Science Rendezvous

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Upcoming Programs

THEMATIC PROGRAM ON FORCING AND ITS APPLICATIONS

FOCUS PROGRAM ON WHITNEY PROBLEMS
Focus Program on Whitney Problems

The focus program on Whitney problems will take place August 27 to September 30, 2012. It is organized by Alex Brudnyi (University of Calgary), Charles Fefferman (Princeton University), Pierre Milman (University of Toronto) and Nahum Zobin (College of William and Mary).

The program will focus on some of the most vibrant developments in function theory related to the celebrated Whitney extension and trace problems for classes of smooth functions. These include new analytic and geometric methods in the study of Lipschitz structures on finite sets, extension and trace problems for functions in Sobolev spaces, simultaneous extension of Lipschitz functions from subsets of metric spaces, Helly-type Lipschitz selection problems, and geometric descriptions of Sobolev extension domains.

The program will bring together a group of international experts in the areas of function theory and functional and geometric analysis to discuss recent progress and open problems in the area of Whitney type problems, and thus to foster interaction and collaboration between researchers in these fields.

Whitney Problems

Motivated by boundary value problems for partial differential equations, classical trace and extension theorems characterize traces of spaces of generalized smoothness (e.g., Sobolev, Besov, etc.) on smooth submanifolds of a Euclidean space. But in many cases one needs similar results for subsets of a more complicated geometric structure (for example, after a change of variables, initial data may be situated on a Lipschitz surface). The subject originated in Hassler Whitney's seminal papers of 1934 that, in particular, deal with the following problem: Given a real function on an arbitrary subset of a Euclidean space, how can we determine whether it is extendible to a function of a prescribed smoothness on the whole space?

Whitney developed important analytic and geometric techniques that allowed him to solve this problem for extension of functions defined on subsets of the real line to \( C^m \) \( (m\text{-times continuously differentiable}) \) functions on the line. He also formulated and solved similar problems related to jets of functions defined on a subset of a Euclidean space, in any dimension. (A jet can be thought of as a family of Taylor polynomials at points of the subset).

Another important result of Whitney (later generalized by G. Glaeser) asserts that a Whitney-regular (or quasi-convex) domain allows for extension of functions with bounded derivatives of a given order to functions of the same smoothness on the whole space.

In the decades since Whitney's seminal work, fundamental progress on the problem has been made by Georges Glaeser, Yuri Brudnyi and Pavel Shvartsman, and Edward Bierstone, Pierre Milman, and Wieslaw Pawłucki.

In 1958, Glaeser gave a geometric description of traces of \( C^m \) functions on subsets of a Euclidean space, based on his notion of the "iterated paratangent space". Later, Brudnyi and Shvartsman conjectured a "finiteness principle" for traces of \( C^m \) functions with \( m \)-th derivatives having a given modulus of continuity (a similar principle for traces of smooth functions on the real line was established by Whitney), and proved this conjecture for \( m = 1 \) by establishing a deep Lipschitz selection theorem—an analog of the classical Helly theorem on convex sets. In the 1990s, Bierstone, Milman and Pawłucki proved a variant of \( C^m \) extension from closed subanalytic sets, based on their \( C^m \) analogue of Glaeser's iterated paratangent space (i.e., a variant of the Whitney problem for traces of \( C^m \) functions on subanalytic sets).

Building on this work, in a series of recent papers Fefferman solved the original problem of Whitney in full generality. His methods have led to a number of very important developments in the field, including new analytic and geometric methods in the study of Lipschitz structures on finite sets. In addition, Fefferman, partially in collaboration with Bo'az Klartag, has developed powerful methods of computation of extensions.

It is natural to consider similar extension and trace problems for functions in Sobolev spaces. These results are at a much earlier stage. Substantial progress for functions on subsets of a Euclidean space was recently made by Fefferman together with Arie Israel and Garving Luli, and, by very different methods and in different terms, by Pavel Shvartsman.

Lipschitz Extensions

Closely related to the Whitney problems are problems on simultaneous (i.e., linear) extension of Lipschitz functions defined on subsets of a metric space. This area of research, going back to classical works of Joram Lindenstrauss and Aleksander Pelczynski, is related to important problems in geometry, stochastic programming and functional analysis. In a recent paper by Alexander and Yuri Brudnyi, a new bi-Lipschitz invariant of a metric space was introduced whose finiteness is equivalent to

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FIFTY YEARS AGO, PAUL COHEN DEVELOPED THE method of forcing to establish that the Continuum Hypothesis is not provable from the axioms of ZFC. Together with Gödel’s earlier work on the constructible universe L, this resolved Hilbert’s first problem. While this opened the door to many more independence results to come, it also marked the begin of an era when mathematics became capable of systematically dealing with independence phenomena.

The following is a sampling of problems that have occurred naturally in mathematics but turned out to have an interesting set-theoretic content:

- (E. Borel) Suppose that $A \subseteq \mathbb{R}$ is such that for every sequence $e_n \ (n < \infty)$ of positive numbers, $A$ can be covered by intervals $(a_n, b_n) \ (n < \infty)$ with $b_n - a_n < e_n$. Must $A$ be countable?
- (Whitehead) If $A$ is an abelian group and $\operatorname{Ext}^1(A, \mathbb{Z}) = 0$, must $A$ be free?
- (Rado) If the intersection graph of a collection of intervals in a linear order is uncountably chromatic, must it have an uncountably chromatic subgraph of cardinality $\aleph_1$?
- (Brown, Douglas, Fillmore) If $H$ is a separable Hilbert space, can there be an automorphism of $B(H) / K(H)$ that is not inner? ($B(H)$ and $K(H)$ are the bounded and compact operators on $H$, respectively).
- (Banach, Pelczynski) Does every infinite dimensional Banach space have an infinite dimensional quotient with a basis?
- (Naimark) If all pure states on a $C^*$-algebra $A$ are equivalent, must $A$ be isomorphic to the algebra of compact operators on a separable Hilbert space?

Of the above problems, all except the last two have been solved using the method of forcing and methods that grew out of forcing are a relatively rare commodity. Still, such set-theoretic methods that grew out of forcing are relevant to settling long-standing problems in operator algebras such as those of Brown-Douglas-Filmore and Naimark mentioned above. The first workshop will bring together experts in set theory and operator algebras in order to foster further interaction between these two fields.

The second workshop will focus on the applicability of the so-called forcing axioms to other areas of mathematics, and analysis in particular. Forcing axioms were developed in the 1970s and 1980s out of Solovay and Tennenbaum’s solution to Souslin’s Problem. They have since proved extremely useful in applications, often providing the framework for one half of an independence proof that complements the influence of the Continuum Hypothesis.

In addition to developing new applications of set theory to other fields of mathematics, the Program will also focus on basic research in set theory. For example, the techniques we presently have for building models of set theory often result in models in which $|\mathbb{R}| = \aleph_n$. This has remained a great mystery ever since the 1970s. Recently, new methods have been obtained by Aspero and Mota and by Neeman for obtaining models of set theory in which $|\mathbb{R}| = \aleph_n$. On the other hand, recent work of Aspero, Larson, and Moore has revealed new obstacles to obtaining models of $|\mathbb{R}| = \aleph_n$ by iterated forcing. Another area of research in pure set theory concerns the combinatorial properties of singular cardinals $\kappa$ — cardinals such as $\aleph_n$ that can be expressed as a sum of fewer than $\kappa$ cardinals, each less than $\kappa$. Work of Easton in the early days of forcing showed that any plausible cardinal arithmetic at regular cardinals can actually be achieved in a model of ZFC. At singular cardinals, the situation is much

The Program aims to bring the method of forcing and the tools it provides to a broader mathematical audience, and to improve our understanding of what problems in other fields of mathematics are amenable to the method of forcing. For instance, only within the last five years was it realized that set-theoretic methods that grew out of forcing are relevant to addressing questions in other fields of mathematics.

The Distinguished Lecture Series by Matthew Foreman (UC Irvine), Thomas Johnstone, and Stevo Todorčević (University of Toronto and CNRS). The semester will feature:

- Two semester-long graduate courses on forcing (taught by Alan Dow) and large cardinals (by Paul Larson).
- Preparatory courses will be offered in July and August.
- The CRM-Fields-PIMS Prize Lecture by Stevo Todorčević (September 6).
- Three week-long workshops: Applications to Operator Algebras (September 10–14), Forcing Axioms and their Applications (October 22–26), and Iterated Forcing and Large Cardinals (November 12–16).
- The Distinguished Lecture Series by Matthew Foreman (UC Irvine).

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Remembering Margaret Sinclair

MARGARET SINCLAIR, PROFESSOR OF MATHEMATICS Education at York University, passed away peacefully at home on February 21, 2012 at the age of 62, after a long and courageous battle with cancer.

Margaret made major contributions to mathematics education in Ontario, not the least of which was her term co-chairing the Fields Institute Mathematics Education Forum, from 2005 to 2007. During that period she pioneered a number of Forum activities, including the annual "Mathematics Education Research Day". She was the lead writer for the Forum’s 2005 submission to the Ontario College of Teachers on teacher training, which forcefully made the case for improved mathematics preparation of primary school teachers. The Forum is a unique Ontario institution, promoting discussion and collaboration among classroom teachers, mathematics and statistics faculty/students, and mathematics education researchers. The forum meets one Saturday each month of the school year, and has done so since 1997. During that time, it has provided a venue for mathematicians and educators to make a real impact on the training of teachers in Ontario, and on the Ontario mathematics curriculum. Margaret’s contributions to the forum, to mathematics education in Ontario, and to mathematics education research will be the focus of a dedicated session of the Forum, planned for Fall 2012.

Margaret was a passionate advocate for mathematics education in Ontario, and for teachers. She played a leadership role in the “College Mathematics Project”, an Ontario-wide effort to study and support the transition from high school to college, and improve the mathematics achievements of first-year college students. She was co-director of YSIMSTE — the York-Seneca Institute for Mathematics, Science, and Technology Education. She was active in the Canadian Mathematics Education Study Group (CMESG), a national organization that connects mathematics education researchers across Canada. Together with Walter Whiteley, she helped develop a novel graduate diploma program in Mathematics Education, spanning York’s Faculty of Education as well as the Department of Mathematics and Statistics at York University. She was also instrumental in developing the undergraduate major in Mathematics for Education at York to support the development of future teachers of mathematics.

Margaret was a wizard at using dynamic geometry software to reach and inspire students and teachers, a topic that was the focus of her early research projects. This grew over the years into a broader collaborative research program, investigating the learning and teaching of spatial reasoning and developing visual reasoning to support the broader learning of mathematics. She presented this work at local, national, and international conferences, as well as integrating these passions into her own teaching in high school and university and in her graduate supervisions.

A 15-year career with the Toronto Catholic District School Board saw Margaret teaching at both the elementary and secondary levels, rising to serve as vice-principal. In this period she was active in the Ontario Association for Mathematics Education (OAME) and her local chapter, supporting professional development activities and extra curricular student engagement with mathematics. Returning to school part-time, she earned an MA in Mathematics for Teachers, from the Graduate Program in Mathematics and Statistics at York University. She went on to earn (at age 51) a PhD in Mathematics Education from the University of Toronto’s Ontario Institute for Studies in Education (OISE) under the supervision of Gila Hanna. She then joined the Faculty of Education at York University, where her energy, enthusiasm, impact for change, and love for education will be sorely missed.

Margaret is survived by Larry Sinclair, her husband of 43 years, her five children, and her four grandchildren.

Gila Hanna (OISE), Tom Salisbury (York), Walter Whiteley (York)
o-minimal Structures and Real Analytic Geometry Retrospective Workshop

IN THE WINTER OF 2009, Chris Miller (Ohio State), Jean-Philippe Rolin (Bourgogne), and I ran the Thematic Program on o-minimality and Real Analytic Geometry. Its main focus was on extending local resolution of singularities techniques in order to establish the o-minimality of certain expansions of the real field, such as those generated by functions studied by Ilyashenko and Ecalle in their proofs of Dulac’s problem. Many recent developments in the intersection of o-minimality and real analytic geometry use resolution of singularities in crucial ways, and can in turn be viewed as extending the notion to the preparation theorems mentioned above. The “o-minimal Structures and Real Analytic Geometry Retrospective Workshop,” held August 8–12, 2011, surveyed progress made during and after our Program, with particular emphasis on work done by the younger participants.

One of the 2009 Program’s features was its focus on the topics mentioned above. The following speakers represented new developments in these topics at our workshop:

- Gal Binyamini (Weizmann Institute) on Multiplicity and order of contact for regular and singular foliations
- Raf Cluckers (Université Lille 1 and K.U. Leuven) on Lebesgue classes and a preparation theorem for real constructible functions
- Olivier Le Gal (now at Université de Savoie) on Interlaced integral pencils of 3-dimensional analytic vector fields
- Daniel Panazzolo (Université de Mulhouse) on Center manifolds for holomorphic three-dimensional vector fields
- Sanjay Patel (McMaster University) on o-minimal expansions by quasi-analytic functions of one variable
- Fernando Sanz (Universidad de Valladolid) on Restricted Analytic Gradients on Analytic Isolated Surface Singularities
- Tamara Servi (CMAF Lisbon) on Quantifier elimination for generalized quasi-analytic algebras of real functions.

Of course, during the Program participants did not work on these topics exclusively. Indeed, some great new developments arose during the Program, represented at our workshop by the talks of:

- Matthias Aschenbrenner (University of California, Los Angeles) on Vapnik-Chervonenkis density in model theory
- Philipp Hieronymi (University of Illinois at Urbana-Champaign) on A dichotomy for expansions of the real field
- Jana Mříková (Western Illinois University) on Definable sets in o-minimal fields with convex valuations.

Other recent developments—such as Pila’s use of o-minimality in the proof of some cases of the André-Oort conjecture—were represented at the workshop in the talks of:

- Andrei Gabrielov (Purdue University) on Semi-monotone sets and triangulation of tame monotone families
- Gareth Owen Jones (University of Manchester) on Integer-valued definable functions
- Tobias Kaiser (Universität Passau) on Spherical blowings-up
- Masahiro Shiota (Nagoya University) on How to avoid the method of integration of vector fields in singularity theory
- Margaret Thomas (Universität Konstanz) on Counting rational points on certain pfaffian sets
- Michael Tychonievich (The Ohio State University) on The set of restricted complex exponents for expansions of the reals
- Lou van den Dries (University of Illinois at Urbana-Champaign) on the Model theory of H-fields
- Nicolai Vorobjov (University of Bath) on Approximation of definable sets by compact families.

Overall, the workshop provided a forum for many of the young participants in our Program to showcase their recent work to each other and to some of the leading specialists in o-minimality and dynamical systems. It was a great way to put the finishing touches on our Thematic Program, and we are grateful to the Fields Institute for giving us this opportunity.

Patrick Speissegger (McMaster University)
THE FIELDS-MITACS CONFERENCE ON THE MATHEMATICS of Medical Imaging was hosted by the Fields Institute from June 20 to June 24, 2011. This was the major inaugural event of both the Mitacs “International Focus Period on the Mathematics of Medical Imaging” (June 2011–August 2012) as well as the Fields Thematic Program on Inverse Problems and Imaging (January–August 2012). The conference aimed to showcase the crucial role of mathematics in recent advances in the vast field of Medical Imaging. It focused on two very active areas that involve beautiful, deep mathematics: Inverse Problems and Image Analysis, as well as on the emerging area of Patient Specific Modeling.

Inverse problems arise when one wishes to produce images of tissue from the measurements obtained from a medical apparatus. Different imaging methods (such as the widely used CT scans, MRI, and ultrasound) require the solution of different mathematical inverse problems. Very active research in inverse problems also looks towards completely new imaging modalities, yielding clinically relevant information about other fundamental tissue properties: electric impedance imaging, elastography, and photoacoustic tomography. On the mathematics side, the solution of Inverse Problems has involved techniques from, and contributed deep new developments to, fields such as linear and nonlinear partial differential equations, differential geometry, harmonic analysis, integral geometry, and quasiconformal mappings.

Once images have been obtained, image analysis takes over to address a different set of clinically important challenging mathematical problems: noise removal, segmentation (automatically locating objects—such as organs or tumours—or their boundaries), deblurring, registration (aligning two images of the same patient, obtained at different times or by different instrumentation, by spatially transforming one to the other). These problems have led to novel major analytic and geometric developments in nonlinear variational analysis, conformal mapping, Bayesian methods, graph theory, optimal transport, and compressed sensing.

Patient specific modeling seeks to develop

“Medical Imaging” continued on page 19
In 2006, Dan Rosen co-founded R$^2$ Financial Technologies at the Fields Institute as an incubated company. R$^2$ is a financial software company, specializing in risk and portfolio management analytics for financial services companies. In February 2012, the company was acquired by S&P Capital IQ, a branch of publishing company McGraw-Hill. Rosen sat down with Richard Cerezo to discuss what it was like being an incubated company, and how R$^2$ has grown since then.

RICHARD CEREZO: Why did you decide to incubate the company at the Fields Institute?

DAN ROSEN: It just happened. I wasn't sure exactly how I would get started and I needed some time to think about the possibilities. I spoke with Tom Salisbury, and also with Luis Seco, who had started his company at Fields. Luis Seco really recommended the incubation at Fields. I met with the folks there and we found a way to make it work.

We started R$^2$ in 2006, and by February 2007, we knew we were taking off. We were working on three projects and had started to build our software products. Fields was phenomenal. In addition to the great environment, they took care of administration, infrastructure, HR, and benefits. We didn't have to worry about anything and could focus on our clients and the problems we were helping them solve. This really helped getting us going.

Cerezo: How valuable was past experience in building the new company?

Rosen: We have a very strong management team. We had been in the same space for over a decade and learned a lot about the industry, and what works and doesn't work, in our previous roles. The three of us (including co-founders Benoit Fleury and Philippe Rouanet) have very complementary experience and skills. We learned a lot about starting a company along the way and, by the time we were done with our time at Fields, we had the momentum and start up experience needed to succeed on our own.

Cerezo: And that's when S&P Capital IQ came into the picture?

Rosen: That was couple of years after leaving Fields. We had been discussing a strategic partnership with them for a while. Our ambitions were to grow and penetrate the market further with our core software, but we were constantly looking for distribution channels, as well as financial and market data to provide a more integrated solution. S&P was looking to enhance multi-asset risk and portfolio analytics to complement their core capabilities. It is an amazing fit. If we can execute on the integration, it will be game-changing!

Cerezo: Fields is a completely mathematical environment. Did that influence your work in any way?

Rosen: Not directly in making the product, but the environment and intellectual atmosphere has definitely influenced what we do and how we look at things. When we started the company, a couple of the projects we did were based on research papers I was
Celebrating the Fields Institute’s 20th Anniversary

TEN YEARS AGO THE FIELDS INSTITUTE CELEBRATED its first decade of existence with a major colloquium featuring some of the most prominent mathematicians of the time. Now, twenty years after its founding, it is not just the Institute’s age that has doubled. Judging by the thickness of the Annual Report, the number of activities hosted by Fields has doubled, as has the number of participants in these programs. Even provincial funding has doubled—but whether this level of funding will be maintained is uncertain. In response to this uncertainty, the celebrations marking the Institute’s twentieth anniversary will be less grand than the event might have warranted. Nevertheless, the Fields event calendar for 2012 will list a substantial number of memorable events associated with the twentieth anniversary, events closely linked to the Institute’s primary goals.

Of these, the one that will probably attract the greatest public attention and interest will be the Fields Medal Symposium, the first of a series of annual symposia devoted to the work of recent Fields laureates. From October 15–18, 2012, Ngô Bào Châu (University of Chicago) will participate in a week-long symposium devoted to the Langlands Conjecture. He and James Arthur (University of Toronto) will present public lectures on this topic, while several well known researchers will provide more technical talks. As well, the Symposium will include a panel discussion aimed at high-school and undergraduate students.

Fields medalist participation in the anniversary celebrations will not be restricted to this Symposium, nor even to this continent. The newest Fields affiliate, and the first outside of North America, is Université Lille 1 in France. To mark the beginning of its collaboration with the Fields Institute, Université Lille 1 will host a conference featuring talks by Alain Aspect and Alain Connes.

The Mathematics of Planet Earth (MPE) focused year will overlap the 20th anniversary celebrations. The conjuncture of these two themed years should provide an opportunity for the Institute to promote the sort of mathematically educated citizenry that is essential to making sound policy decisions about the future of the planet.

During the month of July the twentieth anniversary celebrations will feature a one-month semester dedicated to the legacy of Jerrold E. Marsden. Jerry Marsden was the founding director of the Institute and continued to be involved in its activities until his death in 2010. The mathematical focus of the semester will be on geometry, mechanics and dynamics. One of the key activities of the semester will be the 2012 PIMS Marsden Memorial Lecture delivered by Richard Montgomery.

An innovation that might provide a legacy of high level scientific talks beyond the twentieth anniversary year is the Back2Fields Colloquium Series. This series celebrates the accomplishments of former postdoctoral fellows of Fields Institute special semesters. These semesters attract the rising stars of their respective fields, and work initiated during these semesters often launches distinguished research careers. This series of colloquium style talks will allow the general mathematical public to become familiar with some of this work. The speakers confirmed so far, and the Programs in which they participated, include: Brett Wick, Harmonic Analysis; Ke Zhang, Dynamics and Transport in Disordered Systems; Philipp Hieronymi, o-Minimal Structures and Real Analytic Geometry; Valentin Ferenczi and Christian Rosendal, Set Theory and Analysis; Andrew Toms, Operator Algebras; Clark Barwick, Homotopy Theory; Andrei Biryuk, Partial Differential Equations; Kristian Bjerklöv, Holomorphic Dynamics, Laminations, and Hyperbolic Geometry.

The celebrations of the 20th anniversary will provide events out of the ordinary as well as the beginnings of some activities that could continue for the next twenty years.

Juris Steprāns (York University)
STEVO TODORČEVIĆ is the winner of the 2012 CRM-Fields-PIMS Prize. The prize recognizes his work in set theory and surrounding areas of mathematics. He is known for introducing some of the far reaching and highly original methods in this area of mathematics. I will try to explain only some of the most typical aspects of the work of Stevo Todorcevic and his influence on mathematics in Canada and the rest of the world.

The common technical power behind most of his work is grounded on a deep understanding when Ramsey-type phenomena appear in different mathematical disguises. For example, in his early work, while solving two major problems in this area of mathematics, he had to clarify a boundary to extend the classical theorem of Ramsey in the realm of arbitrary mathematical structures that are not necessarily countable. This is on one side his classification scheme for transitive relations on the set of countable ordinals (the minimal such uncountable \( \omega \)) of countable subsets \( \min \subseteq \) such that each \( \langle a_n \rangle \subseteq \) for all \( n \in \mathbb{N} \). The second group of\( (\mathcal{I}) \) elements is uncountably large. The \( \max \) of the ideals of the form \( \mathcal{I} \subseteq \).

One of the reasons behind the great success of this dichotomy stems from the fact that it is accessible to a wider group of mathematicians not familiar with the original work of Todorcevic. The other reason is that many mathematical structures do naturally lead to P-ideals and therefore this dichotomy has seen a number of applications not only through the work of Todorcevic and his collaborators but other mathematicians as well.

One spectacular such use of this dichotomy is the recent result of Balcar, Jech and Pazák solving a sixty-year old problem of Maharam and von Neumann about fields of sets supporting strictly positive continuous outer measure. On the technical level the P-ideal dichotomy tends to transfer problems about arbitrary structures to problems about sets of reals that then can be solved by direct means. In fact, frequently the dichotomy transfers such problem to some old and well-studied problems about sets of reals. Another and perhaps more important feature of this dichotomy lies in its great potential in predicting the results that do not depend on this principle or any other additional set-theoretic assumptions.

One such remarkable application is due to Todorcevic himself when he showed that a \( \sigma \)-complete algebra \( \mathbb{B} \) supports a strictly positive continuous submeasure if and only if \( \mathbb{B} \) is weakly distributive and satisfies the \( \sigma \)-finite chain condition. We recall that von Neumann in his 1937 problem of the Scottish book had the countable chain condition in place of the \( \sigma \)-finite chain condition and was asking for a strictly positive countable additive measure. A recent result of Talagrand shows that the existence of the countably additive strictly positive measure has to be relaxed to the existence of a strictly positive continuous submeasure. It was also known that the countable chain condition has to be changed if we are to avoid using additional axioms.

Another famous dichotomy of Todorcevic that is based on the same initial Ramsey-theoretic analysis is the Open-Graph Dichotomy saying that graphs whose vertex sets are separable metric spaces and the edge set open symmetric irreflexive subsets of their squares are either countably chromatic or have uncountable cliques. This dichotomy has an equally rich history of applications over the last thirty years but we choose to mention only the recent result by Todorcevic’s former student Farah showing that the Open Graph Dichotomy implies that all automorphism of the Calkin algebras are inner. This result had immediately initiated a renewed interest in connections between these two areas of mathematics especially among mathematicians working in Canada, an activity that will surely gain in its intensity in the years to come.

Walk on ordinals and their characteristic were introduced by Todorcevic in the 1980s when he lifted the known classical
Prize: Stevo Todorcevic

boundaries of Sierpiński (1933) and Galvin – Shelah (1973) to an ultimate failure of the Ramsey theorem in the realm of uncountable structures.

Walk from an ordinal $\beta$ to a lower ordinal $\alpha$ is a finite sequence $\beta = \beta_0 > \beta_1 \cdots > \beta_k = \alpha$ such that $\beta_n$ is the minimal member of $C_{\beta_n}$ that is not smaller than $\alpha$. Thus, the walk is defined relative to a fixed choice of sets $C_\gamma \subseteq \gamma$ that are closed and unbounded in $\gamma$. To such a walk from $\beta$ to $\alpha$ one can associate various characteristics $\rho_{\gamma}(\alpha, \beta), \rho_1(\alpha, \beta)$, etc., usually given by recursive definitions and characteristics that in some sense resemble distance functions in this realm. This soon emerged into a deep metric theory of ordinals with application far beyond the original purpose of solving an old problem from Ramsey theory.

For example, if we concentrate on walks between countable ordinals with and appropriate choice of $C_1(\gamma < \alpha_1)$, the characteristic $\rho_{\gamma}(\alpha, \beta) = \max(\rho(\alpha, \min(C_{\beta_1} \setminus \alpha)), |C_{\beta_1} \cap \alpha|)$ that identifies the maximal weight $|C_{\beta_1} \cap \alpha|$ in a walk from $\beta$ to $\alpha$ gives us a total ordering $C = C(\rho_{\gamma})$ on $\alpha$ whose Cartesian square can be covered by countably many chains and, therefore, a canonical object that must appear in any classification result of this category of structures.

Deeper applications of this method have been made either by supplementing it by the theory of oscillations of traces, also initiated by Todorčević, or by implementing this method in other areas of mathematics. For example, J. Moore, a former student of Todorčević, using the characteristic $\rho_{\gamma}(\alpha, \beta)$ together with the oscillation theory of lower traces was recently able to describe a regular hereditarily Linedelöf space that is not separable solving an old and difficult problem (the L-space problem) in this area of mathematics. It should be mentioned here that the corresponding dual problem (the S-space problem) was solved by Todorčević in the piece of work already described above, the work that eventually led to the isolation of the P-ideal Dichotomy and the Open Graph Dichotomy.

Out of the applications of the second form, I mention the work of Argyros – López-Abad – Todorčević where $\rho$-functions are used to implementing conditional structure into norms on vector spaces, a method which together with the Gower – Maurey technique of building hereditarily indecomposable Banach spaces resulted into a remarkable example of a non-separable reflexive Banach space that has no infinite unconditional basic sequence. We recall that Gowers and Maurey originally introduced their technique in order to solve the unconditional basic sequence problem by producing a separable reflexive Banach space that is hereditarily indecomposable, a stronger condition that cannot hold in the realm of non-separable reflexive spaces.

Some of the recent work of Todorčević concentrates on connections between Ramsey theory and other areas of mathematics. As is well-known, the work of Furstenberg and Glaser from the 1970s has shown that ideas and results from these two areas of mathematics can be used not only to reprove deep Ramsey-theoretic results such as, for example, the Szemerédi theorem, the Hales – Jewett theorem, or the Hindman theorem, but also to obtain some far reaching extensions of these results.

The joint work of Kechris, Pestov and Todorčević have recently revealed another such deep connection, from another area of Ramsey theory and towards (rather than from) topological dynamics. Ramsey theory of finite mathematical structures, or Structural Ramsey Theory how usually it is called, is an area of Ramsey theory developing over the last forty years throughout the work of numerous mathematicians who were able to identify various Ramsey classes of finite structures such as, for example, finite-dimensional vector spaces over finite fields (Graham – Leeb – Rothchild), or the class of finite ordered triangle-free graphs (Nešetřil – Rödl).

What Kechris – Pestov – Todorčević showed is that, if one takes the Fraïssé limit of these classes of finite structures, such kind of results become equivalent to a specific dynamical property of the automorphism group of the limit structure, a dynamical property commonly designated as the extremal amenability of the corresponding group of automorphisms, a property saying that any continuous action of the group on a compact space must have a fixed point.

Using this characterization they went further and showed how it can be used to compute the universal minimal flows of this kind of topological groups. For example, they show that the universal minimal flow of the group of linear isomorphisms of the countably-dimensional vector space $V_{\mathbb{N}}(\mathbb{F})$ over a finite field $\mathbb{F}$ is equal to its action on the space of all natural orderings of the vector space $V_{\mathbb{N}}(\mathbb{F})$.

This initiated a large scale activity for further exploration of this connection an activity that is still expanding and in which several of the former students of Todorčević are playing an important role. For example, motivated by this work, Jasiński and Sokić have made some deep contributions to the structural Ramsey theory itself, while Nguyen Van Thé in a series of two joint works, one with López-Abad and other with Sauer, has shown that the unit sphere of the famous Urysohn metric space is oscillation stable, i.e., Lipschitz maps on the sphere must be $\varepsilon$-constant on isometric copies of the sphere itself. This deep result besides the one of Gowers about the sphere of $c_0$ identifies essentially the only two known example of metric structures with this strong dynamical property.

Claude Laflamme (University of Calgary)
ON SATURDAY, MAY 12, 2012, THE FIELDS Institute hosted a Mathematics Pavilion for Science Rendezvous, a nation-wide day of science. This annual event aims to make science more accessible by opening up labs and buildings not normally reachable by the public.

The Math Pavilion, organized by Pam Brittain (Toronto Math Department), Richard Cerezo, and Andrea Yeomans (Fields Institute), featured a wide-variety of math-related stations, including origami, knot theory (taught with licorice), geometry, probability, and bubbles. One station featured the Monty Hall Problem, in which participants would play the classic game show “Let’s Make a Deal” while learning the mathematics behind the problem. Participants could also learn how to count the number of jellybeans in a jar using mathematics, then try their newfound knowledge by making a guess and submitting it for a chance to win the whole jar.

The Pavilion had over 300 visitors throughout the day. There were lots of smiling faces as children and parents alike learned new aspects of mathematics. Many thanks to the wonderful volunteers who played a huge role in the event’s success. We’re already looking forward to next year!

Andrea Yeomans (Fields Institute)

PHOTOS
1 Volunteer and master cuber Harris Chan teaches a participant how to solve a Rubik’s Cube
2 Participants learning about the Monty Hall Problem
3 Young participants hold up their origami creations, made at the Math Pavilion with the help of volunteers from University of Toronto origami club F.O.L.D.
4 Volunteer Matt Sourisseau gives a math lesson
5 Volunteer Raymond McTaggart explains the Monty Hall Problem to a participant who has just won the game
6 Nikita Khesin and the building he built at the Math Pavilion’s Lego station
7 Participants making geometric nets out of paper
New Publication Agreement with Springer

LAST FALL, THE INSTITUTE BOARD OF DIRECTORS decided to change from the AMS to Springer in the publication of our two book series, the Fields Institute Monographs and the Fields Institute Communications. Although it was a difficult decision to make because of our long-standing arrangement with the AMS, we were excited by the opportunities afforded by publishing with Springer. Some of these are:

1. Springer has an electronic publishing program. Thus our Monographs and Communications series will now appear in traditional print form and in electronic editions as well.

2. Inexpensive versions (that Springer calls “MyCopy”) of all of our books will be available to members of an institution whose university library owns and/or subscribes to at least one Springer eBook Subject Collection. MyCopies are lower resolution, softcover versions, which cost $24.95 (including shipping and handling). Most universities do subscribe to such a collection.

3. Students and faculty associated with these universities will be able to download a pdf version of any of our books free of cost through SpringerLink on their library website.

4. Editorial work such as copy-editing and more of the formatting will be done by Springer, relieving the Institute staff of some of our responsibility.

5. Springer’s attitude towards publishing with the Institute is very flexible. For example Fields Institute authors can also publish in regular Springer series such as Lecture Notes in Mathematics and Springer Briefs if those series seem more appropriate to their work, and we anticipate that publication of summer school lectures and thematic program graduate courses will become more common.

The first Fields Institute Monograph with Springer, *Optimal Stochastic Control, Stochastic Target Problems and Backward SDE*, by Nizar Touzi (Ecole Polytechnique, Paris), will appear very soon. This book was developed from Touzi’s graduate course given during the 2010 Winter Thematic Program on Quantitative Finance: Foundations and Applications, and we hope that it will be the first of many future monographs derived from thematic program graduate courses.

The first Fields Institute Communications volume to appear will be *Lecture Notes on o-Minimal Structures and Real Analytic Geometry*, edited by Chris Miller, Jean-Philippe Rolin and Patrick Speissegger. It arises from the Winter 2009 Thematic Program of the same name.

Please keep the Fields Institute in mind when planning your publishing program!

Carl Riehm
Erik Demaine on Algorithms, Linkage Folding, and Geometric Puzzles

FOR ONE WEEK IN OCTOBER 2011, the Fields Institute was enlivened by a visit from Erik Demaine, who delivered three talks as part of the Distinguished Lecture Series for the Thematic Program on Discrete Geometry and Applications.

Demaine is a leader in the field of computational geometry, with research interests ranging throughout the broad field of algorithms, and has authored books on the theory of folding, and the complexity of games. In 2003, he joined the exclusive group of recipients of the MacArthur “Genius Awards,” a fellowship awarded for exceptional creativity. All this is made more impressive after factoring in his relative youth: now 30, he has held his PhD for a decade. He was hired at MIT immediately after graduating from the University of Waterloo, making him the youngest professor in the history of MIT. Despite all of his success, Demaine is undeniably down to earth, and his approachable, entertaining style made his three lectures at Fields very popular.

Demaine delivered his first talk, entitled Algorithms Meet Art, Puzzles and Magic, to a packed lecture theatre. There Demaine delighted an audience of varied backgrounds and ages with images, movies, demonstrations, stories, and of course, mathematics. He displayed beautiful and complex sculptures of folded paper, which are collaborative works with his father, Martin Demaine. Some of these extraordinary examples of mathematical origami belong to the permanent collection of the Museum of Modern Art (MoMA) in New York. A key idea underlying this talk was the notion that questions that at first may be purely artistic or recreational in nature can spark mathematical innovation and discovery. Conversely, artistic endeavors can facilitate the dissemination of mathematical ideas to a broader audience. In this case, the broad audience included a small but keen delegation from the “under-ten” set, who were willingly tied together only to be “magically” released.

In his second lecture, Linkage Folding: From Erdős to Proteins, Demaine talked about some problems related to linkages. He described some old problems dating back to Paucellier and Kempe, who showed that it is possible to create a mechanical linkage that signs your name (or indeed any algebraic curve). Demaine also discussed a problem due to Paul Erdős that states it is always possible to convexify an arbitrary polygon through a finite sequence of flips about its convex hull. He outlined the interesting history of attempted proofs of this statement, pointing out that there are only a handful of correct proofs among the many claimed solutions. Demaine interested some undergraduate students in the problem while struggling over several classes to find a correct proof of the statement, and finally proved a new (and correct) version with them. Demaine concluded this talk by describing the difficult problem of protein folding. It is not known how these fundamental building blocks of life fold from their one-dimensional ingredients into their three-dimensional form, or how they do it so quickly. Demaine suggests that the solution to this problem could be found using some of the ideas from linkages and related topics.

‘Demaine’ continued on page 18
Distinguished Lecture Series

Christophe Breuil on the $p$-adic Langlands Program and Fundamental Algebraic Representations

THE LOCAL $p$-ADIC LANGLANDS PROGRAM IS A relatively recent area of number theory that has quickly grown to be of central importance in the study of Galois representations and the arithmetic of automorphic forms and its ultimate aim to elucidate the appearance of $p$-adic Hodge theory on the Galois side by representation theoretical means. Such a program, initially developed under the impulse of Christophe Breuil, has now reached complete maturity for the reductive group $GL_2(\mathbb{Q}_p)$ thanks to the work of Breuil, Berger, Colmez, Kisin, Emerton, Paskunas, and others.

Nevertheless, the situation for other groups is far from clear, and the Distinguished Lecture Series given by Christophe Breuil was devoted to illustrating recent work (joint with Florian Herzig in Toronto) giving strong evidence for such a correspondence for an extensive class of reductive groups over $\mathbb{Q}_p$.

The lectures began with a general overview of the classical local Langlands correspondence for $GL_n$ and its relation with the $p$-adic program. If $\ell$ is a rational prime different from $p$ and $E$ is a finite extension of $\mathbb{Q}_p$, with ring of integers $\mathcal{O}_E$ and residue field $k_E$, the local Langlands correspondence for $GL_n(\mathbb{Q}_p)$ is a “natural” bijection

$$
\begin{align*}
\text{smooth absolutely irreducible representations} & \quad \leftrightarrow \quad \text{smooth semi-simple Weil-Deligne representations over } \mathcal{O}_E \text{-vector spaces} \\
\text{of } GL_n(\mathbb{Q}_p) & \quad \text{over } E \text{-vector spaces}
\end{align*}
$$

(1)

A smooth Weil-Deligne representation is a representation of the Weil group of $G_{\mathbb{Q}_p} \cong \text{Gal}(\overline{\mathbb{Q}}_p/\mathbb{Q}_p)$, with open kernel and endowed with a convenient nilpotent morphism. On the other side, a smooth representation of $GL_n(\mathbb{Q}_p)$ is the datum of a continuous action of $GL_n(\mathbb{Q}_p)$ on an $E$-vector space endowed with the discrete topology.

Such correspondence can furthermore be realized in the cohomology of local systems on simple Shimura varieties and it is compatible with the reduction modulo $\ell$ of coefficients ($\ell$-modular correspondence).

The smoothness properties of the objects involved in (1) show that there are no topological issues in the $\ell$-adic correspondence. Indeed, by classical results of Grothendieck and Deligne, the datum of a continuous Galois representation on finite dimensional $E$-vector spaces is equivalent to the datum of a smooth integral Weil-Deligne representation. Similarly, work of Vignéras shows that there is a bijection between smooth irreducible representations of $GL_n(\mathbb{Q}_p)$ that are integral (i.e. admitting an $\mathcal{O}_p$-invariant lattice) and unitary topological irreducible Banach space representations for $GL_n(\mathbb{Q}_p)$. The hypothesis that $\ell \neq p$ is crucial in order to have this topological dictionary.

Therefore, it is equivalent to restate correspondence in topological terms as a natural bijection between semisimple continuous Galois representation on $n$-dimensional $E$-vector spaces and topologically irreducible unitary Banach space representations of $GL_n(\mathbb{Q}_p)$.

A goal of the $p$-adic Langlands program is to investigate the nature of such a bijection for $\ell = p$. In this case the topological problems are extremely subtle: for instance, it is known by the work of Fontaine that the Weil-Deligne representation associated to a smooth $GL_n(\mathbb{Q}_p)$-representation is not sufficient to determine a continuous $p$-adic Galois representation uniquely. Already in the case of $GL_2(\mathbb{Q}_p)$, the phenomenology of the $p$-adic Langlands correspondence appears to be completely new: for instance, if $\Pi(\rho)$ is the unitary Banach space representation associated to a $p$-adic 2-dimensional Galois representation by the construction of Colmez, one can show that the subspace of $\Pi(\rho)$ formed by smooth vectors can be zero. Moreover, $\Pi(\rho)$ can be reducible; indeed, if $\chi_1, \chi_2$ is a generic pair of smooth $k_E$-valued characters of $\mathbb{Q}_p^*$, we have

$$
\rho \sim \begin{bmatrix} \chi_1 & * \\ 0 & \chi_2 \end{bmatrix}
$$

where $\chi_i$ are $p$-adic characters, $G = GL_2(\mathbb{Q}_p)$, $B$ is the Borel subgroup of lower triangular matrices and $\Pi(\rho)$ is the smooth $p$-modular representation associated to $\rho$ by Colmez’s construction.

The second and the third lectures were devoted to widen this picture to more general linear groups over $\mathbb{Q}_p$. For the sake of simplicity we restrict ourselves to the case of $G = GL_n(\mathbb{Q}_p)$ and representations over $k_E$-vector spaces. We fix a Borel subgroup $B \subset G$, a maximal split torus $T \subset B$, we write $R^+$ for the corresponding choice of positive roots and $W$ for the Weyl group of $G$.

More precisely, $\Pi(\rho)_{\text{ad}}$ is conjectured to be the maximal sub-representation of $\Pi(\rho)$ whose Jordan-Hölder constituents are formed by principal series representations (whose nature is nowadays completely understood by the work of Herzig and Ollivier).

Stefano Morra (Fields Institute)

To read an expanded version of the article, please visit www.fields.utoronto.ca/press/DLS_Breuil.pdf
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* over several years
The (universal) simultaneous extension property, Finiteness of this invariant has been established for many important classes of spaces (e.g., for doubling metric spaces, Gromov hyperbolic spaces of bounded geometry and generalized hyperbolic spaces). Other approaches to these problems have been suggested by Urs Lang and Thilo Schlichenmaier, based on the notion of the Nagata dimension, and by James Lee and Assaf Naor, based on random partitions of metric spaces.

POSSIBLE FUTURE DIRECTIONS AND DEVELOPMENTS

The Focus Program on Whitney Problems aims towards progress on the following problems:

- finiteness principle for traces of functions from Sobolev spaces;
- extension and trace problems for geometric classes (e.g., subanalytic, semialgebraic, Ahlfors regular, etc.);
- description of Sobolev extension domains;
- finiteness principle and simultaneous extension for functions from generalized Zygmund spaces;
- simultaneous Lipschitz extension property for certain classes of metric spaces (e.g., hyperbolic metric spaces in the sense of A.D. Aleksandrov, finitely presented groups with word metrics, etc.).

Participants will be invited to suggest open problems and questions before the Program begins, and these will be posted on the Program website. These include specific problems on which there is hope of making progress during the Program, as well as more ambitious problems that may influence future activity in the field. Lectures will familiarize participants with the background material leading up to specific problems, and the schedule will include discussion and parallel working sessions.

There will be mini graduate courses by Charles Fefferman, on “Whitney Trace and Extension Problems for Spaces of Smooth Functions”, and by Urs Lang (ETH Zürich) on “Absolute Lipschitz Retracts”. Assaf Naor (Courant Institute) will give a Coxeter Lecture Series associated with the Program. Please see the detailed description of the Focus Program on Whitney Problems on the Fields website.

Alex Brudnyi (University of Calgary)

more subtle. For instance, by deep work of Shelah,
\[ \aleph_\omega \leq \max(2^{\aleph_0}, \aleph_\omega) \]

The extent to which Shelah’s result is sharp has long been a celebrated open problem in the field: Can \( \aleph_\omega \) be reduced to \( \aleph_\omega \)? Recent work of Moti Gitik indicates that this may not be possible and utilizes sophisticated techniques that combine the method of forcing with that of large cardinals. The interaction between large cardinals and forcing is one the main themes of the third workshop.

We extend an invitation to the mathematical community in Toronto to come and talk to a set theorist this autumn. Do you know of a problem that might be independent of ZFC?

Justin Moore (Cornell University)

The final talk in this lecture series, Geometric Puzzles: Algorithms and Complexity, addressed the question of puzzles or games that can be solved efficiently using computer algorithms. In particular, Demaine focused on puzzles with a geometric flavour, including such popular games as Tetris and the Rubik’s cube. A team of researchers has recently demonstrated that the diameter of the graph of all possible configurations of the Rubik’s cube is 20. That is, given the Rubik’s cube in any configuration, 20 moves will always suffice to bring the cube back to its initial position, and examples exist to show that 20 moves are sometimes necessary. Due to the huge number of possible configurations of the Rubik’s cube—more than 43 quintillion configurations—Demaine posits that no similar result will be determined for even the 4 x 4 x 4 Rubik’s cube, let alone the largest Rubik’s cube in existence, the 17 x 17 x 17 cube.

Despite the vast range of topics presented in the three lectures, perhaps the most striking feature of Demaine’s talks was his enthusiasm for the subjects he studied, and his willingness to share this with his audience. In trying to understand how he has accomplished so much in so little time, one might conclude it’s his deep passion for the subjects he studies that allows him to blur the line between his work and his hobbies, and contribute to his prolific research record. During one of his talks he recalled a moment during graduate school in which he was given advice to “stop working on games and start thinking about serious problems.” He did not heed this advice, and this has not hindered him in the slightest. Demaine has carved out a substantial niche for his work within the body of mathematical research, and has generated sufficient gravity to attract many others to the area. Indeed, the scope of his research is impressive. But more than that, his enthusiasm for all of his pursuits is infectious.

Elissa Ross (York University)
accurate mathematical models of the heart, the brain, blood flow, or the spread of tumours, from data obtained from the solution of some of the imaging methods mentioned above.

The conference featured:
- 20 plenary lectures by some of the most distinguished world researchers in the field
- 16 special sessions on a broad range of active research areas
- An industry-academia connector event (hosted by Mitacs), coupled with a graduate student poster session.

To give an indication of the scope of the conference, these are some of the topics covered by the plenary lectures and the special sessions:
- Compressed Sensing in Medical Imaging
- Geometry of Spaces of Diffeomorphisms in Computational Anatomy
- Statistical Analysis on Riemannian Manifolds
- New Hybrid Imaging Modalities (Photoacoustic Tomography, Elastography, Current Density Impedance Imaging, Thermoacoustic Tomography)
- Dynamic Image Analysis
- Imaging Electric Tissue Properties
- Computational Hemodynamic Imaging
- Numerical Methods in Medical Imaging
- Cardiac Segmentation and Registration
- Brain Imaging
- Magnetoencephalography
- Recent Progress in Tomography
- Personalization of Differential Equations for Cardiac Electrophysiology
- Statistical Methods in Medical Imaging
- Graph-theoretic methods in Medical Imaging
- Industrial Applications
- Mathematical Methods in Biophotonics.

Slides of the talks and audio recordings of the plenary lectures can be found at www.fields.utoronto.ca/programs/scientific/10-11/medimaging/.

The industry-academia afternoon featured a special plenary talk by David Jaffray (Ontario Cancer Institute), who presented some of the success stories achieved in Toronto by close and well-planned collaboration between academic inventors and medical instrumentation manufacturers. He also highlighted health sector opportunities for postgraduates with strong mathematical backgrounds. The networking lunch and poster session were well attended and provided a great atmosphere for informal interactions between the representatives from Ontario medical imaging companies and junior and senior conference participants.

The posters were well received and covered a wide range of topics in various imaging modalities. A panel of seven international experts selected the top three posters for prizes based on their scientific content, clarity and effectiveness of presentation, and significance for medical imaging. The first poster prize was awarded to Thermophotonic imaging: a novel diagnostic imaging methodology for detecting early caries in human teeth presented by Nima Tabatabaei (University of Toronto). Second prize went to A comprehensive study of differential diagnosis among Alzheimer's disease, frontotemporal disease and healthy aging presented by Pradeep Reddy Ramana (Simon Fraser University), and third prize was for Real time compressive sampling based FDOCT image acquisition and registration by Evgeniy Lebed (Simon Fraser University).

The conference was a spectacular success. It attracted more than 200 participants from a broad spectrum of disciplines, ranging from pure mathematics to clinical imaging (including 45 researchers from hospital centers in Canada, U.S., Europe, and Asia). Experts in various aspects of pure or applied medical imaging were excited by the wealth of ideas and novel techniques presented in the top level talks from different areas. Graduate students, some of whom confessed initial trepidation about the conference being "too theoretical," were surprised and inspired by how much they learned.

Dhavide Aruliah (University of Ontario Institute of Technology), Adrian Nachman (University of Toronto), and Hongmei Zhu (York University)
For more information about our activities, please visit www.fields.utoronto.ca/programs

JUNE 5 – JULY 3, 2012
Sojourns in Nonlinear Economics
Held at the Fields Institute

JUNE 11 – 16, 2012
12th Canadian Summer School on Quantum Information
Held at the Institute for Quantum Computing, Waterloo

JUNE 18 – 22, 2012
9th Canadian Student Conference on Quantum Information/2nd AQuA Graduate Student Congress on Quantum Information and Computation
Held at the Institute for Quantum Computing, Waterloo

JUNE 18 – 22, 2012
Workshop on the Corona Problem: Connections Between Operator Theory, Function Theory and Geometry
Held at the Fields Institute

JUNE 20, 2012
Back2Fields Colloquium Series: Brett Wick (Georgia Tech)
Held at the Fields Institute

JUNE 24 – 28, 2012
The 2012 Annual Meeting of the Canadian Applied and Industrial Mathematics Society (CAIMS)
Hosted by Fields Institute at the University of Toronto

JUNE 24 – JULY 6, 2012
2012 Séminaire de Mathématiques Supérieures
Held at CRM, Montreal

JUNE 25 – 28, 2012
Workshop on Relativistic Quantum Information
Held at the Perimeter Institute

JULY 3 – AUGUST 24, 2012
Fields-MITACS Undergraduate Summer Research Program
Held at the Fields Institute

JULY 3 – 6, 2012
Fields-MITACS International Symposium Asymptotic Methods in Stochastics
Held at Carleton University

JULY 3 – 6, 2012
Workshop on Algebraic Monoids, Group Embeddings and Algebraic Combinatorics
Held at the Fields Institute

JULY 5, 2012
PUBLIC LECTURE: Why the Crisis is Not Over
Steve Keen (University of Western Sydney)
Held at the Fields Institute

JULY 19 – 21, 2012
International Workshop on New Advances in Statistics
Held at the University of Manitoba

JULY 23 – 27, 2012
Workshop on Discrete and Computational Geometry
Held at Carleton University

AUGUST 8 – 10, 2012
24th Canadian Conference on Computational Geometry
Held in Charlottetown, PEI, Supported by the Fields Institute

AUGUST 9 – 10, 2012
Fifth International Conference on Similarity Search and Applications (SISAP 2012)
Held at the Fields Institute

AUGUST 12 – 25, 2012
Two Weeks at Waterloo: A Summer School for Women in Math
Held at the University of Waterloo

AUGUST 21 – 24, 2012
Infinite Dimensional Lie Theory: Algebra, Geometry and Combinatorics
Held at CRM, Montréal
Mathematics of Planet Earth 2013

The Fields Institute invites proposals for activities related to the 2013 year of emphasis on the Mathematics of Planet Earth. Mathematics plays a key role in many of the processes affecting Planet Earth, both as a fundamental discipline and as an essential component of multidisciplinary and interdisciplinary research. We encourage proposals for events connecting mathematics with areas such as natural disasters, resource management, transportation, energy production and utilization, the World Wide Web, health care delivery, climate change, sustainability, and control of disease and epidemics.

For more information on the Mathematics of Planet Earth 2013, please visit: www.mpe2013.org

THEMATICAL AND FOCUS PROGRAMS

The Fields Institute solicits proposals for a variety of programs in areas of current research interest in the mathematical sciences: (1) Major thematic programs, six months in length. (2) Thematic or focus programs, from one to two months in length to run concurrently with our major thematic programs; in particular, two-month summer programs of an interdisciplinary nature. Proposals or letters of intent should be submitted by March 15 or September 15, with a lead time of at least two years recommended for six-month programs.

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.

POSTDOCTORAL FELLOWSHIPS

The Fields Institute's Postdoctoral Fellowships provide for a period of research activity at the Institute and participation in our programs. We are currently soliciting applications for Fields Postdoctoral Fellowships and Jerrold E. Marsden Postdoctoral Fellowships. Qualified candidates who will have a recent PhD (awarded normally not more than five years before tenure of the Fellowship) are encouraged to apply.

OUTREACH PROPOSALS

The Fields Institute 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 are invited to submit a proposal to the Fields Outreach Competition. There are two submission deadlines each year, June 1 and December 1. Proposals should include a detailed description of the proposed activity and the target audience. A budget indicating other sources of support is also required.

CRM-FIELDS-PIMS PRIZE NOMINATIONS

The CRM-Fields-PIMS Prize is the premier Canadian award 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. Nominations for the 2013 CRM-Fields-PIMS Prize should be sent to PIMS. Please send nominations no later than November 1, 2012.

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### CURRENT THEMATIC AND FOCUS PROGRAMS

#### THEMATIC PROGRAM ON GALOIS REPRESENTATIONS AND AUTOMORPHIC FORMS
**January – June 2012**

Organizers: Frank Calegari (Northwestern), Matthew Emerton (Chicago), Florian Herzig (Toronto), Mark Kisin (Harvard), Stephen Kudla (Toronto)

- **January – April, 2012**
  - Graduate Course on Deformation theory, Galois Representations, and Automorphic Forms and Course on the mod $p$ representation theory of $p$-adic groups
- **February 29 – March 2, 2012**
  - Coxeter Lecture Series: Michael Harris (Université Paris 7)
- **March 12 – 16, 2012**
  - Workshop on Galois Representations, Shimura Varieties, and Automorphic Forms
- **March 19 – 23, 2012**
  - Workshop on Cohomology of Shimura Varieties: Arithmetic Aspects and the Construction of Galois Representations
- **April 18 – 20, 2012**
  - Distinguished Lecture Series: Christophe Breuil (Université Paris-Sud)
- **February 29 – March 2, 2012**
  - Workshop on the $p$-adic Langlands program: Recent Developments and Applications

#### THEMATIC PROGRAM ON INVERSE PROBLEMS AND IMAGING
**January – August 2012**

Organizers: Tony Chan (Hong Kong U. of Science and Technology), Charles Epstein (Pennsylvania), Allan Greenleaf (Rochester), Yaroslav Kurylev (University College London), Jan Modersitzki (Lübeck), Adrian Nachman (Toronto), Gunther Uhlmann (Washington), Luminita Vese (UCLA)

- **January 9 – April 6, 2012**
  - Graduate Course on Mathematics of Medical Imaging (A. Nachman) and Graduate Course on Inverse Transport Theory and Tomography (A. Tamasan)
- **March 26 – April 27, 2012**
  - Theme Period on Geometry in Inverse Problems
- **April 30 – May 31, 2012**
  - Theme Period on Variational Methods and Compressive Sensing in Imaging
- **May 7 – 9, 2012**
  - Distinguished Lecture Series: Emmanuel Candès (Stanford)
- **July 3 – 31, 2012**
  - Summer Research School on the Mathematics of Medical Imaging
- **August 13 – 17, 2012**
  - Workshop on Microlocal Methods in Medical Imaging
- **August 20 – 24, 2012**
  - Industrial Problem-Solving Workshop on Medical Imaging

#### FOCUS PROGRAM TOWARDS MATHEMATICAL MODELING OF NEUROLOGICAL DISEASE FROM CELLULAR PERSPECTIVES
**May 14 – June 15, 2012**

Organizers: Larry Abbott (Columbia), Sue Ann Campbell (Waterloo), Nancy Kopell (Boston), Frances Skinner (TWRI/UHN and Toronto), David Terman (Ohio State)

- **May 15 – 17, 2012**
  - Mathematical Neuroscience and Neurobiology Introductory Courses
- **May 24 – 25, 2012**
  - Schizophrenia Workshop
- **May 22 – 23, 2012**
  - Parkinson’s Disease Workshop
- **May 29 – 30, 2012**
  - Epilepsy Workshop
- **May 31 – June 1, 2012**
  - Alzheimer's Disease/Pharmaceuticals Workshop
- **June 4 – 5, 2012**
  - Anesthesiology/Sleep Disorders Workshop
UPCOMING THEMATIC AND FOCUS PROGRAMS

FOCUS PROGRAM ON GEOMETRY, MECHANICS AND DYNAMICS: THE LEGACY OF JERRY MARSDEN

July 2012

Organizers: Dong Eui Chang (Waterloo), Darryl Holm (Imperial College), George W. Patrick (Saskatchewan), Tudor Ratiu (Bernoulli Center)

July 2 – 6 and July 9 – 13, 2012
Focus on Geometric and Structure Preserving Integration

July 16 – 20, 2012
Informal collaborations and Mechanics and Geometry in Canada (MAGIC) Summer School

Focus on Control and Nonholonomic Mechanics, Geometric Fluid Dynamics and Elasticity, Field Theory and Relativity

FOCUS PROGRAM ON WHITNEY PROBLEMS

August–September 2012

Organizers: Alexander Brudnyi (Calgary), Charles Fefferman (Princeton), Pierre Milman (Toronto), Nahum Zobin (William and Mary)

August 27 – 31, 2012
Workshop on Whitney type extension and trace problems

August 28 – 30, 2012
Distinguished Lecture Series: Assaf Naor (Courant Institute)

September 4 – 7, 2012
Graduate Course on Whitney Trace and Extension Problems for Spaces of Smooth Functions on \( \mathbb{R}^n \) (C. Fefferman) and Graduate Course on Absolute Lipschitz Retracts (U. Lang)

THEMATIC PROGRAM ON FORCING AND ITS APPLICATIONS

Fall 2012

Organizers: Andreas Blass (U. Michigan), Alan Dow (North Carolina, Charlotte), Justin Tatch Moore (Cornell), Juris Steprans (York), Stevo Todorcevic (Toronto)

September 10 – 14, 2012
Workshop on Applications to Operator Algebras

October 22 – 26, 2012
Workshop on Forcing Axioms and their Applications

November 12 – 16, 2012
Workshop on Iterated Forcing and Large Cardinals

October/November 2012
Distinguished Lecture Series: Matthew D. Foreman (UC Irvine)

Semester-long
Graduate Course on Forcing (A. Dow) and Graduate Course on Large Cardinals (P. Larson)
Message from the Director

A spring that began very early and then remained calm and cool until mid-May has made the streets around the Fields Institute particularly beautiful this year. Spring flowers lasted for weeks and the trees leafed out gently. Queen's Park, the University of Toronto Campus and the residential streets south of Fields are now in full summer green. Visitors to the Institute have been enjoying the cafes along College and Baldwin Streets.

There have been many visitors this spring. The Fields Institute has been running two Major Thematic Programs, on Galois Representations and on Inverse Problems and Imaging. We have had to supplement Institute space by using lecture rooms in nearby university buildings in order to accommodate all of the activities. Remarkable this year has been the number of students attending the workshops in both programs, and the efforts made by brilliant scientists to reach out with inspirational lectures that were both at the frontiers of fast-developing areas and, at the same time, accessible to students and novice researchers.

The past couple of months have been truly exceptional. In addition to the activities above, the Institute hosted short courses by Fields Board member Charlie Fefferman (Princeton) and Gunther Uhlmann (UC Irvine), again in the Inverse Problems Program, a Distinguished Lecture Series by Christophe Breuil (Orsay) in Galois Representations, the Keyfitz Lecture in Mathematics and Social Sciences by Stephen Fienberg (Carnegie Mellon) on Counting the People, and a terrific public lecture by Avi Wigderson (Institute for Advanced Study) on Randomness (the Avner Magen Memorial Lecture of the University of Toronto’s Computer Science Department)!

The Galois Representations Program is now winding down, and Inverse Problems is gearing up for a Summer Theme Period on The Mathematics of Medical Imaging, which will include a Summer Research School and an Industrial Problem-Solving Workshop on Medical Imaging in collaboration with Mitacs. We anticipate further synergy between these activities and the third annual Fields-Mitacs Undergraduate Summer Research Program. Mathematics in medical research is a current highlight of activity at the Fields Institute; in addition to the preceding, we are running a one-month Focus Program on Towards Mathematical Modeling of Neurological Disease from Cellular Perspectives, bringing together participants with clinical, experimental, modeling and mathematical perspectives.

The activities above reflect the ways that the Institute best fulfills its mandate to advance research and communication in the mathematical sciences—by bringing brilliant people to inspire, and by organizing programs that cut across boundaries. We have been encouraging programs within which there is a broad span of activity, from fundamental mathematics to deep connections with computation and applications, and from leading-edge research to the training of students to industrial collaboration.

Both of the upcoming major programs recently approved by our Scientific Advisory Panel promise to continue this trend—Mathematics of Oceans, scheduled for May–June 2013 as part of the international Mathematics of Planet Earth initiative, and Variational Problems in Physics, Economics and Geometry, to take place July–December 2014. Please stay tuned to the Fields website for information about these and other upcoming programs.

Recent visitors to our website will have noticed a yellow “FieldsLive” tag attached to certain events. The tag announces that the event is available for live interactive viewing via the brand-new FieldsLive Streaming System, created by our Director of Computing Services Philip Spencer. This system has two unique features: You can choose your own view—click to zoom in or out, and pan from side to side—and, for selected events, you can participate remotely, asking questions as if you were present, using only a web browser and webcam. The system is still undergoing development and testing. It most recently tested very successfully in Wigderson’s lecture—the live broadcast attracted remote viewers from as far away as Israel. When FieldsLive is fully operational, it will be available for most of our activities; in particular, for remote interactive participation by students of Fields partner universities in graduate courses given at the Institute.

FieldsLive is an important new way to help the Institute work together with the world scientific community and, in particular, with our growing circle of partner universities. The Institute’s partners are crucial to the success of our programs. We are very pleased that the Organizing Committees of Fields’ major programs scheduled for the next couple of years include representatives of every one of our Principal Sponsoring Universities.

This is the beginning of the Fields Institute’s Twentieth Anniversary Year. Anniversary activities will kick off in July with a Focus Program on Geometry, Mechanics and Dynamics—The Legacy of Jerry Marsden, the Institute’s first Director. The Back2Fields Colloquium will highlight the achievements of rising young scientists whose careers were launched by their participation as postdocs in Fields programs. The inaugural Fields Medal Symposium will take place October 15–18, 2012. The Symposium has received tremendous support, and we are delighted to acknowledge Great-West Life, London Life and Canada Life as a Gold-Level Sponsor.

The academic year 2011–12 has been a year of wonderful scientific growth of the Fields Institute. In a period of financial restraint by governments at all levels, it has also been a challenging year. The Institute’s greatest strength is the people who plan and participate in our programs, oversee and staff our operations, and provide dedicated support. With your ongoing help, the Fields Institute will continue to flower.

Edward Bierstone