is on the presence and determination of phase transitions. A method was provided in the course to detect the where the phase transition occurs. Several examples from the analysis of algorithms were given, such as for random search trees.

In addition to these short courses, Neal Madras gave a tutorial on Markov Chain Monte Carlo, which is now a standard method in simulation, representing a class of algorithms for sampling from probability distributions based on constructing a Markov chain that has the desired distribution as its equilibrium distribution. He also touched a more challenging problem, that is how many steps are needed to converge to the stationary distribution within an acceptable error. Connections to random walks on graphs and applications to problems such as the Ising model and self-avoiding walks were provided, which were used to demonstrate concepts in the Metropolis-Hastings algorithm and Gibbs sampler, and also the convergence.

Moreover six invited research talks were given by Florin Avram, Ed Bender, Hui Li, Marni Mishna, Alfredo Viola and Nick Wormald. Finally 15 students gave short presentations related to their thesis work.

Daniel Panario

Invited Speakers:
Jim Fill (Johns Hopkins)
Markov Chains: Intertwinings, Strong Stationary Times and Duality, Perfect Simulation, and Absorption Times
Hsien-Kuei Hwang (Academia Sinica)
Asymptotic and Probabilistic Properties of Combinatorial Structures,
Part II: Phase Changes in Random Structures and Algorithms
Johan van Leeuwaarden (Eindhoven)
Queues, reflected random walks and the kernel method.
Conrado Martinez (Catalunya)
Asymptotic and Probabilistic Properties of Combinatorial Structures
Part I: Analytic Combinatorics: A Primer
G. George Yin (Wayne State)
Selected Topics in Stochastic Approximation, Two-time-scale Systems, Switching Diffusions, and Applications

WaterMellon Workshop on Extremal Graph Theory
May 21–23, 2009
Held at the University of Waterloo

Organizers: Nick Wormald and Penny Haxell (Waterloo)

This was a three-day workshop on extremal graph theory and related areas. The inaugural WaterMellon workshop on extremal graph theory was held in 2005 in Pittsburgh. These workshops aim to take advantage of the proximity of two strong centres in extremal graph theory and related areas — the University of Waterloo and Carnegie Mellon University — to create a focused meeting. This has been of particular benefit to the graduate students in these two centres, allowing them to interact with one another, and with the research faculty, leading to new ideas and potentially joint research projects.

Extremal graph theory can be described as the study of how global properties of a graph can guarantee the existence of
local substructures. A simple example is the classical theorem of Mantel, which states that if a graph with \( n \) vertices has more than \( n^2/2 \) edges, then it must contain a triangle. This theorem is best possible in the sense that there exists a graph with \( n^2/2 \) edges that does not contain a triangle, namely the balanced complete bipartite graph with \( n \) vertices. This graph is called *extremal* for the problem, and in fact it is unique with this property. Many natural questions can be formulated as extremal graph problems, and the subject has developed into a rich theory. Applications abound in many fields, including number theory, optimization, theoretical computer science, economics, hardware design, and optical networks.

Probabilistic methods form an important component of the toolkit used by researchers in extremal graph theory. This area was a secondary focus of the workshop, with experts in probabilistic methods among the invited speakers.

The workshop contained talks of 50 minutes from seven invited speakers: Alan Frieze, Thomas Bohman and Oleg Pikhurko, Tibor Szabo, Felix Lazebnik, Bruce Richter and Chris Godsil.

Topics included properties of random hypergraphs, analysis of a greedy matching algorithm on random graphs, applications of algebraic and geometric techniques, in particular linear algebra, to prove extremal results in combinatorics, maximization of the number of colourings of graphs, extremal graphs with crossing number at least 2, two-player games on graphs.

There were also ten half-hour talks (no multiple sessions) given almost entirely by graduate students. These included topics such as thresholds for random hypergraphs, extremal combinatorial number theory, extremal subgraphs of the hypercube, and work relating to the Hadwiger conjecture, which is one of the big open problems in graph theory today. Roughly 50 people attended the workshop, including a large number of graduate students. Most attendees and presenters were from Ontario and nearby states in the U.S., but it was notable that one came from Israel to Waterloo, to attend his first conference!

The talks at the workshop were generally regarded as being of very high quality. One of the student attendees remarked that the method used in one of the talks “… is quite amazing and has been an eye-opener at least for me. It is a wonderful way of making use of a continuous method (which is a very mature field from my standpoint) to apply to problems in discrete math and graph theory (which is a relatively young field).”

The workshop was supported by the Fields Institute and also in part by Elsevier Inc.

**Nick Wormald**

**Speakers:**

- Tom Bohman (Carnegie Mellon)  
  *Intersecting families in random hypergraphs*

- Andrzej Dudek (Carnegie Mellon)  
  *Graphs with the epsilon-density property.*

- Alan Frieze (Carnegie Mellon)  
  *The Karp-Sipser Matching Algorithm and refinements*

- Jane Gao (Waterloo)  
  *Orientability thresholds for random hypergraphs*

- Chris Godsil, (Waterloo)  
  *Erdös-Ko-Rado theorems*

- Elad Horev (Ben-Gurion)  
  *Extremal graphs avoiding a certain subdivision of the wheel graph*

- Glenn Hurlbert (Arizona)  
  *On Erdos-Ko-Rado Graphs*

- Ida Kantor (UIUC)  
  *List colorings with distinct list sizes, the case of complete bipartite graphs*

- Felix Lazebnik (Delaware)  
  *Algebraic and geometric constructions in extremal combinatorics*

- Hoi H. Nguyen (Rutgers)  
  *Squares in Sumsets*

- Lale Özkahya (UIUC)  
  *On Even-cycle-free Subgraphs of the Hypercube*

- Xavier Pérez-Giménez (Waterloo)  
  *Critical Hamilton cycles and perfect matchings on a random geometric graph*

- Oleg Pikhurko (Carnegie Mellon)  
  *Maximizing the number of colourings*

- Bruce Richter (Waterloo)  
  *Minimal graphs having crossing number at least two*

- Tibor Szabo (McGill)  
  *On the rules of avoiding*

- Linh Tran (Rutgers)  
  *Piercing Random Boxes*
General Scientific Activities

Van Vu (Rutgers)
*The structural approach to extremal problems in combinatorial number theory*

Hehui Wu (UIUC)
*Independence number and Hadwiger number*

Ottawa-Carleton Discrete Mathematics Days
May 22–23, 2009
Held at the University of Ottawa

Organizers: Mike Newman (Ottawa), Daniel Panario (Carleton), Mateja Sajna (Ottawa)

This conference brought together over 50 researchers from across Ontario, Canada and abroad, including over 30 graduate students and postdoctoral fellows. It proved to be a lively and productive meeting, one of the larger Discrete Math Days: six invited speakers and twelve contributed talks over two days. Younger researchers were able to bounce ideas off some of the more senior attendees – and share their own results. Virtually every talk generated discussion and questions. It would be hard to pick a single high point.

Rod Canfield surveyed two problems in combinatorial asymptotics: exceptional numbers among the Stirling numbers of the second kind and matrices with equal row sums and equal column sums.

Patric Östergård described the Russian Doll Search method for finding cliques in graphs, showing how this method is very effective in practice, with wide applicability to other problems.

Heather Jordon spoke on cycle decompositions, and constructions arising from Skolem sequences.

Peter Cameron gave a fascinating talk on how questions on reset words in automata lead to surprising and deep connections with graph cores and synchronizing groups.

Marni Mishna gave a lively exposition of exact and asymptotic methods in enumerating lattice walks in the plane.

Shuhong Gao talk dealt with multivariate cryptography, one of the recently proposed lines of research in the area of cryptography. He covered new encryption schemes as well as a new cryptosystem.

The contributed talks dealt with graphs, designs, groups, optimization, enumeration, … covering all key areas of discrete mathematics.

By an unintended coincidence, the Ottawa marathon immediately followed Discrete Math Days, making accommodation tricky for some. Undeterred, two of the DMD participants went from the last talk straight to the 10K run. It was an energetic weekend!

Ottawa proved once again to be a great place for combinatorialists: great people, stimulating talks, and fascinating math.

Mike Newman, Daniel Panario and Mateja Sajna

Invited Speakers:

- P. J. Cameron (Queen Mary, University of London)
  *Synchronization*

- Rod Canfield (Georgia)
  *Problems and results in asymptotic combinatorics*

- Shuhong Gao (Clemson)
  *New Directions in Multivariate Public Key Cryptography*

- Heather Jordon (Illinois State)
  *Skolem-type Difference Sets for Cycle Systems*

- Marni Mishna (Simon Fraser)
  *The combinatorics of walking around: Strategies for exact lattice path enumeration*

- Patric Östergård (Helsinki University of Technology)
  *Russian Doll Search for Clique-Type Problems*

Workshop on Geometry Related to the Langlands Programme
May 27–May 31, 2009
Held at the University of Ottawa

Organizers: Clifton Cunningham (Calgary), Monica Nevins (Ottawa)

As its title suggests, this workshop was largely concerned with applications of algebraic geometry to the Langlands Programme, but the focus of the workshop was not so narrow as to preclude exciting recent developments in the field. The atmosphere of the workshop was a very lively one, with about 40 participants, mainly graduate students and young researchers. All speakers and most participants were funded by the Fields Institute; several participants from Western Canada were funded by the Pacific Institute for Mathematical Sciences.

The structure of the workshop followed that of two earlier Fields Institute workshops on admissible representations of p-adic groups held at the University of Ottawa in 2004 and 2007: three days of mini-courses followed by a weekend conference. Some notes and references were provided by the
Since this workshop was focused on recent applications of geometric tools to the Langlands programme, the first mini-course concerned perverse sheaves. Regrettably, Anne-Marie Aubert, who was slated to give this mini-course, was unable to give these lectures, so Clifton Cunningham and David Treumann stepped in to fill the gap on short notice. Clifton’s “character sheaves in six easy steps” will not soon be forgotten!

The second mini-course consisted of a beautiful series of lectures on the Jacquet-Langlands correspondence by Ioan Badulescu. In just five hours, he provided a remarkably comprehensive review of the proof of the most general version of the theorem currently available and earned a standing ovation.

The third and final mini-course, given by Pierre-Henri Chaudouard, focused on the geometry of the Hitchin fibration and affine Springer fibres and thus provided key tools necessary to understand Ngo Bao Chau’s proof the Fundamental Lemma. In fact, this course went further, including a sketch of the proof of the weighted Fundamental Lemma, due to Pierre-Henri Chaudouard and Gerard Laumon. Chaudouard’s elegant and meticulous course won the award for the most complete use of all (six) chalkboards available.

The weekend conference, which featured Jeffrey Adler, Atsushi Ichino, Syo Kato, Paul Mezo, Mark Reeder, Hadi Salmasian, Jeremy Sylvestre and David Treumann, was informal and engaging, with lively give-and-take in several of the talks. Even the local organizer had to defend herself when mocked for giving the promise (on the poster and in the invitations!) that “the weather in Ottawa in May is absolutely lovely”, which turned out to be very far from the truth this year. Nevertheless, even constant rain and grey skies could not dampen the spirits of this successful workshop.

**Clifton Cunningham**

Invited Lecturers:

- Ioan Badulescu (Montpellier)  
  *The Jacquet-Langlands correspondence.*

- Pierre-Henri Chaudouard (CNRS, Paris)  
  *On the geometry of the Hitchin fibration.*

- Clifton Cunningham (Calgary)  
  *An introduction to character sheaves*

- David Treumann (Minnesota)  
  *An introduction to perverse sheaves*

**Fu-Fest 2009: A Symposium in Honour of James C. Fu**

*May 27–28, 2009*  
*Held at the University of Manitoba*

Organizers: Brad Johnson (Chair), Xikui Wang, John Brewster, Alexandre Leblanc and Katherine Davies (Manitoba)

The symposium was held in honour of James C. Fu’s retirement after a long and distinguished career with the Department of Statistics at the University of Manitoba. There was a total of 36 participants.

Roughly half of the invited talks were (at least loosely) related to both the theory and applications of the finite Markov chain imbedding technique (FMCI) which was introduced by Fu and Markos Koutras in 1994.

In addition to the presentations on the FMCI technique and its applications, there were a number of very interesting talks on a wide variety of topics.

Three of the speakers (John Aston, Markos Koutras and Grégory Nuel) also made a trip to Vancouver to participate in an invited session at the Annual Meeting of the Statistical Society of Canada entitled *Runs, patterns and the finite Markov chain imbedding technique.*

In conclusion, the symposium was a great success and brought together many of James’ long time collaborators and colleagues from around the globe. A number of new friendships were made and the possibilities for new collaborative research in the future have been enriched.

*Brad Johnson*
General Scientific Activities

Speakers:
John Aston (Warwick)
Using FMCI within statistical analysis

Yung-Ming Chang (National Taitung University)
Average run lengths of control charts for autoregressed processes

Brad C. Johnson (Manitoba)
On the normal, Poisson and finite Markov chain imbedding approximations for runs and patterns

Markos V. Koutras (Piraeus)
Consecutive covering arrays

Lung-An Li (Academia Sinica)
Interpreting the finite Markov chain imbedding approach

Wendy Lou (Toronto)
FMCI and some selected biomedical applications

Grégory Nuel (Paris Descartes)
Computing the first k moments of a pattern count in a random sequence generated by a Markov source and application to near Gaussian approximations

Tung-Lung Wu (Manitoba)
Linear and non-linear boundary crossing probabilities for Brownian motion and related processes

Zhidong Bai (National University of Singapore)
Corrections to LRT on large dimensional covariance matrix by RMT

N. Balakrishnan (McMaster)
Nonparametric tests for panel count data and current status data

Leo Wang-Kit Cheung (Loyola)
Kernel-imbedded Gaussian processes for microarray gene expression data analysis

Richard A. Johnson (Wisconsin)
Bayesian nonparametric quantile processes and inference about percentiles and functions of percentiles

Gang Li (Johnson & Johnson)
Hypothesis testing in interim treatment selection

Jiann-Ming Wu (National Dong Hwa University)
Levenberg--Marquardt learning of multilayer Potts perceptrons for function approximation and time series prediction

Appalachian Set Theory Workshop

May 29–30, 2009

Organizers: Elizabeth Brown (James Madison), John Clemens (Pennsylvania State), James Cummings (Carnegie Mellon), Alan Dow (UNC Charlotte), Todd Eisworth (Ohio), Paul Larson (Miami), Justin Moore (Cornell) and Ernest Schimmerling (Carnegie Mellon)

This was a special installment of the Appalachian Set Theory workshop series, which also receives financial support from the National Science Foundation through a conference grant to Carnegie Mellon University.

The workshop at the Fields Institute was on Iterated Forcing and the Continuum Hypothesis. In particular, it was on techniques developed by Saharon Shelah for iterating proper forcing without adding reals. His results in this area are often quoted but the proofs are difficult and known to only a handful of experts. This is especially troubling because there are interesting open questions that seem to require new extensions of his methods.

The workshop at the Fields Institute did much to correct the situation. It consisted of two experts – Todd Eisworth of Ohio University and Justin Moore of Cornell University – speaking for 12 hours over two days. There were 52 participants, of which half were students or postdoctoral faculty, making it the best attended workshop in the series so far. Although there were several participants from Europe, most came from Canada and the United.

Here is a mathematical overview:

In 1965, Solovay and Tennenbaum introduced the technique of iterated forcing in their proof of the consistency of Souslin’s Hypothesis (SH). Since then, iterated forcing has assumed a central role in establishing consistency results. The associated technology has grown increasingly sophisticated and, many times, advances in set theory have been fueled by corresponding breakthroughs in iteration theory. Although we know much about iterated forcing, there are still many general questions, and in this workshop we addressed one such: Why is it so difficult to use iterated forcing to produce “interesting” models of ZFC + CH? What sorts of difficulties arise? Consider, for example, the problem of obtaining a model of CH in which SH holds. Recall that a Souslin tree is an ω₁-tree with no uncountable chains or antichains, and SH says there are no such trees. Early on, Jensen showed that the combinatorial principle □ implies there is a Souslin tree. Given a Souslin tree, forcing with the
tree turned upside down adds a generic chain through the tree, thereby making it non-Souslin. This forcing does not add reals, so it does not collapse $\sigma_1$, and the tree remains an $\sigma_1$-tree. A natural way to proceed is to start with a model of GCH and iterate killing Souslin trees – those in the ground model, as well as those that arise in intermediate models – until none is left. This procedure yields a model of SH. One might hope, because we are not adding reals at successor stages, that CH is preserved by the iteration. However, Jensen showed that this naive approach runs into problems in that new reals may appear at limit stages of the iteration. A large part of the monograph by Devlin and Johnsbraten is devoted to an exposition of how Jensen overcame these issues to produce a model of ZFC + CH + SH.

Things have progressed significantly since Jensen’s work in the late 1960s. For example, a close study of the way in which iterated forcing with Souslin trees can add reals culminated in the isolation of weak $\Diamond$ by Devlin and Shelah. In 1984, Shelah’s seminal monograph, *Proper Forcing*, introduced the notion of $D$-completeness, a key ingredient in proofs that certain iterations do not add reals. Many other tools for preserving CH in iterations have been developed, but the new methods are complex and understood by only a handful of experts. This workshop did much to remedy the situation.

The speakers organized their talks around two guiding principles. First, they gave attention to examples of “single-step” forcings, that is, partial orders that accomplish a particular task without adding reals. Second, they gave an account of how iterations can be done without adding reals. Many examples were presented, and many open questions were formulated – the talks were pedagogical, and not merely the reporting of results. Participants left with a firm understanding of how the basic iteration theorems work, in addition to acquiring reasonable knowledge of the current state of affairs.

A detailed set of lecture notes is being prepared by one of the participants, David Milovich of Wisconsin, in collaboration with the speakers. It is now available at www.math.cmu.edu/users/eschimme/Appalachian/Index.html.

*Ernest Schimmerling*
General Scientific Activities

Plenary Speakers:
Chris Wild (Auckland)
*Building the Pyramids*
Luc Devroye (McGill)
*Randomness is not a Bad Word*
Hugh Chipman (Acadia)
*Statistical Learning with Trees*
Qing Pan (George Washington) and Douglas Schaubel (Michigan)
*Proportional Hazards Models Based on Biased Samples and Estimated Selection Probabilities*
Baojiang Chen (Washington)
*Statistical Methods for Multi-State Analysis of Incomplete Longitudinal Data*

Invited Speakers:
Tony Cohn (Leeds)
*Acquiring Commonsense Knowledge from Perceptual Observation*
Ernie Davis (NYU)
*Commonsense Reasoning About Chemistry Experiments: Ontologies and Representations*
Sheila McIlraith (Toronto)
*Diagnosis Revisited*

Ninth International Symposium on Logical Formalizations of Commonsense Reasoning
June 1–3, 2009
Organizers: Hojjat Ghaderi (Chair, Toronto), Sheila McIlraith (Toronto), Hector Levesque (Toronto)

The symposium aimed to bring together researchers who have studied the formalization of commonsense reasoning. The focus of the symposium was on representation rather than on algorithms, and on formal rather than informal methods. While mathematical logic was the primary lingua franca of the symposium, other rigorous but not logic-based representations of commonsense domains were also considered.

**Fields staff**

**Invited Speakers:**
Tony Cohn (Leeds)
*Acquiring Commonsense Knowledge from Perceptual Observation*
Ernie Davis (NYU)
*Commonsense Reasoning About Chemistry Experiments: Ontologies and Representations*
Sheila McIlraith (Toronto)
*Diagnosis Revisited*

Workshop on Cocliques and Colourings
June 1–5, 2009
Held at University of Waterloo
Organizers: Chris Godsil (Waterloo) and Karen Meagher (Regina)

Finding maximal cocliques in graphs and finding optimal colourings of graphs are classical problems in combinatorial optimization. For example, the problem of determining the maximum size of a coclique in the Kneser graph, and then characterizing which cocliques are of this maximum size, is easily seen to be equivalent to the classic Erdos-Ko-Rado theorem which specifies the size and structure of the largest system of intersecting sets. Part of the appeal of this theorem is that the solution is so elegant: under modest constraints, the largest such system is the collection of all sets that contain a common element. It is one of the central results in combinatorics.

Recently there has been a lot of work on extensions on the Erdos-Ko-Rado theorem and related areas. Many of the best results use algebraic techniques. The goal of this workshop was to bring together leaders to discuss recent results, new techniques and future directions for this area.

The format for this workshop was unusual in that most days had only two lectures. The focus was on working together. It was excellent to meet and informally discuss each others’ work, to ask for details in people’s work and to present problems we had been thinking about but were unable to resolve. The atmosphere was very friendly, everyone was relaxed and it was easy to approach and ask questions.
There were a total of nine scheduled prepared talks at the workshop. Other impromptu lectures were delivered that either outlined interesting problems that attendees had been studying, or showed new ways to look at problems.

All and all, this was a fun workshop and everyone attending learned lots. But many of the benefits of this workshop have not yet been realized. It has served as an introduction and the first step in collaboration – this is particularly advantageous since many of the participants were early career researchers. Several graduate students left this workshop with a long list of open problems to start their research that will hopefully become form a basis for their graduate work. One graduate student said that it was good to be able to talk to the people wrote the papers that she was studying and that it will make it easier for her to contact them in the future.

Chris Godsil

Speakers:
Karen Meagher (Regina)
An introduction to Erdos-Ko-Rado problems
Chris Godsil (Waterloo)
Algebraic bounds for graphs
Cheng Yeaw Ku (Singapore)
Erdős-Ko-Rado theorems for partitions and permutations
David Ellis (Cambridge)
Cross intersection
Ameerah Chowdhury (California Institute of Technology)
Katona-type results for vector spaces
Mike Newman (Ottawa)
Open problems with the partition graph
Bill Martin (Worcester)
An introduction to linear programming
Claude Tardif (RMC)
Graph homomorphisms
Reza Naserasr (Carleton)
A conjecture of Alon-Saks-Seymour

Bridging from Mathematics to Mathematics Education & Canadian Mathematics Education Study Group Annual Meeting 2009
June 5–9, 2009
Held at York University

Organizers: Walter Whiteley and Margaret Sinclair (York)

On June 5th, 45 people gathered at the Mathematics Department at York University to discuss the connections between mathematics departments and faculties of education in areas such as: (i) the preparation of future teachers of mathematics within courses in mathematics and mathematics education; (ii) issues of recruitment, pedagogy, and retention of students in undergraduate mathematics courses; (iii) how research in mathematics education could inform this work within mathematics departments. Starting from presentations on collaborative work over the last several decades at a number of Canadian Universities, including Queen’s, Brock, Simon Fraser and York, we discussed our shared responsibilities for preparation of highly qualified teachers of mathematics at all levels, and what could be gained by closer collaboration. A majority of participants were faculty and graduate students from mathematics departments, with a significant number of graduate students and faculty from faculties of education – leading to a lively and productive conversation. A number of important issues were identified and possible follow up gatherings are being discussed.

The annual meeting of the Canadian Mathematics Education Study Group (CMESG) that followed was a wonderful experience – a chance for 110 mathematicians, mathematics education faculty, teachers, and graduate students from Canada and abroad to gather and discuss key issues around mathematics teaching and learning.

CMESG is not a typical academic conference. The core of the program consists of working groups that meet for 9 hours throughout the conference and provide an opportunity for participants to confer. This year, there were six working groups: Mathematically Gifted Students; Mathematics and the Life Sciences; Contemporary and Emergent Research Methodologies in Mathematics Education; Reframing Learning (Mathematics) as a Collective Action; Studying Teaching in Practice; and Mathematics as Social Injustice.

In addition to working groups, CMESG includes plenary lectures, topic study sessions, ad-hoc sessions, and presentations by new PhD’s in the field. There are also shared meals
General Scientific Activities

During the first week of the school, introductory courses were given by Joel Kamnitzer (Toronto), Seok-Jin Kang and Erhard Neher. The course of Kamnitzer presented three geometric constructions of the irreducible representations of the general linear group. These included Borel-Weil theory, Ginzburg’s convolution realization, and the geometric Satake construction. In his lectures, Kang introduced the participants to the theory of quantum groups and crystals, including the topics of Young tableaux, Young walls, perfect crystals, and the Kyoto path model. Finally, Neher’s course gave an introduction to the theory of affine, toroidal and extended affine Lie algebras. Each course consisted of five lectures of 80-90 minutes. Kang’s mid-lecture choreographed stretch was especially popular among the students.

The second week of the summer school followed the same format. Courses were given by Wang, Savage, and Vyjayanthi Chari. Wang’s course was an introduction to nilpotent orbits and W-algebras. The course of Savage followed up on the material participants learned in the courses of Kamnitzer and Kang. It presented a realization of crystals using the geometry of quiver varieties. Chari presented a comprehensive overview of the representation theory of affine and toroidal Lie algebras.

The majority of students stayed in the residences at the University of Ottawa, in close proximity to the lecture rooms and library. Many participants took advantage of the downtown location of the university and visited nearby – an integral part of the conferring that makes CMESG such a special conference.

Margaret Sinclair

Summer School in Geometric Representation Theory and Extended Affine Lie Algebras
June 15–27, 2009
Held at the University of Ottawa

Organizing committee: Erhard Neher and Alistair Savage (Ottawa)

Scientific committee: Erhard Neher, Alistair Savage (Ottawa), Weiqiang Wang (Virginia)

More than 130 participants from 14 different countries took part in this two week summer school held at the University of Ottawa. In addition to many Canadian students, a particularly strong contingent of students came from Korea and, of course, from the USA. Financial support from the Fields Institute and the National Science Foundation allowed us to offer financial support to 95 students. The central objective of the school was to offer graduate students and postdoctoral fellows an introduction to current trends in geometric representation theory and the theory of extended affine Lie algebras as well as to encourage them to examine the relations between these fields. It also served as preparation for the conference in the same topics that followed the summer school.

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The lectures of the summer school were videotaped and are available online, in addition to the lecture notes of the speakers. There is a plan to publish these notes in the Fields Institute Monograph series.

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landmarks such as parliament and the many museums in the area during their stay. After an opening dinner, students became well acquainted and organized several activities on their own. These included visiting the dragonboat festival and partaking in Ribfest. There was also a closing dinner near the end of the summer school. Many students stayed for the Conference in Geometric Representation Theory and Extended Affine Lie Algebras that took place at the University of Ottawa in the week following the summer school.

The organizers of the conference consider the summer school a great success. The quantity and quality of the students was exceptional. It was by far the largest summer school organized at the University of Ottawa in recent years. The enthusiasm of the participants was evidenced by the frequent occurrence of a long line of students waiting to ask questions of the speakers after each lecture. We feel that the material these participants learned during their time in Ottawa will prove to be very valuable in their research and will undoubtedly have a positive impact on the research activity in the area.

**Alistair Savage**

**Invited Speakers:**

Michael Ehrig (Cologne)  
*MV-polytopes/cycles and affine buildings*

Farkhod Eshmatov (Michigan)  
*Automorphism groups of rings of differential operators and the Calogero-Moser correspondence*

Ghislain Fourier (Cologne)  
*A categorical approach to Weyl modules*

Victor Ginzburg (Chicago)  
*Quantization of Bezrukavnikov's equivalence*

Jacob Greenstein (UC Riverside)  
*Quivers with relations and representations of graded current algebras*

Naihuan Jing (NC State)  
*Realizations of classical toroidal Lie algebras*

Brant Jones (UC Davis)  
*Affine structures for certain E6 crystals*

Joel Kamnitzer (Toronto)  
*Categorified geometric skew Howe duality*

Aaron Lauda (Columbia)  
*Categorifying quantum groups*

Anthony Licata (Stanford / MPI)  
*Goresky-Macpherson duality and deformations of Koszul algebras*

Anton Malkin (UIUC)  
*Stacky geometric quantization*

Ivan Mirkovic (Amherst)  
*Modular representations and critical quantization*

Kailash Misra (NC State)  
*Imaginary Verma modules and Kashiwara algebras for Uq[sl(2)]*

Eugene Mukhin (IUPUI)  
*Bethe algebras*

Hiraku Nakajima (Kyoto)  
*Quiver varieties and cluster algebras*

Olivier Schiffmann (Paris 6)  
*Hall algebras of smooth projective curves*

Anne Schilling (UC Davis)  
*Kirillov–Reshetikhin crystals for nonexceptional types*

Michela Varagnolo (Cergy-Pontoise)  
*KLR algebras and canonical bases*

Eric Vasserot (Paris 7)  
*Hall algebras and Hilbert schemes*

Kari Vilonen (Northwestern)  
*Langlands duality for real groups*

Weiqiang Wang (Virginia)  
*A new approach to the representation theory of Lie super-algebras*

**OCCAM-Fields-MITACS Biomedical Problem Solving Workshop**

June 22–26, 2009

Held at the University of Toronto

Organizers: C. Breward (Oxford), C.S. Bohun (UOIT), H. Huang (York), N. Nigam (Simon Fraser), D. Schwenderman (RPI), S. Sivaloganathan (Waterloo), B.S. Tilley (Olin College of Engineering), J.F. Williams (Simon Fraser)

The objectives of the workshop are four-fold: to introduce mathematicians and modelers to problems arising in medical science; to effectively aid practitioners and researcher in medicine exploit current mathematical tools; to train a new generation of mathematicians in problem-solving, and to provide a natural opportunity for long-term research collaborations to develop in an interdisciplinary setting.
General Scientific Activities

The format of the workshop followed the well-established Study Groups at Oxford. On the first day of the workshop, six problems were presented by researchers in the biological and medical sciences (including hospitals). The first problem was on the classification of tumors using mechanical properties of the biological tissues, brought by Corina Drapaca from the Departments of Engineering Science & Mechanics and Neural Engineering and the Huck Institute of Life Sciences of Penn State University. The second problem came from Miles Johnston, a senior scientist from the SunnyBrook Health Sciences Center in Toronto. Johnston’s group has conducted experiments related to the so-called normal-pressure hydrocephalus. The medical community has long been puzzled that this pathological condition occurred most often in infants and children. Johnston came to the workshop asking for a mathematical model for a possible mechanism to explain the experimental results and ultimately the connection between the laboratory experiments and the disease. Sushrut S. Waikar, an MD and a clinician from the Brigham and Women’s Hospital, Harvard University, brought experimental data on hemo-dialysis. He asked the workshop participants to develop a mathematical model that can be used to predict sodium influx during dialysis. Mustafa Al-Zoughool and Susie El Saadany from the McLaughlin Center for Population Health Risk Assessment, University of Ottawa brought a problem on the risk of variant Creutzfeldt Jackob Disease by transmission of blood and surgery. The last two problems came from McGill University, by David C. Bassett and Jake E. Barralet at the Faculty of Dentistry, on Calcium carbonate formation in the presence of serum protein, and by Svetlana V. Komarova at the Department of Biology, on identifying the mediators of mechano-transduction between bone cells.

Over 60 participants, from Canada, China, New Zealand, US, UK and elsewhere, were divided into teams of 6-15 people, to work on these problems for the next three and a half days. On the final day of the workshop, progress on these problems was reported. The final reports will be available online at the workshop website: http://www.fields.utoronto.ca/programs/scientific/08-09/biomedical/

This workshop is co-sponsored by OCCAM, Fields (including the Center for the Mathematical Medicine) and MITACS.

Huaxiong Huang
Seminars on Automorphic Forms and L-functions: Computational Aspects
June 22–July 3, 2009
Held at University of Montreal

Organizers: Michael Rubinstein (Waterloo) and Andreas Strömbergsson (Uppsala)

This gathering, funded by the NSF, CRM, Fields Institute, ISM, University of Waterloo, and ESF, brought together a number of experts who have been leaders in both the theoretical and more computational aspects of the theory of automorphic forms and L-functions. They each gave courses lasting 3-5 hours aimed at presenting graduate students and post-doctoral fellows with the state of the art in the subject and report on new advances which have not yet been covered in a forum such as this.

A total of fifteen speakers covered the theory of automorphic forms and L-functions from various perspectives, analytic, arithmetic, and algebraic, with a focus on techniques for their numerical evaluation.

The program for the two weeks was as follows:

Eyal Goren and Henri Darmon gave introductory courses on elliptic curves, holomorphic modular forms and L-functions.

Dorian Goldfeld spoke on Automorphic forms and L-functions in higher rank, covering material from the first half on his recent book *Automorphic forms and L-functions for the group GL(n)*, and also discussing the translation between classical and adelic language.

Fredrik Stromberg discussed Maass waveforms for SL(2,Z) and subgroups from a computational point of view; one additional lecture in this course was given by Dennis Hejhal.

Noam Elkies lectured on K3 surfaces of high Picard number and their moduli. Michael Rubinstein spoke about algorithms for the computation of L-functions. Akshay Venkatesh covered the theory of Eisenstein series. John Voight gave a course on the algorithmic theory of quaternion algebras.

Andrew Booker presented techniques from Fourier analysis, such as the FFT and band limited interpolation, for computing L-functions, and discussed his work with Ce Bian for finding GL(3) Maass forms.


In addition, two shorter talks were given presenting fairly recent breakthroughs in computation of L-functions: Hiary Ghaith reported on his new algorithm for fast computation of the Riemann Zeta function on the critical line (complexity exponent 4/13, improving on the previously best known exponent 1/3 by a noticeable margin). Pankaj Vishe reported on a new fast algorithm for computation of the L-function associated to a modular form (holomorphic or nonholomorphic). Also Andrew Booker in his last talk presented his fairly recent (joint with Ce Bian) breakthrough of being able to compute the first few genuine GL(3) L-functions.

The summer school had a total of 68 participants, besides the 15 speakers. Of these 24 were from Canada, 16 from the USA, 22 from Europe (of which 9 were funded by the Alcant program - Algebra, Geometry and Number Theory - part of the European Erasmus Mundus Programme), and 6 from other parts of the world.

The organizers received feedback from a number of the students and postdocs attending the courses. All were very pleased with the structure and content of the program and several offered that it was the most useful and interesting summer school they had attended.

Michael Rubinstein

Speakers:
Andrew Booker (Bristol)
Maass Forms and L-functions
Henri Darmon (McGill) and Eyal Goren (McGill)
Background and Prerequisites
Noam Elkies (Harvard)
K3 Surfaces of High Picard Number and Their Moduli
Dorian Goldfeld (Columbia)
Automorphic Forms and L-functions in Higher Rank
Dennis A. Hejhal (Minnesota)
Title not available
Kamal Khuri-Makdisi (Beirut)
Modular Interpretation and Equations for Modular Varieties
Erez Lapid (Jerusalem)
The Arthur-Selberg Trace Formula and Applications
Michael Rubinstein (Waterloo)
Algorithms for the Computation of L-functions
General Scientific Activities

Harold Stark (UC San Diego)
*Artin L-functions and Special Values at s=0*

Fredrik Strömberg (Darmstadt)
*Maass Waveforms for SL (2,Z) and Subgroups, from a Computational Point of View*

Andreas Strömbergsson (Uppsala)
*Computations Using the Selberg Trace Formula*

Audrey Terras (UC San Diego)
*Zeta and L-Functions of Graphs*

Akshay Venkatesh (Courant)
*Eisenstein Series*

John Voight (Vermont)
*The Algorithmic Theory of Quaternion Algebras*

Conference in Number Theory
June 27 - 29, 2009
Held at Carleton University

Organizers: Saban Alaca (Carleton), Gary Walsh (Ottawa), Kenneth Williams (Carleton)

The goal of this conference, supported by the Fields Institute, MITACS and Carleton University, was to bring together top researchers in number theory from Canada and abroad in order to foster collaboration and to expose students to important problems in the field. There were 11 main speakers and 12 contributed talks. The total number of participants was 50, of which approximately half were graduate students.

The first day’s lectures were given by Ken Ono, Nathan Ng, S. Ahlgren and H. Kadiri. Ken Ono described his construction with Brunier of generalized Borcherds products and their application to the parity of the partition function. Nathan Ng discussed the problem of evaluating integral and discrete moments of the Riemann zeta function. Scott Ahlgren described some recent results on modular forms of half-integral weight and level four. Habiba Kadiri proved an upper bound for the least prime ideal in the Chebotarev density theorem.

The second day’s lectures were given by R. Murty, K. Soundararajan, G. Andrews and S. Gonek. Ram Murty described the transcendental nature of special values of Hecke L-series of imaginary quadratic fields. Kannan Soundararajan described some recent progress which has led to a resolution of a conjecture of Rudnick and Sarnak concerning equidistribution of high energy eigenfunctions in quantum chaos. George Andrews spoke about certain combinatorial aspects of integer partitions. The final lecture of the day was held in the evening after a group outing to a Chinese buffet. Angelo Mingarelli had pointed out that 2009 is the 150th anniversary of Riemann’s pivotal 1859 paper on the number of primes less than a given number and this special evening lecture commemorated this event with a survey talk by Steve Gonek for a general mathematical audience in which he described the contents of Riemann’s paper and the theory that developed from it. A number of members of the general public attended this talk.

The third and final day’s speakers were B. Berndt, J. Friedlander and H. Williams. Bruce Berndt described in his lecture some of the entries from six partial manuscripts of Ramanujan in the handwriting of G. N. Watson, which were published with Ramanujan’s Lost Notebook. The original manuscripts no longer exist. John Friedlander described some joint work with H. Iwaniec in which the semi-linear (or half-dimensional) sieve comes very close to giving the true order of magnitude of a certain class of arithmetic functions. The final talk of the conference was given by Hugh Williams. He discussed some joint work with Richard Guy giving the number theoretic properties of a general fourth order divisibility sequence.

Two problems sessions were run by Gary Walsh. The proposed problems will be listed on the conference’s website.

Saban Alaca
Invited Speakers:
Scott Ahlgren (Illinois)
Congruences for modular forms of half-integral weight
George Andrews (Pennsylvania State)
Combinatorial aspects of integer partitions
Bruce C. Berndt (Illinois)
Analysis in Ramanujan’s Lost Notebook
John Friedlander (Toronto)
Brinkmanship in the Semi-linear Sieve
Steve Gonek (Rochester)
The First 150 Years of the Riemann Zeta Function
Habiba Kadiri (Lethbridge)
A bound for the least prime ideal in the Chebotarev density problem
Ram Murty (Queen’s)
Special values of L-series
Nathan Ng (Lethbridge)
Moments of the Riemann zeta function
Ken Ono (Wisconsin)
Generalized Borcherds products and two number theoretic applications
Kannan Soundararajan (Stanford)
Quantum Unique Ergodicity and Number Theory
Richard Guy and Hugh Williams (Calgary)
Some Interesting Divisibility Sequences
Seminars

Actuarial Science & Financial Mathematics Seminar Series Meetings
September 2008–June 2009
Held at the Fields Institute
Organizer: Sebastian Jaimungal (Toronto)

Actuarial Science and Mathematical Finance (ASMF) are two fields which have immense impact in our global economy. Understanding how to measure, manage, and value the risks embedded in complex financial and insurance products is of paramount importance. The mathematical sciences play a major role in this enterprise and the synergy brought together from mathematics, statistics, computer science, engineering and business helps to push the field forward.

The ASMF Seminar Series has been running since September 2005. It began as a forum for PhD. students, post doctoral fellows and faculty members to discuss current topics in ASMF, partially completed research, as well as reviews of classical works and methods. The seminars have always been informal to promote discussions, to open debate, and to allow the audience to interact.

This past year showcased talks ranging from energy markets modeling to high frequency data analysis to credit and market risks. The speakers are all experts in their respective fields and showcase cutting edge research. Several industry professionals regularly participate in the event and bring a very valuable grounded real world perspective to the discussions and presentations.

Sebastian Jaimungal

Speakers:
Alvaro Cartea (Universidad Carlos III de Madrid)
*Volatility and covariation of financial assets: A high-frequency analysis*

Tim Leung (John Hopkins)
*Exponential hedging in an incomplete market with regime switching*

Birgit Rudloff (Princeton)
*Optimal investment strategies under bounded risk*

Yukio Muromachi (Tokyo)
*Analysis of the concentration risk: decomposing the total risk of a portfolio into the contributions of individual assets*

Alex Levin (Algorithmics Inc.)
*Affine extensions of the Heston model with stochastic interest rates*

Alexey Kuznetsov (York)
*Computing distributions of the first passage time, overshoot and some other functionals of a Levy process*

Adam Metzler (UWO)
*A multiname first passage model for credit risk*

Cody Hyndman (Concordia)
*Forward-backward stochastic differential equations and term structure derivatives*

Angelo Valov (Toronto)
*Integral equations arising from the first passage time problem via martingale methods*

Matt Davison (UWO)
*Applied stochastic modelling in energy finance*

Algebraic Combinatorics Seminar
October 2008–January 2000
Held at the Fields Institute
Organizer: Nantel Bergeron (York)

This seminar is mostly a working seminar. Each year, as a group including postdocs and graduate students, we choose a few problems to work on and present background material, conjectures and lines of attack in trying to solve the problem. From time to time we also have outside speakers who are often related to our current problems. We aim to have publications resulting from this work.

This year, we worked on the Littlewood-Richardson Rule, Shifted Tableaux and P-Schur functions. We had many interesting conjectures but further computer exploration showed them to be false and no publication resulted out of this year. We cannot always be so lucky! On the other hand, because of the strike at York, we used the seminar at Fields for more regular talks. For this reason we had very interesting talks at Fields by outside speakers. I should mention that three of the talks, namely those of Alexander Rossi Miller, Carolina Benedetti and Amel Kaouche, covered outstanding results by graduate students.

For more information about the seminar, please visit garcia.math.yorku.ca/fieldseminar/
General Scientific Activities

Speakers:
Carolina Benedetti (University of Colombia, South America)
Volumes of matroid polytopes
Amel Kaouche (UQAM)
Imperfect gases and graph invariants
Luis Guillermo Serrano Herrera (Michigan)
The shifted plactic monoid
Joel Kamnitzer (Toronto)
MV polytopes and components of quiver varieties
Janvier Nzeutchap (York)
Robinson-Schensted Algorithm for Shifted Tableaux, P-Schur and Q-Schur functions
The Poirier-Reutenauer Hopf algebra of tableaux
Alexander Rossi Miller (Minnesota)
Differential posets and Smith normal forms
Hugh Thomas (New Brunswick)
Antichains in the poset of positive roots, Catalan phenomena, and some conjectures of Panyushev

Bimonthly Noncommutative Geometry Seminar
Held at the Fields Institute
Organizers: Masoud Khalkhali (UWO), Dan Kucerovsky (New Brunswick), and Bahram Rangipour (UNB)
The general theme of the Bimonthly Noncommutative Geometry and Topology Meeting in 2008-2009 has been index theory.
The speakers have covered topics such as spectral flow, eta invariants, characteristic classes in index theory, and the heat equation approach to index theory.
The First Canadian Hopf algebra conference, held in September 2008, was associated with this seminar.
The present series of meetings, which began in December 2007, is a continuation of an earlier Fields Institute workshop (the Ontario Noncommutative Geometry Seminar) organized by G. Elliott and M. Khalkhali from about 2001 to 2003.

2008-2009 Speakers:
Alexander Gorokhovsky (Colorado)
Superconnections, index theory and noncommutative geometry
Markus J. Pflaum (Colorado)
Higher index theorems on orbifolds

2007-2008 Speakers:
Henri Moscovici (OSU)
Characteristic classes in noncommutative geometry
Nigel Higson (PSU)
K-Homology, assembly and rigidity theorems for relative eta-Invariants
John Phillips (Victoria)
An index theory for certain gauge invariant KMS weights on C*-algebras

Colloquium/Seminar in Applied Mathematics
Organizers: Jim Colliander (Toronto), Walter Craig (McMaster), Barbara Keyfitz (Fields), Robert McCann (Victoria), Mary Pugh (Toronto), Catherine Sulem (Toronto)
The Fields Institute Colloquium/Seminar in Applied Mathematics is a monthly colloquium series for mathematicians in the areas of applied mathematics and analysis. The series includes both colloquium talks by internationally recognized experts in the field, and less formal, more specialized seminars. In recent years, the series has featured applications to diverse areas of science and technology; examples include super-conductivity, nonlinear wave propagation, optical fiber communications, and mathematical biology. The intent of the series is to bring together the applied mathematics community on a regular basis, to present current results in the field, and to strengthen the potential for communication and collaboration between researchers with common interests. The activities of this Colloquium/Seminar during the 2008-09 academic year are briefly described below.
Yuan Lou’s talk on October 8, 2008, The Evolution of Dispersal, addressed the fascinating question of how competing species might evolve strategies to garner the resources they need to survive. His research focuses on a simple but illuminating model. The dynamics of organisms that can move is usually modelled by a reaction-diffusion equation, with the diffusive term a model for “random” diffusion – that
is, motion without a preferred direction. A classic result of Dockery et al proves that the slower-diffusing species drives the faster one to extinction. By contrast, one can consider species that move conditionally, following the gradient of some fixed quantity (representing, say, a nutrient). Then under some conditions co-existence is possible. Lou’s work examines cases where both forces are at play, with species differing perhaps in the strength of one or both drives. Then it turns out that either domination or co-existence is possible, depending on relative strengths in rather complicated ways that involve such things as the principal eigenvalue of the domain. One of the most intriguing things about the research was the interplay of technical analytical results (new types of eigenvalue problems) with ecological interpretations.

Michael Stiassnie (Technion) also spoke on the October 8 date, on the problem of ocean waves and their modeling with partial differential equations. His talk, Recurrent solutions of Alber’s equation for random water-wave fields, addressed questions of the nature of solutions to homogenization limits of the equations for surface water waves, and in particular gave conditions under which periodic solutions would exist. The question of wave propagation over a random bathymetry is a problem that has been at the centre of much interest in the past, and it has a both practical significance to the research community of physical oceanographers as well as to applied mathematics.

Jeremie Bec (CNRS - Nice) lectured on October 22, 2008 on the statistics of entrained heavy particles in a turbulent fluid flow. His analysis accounts for phenomena on a variety of spatial scales, including a droplet concentration scale and a smaller dissipative scale. These phenomena are relevant to a wide variety of physical processes, from the formation of stars in the interstellar media, to raindrop formation in clouds, to specific industrial processes.

Andrei Sobolevskii (Moscow) spoke on November 5, 2008, on his collaboration with Julie Delon (France Telecom) and Julien Salomon (CEREMADE) concerning algorithmic approaches to optimal transportation on the circle and their application to computer vision. In the vision setting, one wants a method of quickly comparing images to decide how similar or dissimilar they may be. One of the challenges is to find a way of successfully extracting some kind of digital signature from the image which contains just enough information to identify it but not so much as to become cumbersome to work with. The approach explored here relies heavily on the presence or absence of different colors in the image, which can be expressed as a probability measure defined on the circle, representing the color wheel. Two such probability measures from different images can then be compared by trying to transport one of them onto the other. Fast algorithms to solve this problem are known on the line, but are complicated considerably on the circle due to its rotational invariability. This was the problem addressed by the talk. A significant benefit of Sobolevski’s visit to Fields was the resulting collaboration which has developed between him and Kostya Khanin (University of Toronto), concerning the possibility to uniquely extrapolate velocities in a continuum of particles modeled by a Hamilton-Jacobi equation beyond shock discontinuities. They explore both variational and probabilistic approaches to this problem, showing that the former results in a unique extension while the latter does not (except in two or fewer dimensions).

Neil Turok who is the new Director of the Perimeter Institute for Theoretical Physics, gave a talk on December 10, 2008 called What Banged? – about cosmology, of course. Now, he admitted some difficulties in giving this answer – in fact, he offered two, which he pointed out is a weakness. One of the models is his own theory of an ‘ekpyrotic universe’, which permits space-time to undergo an infinite series of big crunch collapses/big bang origins, using a topological feature of higher-than-four dimensional Lorentzian manifolds. The theme of his talk was the power of mathematical models – and their immense complexity – to describe the universe, and, in a lecture of one and one half hours he gave the grand tour, from Einstein’s equations to string theory and what is to come beyond.

Robert Krasny (Michigan) gave a talk entitled Lagrangian Simulations of Fluids and Plasmas on January 14, 2009. His talk gave an overview of recent Lagrangian simulations of incompressible fluids and collisionless plasmas, for which the standard Eulerian formulation is replaced by a Lagrangian version given in terms of the flow map. This leads naturally to a particle discretization approach for numerical simulations. The particles carry vorticity in the case of a fluid and electric charge in the case of a plasma. The induced velocity and electric field are expressed as singular integrals. The numerical method employs kernel regularization for stability, adaptive particle insertion for accuracy, and a multipole treecode for efficiency. Examples included electron beams in 1D plasmas, and vortex sheets and vortex rings in 2D and 3D fluids.

Ehud Meron (Ben-Gurion) gave two joint Physics Colloquia/Applied Mathematics Colloquia on March 4 and 5, 2009. He discussed the occurrence of periodic pattern
formation versus scale-free fields, and applied his ideas to environmental problems of desert vegetation. The theme was to use mathematical models that capture basic feedbacks between biomass and water and between above-ground and below-ground biomass, in order to elucidate mechanisms that control patch-size distributions in water-limited systems, and to identify physical and ecological circumstances that lead to periodic patterns or to scale-free distributions of desert vegetation.

The Fields Colloquium in Applied Math concluded its season with a talk by Giuseppe Savaré (Pavia), who was a visitor at the University of Toronto and also a contributor to the Fields Analysis Working Group and the University of Toronto Geometry and Topology seminar. Savaré gave one lecture in each of these three venues, concerning rough dynamical processes in geometric settings: gradient flows in Alexandrov spaces, fourth order diffusion equations, and rate independent motion. His talk in the Fields Institute Applied Mathematics Colloquium took place on May 13, 2009.

Walter Craig

**Fields Analysis Working Group**

July 2008–June 2009  
Held at the Fields Institute  
Organizers: Jim Colliander, Larry Guth and Robert McCann (Toronto)

Spurred by the arrival of new faculty member Larry Guth at the University of Toronto, the Fields Analysis Working Group (aka FAWG) experimented with a new format this year, in which seminar organizers laid out a program of mathematics to explore at the beginning of the fall, that was pursued by students, postdocs, and other participants throughout the academic year. The focus chosen this year was the Kakeya conjecture: namely, that no subset of \( n \)-dimensional Euclidean space which includes segments in every direction can have Hausdorff dimension less than \( n \). This conjecture has important applications in harmonic analysis, among other area of mathematics, concerning for example boundedness of Fourier integral operators. It is known to be true in dimension two (although the set can have zero area) and remains open in three or more dimensions.

At least three Fields medallists have worked on aspects of the conjecture (Fefferman, Bourgain, Tao), and the topic stimulated a lot of interest among local participants, including several students and postdocs who agreed to read research articles on the subject and give lectures to the group. They followed a program laid out beautifully by Guth, which culminated in a series of lectures by distinguished visitor Netz Hawk Katz (Washington University in St. Louis). Outcomes from this year’s seminar include a preprint posted to the arXiv by Guth in which he resolves the endpoint case of a multilinear Kakeya estimate conjecture by Bennett-Carbery-Tao using ideas from the recent proof of a finite field Kakeya conjecture by Dvir, simplifications of some of the deep results of Katz, Laba, and Tao, and a budding collaboration between Guth, Katz, and graduating mathematics specialist student Conan Wu. Other highlights of the year include Jim Colliander’s lectures on fluid mechanics, and a beautiful series of lectures by distinguished visitor Giuseppe Savaré (Pavia) on gradient flows in metric measure spaces, with applications to nonlinear equations. This series stimulated much contact between seminar participants and local geometers, who hosted one of his three talks in their Geometry and Topology seminar. A question posed by Savaré during his visit concerns corrections to the isoperimetric problem: namely, if a set has volume equal to the ball and surface area not much larger than the ball, must it be close to a ball, and in what sense?

Recently progress on this problem was achieved by Italian researchers Nicola Fusco, Francesco Maggi, Aldo Pratelli and Alessio Figalli. The variant proposed by Savaré is currently being pursued jointly with Robert McCann’s PhD. student Shbing Chen, and has the potential to lead to interesting developments.

Robert McCann and Jim Colliander

**Geometry and Model Theory Seminar**

February 2009–June 2009  
Held at the Fields Institute  
Organizer: Patrick Speissegger (McMaster)

The idea of this seminar is to bring together people from the group in geometry and singularities at the University of Toronto (including Ed Bierstone, Askold Khovanskii, Grisha Mihalkin and Pierre Milman) and the model theory group at McMaster University (Bradd Hart, Deirdre Haskell, Patrick Speissegger and Matt Valeriote). As we discovered in the thematic programs on algebraic model theory and on singularity and geometry at the Fields Institute in 1996-97, geometors and model theorists have many common interests. The goal of this seminar is to further explore interactions between the areas.
This was a special year for our seminar, as it was used as the venue of choice for many of the talks given during the Thematic Program in o-Minimality and Real Analytic Geometry, held from January to June 2009.

Patrick Speisegger
Speakers include:
Malgorzata Czapla (Jagiellonian University)
On the weak Lipschitzianity and definable triangulations with regularity conditions
Joris van der Hoeven (Paris-Sud)
Transseral Hardy fields
Andreas Fischer (Fields Institute)
Recovering o-minimal structures
Kobi Peterzil (Haifa)
Applications of o-minimality to arithmetical questions in algebraic geometry
Mickael Matusinski (Fields Institute)
Differential Puiseux theorem for generalized power series field of finite rank
Franz-Viktor Kuhlmann (Saskatchewan)
Immediate mappings and differential Hensel’s lemmas
Dinh Si Tiep (Fields Institute)
On the trajectories of horizontal gradient of polynomial functions
Lorena Lopez Hernanz (Valladolid)
Parabolic curves and separatrices in $\mathbb{C}^2$
Dmitry Novikov (Weizmann Institute)
Non-oscillation of pseudo-Abelian integrals
Andrei Gabrielov (Purdue)
Approximation of definable sets by compact sets
Alex Rennet (UC Berkeley)
Differential equations over polynomially bounded o-minimal structures
Grisha Kolutsky (Lomonosov Moscow State University)
On the Hilbert-Smale problem
Alex Wilkie (Manchester)
Model theory and analytic continuation for implicitly defined functions
Vincent Grandjean (Bath)
Conormal spaces, Gauss mappings, limits of tangents (and everything) in a rigid real tame setting

Olivier Le Gal (Fields Institute)
A generic condition implying o-minimality for restricted $C^\infty$ functions
Artur Piekosz (Politechnika Krakowska)
Grothendieck topology and o-minimality
Tamara Servi (CMAF, Lisbon)
Pfaffian closure for definably complete Baire structures
Armin Rainer (Toronto)
Perturbation of polynomials and normal matrices
Philipp Hieronymi (Fields Institute)
The real field with two discrete multiplicative subgroups
Yosef Yomdin (Weizmann Institute)
Moment vanishing, compositions, and the Mathieu conjecture
Guillaume Valette (PAN)
Classification of definable sets from the metric point of view
Ayhan Gunaydin (Fields Institute)
The real field with the rational points of an elliptic curve
Serge Randriambololona (Fields Institute)
Some (non-)elimination results for curves
Anna Valette (Jagiellonian University)
Asymptotic variety of polynomials mappings
David Trotman (University of Provence, Marseille)
An index theorem for generic vector fields on closure orderable finite partitions by definable manifolds

Operator Algebras Seminar
July 2008–June 2009
Organizer: George A. Elliott (Fields Institute and Toronto)
The Fields Institute Operator Algebra Seminar began with the first major thematic program on operator algebras in 1994, and for some time has had the format of two meetings a week, year-round, of one to five hours’ duration each. It has been of a very informal nature, with not only in most cases titles not announced ahead of time, but also often even the speakers only deciding to report on the spot, concerning results either of themselves or of others. The seminar is associated with the ongoing operator algebra program directed by Fields Institute Senior Distinguished Member George Elliott. Its day-to-day operations have been coordinated by Greg Maloney, now for the second year.

During the year 2008-2009 year, mathematicians of various levels of seniority, ranging from very senior to undergraduate, have spoken in the operator algebra seminar. Some
titles were announced, as for instance in the case of Professor Shoichiro Sakai, who gave two very interesting lectures, one concerning the famous Kadison-Singer problem on extensions of states, and one concerning a question related to quantum computing, but often, a title or even a speaker’s name was not announced.

George Elliott

Speakers:
Shoichiro Sakai (Sendai)
On the Kadison-Singer Problem
Extremal marginal tracial states in coupled systems

Benoît Jacob (Paris 6)
Understanding Dixmier-Douady’s first triviality theorem
Some aspects of the state space of a C*-algebra

Aaron Tikuisis (Toronto)
The Cuntz Semigroup for Commutative C*-algebras whose Spectrum has Dimension At Most Three
Exploring the Cuntz Semigroup for Commutative C*-algebras
Radius of Comparison for C(X)
The Cuntz Semigroup of C(X): Well-supported Approximants
Matrix Algebras over C*-algebras Generated by Stable Relations
Proving Stability
Proving Relations are Stable
Stability of C*-algebra Presentations
C*-Algebra Presentations

Greg Maloney (Toronto)
Talks on his most recent work

Leonel Robert (York)
Villadsen’s constructions and the ones that followed
Talks on his most recent work

Teodor Banica (Université Paul Sabatier)
Half-liberated quantum groups

Andrew Toms (York)
Classification of C* algebras associated to minimal uniquely ergodic homeomorphisms

Luis Santiago (Fields Institute)
Talks on his most recent work

Fernando Mortari (Toronto)
Talks on his most recent work

Barry Rowe (Toronto)
The Left Regular Representation of a Semigroup
Talks on his most recent work

Branimir Cacic (Toronto)
Talk on his most recent work

Alin Ciuperca (Fields Institute)
Talks on his most recent work

Julien Giol (Bucknell)
Survey talk on hyperreflexivity and derivations

Nadish de Silva (Toronto)
Talks on his most recent work

Maria Grazia Viola (Lakehead, Orillia)
Talks on her most recent work

John Quigg (Arizona State)
Coverings of skew-products and crossed products by coactions

Kevin Teh (Toronto)
Derivation of the smooth functional calculus for spectral triples that satisfy the axioms of commutative geometry

Toronto Set Theory Seminar
July 2008–June 2009
Held at the Fields Institute

Organizers: Paul Szeptycki and Illijas Farah (York)

The Toronto Set Theory Seminar is devoted to the dissemination of research on set theory and its applications. This includes the research of the core participants – faculty, graduate students and post-doctoral students from the University of Toronto, York University and the Fields Institute, as well as visitors. The Seminar continues to offer a venue for young mathematicians (students and post-doctoral fellows) to be exposed to the frontiers of research in set theory and to present their own research. The Seminar has long been devoted to all areas of set theory with a particular focus on its applications to areas of analysis, topology, algebra, and measure theory. This focus continued with a number of talks devoted combinatorial set theory, descriptive set theory, real analysis, set-theoretic topology, and recent developments of applications to C*-algebras.

The set theory seminar continues to be enriched through its association with the Fields Institute. There were an unusual number of visitors this year whose visits were supported through the Set Theory Seminar funds provided by the Fields and through the grants of the permanent members of the Seminar. There were also many talks by graduate students and postdoctoral fellows supported either directly or indirectly by the Fields Institute. In addition, a number of speakers were recently supported by the Fields Institute.
as students or postdoctoral fellows and are now well-established research mathematicians. In the spring of ’09 the Fields hosted the Appalachian Set Theory Workshop. It was, by all accounts, the best attended of all the previous Appalachian Workshops and the Seminar took advantage of this Fields hosted event by organizing a short “mini-conference”, J.T. Moore, G. Gruenhage, P. Larson, K.P. Hart, and M. Scheepers all attended the conference and gave talks in the Seminar in the days just before and just after the Workshop.

Paul Szeptycki

Speakers:
Jordi Lopez Abad (Denis-Diderot Paris 7)
Generic constructions of Banach spaces
Leandro Aurichi (Sao Paolo)
D-spaces and products of Lindelöf spaces
D-spaces and games
Rothberger and Menger properties
Trees with fine wedge and coarse wedge topologies.
Carlos Azarel (Toronto)
Well quasi-ordering Aronszjan lines (series of two talks)
Adam Bjorndahl (Toronto)
Modal logic: The logic of space
Carlos DiPrisco (IVIC, Venezuela)
Chromatic numbers of analytic shift graphs
Natasha Dobrinen (Denver)
Tukey degrees of ultrafilters
Ilijas Farah (York)
Nonseparable UHF algebras
Matthew Foreman (UC Irvine)
Rational invariant measures
Gary Gruenhage (Auburn)
Slim dense sets
K.P. Hart (Delft)
Elementarity my dear Watson
Bernhard Koenig (Toronto)
Variations of Axiom R (series of two talks)
Paul Larson (Miami)
Universally measurable sets in generic extensions.

Tamas Matrai (Toronto)
Sigma-ideals of compact sets in the Tukey ordering (series of two talks)
Infinite dimensional perfect set theorems
Hurewicz testing
Tukey and Borel reducibility
Arnold W. Miller (Madison)
The hierarchy of \(\omega_1\)-Borel sets
Christopher Miller (Ohio State)
Tameness in expansions of the real field
Justin Moore (Cornell)
Fast growth of the Folner function for Thompson’s group \(F\)
Lionel Nguyen Van Thé (Calgary)
Problems and results around metric oscillation stability
Alexander Pyshchev (Nipissing)
On nonstandard hull-like spaces
Dilip Raghavan (Toronto)
Separable and indestructible MAD families
Suslin lattices
Proof of a conjecture of Brendle
A van Douwen MAD family in ZFC
Marion Scheepers (Boise State)
Selection principles and Lindelof spaces
David Sherman (Virginia)
Ultraproducts in model theory and functional analysis
Frank Tall (Toronto)
Lindelof spaces and selection principles,
Lindelof spaces which are indestructible, productive, or \(D\) -Abstract
Simon Thomas (Rutgers)
Some consequences of Martin’s conjecture
Stevo Todorcevic (Toronto and CNRS Paris)
Forcing with a coherent Souslin tree
Asger Tornquist (Vienna)
Borel reducibility and von Neumann equivalence
Beatriz Zamora (York)
Analytic \(P\)-ideals on \(B(H)\)
Toronto Probability Seminar
July 1, 2008–June 30, 2009
Held at the Fields Institute

Organizers: Tom Alberts and Balint Virag (Toronto)

During the past year this seminar has seen a total of 17 different talks from 14 different speakers representing 10 different institutions. Six of the 17 talks were given by University of Toronto faculty members or postdocs, ten were given by guests of U of T faculty, and one was given by a visiting member of the Fields Institute.

Attendance at the seminars has been strong. We maintain a core group of approximately 10 people that attends all seminars, but depending on the topic we often draw as many as 25. Regular attendees come from both the University of Toronto and York University, while the variable crowd usually comes from the U of T math and physics departments, and from interested visitors at the Fields Institute. We advertise our seminars through the seminar announcements of both the Fields Institute and the U of T math department, and also via a separate mailing list that we independently maintain.

Given the usual audience size, the Stewart Library at the Fields Institute has proven to be an ideal seminar location. The room is the perfect size for creating an intimate setting which does not intimidate the audience from asking questions, and visitors enjoy being able to speak in such a prestigious place. The funding we receive from Fields has also allowed us support the travel costs of five of our ten outside speakers, and is greatly appreciated.

The seminar webpage at www.math.toronto.edu/probsem/ is an up-to-date source for the latest news and schedule.

Balint Virag

Speakers:
Siva Athreya (Indian Statistical Institute)
Survival of the contact process on the hierarchical group

Tom Alberts (Toronto)
Dimension and measure of SLE on the boundary

Gideon Amir (Toronto)
The speed process of the totally asymmetric simple exclusion process

Jeff Steif (Chalmers University of Technology)
Dynamical sensitivity of the infinite cluster in critical percolation

Seminar Series on Quantum Information
July 2008–May 2009
Held at the Fields Institute

Organizing committee: Daniel James, Aephraim Steinberg, Paul Brumer and Hoi-Kwong Lo (Toronto)

As in previous years, this seminar series, run jointly by Fields Institute and the University of Toronto’s Center for Quantum Information and Quantum Control (CQIQC – pronounced ‘see-quick’) has had a full and stimulating
program, with some of the most distinguished scientists in the field describing their latest discoveries.

Quantum information and quantum control is a multi-disciplinary field, bringing together mathematicians, computer scientists, physicists, electrical and optical engineers, nano-scientists and physical chemists. This diversity was fully reflected in the variety of seminars presented in this year's series. The list included speakers from eleven different foreign countries (USA, Australia, Israel, Argentina, Mexico, China, the Czech Republic, Japan, Germany, the Netherlands and Norway), and six different Canadian institutions (viz., the Universities of British Columbia, Waterloo, Toronto, Dalhousie and Calgary and the Perimeter Institute). Probably the most thought-provoking talk (which attracted an audience that filled the Fields seminar room to overflow) was given by Alán Aspuru-Guzik of Harvard, who discussed the intriguing and controversial claims of quantum coherence in biological processes such as photosynthesis. Other highlights included Raymond Chiao, the renowned quantum optics researcher and one of the pioneers of non-linear optics, who discussed his ideas for gravitation wave detection; and Kimberley Hall from Dalhousie, a recent graduate of the University of Toronto graduate program, who has been awarded a major research contract from the Lockheed-Martin corporation to investigate experimental quantum computing in Canada using quantum dots.

In summary, 2008-09 was again a very successful year for this seminar series, with new ideas exchanged and collaborations created between University of Toronto researchers and visitors from all over the world.

Daniel James

Speakers:
Jim Rabeau (Macquarie)
Fabrication and measurement of nanodiamonds for quantum and biological science
Hanan Dery (Rochester)
A semiconductor spin-computer
Eric Zhu (Toronto)
From Type II Upconversion to SPDC: A path to broadband polarization entanglement in poled fibers
Cecilia Lopez (MIT)
Scalable error characterization in quantum information processing
Payam Abolghasem (Toronto)
A novel platform for nonlinear and quantum optics in monolithic semiconductor structures
Robert J. Silbey (MIT)
Coherence and decoherence in excited states of light harvesting complexes
Alán Aspuru-Guzik (Harvard)
The role of quantum coherence and the environment in chromophoric energy transport
David Cory (MIT)
Error finding and control in quantum information processing
Christopher Fuchs (Perimeter)
Charting the shape of quantum state space
Raymond Y. Chiao (U.C. Merced)
Looking back on the laser of Schawlow and Townes, and looking forwards to the generation of gravitational radiation
Kimberley Hall (Dalhousie)
Femtosecond control of spin dynamics in semiconductors
Moshe Shapiro (UBC)
Canonical invariance as a unifying symmetry of nature: derivation of the coordinate-momentum commutation relation, the time-dependent Schrödinger equation, and Maxwell equations
Peng Xue (Calgary)
Quantum walk on circles in phase space via superconducting circuit QED
Alex Lvovsky (Calgary)
Towards a universal light storage machine
Jan Bouda (Masaryk)
Tamper resistant encryption of quantum information
Shau-Yu Lan (Georgia Tech)
Towards a practical repeater
Masato Koashi (Osaka)
Security of quantum key distribution using an entangled pair of pulses
Stephanie Wehner (California Institute of Technology)
Cryptography from noisy quantum storage
Christian Schaffner (Centre for Mathematics and Computer Science, Netherlands)
The operational meaning of min- and max-entropy
Andrew Landahl (New Mexico)
Universal quantum walks driven by local Hamiltonians
Centre for Mathematical Medicine

Directors: Jim Drake (Hospital for Sick Children) and Sivabal Sivaloganathan (Waterloo)
Program Coordinator: Irwin Pressman (Carleton)

Interactions with other sciences have often led to the development of new mathematical methods that in turn have contributed to advances in these sciences. In the twenty-first century, there is new synergy between mathematics and the biomedical sciences, such as Mathematical Oncology. Many anticipate significant scientific progress through the mathematization of Medicine and the Life Sciences.

This mathematization is a challenge; fundamental conceptual issues remain to be resolved; e.g., what is the right framework in which to study cancer, or what are the critical biological mechanisms and corresponding scales. Such basic questions formed the setting to the inaugural summer thematic program on Mathematical & Quantitative Oncology held July-August, 2008 at the Fields Institute. The Centre for Mathematical Medicine coordinated the program. It was a multi-institutional and international event, involving the Ontario Institute for Cancer Research (OICR) and the Vanderbilt Integrative Cancer Biology Center (VICBC). The opening workshop on Growth and Control of Tumours (July 2-4, 2008) brought cancer biologists, clinical researchers and mathematical scientists together. Topics included developments in the cancer stem cell hypothesis, advances in the development of targeted drug therapies, novel drug delivery systems, and the optimization of combination therapies. The talks were balanced between theory and experiment; they addressed specific aspects of the multi-scale, multi-factorial nature of cancer. The workshop introduced the remainder of the thematic program.

There were numerous short and long term researchers visiting Fields in July leading up to the Society for Mathematical Biology Conference (SMB2008) held July 30-August 2, 2008 in Toronto and hosted by CMM. This meeting brought together 330 mathematical and biomedical scientists. L. Mahadevan of Harvard University delivered the opening plenary talk on mechanochemistry and motility. It launched the meeting into the various minisymposia and contributed talks that comprised the bulk of the 4-day conference. The sessions spanned a broad range of topics in mathematical biology although “cancer” remained a major theme of the meeting. Seven other plenary talks by T. Secomb (Arizona), H. Levine (UC San Diego), M. Knothe-Tate (Case Western), N. Komarova (UC Irvine), Y. Zhou (Xi’an Jiaotong University, China), M. Lewis (Alberta) and M. Golubitsky (Ohio) gave distinct perspectives on their particular areas of research in mathematical biology – all were uniformly excellent and inspiring. There was no respite and SMB2008 elided smoothly into the CMM/VICBC 4th workshop/summer school Current Challenges in Oncology: Through the mathematical looking glass which ran from August 2-6. This was based on the “hands-on” exemplary workshops pioneered by VICBC over the previous three years. This workshop brought the Vanderbilt efforts to a new level. We were fortunate in managing to assemble an excellent collection of faculty (thanks to the tireless efforts of Lourdes Estrada, VICBC) as well as over 70 graduate students and postdoctoral fellows. The students were divided into four groups, each under the mentorship of several faculty members (mathematical, biological and clinical). They were actively engaged in current problems of interest to basic scientists and clinicians in oncology.

The Fields Institute was a constant hive of activity over this period, with many participants working through the night in a contagiously enthusiastic and stimulating atmosphere – fortified by the constantly flowing coffee and tea that is “on tap” at the Fields Institute and is the staple of every successful mathematical institute! The workshop was a resounding success by all accounts, and extremely successful in exposing and engaging a new generation of researchers to a new paradigm of biomedical research – ultimately, the aim is to generate a critical mass of young researchers, well-versed in both mathematics and oncology to whom the torch will be passed. Energized by the workshop, many of the participants remained for the Coxeter lectures.

CMM and Fields were delighted to welcome Martin Nowak of Harvard University to deliver the Coxeter lectures. He presented three highly engaging and accessible talks in a style perfectly suited to the mixed audience of biomedical and mathematical scientists. In a series of three talks, Nowak covered three directions in his research (in which he has made seminal contributions): the evolutionary dynamics of cancer, discrete models of evolution, and the evolution of co-operation. Nowak expounded masterfully on evolutionary dynamics, the mathematical study and description of evolution. Why is this an important field? Nowak commented that the renowned geneticist T. Dobzhansky had once stated that “nothing in biology makes sense except in the light of evolution” and it is Nowak’s
contention that ideas in evolutionary biology are crying out for a mathematical description, since evolutionary biology is based on very simple and very precise fundamental principles – namely, selection and mutation. A mathematical description of these simple concepts has contributed to more precision and a deeper understanding in evolutionary biology and clearly one of the major applications of the mathematical models developed, is in the study of cancer progression.

Two graduate level courses *An introduction to mathematical oncology* and *medical image processing* were successfully run over the two months attracting significant student attendance. The former will be published as a Fields Institute research monograph in 2009.

The final workshop of the thematic program was *Quantitative cancer modeling: mathematical models, imaging and bioinformatics* August 25-27. A diverse group of researchers discussed the application of time reversal signal processing, robust optimization techniques in radiotherapy, machine learning for automatic cell classification, model based reconstructive elasticity imaging and magnetic resonance elastography, and model selection and network reconstruction for high throughput biological data. In summary, the workshops/conference and the thematic program as a whole brought the experimental sciences (cancer biology, clinical oncology) and the mathematical sciences together to move towards “integrative mathematical oncology”.

Our speaker who travelled the furthest was Graeme Wake from the Centre for Mathematics in Industry, Massey University, Auckland. He is a distinguished scholar with over 160 published papers, and over 25 PhD. students. Since he travelled so far, we asked him to speak twice. A result of this trip is that one of his PhD. students is now a postdoctoral fellow with Siv Sivaloganathan!

In his first talk on July 7, 2008, *Modeling of cancer treatment*, he described the complexities of the responses of tumor cells over time to both anticancer drugs and radiation. The goal is to allow tailoring of cancer therapy for individual patients, an important objective for oncologists. Although many biological techniques and mathematical models have been devised to predict the course of treatment, none are routinely applied to clinical oncology. The complexities of human tumor response to both chemotherapy and radiotherapy are modeled with mathematical equations that can be perturbed to predict treatment effects.

Mathematical equations were developed to describe the behaviour of cancer cells as they progress through the cell division cycle. DNA content gauges the cell cycle stage, so model outcomes can be compared to experimental results. These equations describe the response of human tumors to chemotherapy and radiotherapy. They incorporate programmed cell death (apoptosis) into the model, and perturbations of model parameters by treatment and comparisons of model results with data were performed. Flow cytometry is used to analyze the behaviour of a melanoma cell line (NZM13) exposed to paclitaxel, a drug used frequently in cancer chemotherapy. The flow cytometry profiles included a complex mixture of living cells whose DNA content was increasing with time and dying cells whose DNA content was decreasing with time.

This research provides new analytical and computational insights into the area of non-local equations, where cause and effect are separated in space and time. This aids oncologists concerned with treatment, drug companies producing drugs and managers of clinics.

His second talk, on July 9, 2008 was *A model for phenotype change in a stochastic framework*. In some species, an inducible secondary phenotype will develop some time after the environmental change that evokes it. Stochastic predator-prey models in which the prey has a fixed initial energy budget trade-off reduction in the probability of predation against increase in the energy required to maintain a phenotype with improved defense.

The ability of an organism with a given genotype (the “internally coded, inheritable information”) to change its phenotype (the outward, physical manifestation of the organism), in response to changes in the environment is called phenotypic plasticity. Such plasticity in some cases expresses itself as several highly morphologically distinct results; in other cases, a continuous response describes the functional inter-relationship of a range of environments to a range of phenotypes.

Organisms of fixed genotype can differ in the amount of phenotypic plasticity they display when exposed to the same environmental change. Phenotypic plasticity can evolve and be adaptive if fitness increases by changing phenotype. Immobile organisms such as plants have well developed phenotypic plasticity giving a clue to its adaptive significance and the fitness advantage for the organism. Organisms faced with a change in environmental circumstances minimize energy costs of reproduction.

A stochastic model of plasticity for a population is proposed under which an organism is able to determine the time
He suggested that many interacting nodes within a network might protect the functionality of organisms from minor environmental perturbations. A useful analogy was made with pixels on a television screen such that if only a few pixels die out, the overall function of the screen is preserved. The stance established in the lecture was that one should have a global perspective, i.e., look at the GRN as a system rather than at its individual parts. Hence Kauffman is an advocate of the study of Systems Biology.

Several prospects worthy of note were introduced. The progress on yeast cell dynamics is promising, with respect to giving us insight and tools to study the GRNs of human cells. “Life in test tubes is not too far in the future,” says Kauffman. He emphasized that the thermodynamic wake (a.k.a. energy) cycle of human life and efficiency of GRNs is not far from being understood. This could lead to the creation and understanding of a more general Theoretical Biology.

The usual network configurations for GRNs were modeled as existing “on the edge of chaos”. Hence many networks on one side of the boundary are robust and protected against minor perturbations. Conversely there exist configurations in a chaotic regime where organisms are very sensitive to their environment, and thus not fit to survive or evolve. Kauffman uses Hamming distances on Derrida graphs to classify networks into being chaotic or ordered. Critical networks are those on the boundary between the two. The model elucidates that being on the boundary will optimize robustness of cells to mutations and also optimize the capacity to evolve new cells types and configurations. On the boundary we discover that the Log-Log plot gives us an important slope of -1.5. Also, he gave a summary of other detailed models of critical biological networks and noted that theories of criticality seem to be a prominent theme in biology. This gives a special flavour to his evolutionary theory.

A small and informal forum followed the lecture continuing the conversation between the worlds of mathematics and biology. The discussion concluded with the vision of a bright future for Theoretical Biology and the conviction that mathematicians will play a ‘critical’ role in the understanding of life.

Richard Cerezo and Irwin Pressman
November 28, 2008
Matthew Scott
*Growth laws and mechanisms of global control in bacteria*

Bacteria are among the simplest living organisms; they grow, reproduce, survive and adapt. In a state of balanced growth, the population grows exponentially at a constant rate - as is taught in most first year Calculus classes. The growth laws of Schaechter, Maaloe and Kjeldgaard are among the most outstanding discoveries in bacterial growth physiology. They found that cell composition (mass/cell, RNA/cell, etc.) is a simple function of growth rate alone - irrespective of how that growth rate is established.

Growth means self-replication. Scott would have us think of a bacterium as a ribosome factory. Scott provided the basic differential equations that describe the well-established growth laws, and discussed recent experiments that have uncovered new laws and relationships among the parameters. A phenomenological model was proposed that suggests the growth laws arise from the partitioning of the protein synthesizing machinery of the cell (the ribosomes), and furthermore indicates a deep connection between growth rate control and central metabolism. He showed the impact of global control mechanisms, such as antibiotics, on endogenous and synthetic genetic circuitry, by sophisticated modifications to his fundamental differential equations. This has significant implications for clinical applications as well as synthetic biology.

This work was done together with Carl Gunderson, Eduard Matescu and Terence Hwa at the center for Biological Physics at the University of California, San Diego.

*Irwin Pressman*

January 30, 2009
Michael Yampolsky
*Can we diagnose potential health risks via the shape of a placenta?*

This question pushes Yampolsky to the advent of a new type of dynamical model. His lecture was a summary of results about the growth of the human placental vasculature, otherwise known as angiogenesis. The model’s purpose is to quantitatively measure and classify the effectiveness of human placenta of varying shapes.

Michael Yampolsky became fascinated with non-trivial patterns in the growth of placental vasculature trees at a conference on random shapes. As a result of seeing this pattern, Yampolsky has made progress in connecting the observed phenomena with a model based on random fractals. Yampolsky has been working jointly with Carolyne Salafia from Placental Analytics in New York and Alex Shlakter. Together they develop the theory and simulations of the dynamical model.

The model has a strong potential to be matched against health databases in the aim of verifying the predictions of the model. This is a realistic goal since placentas are essentially ‘waste products’ after the birthing process and can be easily collected and studied.

The presentation was meant to illuminate some of the problems with intuition in these settings. For example, one might think that the underdeveloped placenta may have had a physical obstacle to prevent normal growth. However, approaching the problem from a dynamical systems point of view, one would search for an underlying pattern in the angiogenesis process.

Central to the model is a useful tool from physics called Diffusion Limited Aggregation (DLA) in which angiogenesis is modeled ‘at the tips’. Normally, a placenta is round, but a deviation from the norm can take many possible shapes. It was outlined that the DLA model predicted that when a typical disturbance in the normal branching structure occurs at a specific time we would get definitive shapes. In particular at 5% of the angiogenesis process we would observe a placenta with several lobes and at 50% we would observe a star shaped placenta. Thus the model predicts that the shapes we observe in the clinic might correspond to a specific time dependent biological event.

There have been a number of attempts in the past to draw these connections. In particular the biologist Kleiber tried to observe some scaling laws that could be observed by measuring how body mass scales with metabolic rate. However, Kleiber did not have much data to develop these laws. But in the modern light of much more placental data, it is now possible to develop a placental fetal scaling law which would measure how placental mass scales with fetal mass.

Classification of these shapes presents an interesting and important challenge for mathematicians and placental pathologists. This field holds many interesting questions and opportunities for the applied mathematicians and it was a pleasure to have witnessed such a model and field still in its infancy.

*Richard Cerezo*
A Hopf bifurcation is the birth of a limit cycle from a dynamical system equilibrium generated by ODE’s, when the equilibrium changes stability via a pair of purely imaginary eigenvalues. The parameter boundaries on which a Hopf bifurcation gives birth to a period oscillation in the models were determined. The models predict that an increase in either the ventilation-perfusion ratio or the neurological feedback gain, can give rise to stable oscillations, i.e., CSR.

The predictions of the model agree qualitatively with clinical observations of CSR onset in humans, thus validating the model. The model was able to simulate higher pressures of CO₂ (lower altitudes), congestive heart failure, encephalitis, and athleticism. An increase in the partial pressure of inspired CO₂ in the model shifts the bifurcation curve upward, giving a greater area of stability and potentially curing CSR. The model can simulate both potential treatments and individual differences, and shows promise as an investigational tool in future studies of CSR.

Andree Monette and Irwin Pressman

February 27, 2009
William F. Langford
A Compartmental Model of Cheyne-Stokes Respiration

The circulatory and respiratory system ensures the body has an adequate supply of oxygen and removes carbon dioxide (CO₂). When the regulation of this system is disrupted, remarkable periodic effects can occur. An example of this, Cheyne-Stokes Respiration (CSR) is a periodic pattern, characterized by periods of rapid breathing alternating with periods of apnea (little or no breathing). This is observed in persons with cardiovascular conditions, mountain climbers at high altitude, or before death. Breathing can stop for 15-45 seconds.

Langford modeled the complex triangular relationship between the brain, cardiovascular system, and respiratory system by designating different segments of the cardiovascular system (systemic veins, venules, arterioles, capillaries) as compartments. He modeled each compartment with an ordinary differential equation (ODE). Since the gas exchange in every compartment except the capillaries and the outside is negligible, most compartments were modeled by simple equations with two terms representing flow in from the previous compartment and flow out to the next compartment.

Only the systemic capillaries and pulmonary capillaries have the surface area for gas exchange with tissues, so the former were given an extra positive term equivalent to the metabolic production of CO₂ and the latter were given a negative term representing the clearance of CO₂ through respiration. Cells that detect the concentration of CO₂, or baroreceptors, are located in the systemic arteries and control respiration (and thus the alveolar ODE). They exhibit an individual threshold response, but, as a population, were modeled by the Hill function: \( S(x) = \frac{n^x}{1 + n^x} \), where \( S_n \) represents the response and \( x \) represents the concentration of CO₂. This approaches a step function as \( n \) approaches infinity; \( n \) can be varied as a parameter in the model representing the selectivity of baroreceptors.

Physiological parameters for the system were investigated through a literature review. The two most important parameters were: (i) the ventilation/perfusion ratio, a highly studied, physiological variable, and (ii) the neurological feedback gain, proportional to \( n \) and the average CO₂ level in the baroreceptors, a less studied parameter relating to physiological responses to environmental changes.

April 17, 2009
Robert M. Miura
Migraine with Aura: Treat It with Math

It has been over half a century since A.P. Leao’s discovery of cortical spreading depression (CSD), yet the mechanisms supporting this phenomenon are not completely understood. In this context, depression means a significant drop in the neural electroencephalogram (EEG) readings. Simultaneous with the drop, the sections of the brain which are involved ‘cease’ activity and experience complete loss of function. CSD is characterized by a slow propagating chemical wave, over structures such as the visual cortex. To induce and observe the phenomenon in laboratory animals...
is straightforward. In the 1940s, the neuropsychologist Lashley conjectured a nontrivial link between migraines involving “aura” and an unknown propagating phenomenon that would later be called CSD. Lashley experienced the aura himself – a combination of flashing lights, geometrical objects and distortions in the visual field.

Lashley’s hypothesis was recently confirmed at Harvard by Hajikhani et al., whose research involved measuring fMRI levels during migraines. Blood oxygenated level dependant (BOLD) signal changes were observed to be correlated with aura. Dilation of the blood vessels was linked to an increase of BOLD signaling. These signals were then observed to produce global CSD waves. When the wave passed over the visual cortex, the patients observed the aura in their visual fields. A constriction of the vessels was involved at the end of the phenomenon as well as a decrease in the BOLD signal. Future research established a link between the dynamics of the blood vessels with the aura experienced during a migraine.

Grafstein, a PhD. student at McGill University, studied the correlation of the phenomenon with levels of potassium ions ($K^+$). She conjectured that the large amount of $K^+$ was due to an increased number of action potentials. This conjecture was disproved by a group of Japanese scientists who used tetrodotoxin (TTX) from the puffer fish to inhibit action potentials. They found that CSD could occur and that $K^+$ levels could still reach high levels in the presence of TTX even with the absence of action potentials.

The Tuckwell-Miura model (TMM) was created to understand CSD in light of the $K^+$ levels problem. The TMM is a continuum model based on the plasma physics “two bag” model. The TMM shows how large amounts of $K^+$ in the extracellular space (ECS) can occur as a result of neurotransmitter action. The ECS is assumed to be completely connected in the topological sense. $K^+$ is modeled to propagate in a deterministic direction within the ECS. In the intracellular space (ICS), the ionic diffusion coefficients were set equal to zero. Two non-linear diffusion equations for $K^+$ levels and calcium ($Ca^+$) levels were introduced. $Ca^+$ is involved with the release of neurotransmitters, which in turn release $K^+$. The other major ions, $Na^+$ and $Cl^-$, were held fixed in the model. TMM models the shape and speed of CSD correctly, when compared to observation.

However, a model which gives the correct speed and shape doesn’t mean that you’ve got the right model. If you really want to understand, then you have to figure out what the mechanisms are. If you introduce mechanisms, then hopefully you’ll be able to predict other things that weren’t originally put into the model. It’s a philosophical question but an important one. However, there is no such thing as completely validating a model. It’s always possible that you can do another experiment and something (unexpected) will come out of it”, says Miura.

The insight and knowledge that Robert resented stems from over 30 years of experience in this field. It is exciting to perceive the effectiveness of his modeling in bridging the gap between experimental science and mathematics. He offers us a gateway for understanding a biological fact with mathematical tools.

Richard Cerezo

March 27, 2009
Catherine Beauchemin
The contributions of theoretical models in exploring the dynamics of in-host influenza infections

Beauchemin received her PhD in Physics of the University of Alberta in 2005, working on spatiotemporal modeling of viral infections. She was a postdoctoral fellow at the Los Alamos National Laboratory with Alan Perelson – another CMM speaker this year, and a co-author of four papers with the speaker – and with Stephanie Forrest at the Adaptive Computation Laboratory in Computer Science at the University of New Mexico. Her research interests are in self-organizing systems, and mathematical modeling of infectious disease dynamics. Since the flu virus was first isolated in 1933, much attention has been given to its structure, its genome, the immune response it elicits, vaccines to protect against it, and its epidemiology. There is limited information regarding the kinetics of flu during an infection within an individual. Key parameters such as the rate at which flu-infected cells produce viruses or the fraction of these viruses that are productively infectious, are still unknown, but the determination of these is a key aspect of the research. The approach is to develop a simple mathematical model and fit it to the data. The basic reproductive number determines whether the infection gets worse (greater than 1) or disappears (less than 1).

This talk included a review of the state of the art of flu kinetics. We learned that there are four genera of flu, and that Bird Flu is type A, while the sporadic Type B is normally the biggest overall killer. By the peak day 2 of flu, 40% of a person’s lung cells can be dead. The rate of virus production, the percentage that is infectious, and the mechanism of how a virus leaves are not known. Viruses have a half-life of 3.2 hours; infected cells have an 11-hour life span.
Mathematical and computational models have improved the understanding of specific mechanisms involved in a flu infection. The mathematical models, consisting of dynamical models with systems of linear differential equations, capture the dynamics of a seasonal flu infection within human volunteers. Such data and models are used by Roche to develop Tamiflu. One aspect of the research is to estimate the speed and fitness of Tamiflu-resistant mutants. Resistance has increased to 90% in some flus. Work has been done on the combination therapy of Amantadine and Tamiflu, because viruses resistant to one or both seem susceptible to the combination! Delaying the peak of the viral attack gives the immune system time to ramp up its defenses.

The models are used to extract information about the effect of anti-flu drugs on viral kinetics in vitro, and to characterize the emergence of drug resistance under treatment. Beauchemin discussed how the predictive power of these models helps to guide public health decisions with regard to drug treatment strategies, and rapid strain identification through pairing specific models and experiments, working in synergy.

Irwin Pressman

May 15, 2009
Alan Perelson
The Dynamics of Virus Infection and Treatment

Alan Perelson is a Senior Fellow at Los Alamos and has published over 400 papers. He was honoured in 2009 by being appointed a SIAM fellow. His major accomplish-

ments include the development of mathematical techniques to deal with global epidemics. Perelson’s research on human immunodeficiency virus (HIV) has changed the treatment strategies for HIV and he has applied the same techniques to the study of hepatitis C (HCV).

He describes HIV dynamics after infection as follows: the number of HIV cells in the body rises exponentially then rescinds almost as quickly, to a very low number and eventually to an ‘eclipse phase’ where the number is detectable, but the symptoms are not. The eclipse phase is known as the quasi-stationary state or ‘set point’. Infected individuals may not show symptoms for up to 15 years, but T-cells are significantly negatively affected. Perelson has developed a successful model using a system of linear differential equations that clearly explains the dynamics of infected cells. There are 3 variables, 5 rate parameters and a supply parameter. Perelson solved this system by making an assumption that in the short run, target cells maintain a constant number in the body.

By analyzing the model and using the infection constants, Perelson deduces that the timescale for HIV infection is in fact on the order of days to weeks. Previously, many thought that, since the symptoms of HIV appear only years after, the mechanisms are slow and that the timescale is on the order of decades. Now knowing that this is a fast process (~10^{10} virions produced daily!), drug design has been modified to treat infected patients for immediate needs. Infected cells mutate rapidly and become drug resistant, so combination therapy is used for treatment. Protease inhibitors (ritonavir) are a useful class of drugs discovered by biologists and pharmacists that effectively ‘perturb’ the system of infected cells, in addition to treating HIV. By using the half-life and known viral clearance rates, these perturbations give an approximation as to how many viral particles are needed to maintain the set point for each individual.

Experiments were performed on monkeys to induce HIV infection in order to determine the biological mechanisms involved in HIV infection. It appears that the probability of infection scales with the dose so that the higher the dose, the higher the probability of infection. This study will be repeated to produce a larger data set to provide evidence for Perelson’s theory. He plans to add stochastic parameters to the model to improve model fits with the data and uncover hidden mechanisms in the infection process.

Hepatitis C (HCV) targets the liver by disrupting the immune system. It attacks the liver turning it into a mass...
The format of the workshop followed the guide of the well-established Study Groups at Oxford. On the first morning of the workshop, researchers in medicine presented each of the six technical problems of interest to them. The academics then divided into teams to work on these problems for the next three and a half days. On the final day of the workshop, progress on these problems was reported. A final report on these activities will be prepared subsequently. The six problems were:

2. Intramantle pressure gradients favoring hydrocephalus development generated in the rat brain following disruption of beta-1 integrin-matrix interactions.
3. Identifying the mediators of mechanotransduction between bone cells.
4. Calcium carbonate formation in the presence of serum protein.
5. Sodium flux during hemodialysis.
6. Development of mathematical models for estimating the risk of VCJD transmission by blood and surgery.

The final reports from each of the groups working on the problems will be posted on the OCCAM website in the Fall.

Irwin Pressman
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.

Industrial Optimization Seminar
October 2008–June 2009
Held at the Fields Institute

Organizing and Advisory Committees: Antoine Deza (McMaster), Miguel Anjos (Waterloo), Joaquim Martins (Toronto), Tamás Terlaky (Lehigh), Natalia Alexandrov (NASA), Andrew R. Conn (IBM Watson), John E. Dennis (Rice), Fassi Kafyeke (Bombardier Aerospace), Stefan Karisch (Carmen Systems), Hans Tuenter (Ontario Power Generation), Henry Wolkowicz (Waterloo), Margaret H. Wright (NYU), David Zingg (Toronto)

The inaugural meeting of the Fields Industrial Optimization Seminar took place on November 2, 2004. This year was the fifth year for the seminar series, which is supported by both MITACS and the Fields Institute. The seminar meets in the early evening of the first Tuesday of each month. Each meeting is comprised of two related lectures on a topic in optimization; typically, one speaker is a university-based researcher and the other is from the private or government sector. The series welcomes the participation of everyone in the academic or industrial community with an interest in optimization – theory or practice, expert or student.

This year the seminar series continued its established tradition and brought together a wide range of researchers and practitioners from both Canada and the USA. The October seminar paired researchers from Rutgers University and Fair Isaac Corporation who presented the latest theoretical and applied advances in quadratic unconstrained binary optimization (QUBO), and substantiated their approaches via extensive computational experiments. November talks illustrated the successful combination of mathematical models and advanced software. The speakers from University of California and Defence Research & Development Canada addressed, respectively, sequential quadratic programming (SQP) and the large-scale SQP package SNOT, and Mixed Integer Linear Programming and the GALAHAD package developed to ensure a safe load balance for aircraft used by the Canadian forces. Medical imaging and optimization and health care were the focus of, respectively, the February and June seminars where experts from University of Calgary, Princess Margaret Hospital, North Carolina State University, and University of Iowa explained new methods exploiting graphical processing units, recent achievements in medical imaging, and optimal utilization of operating rooms. The mathematical models as well as numerical results based on real data were presented as illustrations, and the critical importance of being able to communicate the result to individual physicians was stressed. The challenges and opportunities arising from graphical processing units (GPU), already mentioned at the November seminar, were echoed at the February seminar. Combinatorial optimization was the focus of the December seminar with researchers from MIT and IBM showing how...
combinatorial models, such as matroids, can lead to efficient algorithms for approximating submodular functions and nonlinear combinatorial optimization. This research, driven by the search for theoretical efficiency, yielded successful implementations on the BlueGene supercomputer. At the second April seminar, participants learnt about theoretical and computational approaches to problems related to machine learning and training support vector machines, interplaying with techniques and ideas used in computational geometry. Following the previous year’s seminars on the theme of optimization and finance, the March seminar featured researchers from McMaster and Algorithmics who discussed managerial flexibility and credit risk with a combination of theoretical results and numerical computations. At the first April seminar, the speaker from Ecole Polytechnique de Montréal spoke about the impact of degeneracy for non-linear programming and how it could be addressed from both a theoretical viewpoint and an algorithmic perspective. The speaker from Bombardier Aerospace, continuing the established theme of optimization in the airline industry, presented the industrial techniques used in industry to tackle the aero-structural optimization of a large business jet.

The Industrial Optimization Seminar resumes in October 2009.

Antoine Deza

Speakers:
October 7, 2008
Endre Boros, (Rutgers)
Quadratic Binary Optimization and its applications
Gabriel Tavares (Fair Isaac Corporation)
Linear Programming plus branch-and-cut for solving certain difficult QUBO problems
November 4, 2008
Philip E. Gill (UC San Diego)
What’s new in SQP methods?
Bohdan Kaluzny (Defence Research & Development Canada)
Combinatorial Optimization in Canadian Forces airlift modeling
December 2, 2008
Michel X. Goemans (MIT)
Approximating submodular functions everywhere
Jon Lee (IBM TJ Watson Research Center)
Nonlinear Combinatorial Optimization

Quantitative Finance Seminars
June 2008—May 2009
Held at the Fields Institute

Organizers: Ron Dembo (zerofootprint), Matheus Grasselli (McMaster), John Hull (Toronto), Tom Hurd (McMaster), Moshe Milevsky (York), and Dan Rosen (R2 Financial Technologies)

The fall session of the 08-09 seminar series was conducted during what will perhaps become known in history as the “financial meltdown”. September and October saw the world’s financial giants teetering on the brink, with Fannie Mae, Freddie Mac, Lehman Brothers, Wachovia, AIG, Washington Mutual and the entire Icelandic banking system all going down. Then the bank bailouts started. At the
same time the world’s leading economies were entering the severest recession in decades and markets were tanking.

With this in the background, William Morokoff was the first of the year’s seminar speakers. He bravely grasped the bull by the horns and spoke about credit correlation, arguably the least understood problem in mathematical finance and a key aspect of the subprime collapse that triggered the financial crisis. His talk showed how an optimistic view of correlation leads to a dramatic overvaluation of senior tranches of securitized products, and argued that careful analysis of the drivers of credit risk is needed to correct this.

In October, the first speaker was Michael Zerbs who in a wide-ranging talk spoke on the five deadly sins of current risk management methods and how these have contributed to the financial crisis. He emphasized how the “virtuous circle” of liquidity-fueled innovation quickly turned into the “vicious circle” of falling confidence and liquidity. He advocated renewed emphasis on coordinating risk management with strategy at the highest level of banks, which will necessitate improved communication between quants and the executive level. Mark Broadie addressed a long standing puzzle in finance, namely the apparently excessively large returns observed for writing out-of-the-money (OTM) put options. He showed that while indeed their returns have been large, the result is not statistically significant for standard pricing models like Black-Scholes and Heston. Moreover, related option strategies that exhibit large returns can all be consistently explained within a stochastic volatility jump model as resulting from a reasonable “jump-premium”.

Stathis Tompaidis gave a talk in November on the problem of utility-optimal investment under financial constraints. The aim of this work was to explain observed tendencies, particularly the fact that young investors tend to be under-diversified. This tendency was shown to arise in simulations of optimal portfolios under a wide range of model parameters and given the explanation that margin constraints bind more strongly for investors with a low wealth to income ratio.

In the new year, we began with talks by Michael Pykhtin and Adam Metzler. Pykhtin described how counterparty risk, the risk that one party defaults before making a contracted payment, is modeled in the finance industry. One’s exposure to a counterparty is the positive part of the contract value at the time of their default and this risk is often ameliorated by netting agreements and the posting of margins, leaving only a residual exposure. The valuation of contracts subject to such residual counterparty risk involves nonlinear payoffs and time delays, for which Pykhtin has developed a semi-analytical method based on the Brownian bridge. In his talk, Metzler described a structural approach to portfolio credit that treats firm defaults as first passage times for a multivariate process built from independent Brownian motions with correlated diffusion coefficients and drifts. Such a structure presents mathematical difficulties and Metzler showed how certain variations can be dealt with, leading to good agreement with observed prices for index CDOs.

In March, Helyette Geman gave a review of the special characteristics of energy commodity markets (electricity, oil, natural gas, coal) with a particular reference to the relation of prices to inventory. This theme was illustrated in several contexts, notably the recent history of oil prices, where it was shown that the many types of spreads that trade cannot be accounted for without taking care of inventory. In the talk by Erhan Bayraktar, we heard about a model for the joint dynamics of equity and credit securities written on a firm, where the firm’s stock price jumps to zero at the time of default. By implementing an asymptotic stochastic volatility method, he arrived at pricing formulas that prove to be consistent with observations when calibrated to several different datasets.

In the closing session of the year, Andrew Lo questioned whether quants deserve blame for the current crisis, arguing that blaming quants and their methods was similar to blaming arithmetic for accounting fraud. To prove the point that strong quantitative methods are paramount, he described how banks’ poor quantitative understanding of default correlation lead them to securitization strategies (CDO portfolios) that were particularly vulnerable to the
unanticipated broad based decline in the US housing index. The second speaker, Lane Hughston, developed for us an innovative approach to modelling financial securities in which an information signal is masked by noise characterized by either a Brownian or gamma bridge that disappears over time. He gave examples that show how this leads to a description of correlated assets in terms of an underlying Markovian family of state variables.

Tom Hurd

PRMIA Risk Management Seminar
February–June 2009

Launched in Spring 2004, the PRMIA Risk Management seminar presents talks on issues of current interest to both professionals and academics in the fields of risk management. PRMIA is an international association of professional risk managers. The seminar series is co-sponsored by the Toronto chapter of PRMIA and by the Fields Institute. Talks cover a broad range of topics, not necessarily restricted to research in mathematical finance, the topic of the long-standing and complementary Quantitative Finance seminar series.

Speakers:
Phil Wright (CanDeal)
Electronic Trading: OTC Risk Management Crossroads
Christopher C. Finger (RiskMetrics Group)
Modeling issues for capturing traded credit risk
Marcus Cree (SunGard)
Risk Management in Era of Global Turmoil
Gene Guill (Deutsche Bank)
Bankers Trust and the Birth of Modern Risk Management
Ahmet Kocagil (Fitch Solutions)
Assessing Liquidity in CDS Markets
Christopher Holt (AllAboutAlpha.com / CAIA Association), Mark Hannoush (Ontario Teachers' Pension Plan), Christopher Addy (Castle Hall Alternatives)
Assessing Hedge Fund Risks: A View from the Trenches

MICS Electronic Journal
Editors-in-Chief: Alistair Fitt (Southampton) and Hilary Ockendon (Oxford)
Managing Editor: Huaxiong Huang (York)

Mathematics-in-Industry Case Studies (MICS), a new Fields electronic journal launched in January 2008, has continued receiving submissions during the past year. The central theme of MICS is the stimulation of innovative mathematics by the modeling and analysis of such problems across the physical, biological and social sciences.

Although MICS has been conceived as the result of the vibrant Canadian culture of mathematics-in-industry, it intends to publish contributions from around the world, highlighting the commonality of key methodologies and pinpointing areas where mathematical creativity will have the most impact. MICS will also accept and publish unsolicited submissions and it is planned that strong alliances with relevant websites and newsletters will create natural channels for such submissions.

During the past year, MICS has received contributions from applied mathematicians around the world, and published several new submissions. Topics have ranged over a variety of interesting subjects, including wireless networks, fluid bearings in hard disk drives, drying concrete, and optical networks. Several more submissions are currently being edited and are forthcoming, and MICS is preparing to conclude the first volume.

To facilitate rapid publication and support public knowledge dissemination, MICS is entirely electronic and the Open Journal System of the Public Knowledge Project is used to handle manuscript submission and online publication.

The first paper appeared in June 2008 and it is expected that 5-10 papers will be published in the 2008 volume. The time from submission to publication of papers is expected to shorten while the number of submissions is expected to increase after the completion of the 2008 volume during the summer of 2009.

Finally, John Ockendon became the Director of the newly established OCCAM and Hilary Ockendon has taken over the co-Editor-in-Chief position since January 1, 2009.

Richard Michael
START-UP FIRMS FOSTERED BY THE FIELDS INSTITUTE

In 1999, Fields began a program to foster start-up companies that commercialize mathematical ideas and that can benefit from co-location at the Fields Institute. Companies are approved by the Fields Board on recommendation by the IAB. The goal of the program is to enable members of the Fields community to start business ventures by giving them access to the physical, intellectual and logistical resources of the Institute. In early 2009, R² Financial Technologies Inc. graduated from the program and moved off-campus, attaining the designation of a “senior” firm.

The Individual Finance and Insurance Decisions (IFID) Centre

The IFID Centre is a non-profit corporation that is currently housed at the Fields Institute and is closely associated with the Schulich School of Business and the Department of Mathematics and Statistics at York University in Toronto.

The IFID Centre was launched in the winter of 2001 with broad objectives and a mandate to conduct and disseminate applied research in the field of financial risk management for individuals. The IFID Centre supports a wide network of researchers interested in the topic of consumer finance and personal insurance by sponsoring conferences, generating research reports and giving targeted seminars and keynote presentations to audiences in the U.S. and Canada. The IFID Centre’s operating revenues and sponsorship grants are contributed by corporations in the financial services sector who are interested in directing research attention towards this field of growing importance and influence.

QWeMA Group Inc.

Stemming from the activities of the non-profit IFID Centre, QWeMA Group Inc. is privately owned and operated by a group of financial engineers, economic scientists and applied mathematicians. In addition to being incubated at the Institute, QWeMA is also a Corporate Affiliate Member of Fields.

The QWeMA Group – which is an abbreviation for Quantitative Wealth Management Analytics Group – develops intellectual property, software algorithms and product solutions in the fields of wealth management, investments and insurance. We specialize in the business of retirement income analytics and have worked with some of the largest financial services companies in the world. The QWeMA Group has a total of seven full and part time employees that whose offices are on the first floor of the Fields Institute building at 222 College Street.

Moshe Milevsky
R² Financial Technologies Inc.
R² Financial Technologies was founded in 2006 and was incubated at the Fields Institute in Toronto.

Our mission is to deliver actionable, content-driven valuation, risk and capital management solutions, which effectively integrate advanced quantitative methodologies, financial technology and data. We create business value for our clients by delivering superior analytical capabilities in a simple, practical and intuitive way.

The company is founded on the principles of individual’s leadership and creativity, excellence, and proven experience. We believe in a cross-disciplinary approach to solving business problems, which emphasizes the communication of complex ideas with clarity, precision and efficiency. Our senior management team has a combined 50-year practice designing, delivering and implementing technology solutions which are used at most of the top financial institutions around the world.

Dan Rosen
Mathematics Education

Ontario Mathematics Education Forum
September 2008–June 2009
Held at the Fields Institute

Steering Committee Co-chairs: Miroslav Lovric (McMaster) and Juris Steprans (Fields)

Members: Stewart Craven (Science Centre), Shirley Dalrymple (York Region District School Board), John Kezys (Mohawk College), Donna Kotsopolous (WLU), Dragana Martinovic (Windsor), Joyce Mgombelo (Brock), Katie Northcott (Crescent High School), Chris Suurtamm (Ottawa)

The Fields Mathematics Education Forum met at the Fields Institute monthly during the school year, from 10am to 2pm, for a total of eight meetings – the 2008/9 dates were September 20, October 18, November 29, January 24, February 28, March 28, April 25, and May 30). Attendance ranged from 20 to 45, and participants regularly come from as far as Ottawa, Kingston, Peterborough, London, and St. Catharines. Meetings are open to the public and anyone may attend without invitation. Agendas are discussed and defined at the meetings of the Forum’s Steering Committee;

there were a total of five Steering Committee meetings in 2008/9 – the first was a teleconference at the beginning of September 2008 where the dates of the meetings were determined, as well as the agenda for the September meeting.

The Forum brings together individuals from university and college mathematics departments, faculties of education, teachers and mathematics coordinators from school boards, textbook publishers, freelance consultants, government representatives as well as members of the public interested in mathematics education. It serves as a lively venue for sharing ideas and initiatives, discussing current issues in mathematics education and beyond, forging partnerships for mathematics education research, planning activities for mathematics education conferences and presenting numerous outreach activities.

No matter what activity is taking place at a meeting, certain questions are more-or-less constantly present on the agenda, in one form or another. For instance: How do we improve the teaching and learning of mathematics? How do we better prepare mathematics teachers? How do we stimulate interest in studying and teaching mathematics? How do
we improve communication between primary and secondary teachers, and university instructors?

One issue appeared on the agenda several times – preparation and dry-runs of activities that various groups were preparing for the Canadian Mathematics Education Forum, held in Vancouver April 29 – May 3, 2009. A large number of people who attend Math Education Forum meetings in Toronto attended the Forum in Vancouver as well; this is definitely evidence of the enthusiasm and the depth of involvement, as well as the research efforts of Math Ed Forum participants.

In 2008/9 we witnessed a further increase in attendance and active participation among graduate students – mostly in mathematics education, although there were a few mathematics graduate students as well. At some meetings about a quarter of the attendees were graduate students.

Among our guest speakers in 2008/9 we mention:

- Joany Fransman (Northwest University, South Africa)
- Kate Mackrell (Institute of Education, University of London)
- Paul Betts (Winnipeg)
- Sue Wilson (Australian Catholic University Limited, Canberra)
- Carolyn Kieran (Montreal)
- Nathalie Sinclair (Simon Fraser)
- David Spiegelhalter (Cambridge)

Each meeting starts with information about the activities of various mathematics education groups/organizations OAME (Ontario Association for Mathematics Education), OMCA (Ontario Mathematics Coordinators Association), OCMA (Ontario Colleges Mathematics Association), CMESG (Canadian Math Education Forum) and others. Then, the theme of the meeting is announced, and the Steering Committee member in charge of organizing the theme introduces the activities that will follow.

The meeting on September 20 was dominated by topics mostly (but not exclusively) related to primary education. Under the theme ‘Parental Involvement in Their Children’s Math Education K-12,’ we discussed a number of ideas and initiatives that could improve the way parents get involved with their children’s education. It seems that a major obstacle is a lack of adequate resources that parents could use to get informed – in detail – about curriculum and its goals and implementation, as well as about specific academic content of mathematics courses that their children take. Parents expressed a great deal of frustration about their inability to explain to their children a solution to a trivial mathematics problem in the way that is required by teachers.

We also talked about ‘Windows into Elementary Mathematics’ project, sponsored by the Fields Institute. This project invites mathematicians to discuss topics from elementary mathematics, in order to provide students, parents and teachers with insights into mathematics and into the thinking of mathematicians.

The meeting on October 18 was the first meeting of the Forum that was not held in Toronto. In order to expand our reach (and we were quite successful!) we chose the University of Ottawa. In addition to a large number of regular Forum members, we had a good number of people from the Ottawa region as well as Quebec.

Our guest speaker, Joany Fransman (Northwest University, South Africa) talked about teaching “context” in a mathematics literacy training program at her home institution. The theme was expanded through a panel discussion Teaching math in contexts: What is the value of context? What contexts are valuable? The lively discussion that followed focused on many problems related to introducing applications into teaching mathematics at all levels.

The theme of our 29 November meeting was research into secondary and tertiary math education. The speakers were:

Kate Mackrell (University of London)
Engaging students and doing mathematics with Cabri 3D

Cathy Bruce (Trent)
The research-practice relationship and collaborative ventures in mathematics education

Jennifer Hall (Ottawa)
Women’s High School and University Experiences that Influence the Pursuit of Undergraduate Mathematics Degrees

Sue Wilson (Australian Catholic University Limited)
An Aussie reflects on teaching and learning mathematics and science

Without doubt, research dominated the Forum’s 2008/9 meetings’ agenda. I believe that the Math Ed Forum has established itself as one of the top math education research promotion venues in Ontario.

Agenda of our January 24, 2009 meeting again revolved around research presentations:

Alba Agostino (York)
Development of multiplicative reasoning: The role of M-capacity, inhibition, updating and shifting
Mathematical Education

Paul Betts (Winnipeg)
Thinking about embodiment and other philosophies of mathematics with (gifted) high school students

Barbara Graves (Ottawa)
We have no idea how capable children are!

Carolyn Kieran (Montreal)
Technique in algebra: The task of rendering it conceptual

Joan Moss (OISE) and Nathalie Sinclair (Simon Fraser)
Critical evaluation of aspects of the JUMP program.

Research presentations continued, and in our February 28 forum meeting we had three more, focused around elementary and secondary education:

Jamie Pyper (UWO)
Preservice teacher efficacy: Teacher efficacy and contributing factors of teacher concern and teacher orientation

Adrian Jones (Ottawa)
Concepts made concrete: Modeling with manipulatives in secondary school mathematics

Tim Sibbald (Clarke Road Secondary School)
An explanatory mechanism for reflective practice.

In the afternoon, we all happily participated in the session Emotions in mathematics organized by Stewart Craven and Burke Brown. Message: mathematics is far from a cold and austere discipline; in the same way we could describe a piece of music we like, we should talk about working with mathematics problems or theory.

The morning theme of the Forum’s March 28 meeting was early numeracy. Alex Lawson from Lakehead University talked about his longitudinal case study on the development and progression of children’s invented calculation methods from direct modelling to efficient algorithms. The panel that followed (Rina Cohen (OISE), Pat Milot (DSBN), Sandra Rowell (Hamilton Wentworth District School Board) discussed a number of teaching situations where numeracy plays a significant role.

In the afternoon, we had an interactive session, called Learning Mathematics by Reading. Led by Mollie O’Neill, Maritza Branker and Miroslav Lovric, it aimed at a critical appraisal of written sources in mathematics, K-12 and first-year university. This session, in changed format, was replayed at the Canadian Math Education Forum in Vancouver.

The title of the April 25 meeting was ‘Connecting Research, Policy, and Practice in Mathematics Education: Challenges and Successes.’ We had a number of presentations that discussed the U.S. National Mathematics Advisory Panel Report and its potential ramifications for mathematics education in Canada (especially related to the way government agencies might change funding for mathematics education research). As well, there was a panel discussion of the connections between research, policy, and practice in the Ontario context. The discussion of the research community reaction was drawn from Volume 37, Issue number 9 of the journal Educational Researcher.

The theme of our last meeting for 2008/9, on May 30, was statistics, statistical literacy and mathematics for data management. In his excellent, entertaining and rich presentation, David Spiegelhalter talked about real-world probability as part of mathematics outreach. Among other themes, he presented a refreshing view on statistics of the 6/49 lottery. Further activities of the day included:

• Karen Lawrence on statistics literacy in the classroom
• Sandra MacIntyre and Mary Townsend on ESTAT (online learning tool developed by Statistics Canada) as a resource for statistics teachers
• Amy Lin about the Halton Peel Data Fair
• High school teacher panel (Marsha Melnik, Henry Tam, Wayne Erdman, and Anthony Meli) focusing on issues with the grade 12 data management course.

Miroslav Lovric
Outreach Programs and Workshops

SNAP Math Fair and Conference
April 3, 2009
Held at the Fields Institute

Organizer: Tanya Thompson (Thinkfun)

Over 50 educators from across Ontario attended the fourth annual SNAP fair and conference. Since their inception 12 years ago, SNAP math fairs have ignited the mathematical minds of students through the use of classic puzzles and problems. Students solve these interesting problems and then build an interactive, hands-on project which includes a model to help passers-by solve the problems. SNAP math fairs provide an opportunity for elementary school communities to come together to celebrate mathematics.

Tanya Thompson, a former teacher and currently the Director of Education Programs for Thinkfun and a board member of SNAP, once again organized the conference and presented details about SNAP math fairs. Troy Comish, a Resource Teacher for the Simcoe County Board of Education, presented the Top Ten reasons to do a Math Fair based on his experience spreading math fairs throughout Simcoe County schools. John Grant McLoughlin from the University of New Brunswick presented Unearthing mathematics: Shifting our attention to the process. This presentation focused on how mathematics puzzles and problems offer fertile ground for exploration and learning. Bill Ritchie, the co-founder and C.E.O. of ThinkFun and a board member of SNAP, shared his views on how using mind-challenging games can be used to teach problem solving. Qian Wang, a postdoctoral fellow at York University, shared problems appropriate for math fairs as well as her experiences with SNAP math fairs over the past four years at the University of Alberta. Judith Rioux-Wilson, a teacher at St. Catherine Catholic Elementary School in Peterborough, shared her experiences doing a math fair at her school, which has grown to over 400 students with high praise and approval from her Superintendents and Director of Education.

The main highlight of the conference was a SNAP math fair presented by over forty K-8 students of Havergal College in Toronto. These students, under the guidance of their teacher Jennifer Wyatt, astounded the conference participants with their excitement and knowledge of their math fair projects. The participants were able to witness first-hand the many benefits to the students of taking part in a SNAP math fair.

The SNAP math fairs conference at Fields was an outstanding success. Educators learned how to inspire their students through creative, interactive mathematical puzzles and problems. They saw how students took ownership of these age old puzzles and gained confidence in many areas of problem solving. Tanya Thompson presented SNAP math fairs with Andy Liu this past year in Mexico at the International Congress of Mathematics Education and in Washington, D.C. at the Joint Mathematics Meeting. Since the launch of SNAP math fairs in Ontario just over 4 years ago, many schools have begun participating in SNAP math fairs and this movement continues to grow stronger each year!

Tanya Thompson

Math Performance Festival
The Math Performance Festival (available at www.mathfest.ca) is a project by George Gadanidis (UWO), Susan Gerofsky (UBC) and Rick Jardine (UWO). The Festival was initially sponsored by the Fields Institute, the Faculty of Education at UWO, and the Canadian Mathematical Society. The Festival recently received a $50,000 grant from the Imperial Oil Foundation, to evaluate its impact over the next 5 years.

The Festival, now in its second year, invites students and teachers to share their mathematical performances (poems, songs, skits, and artwork) through the Festival’s website. We hope that the Festival will help make mathematics ideas more likely to be discussed outside of mathematics classrooms and the community of mathematicians, just as one might with a favourite book or a good movie.

All performances are posted at www.MathFest.ca. Here are four examples from the 2009 Festival.

Dimensional Yearnings. A dance performed at Eric Hamber Secondary School in Vancouver, BC, which was a collaboration between the dance and math departments. The dance experiments with motion in 1, 2 and 3 dimensional space.

We Made 12 in a Story. A song by grade 2 students expressing the math ideas they explored based on a math story they read.

A Metaphorical History of Math. A song written and performed by grade 7 students.

Jack and the Beanstalk. A math story involving counting principles. 17 such stories were submitted by students from Thornhill Secondary School in Thornhill, Ontario.
Performances submitted to the Festival are adjudicated by a group of mathematics educators and by the following artists:

- Susan Aglukark, singer, songwriter, 3-time Juno Award recipient, Officer of the Order of Canada award in 2005.
- Tracy Bone, singer, songwriter, “Best Female Artist” of the 2007 Canadian Aboriginal Music Awards.
- Douglas Coupland, novelist, playwright, filmmaker and visual artist, author of the bestseller jPod.
- Bob Hallett of Great Big Sea, latest album: Fortune’s Favour
- Jay Ingram, award-winning co-host and producer of DailyPlanet (Discovery Channel).

The Festival is open to all mathematics students, teachers and professors – so please share your math performance!

George Gadanidis

Windows into Elementary Mathematics

Windows into Elementary Mathematics (www.fields.utoronto.ca/mathwindows) is a Fields Institute outreach project developed by George Gadanidis (UWO). The Windows into Elementary Mathematics project invites prominent mathematicians to discuss topics from elementary mathematics. Each Window includes the following components: video clips, interactive content, activities, and a poster on the theme.

One goal of the project is to provide students, parents and teachers with insights into the thinking of mathematicians. Another goal is to help the public better appreciate the beauty of mathematics and mathematical ideas.

The posters that accompany the Windows are available in digital form on the project website and will also be available in print form. We are considering ways of displaying the posters in public places, like libraries, subways, and buses.

So far we have developed five Windows. The first two Windows, by Ken Davidson, focus on mathematical proof. The third Window, by Megumi Harada explores spherical geometry. The fourth Window, by Lindi Wahl is on the topic of growth patterns and the fifth Window, by Peter Taylor is on the topic of telescopes and paraboloids.

In the videos, the mathematicians also talk about their views of mathematics. For example, Lindi Wahl explains that “One of the things that I really love about … mathematics … is that I’m creating something new all the time.”

George Gadanidis

JUMP Training Seminars

JUMP Math (www.jumpmath.org) is a charitable non-profit organization that is committed to improving mathematical literacy by improving mathematics learning and by supporting educational and community networks with resources and research. Started by mathematician John Mighton in 1998 as a tutoring program for struggling students, until December 2004 JUMP Math had its administrative centre at the Fields Institute. Today JUMP Math has expanded to offices at One Yonge Street and its resources are in more than 400 educational and community institutions across Canada as well as in the United Kingdom, the United States, and South Africa.

JUMP Math is committed to educational equity for all students. JUMP – short for Junior Undiscovered Math Prodigies – builds math confidence and skills in both students and teachers, enabling students to overcome math anxiety and succeed in the subject. John Mighton, who is a Fellow of the Fields Institute, obtained his PhD from the University of Toronto, where he has also taught. He is an award-winning playwright and the author of The Myth of Ability and The End of Ignorance. He has received an Ashoka Fellowship as a social entrepreneur for his work in fostering numeracy and building young children’s self-confidence through JUMP Math.

Mighton also conducts many of the professional learning seminars which JUMP Math regularly offers to educators and community volunteers at the Fields Institute and elsewhere across the country. The reputation of the Institute and the professional support of its administrative staff enable JUMP Math to hold very successful training seminars. In the past year the organization has held five seminars at Fields with attendance of over 150 participants. These seminars are also important for training participants.
Think About Math Conference
April 30–May 3, 2009
Held at the University of Waterloo
Organizer: Mary Joy Aitken (Waterloo)

The inaugural Centre for Education in Mathematics and
Computing (CEMC) Think About Math! Conference
involved 40 Grade 9 girls who were selected from more than
150 applicants from high schools across Southern Ontario.
Teachers were asked to give information about the confer-
ence to students with potential in mathematics
(with a mark of at least 70% in Grade 9 math) but who
seemed less likely to consider pursuing mathematics. Fif-
ten professional women involved in mathematics-related
careers volunteered to help CEMC staff design and run the
conference.

The conference’s goal was to show the girls that mathemat-
ics is fun, relevant and leads to exciting careers. Another
objective was to increase the girls’ confidence and interest
in mathematics in the early years of high school.

Six hands-on workshops and two boardroom breakfasts
were held to illustrate the importance of mathematics in a
variety of careers, including software development, envi-
ronmental engineering and investment banking, as well as
in day-to-day activities such as personal finance and social
networks such as Facebook.

The Career Panel discussion included an Information Secu-
rity Consultant from Deloitte, the Executive Vice President
of Product Solutions from Filogix, a Sales Account Manager
at IBM, the Vice President of Finance and Administration
at Ontario Power Authority, and the Leader of the Missis-
sauga e-Health program.

Math Circle
This year’s Math Circle was hosted by The Fields Institute
and led by Daniel Deaconu and Dan Schnaubel, two teach-
ers who contributed to the success of the circle on a weekly
basis. Dan Schnaubel is a very experienced high school
teacher with a wealth of knowledge of the Canadian school
system and Daniel Deaconu, a PhD. from York University,
has experience in the educational system in Eastern Europe –
in particular Romania – and is a former olympian as a
high school student.

The Circle was split into two groups of students, juniors
and seniors, each consisting of anywhere between 10 to 50
students, attending on a weekly basis. As the attendance
matured over time, the two groups were put together into
the senior group. Due to the different backgrounds of the
two teachers, the range of topics covered was very wide,
ranging from in-depth presentations of chapters related
closely to the highschool syllabus, to topics intended to
present materials closely related to high level contests, in
particular the International Mathematics Olympiad. All of
the areas of mathematics that a good high school student
should have knowledge of were covered. These areas consist
of algebra, geometry, combinatorics, number theory and
even elements of calculus. Students were very interested in
actively participating in the Circle and they presented solu-
tions to various problems suggested to them by the teachers
the week before, thus making the Circle very interactive.

While the main goal of the Circle is to attract as many
students as possible and present them with interested topics
in mathematics, a secondary goal of the Circle is to prepare
interested students for IMO type contests.

A generous grant from Angoss Software was used to get
proper advertising for the Circle throughout the GTA area
and provide students with a snack.

Kevin Linder

Daniel Deaconu

Students Jessica Liu and Inah Canlapan

in JUMP Math’s National Book Fund. Now starting its third
year of implementation, the National Book Fund helps to
bring JUMP Math into classrooms and to evaluate how the
program supports mathematics teaching and learning.

The professional learning seminars give educators tools
they need to help students excel in mathematics. The JUMP
Math team is very grateful for the Fields Institute’s contin-
ued support of its mission and hope that the partnership
will continue.

Kevin Linder

Math Circle
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A generous grant from Angoss Software was used to get
proper advertising for the Circle throughout the GTA area
and provide students with a snack.
The Surveys and Stats session gave the participants insight into the reality of being a mathematics graduate by analyzing data from a recent survey of female UW math graduates highlighting career path, salary and personal interests. This online survey was developed and conducted specifically for this session and the response rate was overwhelming. After a single email to alumni pointing them to a survey web page, over 800 women responded.

There were also fun activities to balance the mathematics sessions and keep the girls active, interested and engaged. An Amazing Math Race had the girls running around campus to various checkpoints where they had to answer a math problem as a team in order to receive their next clue.

Parents joined their daughters for the closing ceremonies on Sunday morning. Each girl was presented with a certificate of participation, contact information for all presenters, the charts and graphs they created from the survey data, and a copy of actress and mathematics graduate Danica McKellar’s book *Kiss My Math*. UW President David Johnston addressed the parents about the importance of women in math-related fields. This was reinforced by presenting some of the survey results that showed the major motivators of women pursuing mathematics are teachers, parents and their believed competence in their own mathematical ability.

We hope that this annual conference will inspire a grassroots community of girls, young women and established professional women to work together to reverse the declining number of women pursuing mathematics careers. A reunion is planned in three years to determine how many of the girls who attended *Think About Math!* in 2009 continued to take mathematics courses in high school and plan to study a math-related field in college or university.

The event attracted significant media interest, with articles appearing in the Toronto Star, Waterloo Region Record and Exchange Magazine. It was also featured on the CBC Radio program Ontario Morning and the TV Ontario program *Your Voice*.

*Mary Joy Aitken*
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. Listed below are the names of all Fields Fellows, with the 2009 recipients in bold.

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MARTIN BARLOW University of Toronto
EDWARD BIERSTONE University of Toronto
ALLAN BORODIN University of Toronto
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TAMÁS TERLAKY McMaster University
NICOLE TOMCZAK-JAEGERMANN University of Alberta
KAREN UHLENBECK University of Texas
NORIKO YUI Queen’s University

*deceased
Listed by volume number
11 Shape, Smoothness and Invariant Stratification of an Attracting Set for Delayed Monotone Positive Feedback, by T. Krisztin, University of Szeged, Bolyai Institute, University of Szeged, Bolyai Institute, Hungary, and Jianhong Wu, York University, AMS, 1999, 256pp.
12 Ordered Exponential Fields, by S. Kuhlmann, University of Saskatchewan, AMS, 2000, 166pp.
14 Large Deviations, by F. den Hollander, Mathematical Institute, Nijmegen University , AMS, 2000, 143pp.
15 Lectures on Algebraic Model Theory, eds. B. Hart, M. Valeriote , McMaster University, AMS 2002, 111pp.

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• Introduction to Mathematical Oncology, by S. Sivaloganathan, University of Waterloo.
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Publications

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The Fields Institute Communications Series features proceedings and lecture notes growing out of the various activities at The Fields Institute for Research in Mathematical Sciences. Many of the publications evolve from each year’s main program. Interdisciplinary titles also emerge from programs and workshops focusing on applications of mathematics in science, engineering, industry, and business. All Communications volumes are available for purchase from the American Mathematical Society Online Bookstore. The Institute also has a limited number available at our front desk.

Listed by volume number


13. **Special Functions, q-Series and Related Topics**, eds. M. Ismail, University of South Florida; D. Masson, University of Toronto and M. Rahman, Carleton University, AMS, 1997, 277 pp.


36 *Dynamical Systems and Their Applications to Biology*, eds., S. Ruan, Dalhousie University, J. Wu, York University, and G.S.K. Wolkowicz, McMaster University, AMS, 2003, 268pp.


38 *Calabi-Yau Varieties and Mirror Symmetry*, eds., N. Yui, Queen's University and J.D. Lewis, University of Alberta, AMS 2003, 367pp.

39 *Vertex Operator Algebras in Mathematics and Physics*, eds., S. Berman, University of Saskatchewan, Y. Billig, Carleton University, Y.Z. Huang, Rutgers University, and J. Lepowsky, Rutgers University, AMS 2003, 249pp.


42 *Difference and Differential Equations*, eds., S. Elaydi, Trinity University, G. Ladas, University of Rhode Island, J. Wu, York University, and X. Zou, Memorial University, AMS 2004, 438pp.


50 *Dynamical Systems and Their Applications to Biology*, eds., S. Ruan, Dalhousie University, J. Wu, York University, and G.S.K. Wolkowicz, McMaster University, AMS, 2003, 268pp.


52 *Calabi-Yau Varieties and Mirror Symmetry*, eds., N. Yui, Queen’s University and J.D. Lewis, University of Alberta, AMS 2003, 367pp.
Publications

51 Partially Hyperbolic Dynamics, Laminations, and Teichmüller Flow, eds. Giovanni Forni, University of Toronto, Mikhail Lyubich, SUNY at Stony Brook, Charles Pugh and Michael Shub, University of Toronto, AMS 2007, 339 pp.


53 Holomorphic Dynamics and Renormalization: A Volume in Honour of John Milnor’s 75th Birthday, eds. Mikhail Lyubich, University of Toronto and SUNY at Stony Brook and Michael Yampolsky, University of Toronto, AMS 2008, 395 pp.

54 Modular Forms and String Duality, eds. Noriko Yui, Queen’s University, Helena Verrill, Louisiana State University and Charles F. Doran, University of Washington, AMS 2008, 297 pp.


Forthcoming in the Fields Institute Communications Series:
• Infinite Dimensional Dynamical Systems, ed. J. Mallet-Paret, Brown University, J. Wu, York University, Yingfie Yi, Georgia Tech, and Huaiping Zhu, York University.
• Motives and Algebraic Cycles: A Conference Dedicated to the Mathematical Heritage of Spencer J. Bloch, ed. Rob de Jeu, Durham University, and J. Lewis, University of Alberta.
• Taylor Model Methods, ed. M.Berz, Michigan State University, and K. Jackson, University of Toronto.
• A Survey of Mathematical Biology, ed. S. Sivaloganathan
• Lectures on Noncommutative Geometry, ed. Masoud Khalkhali.

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The Fields Institute publishes a newsletter three times a year, titled Fields Notes. Issues appeared in September 2007, January 2008, and May 2008. Over 3500 copies of each issue are distributed free of charge in mailings to a wide range of universities throughout Canada, the United States, Europe, Asia and Australia.
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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.

STEVEN BOYER is a Professor of Mathematics at the Université du Québec à Montréal. His undergraduate studies were at the University of New Brunswick and graduate work at Cornell University, where he obtained a PhD. in Mathematics in 1983. After two years as an NSERC postdoctoral fellow at the University of Cambridge, he spent several years at the Mathematics Department of the University of Toronto before moving to the Université du Québec à Montréal. He has held visiting positions in Geneva, Dijon, Rennes, Institut Henri Poincaré, Marseille, and Toulouse. Currently, he is on the editorial boards of the Canadian Journal of Mathematics, the Canadian Mathematics Bulletin, the Annales Mathématiques Blaise Pascal, and the Annales des sciences mathématiques du Québec. Over the last few years he has served terms on NSERC grant selection committee 336 and as vice-president (Quebec) of the Canadian Mathematical Society. His research area is the topology and geometry of low-dimensional manifolds and he has been the director of the Centre Interuniversitaire de Recherche en Géométrie et Topologie since 2001.

PAM COOK is a Professor of Mathematical Sciences at the University of Delaware and Associate Dean of Engineering. She also has a secondary appointment as Professor of Chemical Engineering at the University of Delaware. She received her B.A. in Mathematics from the University of Rochester, her PhD. in Applied Mathematics from Cornell University, and was a N.A.T.O. Postdoctoral Scholar at the University of Utrecht, The Netherlands. After 10 years as a faculty member at the University of California at Los Angeles (UCLA) Department of Mathematics she moved to the University of Delaware where she was Department Chair, and later Associate Dean of Arts and Science. As a faculty member she has held visiting appointments at California Institute of Technology; the University of Maryland, College Park; and the Institute for Mathematics and its Applications (I.M.A.) and the Department of Mathematics at the University of Minnesota. She is Editor-in-Chief of the SIAM (Society of Industrial and Applied Mathematics) Journal of Applied Mathematics and she is presently secretary of SIAM. She is the coauthor (with J.D.Cole) of Transonic Aerodynamics. Her current research is focused on modeling complex (viscoelastic) fluids.

ERIC FRIEDLANDER is the Henry S. Noyes Professor of Mathematics at Northwestern University. He received his PhD at M.I.T under the direction of Michael Artin. He taught at Princeton University for five years, and then joined Northwestern University. His research interests include algebraic geometry, algebraic K-theory, algebraic topology, and representation theory. His recent papers can be accessed at www.math.northwestern.edu/~erio/preprints. He has twice served as Chair of the Northwestern Mathematics Department and has also served as Academic Associate Dean of Science. He is currently a member of the Board of Trustees of the American Mathematical Society, co-managing editor of the Journal of Pure and Applied Algebra, and on the editorial boards of various journals. Friedlander gave a surrogate plenary ICM talk in 1986, an invited ICM talk in 1998, plenary talks at the A.M.S.-Mexico (2001) and A.M.S.-Spain (2003) international meetings. He has organized/co-organized numerous meetings and conferences. He was a Humboldt Senior Research Scientist and is a member of the American Academy of Arts and Sciences.

DAVID JACKSON is a Professor of Mathematics at the University of Waterloo. He was an undergraduate at Trinity College, Cambridge, and received his PhD. in Mathematics from the University of Cambridge. He has taught at the University of Warwick, Ohio State University, Cornell and Cambridge, and has had visiting positions at MIT and the Theoretical Division at the Los Alamos National Laboratories. He has given a series of advanced seminars at Academia Sinica in Beijing. Over the past thirty years he has made significant contributions to algebraic combinatorics itself, and to the interaction between algebraic combinatorics and other areas of mathematics. These include representation theory, algebraic geometry, algebra, topology, mathematical physics and statistical mechanics. He is currently working on approaches to intersection theory on the moduli space of curves through algebraic combinatorics and, in particular, he is working on Faber’s top intersection number conjecture for the moduli space of smooth curves. He is a founding Joint Editor-in-Chief of the Journal of Algebraic Combinatorics, and is on editorial boards of several research journals. He was a member of the original committee at Waterloo that initiated plans for
what eventually became the Fields Institute. He has served on one of the CMS prize committees, and has co-organized several international meetings and workshops. For a number of years he served as a mathematical consultant to the Oxford English Dictionary. He is the co-author of two research texts, one on enumerative combinatorics and the other on the enumerative theory of 2-cell embeddings of graphs in orientable and non-orientable surfaces. He is a Fellow of the Royal Society of Canada, and a Member of the Academy of Mathematical and Physical Sciences.

BARBARA LEE KEYFITZ served as Director of the Fields Institute for Mathematical Sciences for the period July 2004-December 2008. In January 2009, she assumed a faculty position in mathematics at the Ohio State University. Barbara Keyfitz received her undergraduate education in mathematics at the University of Toronto and her M.S. and PhD. from NYU’s Courant Institute. Her research area is Nonlinear Partial Differential Equations. She is a Fellow of the American Association for the Advancement of Science, and the recipient of the 2005 Krieger-Nelson Prize of the Canadian Mathematical Society. Until August 2008, she was John and Rebecca Moores Professor of Mathematics at the University of Houston, which she joined in 1983, following appointments at Columbia, Princeton, and Arizona State University. She is Treasurer of the International Council of Industrial and Applied Mathematics.

JERRY LAWLESS is a Professor of Statistics at University of Waterloo. He received his PhD from the University of Waterloo in 1969 and has been a faculty member there since 1972, serving as Department Chair from 1979-84. His research interests include biostatistics, survival and event history analysis, reliability, regression methodology, and process analysis. He is the author of various papers and the book *Statistical Models and Methods for Lifetime Data* (John Wiley and Sons, 2nd edition, 2003) and has served as a consultant to industry and government. Lawless is a past Editor of *Technometrics* and a past President of the Statistical Society of Canada. From 1994-2004 he was holder of the General Motors-Natural Sciences and Engineering Research Council of Canada Industrial Research Chair in Quality and Productivity. He is a Fellow of the American Statistical Association (1983) and of the Institute of Mathematical Statistics (1990), and a recipient of the Gold Medal of the Statistical Society of Canada (1999). He was elected a Fellow of the Royal Society of Canada in 2000.

PHILIP MAINI is a Professor of Mathematics at Oxford University. He received his B.A. in mathematics from Balliol College, Oxford, in 1982 and his DPhil in 1985 under the supervision of Prof J.D. Murray, FRS. After completing his studies he spent a year as an Assistant Master at Eton College before returning to the CMB in 1987 as a Junior Research Fellow at Wolfson College, Oxford. In 1988 he was appointed Assistant Professor in the Mathematics Department at the University of Utah, Salt Lake City for two years, before returning to Oxford, initially as a University Lecturer and then as Professor and Director of the CMB. He is currently on the editorial boards of a large number of journals, including serving as the managing editor for the Bulletin of Mathematical Biology. He has also been an elected member of the Boards of the Society for Mathematical Biology (SMB) and European Society for Mathematical and Theoretical Biology (ESMBTB). Recently he was elected to the Council of the IMA. His research projects include the modelling of avascular and vascular tumours, normal and abnormal wound healing, collective motion of social insects, bacterial chemotaxis, rainforest dynamics, pathogen infections, immunology, vertebrate limb development and calcium signalling in embryogenesis. He has over 170 publications in the field and has held visiting positions at the Universities of Ancona, Cambridge, Central de Venezuela, Degli Studi Di Modena E Reggio Emilia, Pierre et Marie Curie (Paris VI), Minnesota, South Florida, Washington, Williams College, Queensland University of Technology, National Tsing Hua University of Taiwan and was Distinguished Foreign Visiting Fellow, Hokkaido University (2002). He was awarded a Royal Society Leverhulme Trust Senior Research Fellowship for 2001-2. He serves on the Scientific Advisory Committee of the Fields’ Centre for Mathematical Medicine.

MATTHIAS NEUFANG served as Interim Deputy Director of the Fields Institute from January to July 2009. His PhD. was granted Summa Cum Laude by the University of Saarland in 2000 for a thesis entitled “Abstract Harmonic Analysis and Module Homomorphisms on von Neumann Algebras”. The work was done under the supervision of G. Wittstock. This was followed by a PIMS Postdoctoral Fellowship at the University of Alberta under A.T.-M. Lau and V. Runde. He is currently Associate Professor at Carleton University where he served as Director of the Ottawa-Carleton Institute of Mathematics and Statistics and Graduate Director of the Carleton School of Mathematics and Statistics. Subsequently he held the position of Associate Dean of the Faculty of Graduate Studies and Research at Carleton University. He is a member of the Advisory Board of the Centre for Research in Operator Algebras at the University of New Brunswick, as well as member of the Board of Directors of the Canadian Mathematical Society. He is also
Chair of the Canadian Mathematical Society Publications Committee and a member of the NSERC Pure and Applied Mathematics Grant Selection Committee. His research has been recognized by NSERC in the form of a Discovery Accelerator Supplement, and he has also been a member of a research group awarded an NSERC LSI grant. He has held visiting scholar positions at Heidelberg, MSRI, Centre Emile Borel, Oberwolfach and Rutgers.

ROBERT RUSSELL is a Professor of Mathematics and Computing Science at Simon Fraser University. He received his PhD. from the University of New Mexico in 1971. After a year as Assistant Professor at Colorado State University, he joined the faculty at SFU. He has held visiting positions at Stanford, University of New Mexico, Universidad Central de Venezuela, Imperial College London, Universidad Catolica de Chile, University of Auckland, McGill University, Universitat de Barcelona, and University of Bath. His area of research is scientific computing, primarily adaptive methods and software for solving time dependent PDEs. His journal editorships include SIAM J. on Numerical Analysis, the SIAM Book Series Fundamentals of Algorithms, and previously, SIAM J. on Scientific Computing. In 2004 he received the Canadian Applied and Industrial Mathematics Society Research Prize. His service on various committees for SIAM, CAIMS, NSERC, ICIAM, Fields and PIMS include being current President of CAIMS, Director of the SFU Centre for Scientific Computing, and a member of the PIMS Scientific Review Panel.

JURIS STEPRANS is Professor of Mathematics at York University and is currently serving as Deputy Director of the Fields Institute. He obtained his BMath degree from the University of Waterloo in 1977 and completed his PhD. thesis under the supervision of Franklin D. Tall at the University of Toronto in 1982. His research has focused on the applications of set theory to other areas of mathematics, notably, group theory, topology, real analysis and the theory of Banach spaces. He has held visiting positions at various universities and institutions including Dartmouth College, the University of Warsaw, the Fields Institute, the University of Wisconsin at Madison and Rutgers University. He has served in various capacities with the CMS and at NSERC. He was elected a Fellow of the Fields Institute in 2004.

CATHERINE SULEM received a Doctorat d’Etat from the Université de Paris-Nord in 1983 and held a CNRS position at the Ecole Normale Supérieure in Paris before coming to the University of Toronto in 1990 as an Associate Professor. She was promoted to Professor in 1994. In 1998 she was awarded the Krieger-Nelson prize by the Canadian Mathematical Society. She works in nonlinear partial differential equations arising in physics. Her work uses both analytic and numerical methods and has contributed to our understanding of singularities in models of wave propagation. She is a co-author (with her brother Pierre-Louis Sulem) of a monograph on “Nonlinear Schrödinger Equation: Self-Focusing Instability and Wave Collapse” that appeared in 1999 in the Springer series, Applied Mathematical Sciences. Since 2000, she has been Associate editor of the SIAM Journal of Mathematical Analysis.

EVA TARDOS is a Professor of Computer Science at Cornell University. She was awarded the George B. Dantzig Prize at the SIAM Annual Meeting in 2006. She received the prize in recognition for her deep and wide-ranging contributions to mathematical programming, including the first strongly polynomial-time algorithm for minimum-cost flows, several other variants of network flows, integer programming, submodularity, circuit complexity, scheduling, approximation algorithms, and combinatorial auctions. Tardos’ research interest focuses on the design and analysis of efficient methods for combinatorial-optimization problems on graphs or networks. Her recent work focuses on algorithmic game theory, an emerging new area of designing systems to mathematical programming, including the first strongly polynomial-time algorithm for minimum-cost flows, several other variants of network flows, integer programming, submodularity, circuit complexity, scheduling, approximation algorithms, and combinatorial auctions. Tardos’ research interest focuses on the design and analysis of efficient methods for combinatorial-optimization problems on graphs or networks. Her recent work focuses on algorithmic game theory, an emerging new area of designing systems for selfish users. Eva Tardos received her PhD. at Etvos University in Budapest, Hungary in 1984. After teaching at Etvos and the Massachusetts Institute of Technology, she joined Cornell in 1989. She is currently a member of the American Academy of Arts and Sciences and an ACM Fellow. Tardos was a Guggenheim Fellow, a Packard Fellow, a Sloan Fellow and an NSF Presidential Young Investigator. She received the Fulkerson Prize in 1988.

NICOLE TOMCZAK-JAEGERMANN received the CRM-Fields-PIMS prize in 2006. She is one of the world’s leading mathematicians working in functional analysis. She has made outstanding contributions to infinite dimensional Banach space theory, asymptotic geometric analysis, and the interaction between these two streams of modern functional analysis. She is one of the few mathematicians who have contributed important results to both areas. In particular, her work constitutes an essential ingredient in a solution by the 1998 Fields Medallist W.T. Gowers of the homogeneous space problem raised by Banach in 1932. Tomczak-Jaegermann received her Master’s (1968) and PhD. (1974) degrees from Warsaw University, where she held a position until moving to the University of Alberta in 1983. There she holds a Canada Research Chair in Geometric Analysis. She is a Fellow of the Royal Society of Canada.
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Lectured at the 1998 ICM, and has won the CMSs Krieger-Nelson Prize Lectureship. She has served the Canadian and international research community in many ways, including her current position on the BIRS Scientific Advisory Board and previously as a Site Director of PIMS in Alberta.

**DAN- VIRGIL VOICULESCU** is a Professor of Mathematics at U.C. Berkeley. His research is in operator algebras and operator theory, focusing in recent years on free probability theory and the connections of random matrix theory to von Neumann algebras. After receiving his Doctor in Mathematics degree at the University of Bucharest under the supervision of Ciprian Foias in 1977, he held positions at the University of Bucharest, the Mathematics Institute in Bucharest and the INCREST Department of Mathematics and then joined the faculty at UC Berkeley in 1986. The visiting positions he held include the Aisenstadt Chair at CRM Montreal in 1991 and an International Blaise Pascal Research Chair in Paris in 2003 - 2004. He gave invited addresses at the ICM in 1983, the European Congress of Mathematics in 1992 and plenary invited addresses at the ICM in 1994 and at the International Congress of Mathematical Physics in 2003. Professor Voiculescu is the recipient of the 2004 Award in Mathematics of the National Academy of Sciences. He is a member of the US National Academy of Sciences.

**SHOU-WU ZHANG** is a professor of mathematics at Columbia University. He specializes in number theory and arithmetical algebraic geometry. He got his bachelor’s degree from Zhongshan University in 1983, master’s degree from Chinese Academy of Sciences in 1986, and PhD. from Columbia University in 1991. Before he jointed Columbia in 1996, he was a member of the Institute for Advanced Study and an assistant professor at Princeton University. Professor Zhang was an invited speaker of the International Congress of Mathematicians at Berlin in 1998 and was awarded a Morningside Gold Medal of Mathematics in the same year by the International Congress of Chinese Mathematicians for his work on Bogomolov conjecture and Gross–Zagier formula. He was a Sloan Research Fellow, a L.-K. Hua Chair Professor at Chinese Academy of Sciences, a Changjiang Chair Professor at Tsinghua University, and a Prize Fellow at Clay Mathematical Institute. He is in the editor boards of the *Journal of American Mathematical Society*, the *Journal of Number Theory*, the *Journal of Algebraic Geometry*, the *Journal of Differential Geometry*, *Science in China*, etc.
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Carleton University
The School of Mathematics and Statistics at Carleton University has a long history of research and graduate study. Besides the 36 research faculty, there are ten Distinguished Research Professors (including five 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 Premier’s Research Excellence Award, an NSERC Leadership Support Initiative Award, and an Early Research Award from the Ministry of Research and Innovation. The graduate program (MSc 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. The School also offers an MSc 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; probability, logics, and verification; stochastic modeling and probabilistic algorithms. Two MITACS research projects on “Complex Adaptive Networks for Computing and Communication” and “Understanding and Mitigating Malicious Activity in Networked Computer Systems” are directed by Barbeau and Van Oorschot, respectively, and the School is the home of the Carleton-Cloakware Security Research Lab, headed by a CRC in Network Security (Van Oorschot). It 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 a Masters and PhD. degree in Computer Science, as well as the MSc in Information and Systems Science (jointly with the School of Mathematics and Statistics and the Department of Systems and Computer 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 eighty students. As one of the founding universities of the Fields Institute, McMaster’s contribution to the Institute has been substantial. Faculty members from McMaster are principal organizers of thematic programs at the Fields Institute in each of the next three years; as well there have been more than fifteen joint McMaster-Fields postdoctoral fellowships. The department has established the James Stewart Centre for Mathematics in Hamilton Hall, one of McMaster’s two historic buildings, creating an integrated teaching, research, and outreach centre to enhance the visibility, linkage, and impact of mathematics and statistics at McMaster University and the larger community.

The Department of Computing and Software offers undergraduate programs in Software Engineering, including one of the first accredited undergraduate software engineering programmes in Canada, Software Engineering (Game Design), the Mechatronics Engineering program, Computer Science, and Business Informatics. At the graduate level, the Department offers Master of Applied Science, Master of Engineering and PhD. programmes in Software Engineering, and Master of Science and PhD. programmes in Computer Science.

Research initiatives in the department include the Advanced Optimization Laboratory, the Algorithms Research Group, the Applied Computer Systems Group and the Software Quality Research Laboratory. The Department is also spearheading the new School of Computational Engineering and Science. The Department has a complement of 28 faculty members, including three Canada Research Chairs.
University of Ottawa

The Department of Mathematics and Statistics at the University of Ottawa is an active research department. It has about thirty-three faculty members with research grants, working in a wide range of areas, including algebra, analysis, applied mathematics, cryptography, 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 sixty 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. 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 six 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.

The School of Information Technology and Engineering was formed in 1997 by the merger of the Department of Computer Science and of the Department of Electrical and Computer Engineering. SITE is the University of Ottawa’s centre for research and teaching in all areas related to computing, computers and communications.

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 Fulkerson Prize in Discrete Mathematics (A. Lehman), the IJCAI Award for Research Excellence (G. Hinton, R. Reiter) and the Order of Canada (C.C. Gotlieb). The department has produced a large proportion of the computer science PhD.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 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.
Governance

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 over forty-five hundred full-time undergraduate and four hundred 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 ten times in the past twelve years in the Association for Computing Machinery (ACM) International Programming Competition. It has been the world champion twice (1994, 1999) and North American champion five times during that period. As well, the University has placed in the top ten in the Putnam Competition fourteen times in the past fifteen years, placing first in 1999 and sixth 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 twelve years in a row, a group of more than three thousand senior administrators, company presidents, and academic counselors surveyed by Maclean’s Magazine judged the University of Waterloo to be the “Best Overall” university in Canada.

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

The Department of Applied Mathematics is one of only two in the country. The department is research intensive: areas of study include mathematical biology, medical science, financial mathematics, materials modelling and nanotechnology, atomic and high-energy physics, fluid dynamics, engineering science, envirometrics, cryptography and high performance computing using Beowulf clusters. The department participates in the Ontario Research Centre for Computer Algebra, and in the Imperial Oil Centre for Mathematics Education. Members of the department are at the forefront of a recently awarded multi-faculty, multi-university CFI grant for high performance computation.

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

Research and teaching in the Department of Mathematics is traditionally concentrated in the area of “pure” mathematics. The department offers programs at all undergraduate and graduate levels of instruction. Its research team is well known: faculty members have active research programs in homotopy theory, algebraic groups, algebraic K-theory, 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,
in the early 1980s to over 35 faculty today. The department offers a full range of undergraduate and graduate programs including undergraduate three-year and Honours BA and BSc programs, a BASc program, and graduate programs leading to MSc and PhD. degrees. An optional internship is available at all levels which provides students the opportunity to experience computer science in an industrial setting.

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 several major fields of mathematics and statistics. In particular, York has significant representation in many general areas including foundations of mathematics, probability and stochastic processes, analysis (ordinary and partial differential equations, Fourier analysis and functional analysis), mathematical modeling and numerical analysis, algebra and 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. In a 1995 study conducted by the U.S.-based Institute for Scientific Information, which looked at the scientific impact of papers published in top journals, the Department of Mathematics at York University ranked second among Canadian mathematics departments in citations per paper. In addition, a number of York faculty and graduate students are involved in the National Centre of Excellence project “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. There is in place a Graduate Diploma in Mathematics Education offered jointly with the Faculty of Education. An MSc program in Industrial and Applied Mathematics began 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.

The Department of Computer Science and Engineering at York has engaged in a period of sustained growth over the past 20 years, evolving from a small teaching department
Financial Statements

Donors
The Fields Institute conducts an annual giving campaign each fall to raise funds in support of our scientific and educational programs. For further information about donations, please visit our website http://www.fields.utoronto.ca/aboutus/fundraising/

The management and Board of Directors of the Institute wish to express their profound thanks to the following, whose generous donations in the period April 2008 – March 2009 are helping to support the work of the Institute.

Ian Ainsworth
Abdo Alfakih
Mayer Alvo
Rob Andrews
Pradas Ari
Cecily Bradshaw
Stephen Berman
Hermann Brunner
Alison Conway
Walter Craig
John Crow
Colmac Holdings Limited
Matt Davison
George Elliott
Sheila Embleton
Toan Ho
Tatyana Foth
Peter A. Fillmore
Kenneth R. Jackson
Manousos Grillakis
Peter Fillmore
Mikhail Kotchetov
Anthony To-Ming Lau
Georges Livanos

Neal Madras
Vijayakumar Murty
Brenda Orser
J. Paldus
Doug Park
Carl and Elaine Riehm
Philip Siller
Tom Salisbury
Mary E. Salisbury
Bhanu Pratap Sharma
Sigma Analysis & Management Ltd
Amit Sikder
Juris Steprans
Susan Thomas
Mary E. Thompson
Hans J.H. Tuenter
Hari Venkatacharyya
William Weiss
Daniel Wevrick
Ping Wong
William Wong
Graham Wright
Philip Wu
Noriko Yui
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, 2009 and the statements 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, 2009 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.

Ernst & Young LLP
Chartered Accountants
Licensed Public Accountants

Toronto, Canada,
May 29, 2009.
# Financial Statements

## BALANCE SHEET

As at March 31

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2008</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>Cash held by the University</td>
<td>729,928</td>
<td>413,262</td>
</tr>
<tr>
<td>of Toronto [note 7]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accounts receivable</td>
<td>347,219</td>
<td>171,683</td>
</tr>
<tr>
<td>Goods and Services Tax</td>
<td>29,095</td>
<td>28,533</td>
</tr>
<tr>
<td>receivable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepaid expenses</td>
<td>24,435</td>
<td>58,667</td>
</tr>
<tr>
<td><strong>Total current assets</strong></td>
<td>1,130,677</td>
<td>672,145</td>
</tr>
<tr>
<td>Investments [note 3]</td>
<td>73,208</td>
<td>108,133</td>
</tr>
<tr>
<td>Capital assets, net [note 4]</td>
<td>123,006</td>
<td>38,944</td>
</tr>
<tr>
<td><strong>Total assets</strong></td>
<td>1,326,891</td>
<td>819,222</td>
</tr>
<tr>
<td><strong>LIABILITIES AND NET ASSETS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Current</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accounts payable and accrued</td>
<td>186,866</td>
<td>333,228</td>
</tr>
<tr>
<td>liabilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deferred contributions [note</td>
<td>713,413</td>
<td>87,385</td>
</tr>
<tr>
<td>5]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total current liabilities</strong></td>
<td>900,279</td>
<td>420,613</td>
</tr>
<tr>
<td><strong>Net assets</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted surplus</td>
<td>353,404</td>
<td>290,476</td>
</tr>
<tr>
<td>Endowment [note 6]</td>
<td>73,208</td>
<td>108,133</td>
</tr>
<tr>
<td><strong>Total net assets</strong></td>
<td>426,612</td>
<td>398,609</td>
</tr>
<tr>
<td><strong>Total liabilities and net</strong></td>
<td>1,326,891</td>
<td>819,222</td>
</tr>
</tbody>
</table>

*See accompanying notes*
# Financial Statements

## Statement of Operations

Year ended March 31

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ontario Ministry of Training, Colleges and Universities grant</td>
<td>1,350,580</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Natural Sciences and Engineering Research</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Council of Canada grants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Operations</td>
<td>1,185,049</td>
<td>955,967</td>
</tr>
<tr>
<td>- Indirect costs</td>
<td>205,904</td>
<td>209,255</td>
</tr>
<tr>
<td>- National Program on Complex Data Structures</td>
<td>16,852</td>
<td>58,020</td>
</tr>
<tr>
<td>Other scientific program grants</td>
<td>241,310</td>
<td>254,566</td>
</tr>
<tr>
<td>Sponsoring revenue</td>
<td>474,286</td>
<td>498,095</td>
</tr>
<tr>
<td>Commercial/Industrial mathematics grants</td>
<td>5,983</td>
<td>6,519</td>
</tr>
<tr>
<td>Math Education Program grant</td>
<td>5,519</td>
<td>1,809</td>
</tr>
<tr>
<td>Registration fees</td>
<td>332,567</td>
<td>79,183</td>
</tr>
<tr>
<td>Mathematics of Information Technology and Complex Systems grants</td>
<td>54,953</td>
<td>24,241</td>
</tr>
<tr>
<td>Publications</td>
<td>27,760</td>
<td>20,091</td>
</tr>
<tr>
<td>Donations</td>
<td>72,155</td>
<td>177,820</td>
</tr>
<tr>
<td>Interest</td>
<td>5,267</td>
<td>18,910</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>50,388</td>
<td>43,077</td>
</tr>
<tr>
<td><strong>Total Income</strong></td>
<td>4,028,573</td>
<td>3,347,553</td>
</tr>
</tbody>
</table>

| **Expenses**           |       |       |
| Scientific program     |       |       |
| Visitors               | 1,131,100 | 959,168 |
| Post Doctorate Fellows' salaries | 434,139 | 445,094 |
| General scientific     | 382,360  | 266,113 |
| Guests - teaching and lecture fees | 129,348 | 97,595 |
| Salaries and benefits  |       |       |
| Scientific and support staff | 385,612 | 369,134 |
| Directorate staff      | 307,338  | 273,333 |
| Administrative support staff | 401,342 | 1,094,292 |
| Professional services  | 16,821   | 15,608 |
| University of Toronto block fee [note 7] | 518,946 | 518,445 |
| Repairs and maintenance | 48,062  | 13,835 |
| Amortization of capital assets | 38,391  | 14,181 |
| Communications         | 29,598   | 29,671 |
| General and office supplies | 93,522  | 90,180 |
| Administrative         | 27,591   | 8,422 |
| Printed material and publishing | 21,475  | 25,690 |
| **Total Expenses**     | 3,965,645 | 3,501,584 |

**Net operating surplus (deficit) for the year**

62,928  (154,031)

*See accompanying notes*
# Financial Statements

## STATEMENT OF CHANGES IN NET ASSETS

Year ended March 31

<table>
<thead>
<tr>
<th></th>
<th>Unrestricted surplus</th>
<th>Endowment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2009</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance, beginning of year</td>
<td>290,476</td>
<td>108,133</td>
<td>398,609</td>
</tr>
<tr>
<td>Net operating surplus for the year</td>
<td>62,928</td>
<td>—</td>
<td>62,928</td>
</tr>
<tr>
<td>Loss on investments held for endowment [note 6]</td>
<td>—</td>
<td>(34,925)</td>
<td>(34,925)</td>
</tr>
<tr>
<td><strong>Balance, end of year</strong></td>
<td><strong>353,404</strong></td>
<td>73,208</td>
<td>426,612</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Unrestricted surplus</th>
<th>Endowment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2008</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance, beginning of year</td>
<td>444,507</td>
<td>113,087</td>
<td>557,594</td>
</tr>
<tr>
<td>Net operating deficit for the year</td>
<td>(154,031)</td>
<td>—</td>
<td>(154,031)</td>
</tr>
<tr>
<td>Loss on investments held for endowment [note 6]</td>
<td>—</td>
<td>(1,054)</td>
<td>(1,054)</td>
</tr>
<tr>
<td>Amount made available for spending [note 6]</td>
<td>—</td>
<td>(3,900)</td>
<td>(3,900)</td>
</tr>
<tr>
<td><strong>Balance, end of year</strong></td>
<td><strong>290,476</strong></td>
<td>108,133</td>
<td>398,609</td>
</tr>
</tbody>
</table>

*See accompanying notes*
NOTES TO FINANCIAL STATEMENTS

March 31, 2009

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) and, as such, is exempt from income taxes.

2. SIGNIFICANT ACCOUNTING POLICIES

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

Revenue recognition

The Institute follows the deferral method of accounting for contributions. Endowment contributions are recognized as direct increases in net assets in the year in which they are received. 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. 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</th>
<th>Annual Amortization 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>
NOTES TO FINANCIAL STATEMENTS

March 31, 2009

Investments and investment income

Investments in the University of Toronto's Long-Term Capital Appreciation Pool are valued based on reported unit values. Short-term securities are valued based on cost plus accrued income, which approximates fair value. Transactions are recorded on a settlement date basis and transaction costs are expensed as incurred.

Investment income, which consists of interest, dividends, income distributions from the Long-Term Capital Appreciation Pool, and realized and unrealized gains and losses, is recorded as revenue in the statement of operations to the extent that the income is earned and in the Endowment Fund to the extent that the amounts are required to be added to the endowment principal.

Financial instruments


Foreign currency translation

Transactions in foreign currencies are translated at rates of exchange in effect at the time of the transaction. Monetary assets and liabilities denominated in foreign currencies are translated at the year-end rate. Foreign exchange gains and losses are included in the statement of operations.

Change in accounting policies

Capital disclosures

Effective April 1, 2008, the Institute adopted the recommendations of CICA 1535: Capital Disclosures, which require the disclosure of qualitative and quantitative information that enables users of the financial statements to evaluate the Institute's objectives, policies and processes for managing capital. The adoption of these recommendations only required additional disclosures, which are provided in note 10.

Financial statement presentation

Effective April 1, 2008, the Institute adopted retroactively the changes to the recommendations in CICA 4400: Financial Statement Presentation for Not-For-Profit Organizations that eliminate the requirement to separately disclose the amount of net assets invested in capital assets. The Institute
NOTES TO FINANCIAL STATEMENTS

March 31, 2009

has therefore eliminated from the financial statements details about the amount of net assets invested in capital assets and the calculation of this amount. As a result, the Institute has reclassified the prior year financial statements to include the amount of net assets invested in capital assets as at April 1, 2007 of $16,108 and April 1, 2008 of $38,944 in unrestricted net assets.

Future changes in accounting policies

Financial statement presentation

The CICA has issued revisions to the 4400 series and certain other sections to amend or improve certain parts of the CICA Handbook that relate to not-for-profit organizations. With respect to presentation, these changes include making the disclosure of net assets invested in capital assets optional; making CICA 1540: Cash Flow Statements applicable to not-for-profit organizations; and requiring the reporting of revenues and expenses on a gross basis in the statement of operations unless not required by other guidance. A new section, CICA 4470: Disclosure of Allocated Expenses by Not-for-Profit Organizations was included in the revisions which requires certain disclosures when fundraising and general support expenses are allocated to other functions. These changes in accounting policies must be adopted by fiscal years beginning on or after January 1, 2009, with earlier adoption permitted. Management has adopted the recommendations related to the disclosure of net assets invested in capital assets and is assessing the impact of the other revisions. However, the impact will be limited to reclassification of figures in the financial statements and additional disclosures.

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.
NOTES TO FINANCIAL STATEMENTS

March 31, 2009

3. INVESTMENTS

Investments represent funds held for endowment net assets [note 6]. The funds are invested by the University of Toronto [the "University"]. As at March 31, 2009, the funds were invested in the Long-Term Capital Appreciation Pool managed by the University, which includes investments with the following mix:

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash and short-term investments</td>
<td>23.0</td>
<td>6.4</td>
</tr>
<tr>
<td>Government and corporate bonds</td>
<td>9.2</td>
<td>21.9</td>
</tr>
<tr>
<td>Canadian equities</td>
<td>8.7</td>
<td>14.6</td>
</tr>
<tr>
<td>United States equities</td>
<td>9.5</td>
<td>15.2</td>
</tr>
<tr>
<td>Other international equities</td>
<td>11.6</td>
<td>20.9</td>
</tr>
<tr>
<td>Hedge funds</td>
<td>18.2</td>
<td>7.7</td>
</tr>
<tr>
<td>Private equities</td>
<td>14.0</td>
<td>8.1</td>
</tr>
<tr>
<td>Real estate</td>
<td>5.8</td>
<td>5.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>
NOTES TO FINANCIAL STATEMENTS

March 31, 2009

4. CAPITAL ASSETS

Capital assets consist of the following:

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furniture</td>
<td>$29,019</td>
<td>$23,727</td>
</tr>
<tr>
<td>Computer equipment</td>
<td>$101,274</td>
<td>$51,945</td>
</tr>
<tr>
<td>Other equipment</td>
<td>$173,110</td>
<td>$104,725</td>
</tr>
<tr>
<td></td>
<td>$303,403</td>
<td>$180,397</td>
</tr>
</tbody>
</table>

Total capital asset purchases during the year were $122,453 [2008 - $37,017].

5. DEFERRED CONTRIBUTIONS

Deferred contributions consist of grants and donations received for specific projects that will be carried out in future periods.
NOTES TO FINANCIAL STATEMENTS

March 31, 2009

The change in the deferred contribution balance is as follows:

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance, beginning of year</td>
<td>$87,385</td>
<td>$46,892</td>
</tr>
<tr>
<td>Restricted contributions received</td>
<td>$3,484,968</td>
<td>$1,484,773</td>
</tr>
<tr>
<td>Amount recognized as revenue</td>
<td>$(2,858,940)</td>
<td>$(1,444,280)</td>
</tr>
<tr>
<td>Balance, end of year</td>
<td>$713,413</td>
<td>$87,385</td>
</tr>
</tbody>
</table>

6. ENDOWMENT NET ASSETS

Endowment net assets consist of externally restricted donations received by the Institute, the income of which is unrestricted.

The endowment principal is required to be maintained intact subject to the Institute's preservation of capital policy.

Institute policy has been established with the objective of protecting the real value of the endowments by limiting the amount of income made available for spending and requiring reinvestment of income not made available. Under this policy, the income available for spending must normally fall between the range of 3% and 5% of the fair market value of the endowment. In fiscal 2009, due to poor investment markets, no amount was made available for spending from endowments. In fiscal 2008, 3.5% of the fair value per unit of the endowment pool or $3,900 was made available, received from the University and recorded as revenue. In fiscal 2009, there was a loss of $34,925 [2008 - $1,054] which was deducted from endowment net assets.

7. RELATIONSHIP WITH 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 has licensed the Institute to use the premises located at 222 College Street, Toronto, Ontario and charged the Institute an annual "Block Fee" of $518,946 [2008 - $518,445] for the cost of this space and services.

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

March 31, 2009

8. 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.

9. FINANCIAL INSTRUMENTS

The Institute is subject to market risk, foreign currency risk and interest rate price risk with respect to its investment portfolio. To manage these risks, the Institute has invested its funds in the University's Long-Term Capital Appreciation Pool. A target mix of investment types has been established for this pool, designed to achieve the optimal return within reasonable risk tolerances.

10. CAPITAL MANAGEMENT

In managing capital, the Institute focuses on liquid resources available for operations. The Institute's objective is to have sufficient liquid resources to continue operating despite adverse events with financial consequences and to provide it with the flexibility to take advantage of opportunities that will advance its purposes. The need for sufficient liquid resources is considered in the preparation of an annual budget and in the monitoring of cash flows and actual operating results compared to the budget. As at March 31, 2009, the Institute has met its objective of having sufficient liquid resources to meet its current obligations.

11. COMPARATIVE FINANCIAL STATEMENTS

The comparative financial statements have been reclassified from statements previously presented to conform with the presentation of the 2009 financial statements.
Acknowledgements

The Fields Institute edits and is responsible for the Annual Report. However, this project could not be possible without the help and input of many individuals. Layout was by UTP Print based on a design by Scott Thornley & Company. Editorial assistance was provided by Emily Baillie, Carl Riehm and Juris Steprans. Administrative assistance was provided by Tanya Nebesna and Josephine Kavanagh.

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