DISTINGUISHED LECTURE IN STATISTICAL SCIENCE

David Spiegelhalter

“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. 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

continued on page 11

Upcoming Program on Quantitative Finance

Mathematicians have been attracted to the wonders of quantitative finance since time immemorial. When challenged to demonstrate to his fellow Milesians that intellect could lead to financial enrichment, Thales bought options on the use of olive presses during a year for which he predicted a particularly good harvest (around 580 B.C.) and made a fortune. Louis Bachelier, the great-grandfather of modern financial mathematics, modeled prices in the French stock market and correctly derived several option prices in his 1900 thesis, Théorie de la Spéculation, the undisputed origin of several branches of stochastic calculus, such as Brownian motion, Markov process, diffusion processes and weak convergence in functional spaces.

As an identifiable subject, quantitative finance started with the works of Markowitz (1952) and Sharpe (1964) on portfolio allocation, Samuelson (1965) on stock price modeling using geometric Brownian motion, and Black-Scholes-Merton (1973) on option pricing. Its full mathematization occurred in the period between Harrison and Pliska’s (1981) introduction of risk-neutral pricing using martingales and stochastic integrals and Delbaen and Schachermayer’s (1994) functional analytic proof of the Fundamental Theorem of Asset Pricing. This period saw the use of increasingly sophisticated

continued on page 12
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 in what follows.

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 (paffian closure). The second course focused on quasi-analytic classes arising from dynamical systems, such as Ramis and Sibuya’s multissummable functions or Ecalle’s resurgent functions. The lecturers were Fernando Sanz, Jean-Philippe Rolin and myself (multissummability), David Sauzin (resurgent functions) and again Fernando Sanz (quasi-analyticity for non-oscillatory trajectories). The third course dealt with resolution of sing-

continued on page 13
AGM lecture: Matheus Grasselli

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.

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.

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

Watermelon Workshop on Extremal Graph Theory

This was a three-day workshop on extremal graph theory and related areas. The inaugural “Watermelon 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 focussed 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

continued on page 15
The Fields-MITACS Summer School in Applied Probability was held at Carleton University during May 11-21, 2009. It brought together six lecturers, six invited speakers, and over 40 graduate students and postdoctoral fellows, among other researchers; a complete list of attendees is on the webpage of the Summer School.

The event was very successful in bringing together people working in various areas of Applied Probability from Canada and outside. The format of the Summer School allowed for efficient learning by graduate students and helped the exchange of ideas among researchers and students. The presence of several researchers, in addition to the lecturers, broadened areas of interest that foster fruitful interactions with the students.

This two-week event consisted of four short courses given by five lecturers, one two-hour tutorials, six one-hour invited talks by researchers, and 15 thirty minute student presentations. The courses, tutorial and invited talks covered areas in: Markov chains, Markov chain Monte Carlo, probabilistic combinatorics, queueing theory, stochastic approximation and two-time-scale stochastic systems, etc. New development of methodologies in these areas of applied probability were surveyed and selected topics were lectured in detail, which in most of the cases cannot be learned from standard course work of graduate students.

Markovian modelling is one of the most efficient tools in applied probability. Jim Fill’s short course focussed on several aspects of Markov Chains, including intertwinnings, strong stationary times and duality, perfect simulation, and absorption times (roughly one of these topics was covered per lecture). Many concrete examples were given. For example, results due to Diaconis, Fill, Aldous and others for card shuffling strategies were covered in detail to help in understanding of concepts and to demonstrate applications.

...results due to Diaconis, Fill, Aldous and others for card shuffling strategies were covered in detail to help in understanding of concepts and to demonstrate applications...

Johan van Leeuwaarden’s course centered on the study of queues, especially on multi-dimensional systems. The three parts were covered by five lectures, containing: basic concepts in queueing theory, an important field of applications of applied probability started 100 years ago marked by Erlang’s first paper in this area published in 1909, and selected recent development, such as generalization of Erlang’s loss formula and Spitzer’s formula on random walks; heavy traffic lim-

its, an important tool in approximations to complex systems, particularly on new understanding of the Halfin-Whitt regime; and the renewed kernel method, which is an efficient method for tail asymptotics for both probability distributions and combinatorics enumeration problems, which raised many interesting questions and very lively 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. Yin introduced the basic theory of stochastic approximation, and emphasized 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 modeling 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 the course weak convergence analysis was systematically developed, in which the related martingale problems, as an analytical tool, play a central role.

The last course of the Summer School had two parts. Conrado Martinez focussed on analytic combinatorics, and especially 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 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

continued on page 17
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 tangent map over a $C^1$ diffeomorphism of a manifold. In this setting, a linear cocyle $F : E \to E$ is uniformly hyperbolic if and only if there exists an $F$-invariant, continuous (in $x$) splitting of $E_x = E^{-1} (x)$ 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 $F_1(C(x)) \subseteq C(f(x))$. In order to establish basic principles, we specialize to the trivial vector bundle $E = X \times R^2$ with the map $F(x,v) = (f(x), A(x)v)$ where $A : X \to SL(2,R)$ is continuous. Iterates must be computed along orbits: For $n \geq 0$, $F^n(x,v) = (f^n(x), A^{(n)}(x)v)$, where $A^{(n)}(x) = A(f^{n-1}(x)) \ldots A(f(x)) A(x)$, and similarly for $n < 0$. In this case, the space of directions in $R^2$ is the projective space $P^1(R) \equiv S^1$, 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 $SL(2,R)$ cocycles in particular at all. For example, they arise in the study of Schrödinger operators with quasi-periodic potential. Given a continuous potential $V$ from the $d$-dimensional torus $T^d$ to $R$, one can introduce an operator $H = H_\lambda, V, \theta : \ell^2 \to \ell^2$ defined by $(H u)_n = u_{n+1} + u_{n-1} + V(\theta + n \alpha)u_n$. The analysis of the spectrum of such an operator reduces to analyzing a particular matrix $A_{\lambda, V}(\theta) \in SL(2,R)$: $\lambda$ is in the spectrum of $H$ if and only if the cocycle over $\theta \mapsto \theta + \alpha$ 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, $\Sigma = \mathcal{A}^2$, 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 $A_1, \ldots, A_N \in SL(2,\mathbb{R})$ and $F_1$ is multiplication by $A_1$ when $x_0$ is the $i$th element of $\mathcal{A}^j$. So, the parameter space of cocycles is canonically isomorphic to $SL(2,\mathbb{R})^\mathcal{A} \cong SL(2,\mathbb{R})^N$ 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 $SL(2,\mathbb{R})^N$ 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 $\mathcal{H}$ pairwise 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 $\mathcal{H}$ bounded modulo conjugacy? (That is, is there a bounded subset of each component $H$ of $\mathcal{H}$ 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 $P^1(R)$ with finitely many components having pairwise

continued on page 13
OCCAM-Fields-MITACS Workshop

The objectives of this workshop were four-fold: to introduce mathematicians and modelers to problems arising in medical science; to effectively aid practitioners and researchers in medicine to 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.

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 tumours 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 by this pathological condition occurring 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. Waiker, an MD and a clinician from the Brigham and Women’s Hospital, Harvard University, brought experimental data on hemodialysis. 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-Jakob Disease (vCJD) by transmission of blood and surgery.

The last two problems came from David C. Bassett and Jake E. Barralet at the Faculty of Dentistry, McGill University, 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 are available online at the workshop website: www.fields.utoronto.ca/programs/scientific/08-09/biomedical/

This workshop was co-sponsored by OCCAM, Fields (including the Centre for Mathematical Medicine) and MIT-ACS.

Huaxiong Huang

Math Ed Forum

The fourth Canadian Mathematics Education Forum (CMEF) was held in Vancouver from April 30 to May 3, 2009 with about 180 participants, made up of approximately 70 university mathematicians and math educators, 60 teachers and coordinators, 30 graduate students and 20 representatives from government, publishing, parent groups, etc. Its theme was curriculum and assessment, and it was cosponsored by CMS and PIMS with major support from SSHRC, SFU, Fields, CRM, CAIMS, SSC, MITACS, Nelson, Pearson, Wiley and Maplesoft. (Recall that CMEF III was held in Toronto in 2005 and was cosponsored by CMS and Fields.)

...it is rare that so many teachers across the country are able to come together to share ideas and talk with university folk...

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 secondly 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 “wonderful” were the comments

continued on page 14
Workshop on Smooth Structures in Logic, Category Theory and Physics

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 (UC Riverside), Kristine Bauer (Calgary), Thomas Ehrhard (PPS Paris), Anders Kock (Aarhus), Gonzalo Reyes (Montreal), and Andrew Stacey (NTNU Norway). 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.

In addition to the invited speakers, there were several additional talks given at the workshop: Richard Blute (Ottawa) gave a tutorial on differential structures from the perspective of categorical logic — focusing in particular on linear logic and differential categories. Robin Cockett (Calgary) discussed further axiomatic structure relating differential categories to abstract Kähler differentials. Alexander Honung (UC Riverside) described the setting of difieological spaces as a candidate for a reasonable abstract notion of smooth space. Dorette Pronk (Dalhousie) discussed the equivariant homotopy theory for smooth orbifolds; and Konrad Waldorf (UC Berkeley) 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

Appalachian Set Theory Workshop

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 of the Hebrew University for iterating proper forcing without adding reals. His results in this area are often quoted but

...results in this area are often quoted but the proofs are difficult and known to only a handful of experts...

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 States.

Here is a mathematical overview: In 1965, Solovay and Tennenbaum introduced the technique of iterated forcing in

continued on page 14
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 (Toronto), Spiro Karigiannis (Waterloo), Ruxandra Moraru (Waterloo) and McKenzie Wang (McMaster) — 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
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 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 center 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 Béc (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 invariance. 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 (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 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
Multivariate Operator Theory Workshop

A workshop on multivariable operator theory was held at Fields the second week of August. The goal of the workshop focused, as the name suggests, on an analysis of n-tuples of operators on Hilbert space and the algebras that they generate (usually commutative, but not always). Traditionally the theory of bounded operators combined techniques from analysis with analytic function theory. Half a century ago, Sz. Nagy provided a dilation theory that showed that every operator of norm 1 was a part of an isometry in a certain sense. Detailed knowledge of isometries led, over time, to deep structural results for quite general classes of single operators.

More recently, the focus has moved to a multivariable context. The algebra involved becomes more sophisticated, involving ideas from algebraic geometry and several complex variables. Dilation theory has been reformulated in terms of resolutions of Hilbert modules. A number of classical results for one variable fail to have a naive extension to the multi-variable context — the answers are more complex, and depend more on the domain.

To illustrate, von Neumann proved that if T is an operator on a Hilbert space of norm at most 1, and p is a polynomial, then

\[ \| p(T) \| \leq \sup \{ |p(z)| : z \in \mathbb{C}, |z| < 1 \} \]

\[ =: \| p \|_\infty. \]

In the case of two commuting operators T1 and T2 with \( \| T_i \| \leq 1 \) for \( i = 1, 2 \), the same result holds for polynomials of two variables, taking the supremum over \( \mathbb{D}^2 = \{ (z_1, z_2) : |z_i| < 1 \} \). However this is false for 3 or more operators. One can instead try to classify which functions satisfy this inequality for all commuting n-tuples of contractions OR one can classify which operators satisfy the inequality for all functions. Both questions were answered by Agler. One can also consider other domains such as the unit ball \( \mathbb{B}_n \) of \( \mathbb{C}^n \). This corresponds to a commuting n-tuple \( T_1, \ldots, T_n \) such that

\[ \| [T_1 \ldots T_n] \| \leq 1 \] (i.e. \( \sum_{i=1}^n T_i T_i^* \leq I \)).

Here there is a von Neumann inequality, but the norm on the functions is not the sup norm over the ball; it is the norm of the functions as multipliers on a certain model Hilbert space of functions on the ball. This context was a popular choice at the workshop. Once one has two variables, they need not commute. There are a variety of models, depending on norm constraints, which characterize the appropriate von Neumann inequality for non-commuting operators.

The meeting was a great success, with many leaders of the field giving the keynote addresses and many young mathematicians, including several graduate students, presenting their results. In addition to people working directly in operator theory, there were keynote speakers working in interpolation and several complex variables; and many interesting connections were made between those subjects and operator theory.

Ken Davidson
Workshop on Geometry Related to the Langlands Programme

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 mini-course lecturers before the conference; more detailed versions are currently in preparation. (Lecture notes for the 2004 and 2007 workshops are now available as Fields Institute Monograph Series, Volume 26, under the title Ottawa Lectures on Admissible Representations of Reductive $p$-adic Groups.)

Since this workshop was focussed 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

...this workshop was focussed on recent applications of geometric tools to the Langlands programme...

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 “micromort”: 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

continued on page 12
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

Quantitative Finance

mathematics in utility maximization, risk management, and the modeling of interest rates, stochastic volatility and asset prices with jumps. The decade between the Financial Mathematics (1995) and Developments in Quantitative Finance (2005) thematic programs at the Isaac Newton Institute in Cambridge saw the area evolve into a mature academic subject, with the creation of the Bachelier Finance Society, countless master programs around the world, influential research groups in leading universities and several dedicated journals.

It was in this landscape that we envisaged a thematic program on quantitative finance to be held at the Fields Institute in 2010. Our Letter of Intent, written back in 2005, stated that “Mathematical Finance abounds with fresh new applications and new mathematics is constantly being introduced and developed. This trend will continue — over future decades we expect MF will impact many areas as yet undeveloped.” We went on to say that “the general trend of securitization, of which collateralized debt obligations (CDO’s) and general asset backed securities are particularly important examples, offers a new level of mathematical complexity guaranteed to keep MF vigorous, useful and fascinating well into its twilight years.”

Of course even mathematicians (and certainly regulators and the public at large) notice that the CDO’s and other financial innovations that made us so gleeful in our 2005 letter were at the center of the current financial crisis. Justifiably or not, such a prominent role in the crisis put quantitative finance under attack, from the Wired magazine declaring that Li’s copula formula had destroyed Wall Street to Lord Turner, chair of the FSA in the UK, citing the “misplaced reliance on sophisticated maths to manage risks” as one of the causes for the crisis. Public defenses from several of our colleagues didn’t take long to appear, and are best summarized by Steve Shreve in his Don’t Blame the Quants piece at Forbes: “When a bridge collapses, no one demands the abolition of civil engineering. One first determines if faulty engineering or shoddy construction caused the collapse. If engineering is to blame, the solution is better — not less — engineering. Furthermore, it would be preposterous to replace the bridge with a slower, less efficient ferry rather than to rebuild the bridge and overcome the obstacle.”

Such is the modified landscape in which we are going to start our thematic program next year. Over the course of six months we will host workshops on Foundations of Mathematical Finance (January 11-15), Computational Methods in Finance (March 22-24), Financial Econometrics (April 23-24) and Financial Derivatives and Risk Management (May 24-28). Darrel Duffie will deliver the Distinguished Lecture Series (April 21-23) and Nicole El Karoui will deliver the Coxeter Lecture Series (Spring). In addition, Nobel Prize laureate Robert C. Merton will give the Nathan and Beatrice Keyfitz Lecture in Mathematics and the Social Sciences (April 16). Besides these academic activities, we will host a series of two-day Industry/Academic Forums on topics such as financial engineering and insurance, emissions trading, systemic stability, hedge funds, operational risk and others.

Several senior researchers will participate in the program as long-term visitors, including Nizar Touzi as the University of Toronto Dean’s Distinguished Visitor. Complete with graduate students attending three courses on Foundations of Mathematical Finance, Numerical Methods, and Interest Rates and Credit Risk, postdoctoral fellows short-term visitors and program participants will attend an informal weekly seminar series, as well as the monthly Quantitative Finance Seminar Series, the longest running seminar series at Fields, which will continue to take place during the program.

To bring the program to a conclusion, the Fields Institute will host the International Congress on Insurance: Mathematics and Economics (June 17-19) and the World Congress of the Bachelier Finance Society (June 22-26).

In the spirit of not letting a good crisis go to waste, we believe that the events that took place in 2008 offer tremendous opportunities for an academic response from financial mathematics in terms of vigorous research in previously untapped areas. These include the limits of arbitrage, the relationship between liquidity and leverage, the implications of accounting rules, the role of incentive structures, not to mention a mathematical theory for the formation and bursting of bubbles and financial crises themselves. These topics represent a substantial broadening of the scope of mathematical finance. None of them were in the horizon when we first thought of hosting a thematic program at Fields. By incorporating them, we expect our program to be seen as a landmark event in the development of the subject.

Matheus Grasselli
gularities in situations relevant to our focus: Edward Bierstone lectured on resolution of singularities for functions (used extensively in the construction of o-minimal structures), Felipe Cano on the resolution of singularities of vector fields and Daniel Panazzolo on the resolution of singularities of parametric families of vector fields and its relation to H16. These courses were covering a unique blend of material at the forefront of current research, and we are putting together a Fields monograph containing course notes written by the lecturers.

One of the highlights of our program came with the Distinguished Lecture Series. They were given by Fields medalist Jean-Christophe Yoccoz on the topic of uniformly hyperbolic SL(2,R) cocycles. While this topic is not directly related to the focus of our program, it is readily accessible to a general mathematical audience, and Yoccoz’s excellent and inspiring presentation made the lectures a great success.

Another key activity of our program were the mini-workshops, intended to bring a few people together for two to three days to work on one particular project, while allowing anybody to listen in. Each mini-workshop involved between four and ten core participants and typically focused on the understanding of a specific problem or solution thereof. Three of these mini-workshops were directly related to the focus of the program: Sergei Yakovenko presented his recent joint work with Dmitry Novikov and Gal Binyamini (both also program participants) solving the so-called infinitesimal H16 (another non-generic case of the FCC) with explicit uniform upper bounds. Tobias Kaiser and I described in detail how the o-minimality of some of the above-mentioned classes of functions leads to the solution of the FCC for the non-generic cases described earlier. Finally, Abderrahouf Mourtada has independently developed a non-model theoretic approach to solve the FCC in the generic case mentioned above, and he presented some of the details of this work in progress.

Two more mini-workshops dealt with valuation theory and differential algebra: the first, organized by Franz-Viktor Kuhlmann and Bernard Teissier, presented the valuation theoretic approach to resolution of singularities, as used in a particular application by Felipe Cano in his graduate course. The second, organized by Salma Kuhlmann and Mickal Matusinski, centered around the still open question of differentiably embedding Hardy fields into generalized series fields, which can be viewed as a way of establishing quasi-analyticity.

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 break-through on the topic. Mario Edmundo, Artur Pieknosz 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 constructible 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 Sackuel’s conjecture.

We ended the program with a regular week-long workshop organized by Fernando Sanz and myself and entitled Finiteeness 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

Yoccoz continued from page 5

disjoint closures. A multicone with one component is an ordinary cone. The theorem connecting multicones to hyperbolicity is the following. The cocycle \( A_1, \ldots , A_N \) over \( (\Sigma, \sigma) \) is uniformly hyperbolic iff there exists a multicone \( M \) such that for all \( i \in \mathcal{A}, A_i M \) 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 (sparking us notational complexity).

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:

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

\( \bullet \) 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.

John Mayer
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 favored with much the same format as we had this year.

Peter Taylor and Malgorzata Dubiel

**APPALACHIAN SET THEORY**

continued from page 7

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 $\omega_1$ and the tree remains an $\omega_1$-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 Johnsrud 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 ◊ 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. In a few months, it will be available at www.math.cmu.edu/users/eschimme/Appalachian/Index.html.

Ernest Schimmerling

*Souslin tree is an $\omega_1$-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.*
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 from Carnegie Mellon, Tibor Szabo from McGill, Felix Lazebnik from the University of Delaware, Bruce Richter and Chris Godsil from University of Waterloo.

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 the U.S., but it was notable that one came from Israel, 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 form 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

---

**APPLIED MATH continued from page 9**

his own theory of an ‘ekpyrotic universe,’ which permits spacetime 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 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

---

**FIELDS DEPUTY DIRECTOR CALL FOR APPLICATIONS**

This is a call for applications or nominations for the position of Deputy Director of the Fields Institute for a term of three to five years beginning July 1, 2010. The deputy director works closely with the director on all aspects of the Institute’s oversight and program development.

Qualified candidates should be mathematical scientists with good management skills, an excellent research record, and a strong interest in developing the programs of the Institute. Women and members of underrepresented groups are encouraged to apply.

In the past, this position has been filled by a mathematical scientist seconded from a local university, but we are also open to other strategies, such as using this as an opportunity to recruit new faculty to Ontario. Inquiries can be addressed to any member of the search committee: Edward Bierston (bierston@fields.utoronto.ca), Tom Salisbury (salt@pascal.math.yorku.ca) and Mary Thompson (methomps@uwaterloo.ca)

A brief letter of application or nomination and a CV should be sent to:

Edward Bierston, Director
Fields Institute
222 College St.
Toronto, ON M5T 3J1
bierston@fields.utoronto.ca
APPLIED MATH

continued from page 15

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. Professor 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 indepen dent motion. His talk in the Fields Institute Applied Mathematics Colloquium took place on May 13, 2009.

Walter Craig

Call for Outreach Proposals

The Fields Institute occasionally provides support for projects whose goal is to promote mathematical culture at all levels and bring mathematics to a wider audience. Faculty at Fields sponsoring universities or affiliates considering organizing such an activity and seeking Fields Institute support are invited to submit a proposal to the Fields Outreach Competition. There will be two deadlines each year for such submissions, June 1 and December 1, with the first competition scheduled for December 1, 2009.

Proposals should include a detailed description of the proposed activity as well as of the target audience. A budget indicating other sources of support is also required. Submissions should be sent to proposals@fields.utoronto.ca. Questions about this program may be directed to the Director, Edward Bierstone, or the Deputy Director, Juris Steprans.

Postdoctoral Fellowships

2010-11

Applications are invited for postdoctoral fellowship positions for the 2010-2011 academic year. The 2010 (Fall) Thematic Program Asymptotic Geometric Analysis will take place at the Institute July to December 2010 and the 2011 (Winter/Spring) Thematic Program on Dynamics and Transport in Disordered Systems will take place at the Institute from January to June 2011. The fellowships provide for a period of engagement in research and participation in the activities of the Institute. They may be offered in conjunction with partner universities, through which a further period of support may be possible.

In addition to regular postdoctoral support, one visitor for each six-month program will be awarded the Institute’s prestigious Jerold E. Marsden Postdoctoral Fellowship. There will also be a number of two year Postdoctoral Fields-Ontario Fellowships. Applicants seeking postdoctoral fellowships funded by other agencies (such as NSERC or international fellowships) are encouraged to request the Fields Institute as their proposed location of tenure, and should apply to the Institute for a letter of invitation.

Eligibility: Qualified candidates who will have recently completed a PhD in a related area of the mathematical sciences are encouraged to apply. The deadline is December 15, 2009, although late applications may be considered. Application Information: Please consult www.fields.utoronto.ca/proposals/postdocs/postdoc.html or apply on-line at https://www.mathjobs.org/jobs/317

The Fields Institute is strongly committed to diversity within its community and especially welcomes applications from women, visible minority group members, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas.

CALL FOR NOMINATIONS

CRM-Fields-PIMS Prize

The Centre de Recherches Mathématiques (CRM), the Fields Institute, and the Pacific Institute for the Mathematical Sciences (PIMS) invite nominations for the joint CRM-Fields-PIMS prize, in recognition of exceptional research achievement in the mathematical sciences. The candidate’s research should have been conducted primarily in Canada or in affiliation with a Canadian university.

The prize was established as the CRM-Fields prize in 1994. Renamed in 2005, the 2006 and later prizes are awarded jointly by all three institutes. Previous recipients are: H.S.M. Coxeter, George A. Elliott, James Arthur, Robert Moody, Stephen A. Cook, Israel Michael Sigal, William T. Tutte, John Friedlander, John McKay, Edwin Perkins, Donald Dawson, David Boyd, Nicole Tomczak-Jaegermann, Joel Feldman, Allan Borodin and Martin Barlow.

The selection committee, formed by the three institutes, will select a recipient for the 2010 prize on the basis of outstanding contributions to the advancement of the mathematical sciences, with excellence in research as the main selection criterion.

A monetary prize will be awarded, and the recipient will be asked to present a lecture at each of CRM, the Fields Institute, and PIMS.

Nominations should be submitted by November 1, 2009 by at least two sponsors of recognized stature, and should include the following elements: three supporting letters, curriculum vitae, list of publications, and up to four preprints. Nominations will remain active for two years. At most one prize will be awarded during any academic year.

Electronic Submissions only: nominations@pims.math.ca. Questions may be directed to: David Brydges, Deputy Director PIMS, dbrydges@pims.math.ca

FIELDS INSTITUTE Research in Mathematical Science | FIELDSNOTES 16
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 the self-avoiding walks were provided, which were used to demonstrate concepts in Metropolis-Hastings algorithm and Gibbs sampler, and also the convergence.

Moreover six invited research talks were given be Florin Avram, Ed Bender, Hui Li, Marni Mishna, Alfredo Viola and Nick Wormald. Finally 15 students gave short presentations related to their thesis work. The complete information including titles and abstracts can be found in the webpage of the Summer School.

Daniel Panario

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 (Carleton, McMaster, Ottawa, Toronto, Waterloo, Western and York), to our thirteen Affiliate Universities in Canada and the US, and to our Commercial and Industrial Partners. We welcome recent Affiliates Nipissing, Ontario Institute of Technology, Ryerson and Trent! The Fields Institute is committed to providing value to our partners. 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, ways that we can broaden our involvement in the training of students).

During the past year, I attended the meetings of our Board of Directors and Scientific Advisory Panel as an observer, so I can appreciate the scientific, educational and administrative leadership of our many friends who serve on these important committees. I would like to acknowledge the ideas and dedication of Pamela Cook, Eric Friedlander, Jerald Lawless and Catherine Sulem, who completed terms on our Scientific Advisory Panel during the past year, and to welcome new members Maciej Zworski of Berkeley and Charles Newmann of NYU!

I’d also like to express my appreciation to our administrative staff, some of whom I’ve 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. 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

THANKS TO OUR SPONSORS

MAJOR SPONSORS

Government of Ontario—Ministry of Training, Colleges, and Universities; Government of Canada—Natural Sciences and Engineering Research Council (NSERC)

PRINCIPAL SPONSORING UNIVERSITIES

Carleton University, McMaster University, University of Ottawa, University of Toronto, University of Waterloo, University of Western Ontario, York University

AFFILIATED UNIVERSITIES

Nipissing University, Queen’s University, Royal Military College, Trent University, University of Guelph, University of Houston, University of Manitoba, University of Maryland, University of Ontario Institute of Technology, University of Saskatchewan, University of Windsor, Wilfrid Laurier University, Ryerson University

CORPORATE SPONSORS

Algorithmics, General Motors, QWEMA, R2 Financial Technologies, Sigma Analysis and Management

The Fields Institute receives and welcomes donations and sponsorships from individuals, corporations or foundations, and is a registered charity. The Fields Institute is grateful to all its sponsors for their support.
Call for Proposals, Nominations, and Applications

For detailed information on making proposals or nominations, please see the website: www.fields.utoronto.ca/proposals

General Scientific Activities
Proposals for short scientific events in the mathematical sciences should be submitted by October 15, February 15 or June 15 of each year, with a lead time of at least one year recommended. Activities supported include workshops, conferences, seminars, and summer schools. If you are considering a proposal, we recommend that you contact the Director, or Deputy Director (proposals@fields.utoronto.ca). Also see www.fieldsinstitute.ca/proposals/other_activity.html

Thematic Programs
Letters of intent and proposals for semester long programs at the Fields Institute are considered in the spring and fall each year, and should be submitted preferably by March 15 or September 30. Organizers are advised that a lead time of several years is required, and are encouraged to submit a letter of intent prior to preparing a complete proposal. The Fields Institute has started a new series of two-month long summer thematic programs focusing on interdisciplinary themes. Proposals for the summer of 2010 are now being considered. Organizers should consult the directorate about their projects in advance to help structure their proposal.

Fields Research Immersion Fellowship
This program supports individuals with high potential to re-enter an active research career after an interruption for special personal reasons. To qualify, candidates must have been in a postdoctoral or faculty position at the time their active research career was interrupted. The duration of the career interruption should be at least one year and no more than eight years. Examples of qualifying interruptions include a complete or partial hiatus from research activities for child rearing; an incapacitating illness or injury of the candidate, spouse, partner, or a member of the immediate family; or relocation to accommodate a spouse, partner, and/or other close family member. The RIF will participate fully in the thematic program, in the expectation that this will allow her or him to enhance her or his research capabilities and to establish or re-establish a career as a productive, competitive researcher. The award is to be held at the Fields Institute, but there are no restrictions on the nationality or country of employment of the re-entry candidate. For programs in a given program year (which runs July to June) the closing date will be December 31 of the year before. Applications should be sent by email to the Director. Late applications will be considered if the position has not yet been filled. More details can be found at: www.fields.utoronto.ca/proposals/research_immersion.html

Distinguished Lecture in Statistical Science (DLSS)
Nominations are being solicited for the eighth Fields Institute Distinguished Lecture in Statistical Science, to be given in 2010. The awardee will be an internationally prominent statistical scientist, who will give two lectures (one general, one specialized) at the Fields Institute. Nominations for the DLSS should reach the Institute by October 1, 2009, although late applications may be considered. DLSS nominations should be sent to Nancy Reid c/o Fields Institute or directly to reid@utstat.utoronto.ca

Call for Participation: Hong Kong Study Group
Fields is in a partnership to organize the 2009 Hong Kong Workshop on Industrial Applications with the LBJ Center at the City University of Hong Kong. The date for the workshop is Dec 7-11, 2009. Fields will provide support up to $2,000 towards travel expenses for two academic participants while local expenses (accommodation and food) will be covered by the LBJ Center. This 5-day workshop will follow the same format as the Oxford Study Group. Participants will be working on problems coming from nonacademic sources. It is an excellent opportunity for young faculty, postdocs and graduate students to learn modeling and problem solving skills. Interested applicants should email their CVs to programs@fields.utoronto.ca by October 15, 2009.
SEPTEMBER - JANUARY 2009
Thematic Programs

THEMATIC PROGRAM ON THE FOUNDATIONS OF COMPUTATIONAL MATHEMATICS
JULY-DECEMBER 2009
Organizing Committee: Peter Borwein (Simon Fraser), Stephen A. Cook (Toronto), Teresa Krick (Buenos Aires), Adrian Lewis (Cornell), Michael Shub (Toronto), Richard Schwartz (Brown)
SEPTEMBER 22 - 26, 2009
Workshop on Discovery and Experimentation in Number Theory
OCTOBER 20 - 24, 2009
Workshop on Complexity of Numerical Computation
NOVEMBER 16 - 21, 2009
Workshop: Computational Differential Geometry, Topology, and Dynamics

THEMATIC PROGRAM ON MATHEMATICS ON QUANTITATIVE FINANCE: FOUNDATIONS AND APPLICATIONS
JANUARY-JUNE 2010
Organizing Committee: Yacine Ait-Sahalia (Princeton), Matheus Grasselli (McMaster), Vicky Henderson (Oxford Man Institute), Tom Hurd (McMaster), Marcel Rindisbacher (Toronto), Dan Rosen (R2 Financial Technologies)
JANUARY 11-15, 2010
Workshop on Foundations of Mathematical Finance
MARCH 22-24, 2010
Workshop on Computational Methods in Finance
APRIL 23-24, 2010
Workshop on Financial Econometrics
MAY 24-28, 2010
Workshop on Financial Derivatives and Risk Management
THEMATIC PROGRAM ON THE MATHEMATICS OF DRUG RESISTANCE IN INFECTIOUS DISEASES
SUMMER 2010
Organizing Committee: Troy Day (Queen’s), David Fisman (Toronto), Jianhong Wu (York)

General Scientific Activities

at Fields unless otherwise indicated For detailed information please visit: www.fields.utoronto.ca/programs

SEPTEMBER 18-20, 2009
26th Annual Meeting of the Canadian Econometric Study Group
Hosted by Carleton

OCTOBER 1, 2009 - 3:30 PM
CRM-Fields-PIMS Prize Lecture
Martin Barlow, University of British Columbia

OCTOBER 3-4, 2009
Southern Ontario Groups and Geometry Workshop

OCTOBER 13, 2009
The Shape of Content: An event to celebrate creative writing in mathematics and science

OCTOBER 31-NOVEMBER 1, 2009
Workshop on Algebraic Varieties

NOVEMBER 25, 2009
IFID Conference

DECEMBER 4-6, 2009
Fall Colloquium: Methodological Issues in Mathematics Education Research
Hosted by University of Ottawa

DECEMBER 10-12, 2009
Workshop on Modelling Indirectly or Imprecisely Observed Data
Hosted by University of Western Ontario

JANUARY 22-24, 2010
Combinatorial Algebra Meets Algebraic Combinatorics
I’ve been Director of the Fields Institute only since the beginning of July. This is a learning period for me, but I’ve already been here long enough to know that my job is a lot of fun and a lot of work! 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’s 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 Keyfitz for her care and generous guidance over the past year, and especially for having left the Fields Institute in great shape, both scientifically and financially. The vision that Barbara brought to the 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 Steprans during the coming year. He and Matthias Neufang deserve enormous credit for serving as Acting Director and Deputy Director from January-June 2009. It’s a tough job to step into an important position for a short time, with so many responsibilities and so little time to learn. Juris and Matthias have guided the Institute with wisdom and aplomb.

I was on sabbatical from my position at the University of Toronto during the 2008–09 year, and tried to keep a little distance from the Fields Institute administratively. But I participated in activities in both the Fall Thematic Program on Arithmetic and Hyperbolic Geometry and the Winter/Spring Program on O-minimal Structures and Real Analytic Geometry, so I can well appreciate the very high scientific level of our recent programs and the Institute’s focus on areas of mathematics that are of great promise for future development.

The Institute was a beehive of activity during both of these programs, as well as during our Summer 2009 Thematic Program on Mathematics in Quantum Information, organized by David Kribs, Raymond Laflamme, Kevin Resch and Mary Beth Ruskai. This program, which included a workshop at the Institute for Quantum Computing at the University of Waterloo, ended with a Distinguished Lecture Series by Matthew Hastings of Microsoft Research Station Q, followed by the Canadian Quantum Information Summer School. Matt Hastings’ lectures on Communicating over Quantum Channels were particularly inspiring in his use of ideas of either mathematics or physics to illuminate fundamental questions in the other.

When this Newsletter appears, our Fall Thematic Program on Foundations of Computational Mathematics will be in full swing. September activities include a Distinguished Lecture Series by Hendrik Lenstra of the University of Leiden and a Workshop on Discovery and Experimentation in Number Theory held (using our new “smart room”) simultaneously at the Fields Institute and at Simon Fraser’s Interdisciplinary Research in the Mathematical and Computational Sciences Centre (IRMACS)!

The increased level of activity of our recent programs 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 and the Clay Institute.

The success of all of our activities depends on our partner institutions, not continued on page 17