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Pacific Institute for the Mathematical Sciences

Looking Towards the Future

This is a 10th anniversary issue and the question naturally arises: what is PIMS going to look like in 10 years? Now generally, what is the scientific world going to look like in 2017?

It seems to us that, by that time, problems arising from the global effects of human activity will feature much more prominently in the scientific agenda than they do now. Understanding and mitigating global warming, preserving biodiversity and natural resources, preventing new infectious diseases from arising and spreading, creating the conditions of fair economic development and just societies around the world, all these challenges will have to be dealt with, and all of them have some component of mathematical modeling.

This is where PIMS wants to go. Three of the CRGs we will open in 2007 are oriented towards the environment. But no institute, in fact no country by itself can make a significant contribution to solving such problems. This is really a problem for global scientific networks, stretching across oceans and boundaries. PIMS by itself is a regional network, and we are now associating with others to create international networks. In 10 years, we hope that the PRIMA network, which is barely one year old, will have become a global enterprise for training and research in emerging areas of mathematics. We also hope that PIMS will have become an active part of the CNRS network and through the CNRS a member of the European research community. In this way PIMS will stand as a gateway, a crossroads between the Pacific Rim, the Americas and Europe, bringing different mathematical traditions to study global problems. Let this be our wish for the future.

Inside this issue

Fields Medals 2006

The 2006 Fields Medals were awarded on Aug. 22, 2006, at the International Congress of Mathematicians in Madrid. The winners are: Andrei Okounkov, for his contributions bridging probability, representation theory and algebraic geometry; Grigori Perelman, for his contributions to geometry and his revolutionary insights into the analytical and geometric structure of the Ricci flow (Dr. Perelman declined to accept the Medal); Terence Tao, for his contributions to partial differential equations, combinatorics, harmonic analysis and additive number theory; and Wendelin Werner, for his contributions to the development of stochastic Loewner evolution, the geometry of two-dimensional Brownian motion, and conformal field theory.

Andrei Okounkov

Please turn to page 4 for an article on Dr. Werner's work, and page 6 for an article on Dr. Okounkov's work, exclusive in this issue of the PIMS Newsletter.

Four New CRGs Approved by PIMS Scientific Review Panel

Please see page 3

PIMS partners with Cinvestav

PIMS is pleased to announce a new collaborative agreement with Centro de Investigación y Estudios Avanzados, Cinvestav (Center for Research and Advanced Studies), Mexico.

As part of the agreement, PIMS and Cinvestav will collaborate on research projects in the mathematical sciences. The institutes plan to hold joint events and conferences to facilitate the exchange of researchers and knowledge between Canada, the USA, and Mexico.

http://www.cinvestav.mx

Director's Notes

by Ivar Ekeland, PIMS Director

In this issue we will be celebrating the 10th anniversary of PIMS. It will be for others to say to what extent this new concept of a mathematical institute distributed across six different universities and an international border has been a success. What we can say is that during these 10 years, mathematics has changed, and PIMS is proud to have contributed to some of these changes.

The 2006 Fields Medalists have been announced, and PIMS is proud to have connections to three of this year's winners. The work of Terence Tao and Ben Green on arithmetic sequences of prime numbers was done while Ben Green was a PIMS postdoctoral fellow. Andreai Okounkov and Wendelin Werner have close collaborators at PIMS universities, who report on their award-winning work in this issue. These achievements stand out among so much excellent work that has been done within the Collaborative Research Groups over the past 10 years, in mathematical biology and in number theory, in inverse problems and in probability theory, and in so many other fields of pure and applied mathematics.

(l to r) Alejandro Adem, (PIMS Deputy Director), Ivar Ekeland (PIMS Director), Nassif Ghoussoub (BIRS Scientific Director and Past PIMS Director)

The past 10 years have also seen many structural changes in Canadian mathematics – the emergence of PIMS, of course, but also the creation of MITACS and BIRS. PIMS is proud to have been the driving force behind these changes. We feel that, with the three institutes (PIMS, CRM and the Fields Institute), MITACS, BIRS and the professional societies, Canada now has the necessary tools to sustain a vibrant research community in mathematics, and to connect mathematics with other disciplines, with industry, with education and with society in general.

This is no small feat. It would be extremely easy to have a purely academic community, incased in its ivory tower, or to have a community cut off from basic research, which is the heart and soul of mathematics. Any science that consists only of repeating what is already known, or applying old solutions to new situations, will soon wither and die. The Canadian mathematical community has found a unique and perhaps fragile equilibrium. The three institutes, MITACS, BIRS and the professional societies have all found their place in a complex network of relations and exchanges between universities, industry, education, provincial governments, federal agencies and the international scientific community.

I feel the time has come to think about institutional means to consolidate that equilibrium. NSERC has started a process of reforming the grant selection communities and this may be an opportunity. A global envelope for mathematics at NSERC would be the right frame work to develop a strategic vision for mathematics in Canada. It would also be an excellent observatory, where one could centralize information about the various aspects of mathematics in Canada, and develop indicators truly adapted to the unique position of mathematics as a non-experimental but pluri-disciplinary science.

Having appropriate institutions will be crucial for the future of mathematics in Canada – But let us put this aside for the time being and just enjoy mathematics. In this issue, you will find a paper by Jim Arthur on the history of the trace formula that he delivered as a PIMS 10th anniversary lecture. There is no subject that goes deeper into so many different areas of mathematics. You will also find a paper by François Lalonde on the future of mathematics and the role women will play. Both are remarkable papers, and I thank Jim and François for contributing them to the PIMS Newsletter.

What about the next 10 years? Much will depend, of course, on the outcome to the proposal we have submitted to NSERC for 2008-2013. I expect, however, our collaborations with Fields, CRM and MITACS to become ever closer. I expect PIMS to become a gateway to the Pacific Rim Countries, through the PRIMA network. Finally, I would like to announce that PIMS has applied to become an Unite Mixte Internationale of the French CNRS. This will truly put PIMS in a unique position, as a research centre belonging to Canada, the United States and France, and a scientific link between Europe and the Pacific Rim. Happy Birthday, PIMS!

Four New PIMS CRGs Approved at November SRP Meeting

by Alejandro Adem, PIMS Deputy Director

Since its inception, PIMS has fostered research across the entire spectrum of the mathematical sciences, including pure mathematics, computer science, statistics, physics and economics. PIMS aims to nurture the development of sustainable networks of researchers in exciting interdisciplinary subjects, where the emerging applications of mathematics beyond classical boundaries play an increasingly fundamental role.

PIMS has established its scientific leadership in North America by actively engaging top researchers in these emerging areas of mathematical applications and working with the researchers to develop large scale international Collaborative Research Groups (CRGs), through which thematic activities will have a wide and lasting impact on the mathematical community.

At its Nov. 4, 2006, meeting, the PIMS Scientific Review Panel approved funding for three interlocking CRGs, where the common overarching theme is the mathematics of climate and the environment. In a time of growing concern about climate change, the enhanced development of effective mathematical and statistical methods to model the environment is truly compelling. Our three projects thread together different aspects of this theme, and they complement each other naturally. The potential synergy of the thematic activities is enormous, and the combined impact will establish PIMS as a worldwide leader in this important emerging area of mathematics.

CRG in Mathematical Problems in Climate Modeling: Multiscale Processes in the Tropics (2007-2010)

This CRG will be a multidisciplinary effort bringing together mathematicians and earth/ocean scientists to understand some of the many outstanding problems in climate modeling and numerical weather prediction. Particular emphasis will be placed on multiscale processes in the tropics, to bridge the gap between idealized models and the general circulation models used by government forecasters. One of the main objectives is to provide a venue for mathematicians and atmospheric scientists to interact, as well as to train young researchers in a fully interdisciplinary setting. It is based at UVic, the Canadian Centre for Climate Modeling and Analysis (CCCMA), SFU, UA and UBC, with the participation of Austin (UBC), Bush (UA), Khouider (UVic), McFarlane (CCCMA), Merryfield (CCCMA), Monahan (UVic), Muraki (SFU), Scinocca (CCCMA), Sutherland (UA), von Salzen (CCCMA) and Weaver (UVic).

CRG in Interdisciplinary Research in Geophysical and Complex Fluid Dynamics (2007-2010)

The primary focus of this CRG is the mathematical modeling of complex and classic geophysical fluid dynamics, which are key elements in many geophysical phenomena such as volcanic eruptions, mud slides and avalanches. Bringing sophisticated mathematical and computational elements to bear on these problems is the main motivation for this project, which will involve geophysicists as well as applied mathematicians. Particular emphasis will be on complex geophysical fluids, multiphase flow in volcanic systems, waves in geophysical fluids, and particle-driven geophysical flow. Activities will include lecture series by distinguished visiting scientists, workshops, collaborative research visits and postdoctoral and graduate student training. It is based at UA, UBC and SFU, with the participation of Balmforth (UBC), Bergantz (UW), d'Asaro (UW), Frigaard (UBC), Gingras (UA), Hsieh (UBC), Hungr (UBC), Jellinek (UBC), Kunze (UVic), Lawrence (UBC), Milewski (U. Wisconsin), Moodie (UA), Muraki (SFU), Parsons (UW), Rhines (UW), Sutherland (UA) and Tung (UW).

CRG in Environmetrics: Georisk and Climate Change (2007-2010)

The eventual goal of this CRG is to develop a multisite, distributed environmetrics research centre. The main research themes are statistical and deterministic models in georisk analysis, modeling space-time fields, agroclimate risk analysis, environmental quality assessment (with emphasis on water and linkages to agriculture and species at risk), and modeling changes in the diversity and structure of forests as a consequence of climate change. This project will enable the strong statistics community in the Pacific Northwest to address important environmental questions where deterministic and statistical models are critically important. It will be based at UW, UBC and SFU, with the participation of Bingham (SFU), Brauer (UBC), Braun (U. Western Ontario), Brillinger (UC Berkeley), Campbell (UBC), Dean (SFU), El-Shaarawi (McMaster), Esterby (UBC Okanagan), Gill (UBC Okanagan), Guttorp (UW), Hawkins (UNBC), He (UA), Heckman (UBC), Hergel (Duke U), Johnson (UC), Lindgren (Lend U), Le (UBC), Loeppky (UBC Okanagan), Martell (U Toronto), Nathoo (UVic), Petkau (UBC), Ramsey (McGill), Reed (UVic), Routledge (SFU), Sampson (UW), Schwartz (SFU), Shen (San Diego), Steyn (UBC), Welch (UBC) and Zidek (UBC).

At the same time, PIMS has a long tradition of supporting excellence in pure mathematics. The SRP gave enthusiastic approval for funding a period of concentration for the new CRG in Differential Geometry and Analysis. The main theme is geometric analysis, which is recognized as one of the hottest areas of mathematics in light of the role it has played in the solution (by G. Perelman, recent Fields Medallist) of the Poincaré Conjecture, which was recently named the top scientific achievement of 2006 by the journal *Science*. PIMS will sponsor a wide range of international activities in this area, under the scientific leadership of excellent geometers at UBC and UW.

CRG in Differential Geometry and Analysis (2007-2010)

The general theme of this CRG is the use of analytical methods to solve geometric problems, such as constructing special submanifolds of given manifolds: minimal hypersurfaces, which are important in the study of Khler manifolds or Calabi-Yau manifolds; hypersurfaces of constant mean curvature, which are important in general relativity. It is hoped, for instance, to determine to which extent spacetimes with non-constant mean curvature Cauchy surfaces are prevalent among solutions of the Einstein equations. The CRG will be based at UBC, SFU and UW, with the participation of Chen (UBC), Fraser (UBC), Graham (UW), Lee (UW), Oberman (SFU), Pollack (UW), Toro (UW) and Yuan (UW).

A full description of all the CRG activities, which will include workshops, summer schools, graduate training programs and postdoctoral fellowships, will be available on the PIMS website at http://www.pims.math.ca/Collaborative_Research_Groups/.

In addition to the new CRGs, the PIMS SRP approved 20 individual events in many different areas of mathematics. Details can be found on the PIMS website.

As can be easily seen, these are all exciting, high quality programs which will further establish PIMS scientific programs as among the most innovative in North America. They represent the high value we assign to interdisciplinary mathematical research, as well as our commitment to supporting high quality fundamental research in pure mathematics.

Fields Medalist 2006: Wendelin Werner

by Gordon Slade, University of British Columbia

Wendelin Werner

Wendelin Werner, Professor at the Université Paris-Sud (Orsay), member of the Institut Universitaire de France, and part-time Professor at the Ecole Normale Supérieure, was awarded the Fields Medal at the 2006 International Congress of Mathematicians in Madrid. According to the citation, the Medal was awarded "for his contributions to the development of the stochastic Loewner evolution, the geometry of two-dimensional Brownian motion, and conformal field theory."

Werner has been a leading figure in the remarkable advance in our understanding of two-dimensional critical phenomena which has taken shape during the last eight years or so. The theory of critical phenomena is a central part of statistical mechanics and is intertwined with the study of phase transitions. It has been an important branch of probability theory for decades. The subject studies apparently diverse phenomena such as ferromagnetism (Ising and Potts models), the structure of polymer molecules (the self-avoiding walk), and the percolation of fluid through a random medium (percolation theory). These phenomena can be modelled in two or three or higher dimensions, and their behaviour is dimension-dependent. The work of physicists had indicated that the two-dimensional case is particularly rich and intriguing, due to a connection with conformal invariance which they understood using conformal field theory and the theory of quantum gravity. But despite the profound insights from physics, the role of conformal invariance in two-dimensional critical phenomena remained mysterious to mathematicians, and most of the major mathematical problems remained wide open.

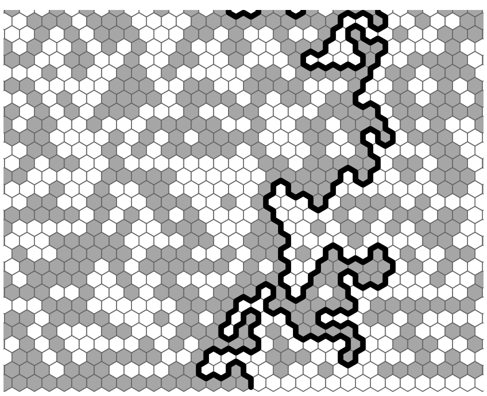


Figure 1: The lower row of hexagons is half black and half white, and the hexagons in the upper half plane are independently white with probability ½ and black with probability ½. The exploration process emerges from the lower row keeping a black hexagon on its left side and a white hexagon on its right side. In the limit of vanishingly small hexagons, the exploration process converges to SLE_6, and describes the phase boundaries in critical site percolation on the triangular lattice. (Illustration by Bill Casselman.)

Werner, his collaborators Greg Lawler and Oded Schramm, and others have now shed a bright light on the mathematics of two-dimensional critical phenomena and the associated conformal invariance. Their work illuminates also the physics, with its introduction of a new geometric framework which directly describes the random fractal curves that are the phase boundaries in the various models. This new framework is based on a marvellous and highly original discovery of Schramm known as SLE_κ (the stochastic Loewner evolution with parameter κ, or, often, the Schramm–Loewner evolution). The theory of SLE is a rich blend of probability theory and classical complex analysis, which analyzes the growth of random fractal curves in the half-plane via the evolution of the conformal map that maps the half-plane minus the growing curve onto the half-plane itself. Tom Kennedy's webpage (http://math.arizona.edu/~tgk/) contains many pictures of SLE. The parameter κ in SLE_κ has a great unifying effect, as variation of κ corresponds to a change in the physical model. For example, the value $\kappa=6$ corresponds to percolation, $\kappa={}^8/_3$ corresponds to the self-avoiding walk, $\kappa=2$ corresponds to the loop-erased random walk, and $\kappa=8$ corresponds to the uniform spanning tree.

Figure 2: A Brownian path in the plane. Its external boundary is the "outer edge" of the path, or, more technically, the set of points in the path that are in the closure of the unbounded connected component of its complement. The external boundary was proved by Lawler-Schramm-Werner to have Hausdor dimension ${}^4/_3$, with probability 1. (Illustration by Bill Casselman.)

In 2001, Stanislav Smirnov proved conformal invariance for critical site percolation on the triangular lattice. Combined with work of Lawler, Schramm and Werner, this led to description of the model's phase boundaries by SLE_6. This was extended by Smirnov and Werner, using a result of

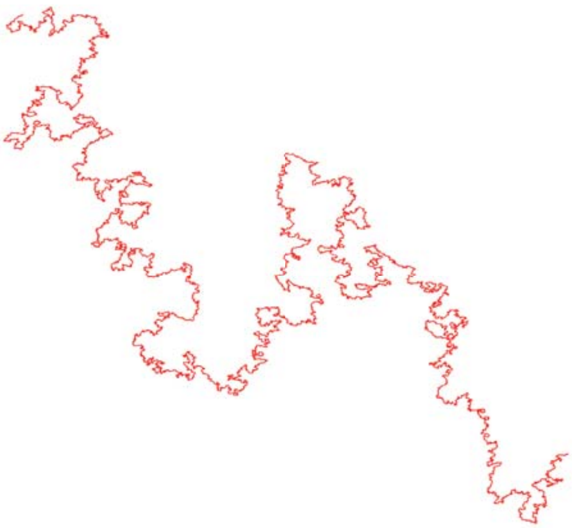


Figure 3: A one-million-step self-avoiding walk in the plane. Lawler-Schramm-Werner have provided convincing evidence that the scaling limit should be described by $SLE_{8/3}$, but it remains an open problem to prove existence of the scaling limit. (Illustration by Tom Kennedy.)

Harry Kesten, to prove existence and compute the values of the critical exponents that govern the percolation phase transition. This was one of the many triumphs of the theory. Another was the use of SLE by Lawler, Schramm and Werner to prove Mandelbrot's conjecture that the external boundary of a two-dimensional Brownian motion has Hausdorff dimension $^4/_3$. A third, which traces its origins back to work of Rick Kenyon, was the proof by Lawler, Schramm and Werner that SLE_2 and SLE_8 are the scaling limits of the two-dimensional loop-erased random walk and the two-dimensional uniform spanning tree, respectively.

The work of Werner and his collaborators has provided a new understanding of two-dimensional critical phenomena, has solved several of the important questions of the subject, and has opened up a rich new area of research. However, there is much that remains to be done. One major open problem is to provide a mathematical theory of universality. Universality can be understood as the statement that critical behaviour is independent of the precise microscopic details of how a model is defined. For example, site percolation on the triangular lattice should have the same critical behaviour as bond percolation on the square lattice.

But although site percolation on the triangular lattice is now well understood via SLE_6, the critical behaviour of bond percolation on the square lattice, which is believed to be identical, is not at all understood from a mathematical point of view. Kenneth G. Wilson was awarded the 1982 Nobel Prize in Physics for his work on the renormalization group which led to an understanding of universality within theoretical physics. However, there is as yet no mathematically rigorous understanding of universality for two-dimensional critical phenomena. Perhaps a future Fields Medal will be awarded when that is achieved.

Sur les travaux de Wendelin Werner

by Jean-François Le Gall, DMA - ENS

Les travaux du mathématicien français Wendelin Werner ont été récompensés par la prestigieuse Médaille Fields lors du dernier Congrès International des Mathématiciens qui s'est tenu à Madrid du 22 au 30 août 2006. Ancien élève de l'Ecole normale supérieure de Paris, Wendelin Werner a d'abord été chercheur au CNRS et il est depuis 1997 professeur à l'Université Paris-Sud (Orsay). Il est aussi membre de l'Institut Universitaire de France et professeur à temps partiel à l'Ecole Normale Supérieure.

Avec Wendelin Werner, la Médaille Fields distingue pour la première fois un spécialiste de la théorie des probabilités. Ses travaux se placent à l'interface entre cette théorie et la physique statistique. Le fait que les modèles étudiés possèdent des propriétés asymptotiques d'invariance conforme conduit aussi à l'utilisation d'outils sophistiqués d'analyse complexe. Un exemple simple mais significatif des résultats de Wendelin Werner est fourni par l'étude de la probabilité de non-intersection de deux marches aléatoires planes. Considérons une particule qui se déplace de manière aléatoire sur le réseau Z^2 selon les règles suivantes: à l'instant initial la particule se trouve à l'origine puis, à chaque instant entier strictement positif, elle saute en l'un des quatre plus proches voisins du point occupé précédemment, avec la même probabilité 1/4 pour chacune des possibilités, indépendamment du passé. La trajectoire de la particule entre les instants 0 et *n* est l'ensemble des points qu'elle visite entre ces deux instants. Considérons aussi une seconde particule qui se déplace selon les mêmes règles, indépendamment de la première. On s'intéresse alors à la probabilité que l'origine soit le seul point commun aux trajectoires des deux particules entre les instants 0 et *n*. On savait depuis assez longtemps que cette probabilité se comporte comme (une constante fois) n^{-a} quand *n* est grand. La valeur exacte de l'exposant a=5/8, conjecturée par les physiciens théoriciens Duplantier et Kwon en 1988, n'a pu être calculée rigoureusement que grâce aux travaux récents de Wendelin Werner et de ses collaborateurs Gregory Lawler et Oded Schramm. De manière inattendue, ce calcul a nécessité l'introduction de nouveaux processus aléatoires, les évolutions stochastiques de Loewner ou SLE en anglais. Les processus SLE ont beaucoup d'autres applications spectaculaires à différents modèles de physique statistique, comme la percolation, les marches aléatoires auto-évitantes ou modèles de polymères, ou encore les arbres couvrants sur un réseau. Le développement de telles applications, par Wendelin Werner et ses collaborateurs, a constitué un pas de géant dans la compréhension mathématique de ces modèles.

Après celle obtenue par Laurent Lafforgue en 2002, la Médaille Fields de Wendelin Werner témoigne une nouvelle fois de la grande vitalité de l'école mathématique française.

The work of 2006 Fields Medalist Terence Tao (UCLA) was featured in the Fall 2004 issue of the PIMS Newsletter (Vol. 8, Issue 1). The article, "Long Arithmetic Progressions of Primes" by Dr. Ben Green, is available on the PIMS website.

http://www.pims.math.ca/Publications_and_Videos/PIMS_Magazines/

PIMS

Andrei Okounkov's Work on the Dimer Model

by Richard Kenyon, University of British Columbia

Andrei Okounkov

Andrei Okounkov, professor at Princeton University, was awarded the Fields Medal "for his contributions bridging probability, representation theory and algebraic geometry" to quote the Fields medal citation. These fields are quite diverse, and it would be impossible to try to sum up Andrei Okounkov's mathematical output in a short article. Moreover I am not qualified to say much about his major contributions to Gromov-Witten theory, much of which has be done with Rahul Pandharipande and other colleagues. I will describe briefly here my interaction with him and our work on stepped surfaces, or equivalently, the planar dimer model.

A "3D partition", or plane partition, is a way to stack unit cubes in the corner of a room, see Figure 1. Mathematically, it is a finitely supported function $f: \mathbb{N} \times \mathbb{N} \to \{0,1,2,...\}$ which is non-increasing in each coordinate: $f(x+1,y) \le f(x,y)$ and $f(x,y+1) \le f(x,y)$. More generally a "stepped surface" is the surface of a stack of cubes, stacked obeying the same rules as 3D partition, that is, in such a way that looking down on it from the (1,1,1)-direction one sees the whole surface – there are no overhangs. When you draw a stepped surface on a piece of paper as in the Figure, you get a tiling of a planar region by 60° rhombi. The connection with the dimer model is that rhombus tilings are dual to dimer coverings (perfect matchings) of a "honeycomb" lattice, see Figure 2.

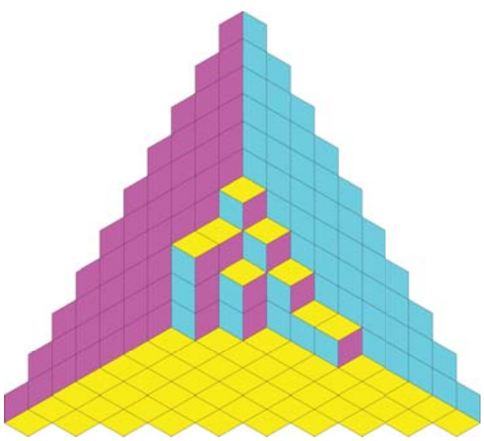


Figure 1: The graph of a 3D partition.

The reason we can understand a lot about stepped surfaces starts with a result of Kasteleyn (concurrently with Temperley and Fisher) from the 1960s which shows how to enumerate stepped surfaces in a finite region with a given boundary using determinants. For example, consider the adjacency matrix of the piece of the honeycomb graph in Figure 2; it is a 24 × 24 matrix with entries in {0,1} whose determinant is the square of the number of dimer coverings (there are 20 coverings in this case). The first result in 3D partitions is much earlier; in 1912 Percy Macmahon showed how to enumerate 3D partitions according to their volume, giving a beautiful generating function

$$M(q) = \prod_{n=1}^{\infty}(1-q^n)^{-n} = 1 + q + 3q^2 + 6q^3 + 13q^4 + ...$$

However it was only in the 1990s that the mathematical study of stepped surfaces (and more generally, the dimer model on planar graphs) took off, due to fundamental work by Cohn, Elkies, Larsen, Kuperberg, Propp and many others.

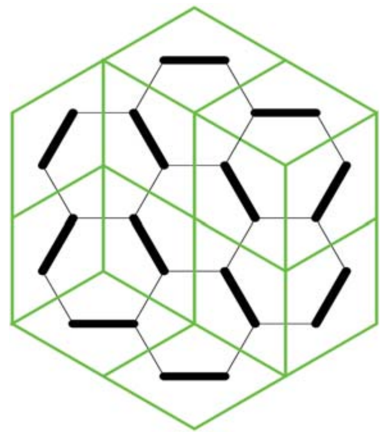


Figure 2: Relationship between dimers (thick edges) and 60° rhombus tilings.

I first met Andrei several years ago when I had just finished, with Raphael Cerf, a paper on the shape of a large 3D partition. It turns out that, when one takes the uniform measure on partitions of a large fixed volume, that is, when all partitions of a fixed volume are equally likely, then "almost all" 3D partitions, when rescaled to have volume 1, lie very close to a fixed shape, the so-called limit shape. He told me about his joint work with Nicolai Reshetikhin, where they gave a general formula for the "local statistics" of the partition, that is, the probabilities of fine-scale random events. (As an example of a local statistic, what is the probability that $f(100,100) - f(99,99)=2$ if the total volume of f is 10^6?) Their method involves the so-called Schur process, a random process on a wedge of infinite dimensional spaces. Essentially, if you scan a 3D partition from left to right in the appropriate coordinates, it can be realized as an excursion of a random walk on a certain infinite dimensional space. This is a wonderful analysis which we are still trying to generalize to the case with more complicated boundary conditions.

Andrei approached me later, saying that he had noticed a remarkable thing about the limit shape (again, this is the shape that a typical large 3D partition will take when it is rescaled appropriately): its graph, projected along the direction (1,1,1), is a shape which occurs in algebraic geometry: the so-called "amoeba" of a straight line, that is, the image of a complex line $\{(z,w) \in \mathbb{C}^2 \mid z+w+1=0\}$ in $\mathbb{C}^2$ under the map $(z,w) \mapsto (\log|z|, \log|w|)$. If you've ever tried to graph a line on log-log paper you'll know what the shape looks like. In fact we realized that the limit shape itself, and not just its projection, was exactly described by another function studied by algebraic geometers: the graph of the Ronkin function $R(x,y)$ of the line $P(z,w)=z+w+1$. The Ronkin function $R(x,y)$ is defined for general 2-variable polynomials P by the formula

$$R(x,y) = \frac{1}{4\pi^2} \int_{|z|=|w|=1} \log P(e^{-x}z, e^{-y}w) \frac{dz}{iz} \frac{dw}{iw}.$$

See Figure 3.

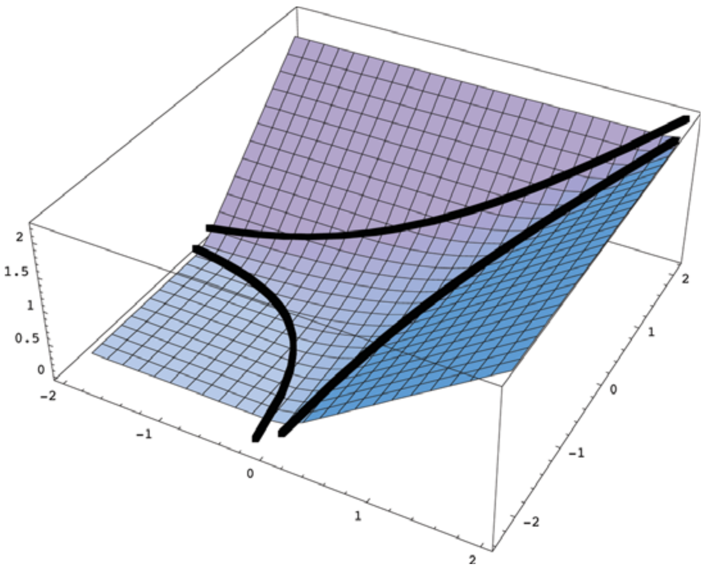


Figure 3: The graph of the Ronkin fuction of $1+z+w$, shown, is (after a simple linear coordinate change) the asymptotic shape of a large 3D partition. The bold curves mark the boundary of the facets.

Amazingly enough, the graphs of the Ronkin functions of other 2-variable polynomials described the limit shapes of other random surface models, all closely related to the initial model of random 3D partitions. These other models can be described as before, as random 3D partitions, but with other natural probability measures, not the uniform measure. Basically each cube in the partition is assigned a weight which is periodic in space; and the weight of a partition is the product of the weights of its cubes.

It turns out, moreover, that the Ronkin function, which determines the limit shape of 3D partitions, contains precisely the information needed to compute the limit shapes in a more general setting: using the same types of random surfaces but with different boundary conditions. See for example Figure 4, which is an example of a stepped surface with boundary constrained to lie along 6 edges of an $n \times n \times n$ box. In some sense knowing the limit shape of a large 3D partition is enough information so that any other shape that the random surface model will take can be deduced (at least in principle) from it. (In the terminology of variational calculus, the 3D partition limit shape is a Wulff shape, whose Legendre dual is the surface tension. The limit shape for any surface with Dirichlet boundary conditions is the unique shape minimizing the integral of the surface tension.)

Carrying out this computation yields an end result with a very simple and satisfying formulation: if we are interested in limit shapes for stepped surfaces with other boundary conditions, for example in a box (see Figure 4), the limit shape is described by a system of equations

$$\begin{cases} P(z,w) & = 0 \\ Q(e^{-cx}z, e^{-cy}w) & = 0 \end{cases}$$

where $P(z,w)=z+w+1$ in the standard case (uniform measure), Q is a two-variable analytic function, and c is a real constant (a Lagrange multiplier controlling the volume under the resulting limit shape). Here $z=z(x,y), w=w(x,y) \in \mathbb{C}$, which are determined implicitly by the above equation, describe the slope of the surface: the coordinates of the slope of the surface at the point (x,y) are arg z and arg w, respectively. This system of equations gives a very simple parameterization of all limit shapes in terms of an analytic function Q. An important problem that remains is to find Q so that the solution matches the boundary conditions. For example one can show that for the 3D partition limit shape we should take $Q(z,w)=1+1/z+1/w$.

One remarkable feature of the limit shapes, which one can see in the figures, is the formation of facets, that is, domains on which the solution is the graph of a *linear* function. These facets are separated by curved portions where the solution is analytic. One of the first results in this area, due to Cohn, Larsen and Propp, shows that for the boundary conditions in Figure 4 the boundary between the facets and the curved part of the limit shape tends for large n to a circle when projected to the plane $x+y+z=0$. While their methods were adapted only to this particular hexagonal shape, the variational solution described above yields similar results for any boundary curve.

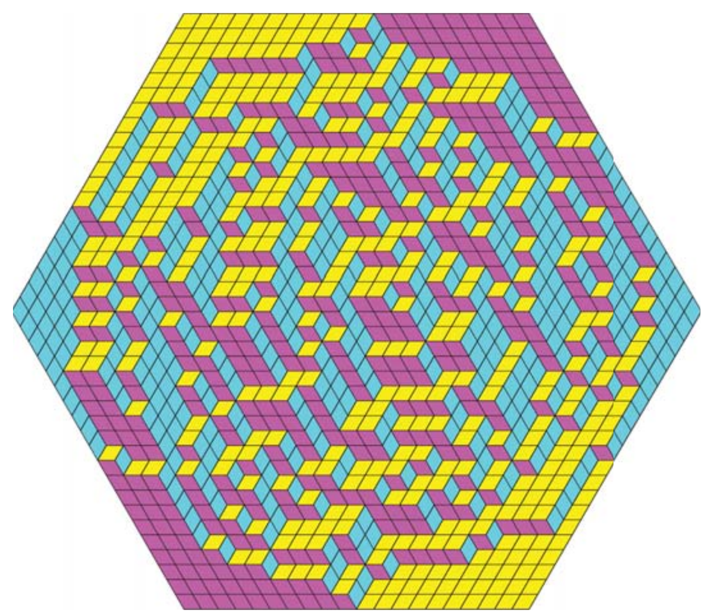


Figure 4: A stepped surface in a box. The limit shape in this setting was first found by Cohn, Larsen and Propp, using a technique specialized to this boundary shape.

A (Very Brief) History of the Trace Formula

by James Arthur

This note is a short summary of a lecture in the series celebrating the 10th anniversary of PIMS. The lecture itself was an attempt to introduce the trace formula through its historical origins. I thank Bill Casselman for suggesting the topic. I would also like to thank Peter Sarnak for sharing his historical insights with me. I hope I have not distorted them too grievously.

As it is presently understood, the trace formula is a general identity

(GTF)
$$\sum\{\text{geometric terms}\} = \sum\{\text{spectral terms}\}.$$

The spectral terms contain arithmetic information of a fundamental nature. However, they are highly inaccessible, "spectral" actually, in the nonmathematical meaning of the word. The geometric terms are quite explicit, but they have the drawback of being very complicated.

There are simple analogues of the trace formula, "toy models" one could say, which are familiar to all. For example, suppose that $A=(a_{ij})$ is a complex $(n \times n)$-matrix, with diagonal entries $\{u_i\}=\{a_{ii}\}$ and eigenvalues $\{\lambda_j\}$. By evaluating its trace in two different ways, we obtain an identity

$$\sum_{i=1}^{n} u_i = \sum_{j=1}^{n} \lambda_j.$$

The diagonal coefficients obviously carry geometric information about A as a transformation of $\mathbb{C}^n$. The eigenvalues are spectral, in the precise mathematical sense of the word.

For another example, suppose that $g \in C_c^\infty(\mathbb{R}^n)$. This function then satisfies the Poisson summation formula

$$\sum_{u \in \mathbb{Z}^n} g(u) = \sum_{\lambda \in 2\pi i\mathbb{Z}^n} \hat{g}(\lambda),$$

where

$$\hat{g}(\lambda) = \int_{\mathbb{R}^n} g(x) e^{-x\lambda} \mathrm{d}x, \qquad \lambda \in \mathbb{C}^n$$

is the Fourier transform of g. One obtains an interesting application by letting $g=g_T$ approximate the characteristic function of the closed ball B_T of radius T about the origin. As T becomes large, the left hand side approximates the number of lattice points $u \in \mathbb{Z}^n$ in B_T. The dominant term on the right hand side is the integral

$$\hat{g}(0) = \int_{\mathbb{R}^n} g(x)\,\mathrm{d}x,$$

which in turn approximates vol(B_T). In this way, the Poisson summation formula leads to a sharp asymptotic formula for the number of lattice points in B_T.

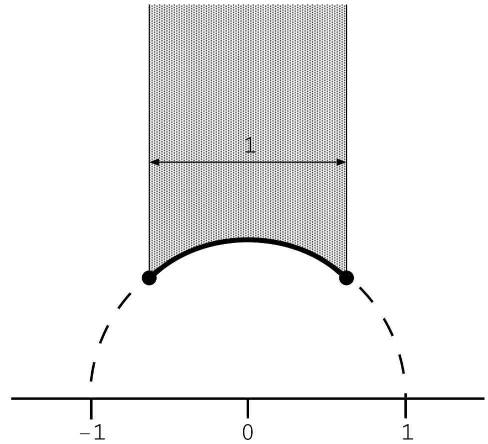
Our real starting point is the upper half plane

$$H = \{z \in \mathbb{C} : \mathrm{Im}(z) > 0\}.$$

The multiplicative group $SL(2,\mathbb{R})$ of (2×2) real matrices of determinant 1 acts transitively by linear fractional transformations on H. The discrete subgroup

$$\Gamma = SL(2,\mathbb{Z})$$

acts properly discontinuously. Its space of orbits $\Gamma\backslash H$ can be identified with a noncompact Riemann surface, whose fundamental domain is the familiar modular region.



More generally, one can take Γ to be a congruence subgroup of $SL(2,\mathbb{Z})$, such as the group

$$\Gamma(N) = \{\gamma \in SL(2,\mathbb{Z}) : \gamma \equiv I (\mathrm{mod}\ N)\}.$$

The space $\Gamma\backslash H$ comes with the hyperbolic metric

$$\mathrm{d}s^2 = \frac{\mathrm{d}x\mathrm{d}y}{y^2}$$

and the hyperbolic Laplacian

$$\Delta = -y^2\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right).$$

Modular forms are holomorphic sections of line bundles on $\Gamma\backslash H$. For example, a modular form of weight 2 is a holomorphic function $f(z)$ on H such that the product

$$f(z)\,\mathrm{d}z$$

descends to a holomorphic 1-form on the Riemann surface $\Gamma\backslash H$. The classical theory of modular forms was a preoccupation of a number of prominent 19th century mathematicians. It developed many strands, which intertwine complex analysis and number theory.

In the first half of the 20th century, the theory was taken to new heights by *E. Hecke* (~ 1920–1940)[1]. Among many other things, he introduced the notion of a *cusp form*. As objects that are rapidly decreasing at infinity, cusp forms represent holomorphic eigensections of Δ (for the relevant line bundle) that are square integrable on $\Gamma\backslash H$.

The notion of an eigenform of Δ calls to mind the seemingly simpler problem of describing the spectral decomposition of Δ on the space of functions $L^2(\Gamma\backslash H)$. I do not know why this problem, which seems so natural to our modern tastes, was not studied earlier. Perhaps it was because eigenfunctions of Δ are typically not holomorphic. Whatever the case, major advances were made by *A. Selberg*. I will attach his name to the first of three sections, which roughly represent three chronological periods in the development of the trace formula.

I. Selberg

(a) Eisenstein series for $\Gamma\backslash H$ (~ 1950).

Eisenstein series represent the continuous spectrum of Δ on the noncompact space $\Gamma\backslash H$. In case $\Gamma = SL(2,\mathbb{Z})$, they are defined by infinite series

$$E(\lambda, z) = \sum_{(c,d)=1} \frac{(\operatorname{Im} z)^{\frac{1}{2}(\lambda+1)}}{|cz+d|^{\lambda+1}}, \qquad z \in \Gamma\backslash H, \lambda \in \mathbb{C},$$

that converges if $\operatorname{Re}(\lambda) > 1$. Selberg[2] introduced general techniques, which showed that $E(\lambda,z)$ has analytic continuation to a meromorphic function of $\lambda \in \mathbb{C}$, that its values at $\lambda \in i\mathbb{R}$ are analytic, and that these values exhaust the continuous spectrum of Δ on $L^2(\Gamma\backslash H)$. One can say that the function

$$E(\lambda,z), \qquad \lambda \in i\mathbb{R},\ z \in \Gamma\backslash H,$$

plays the same role for $L^2(\Gamma\backslash H)$ as the function $e^{\lambda x}$ in the theory of Fourier transforms.

(b) Trace formula for $\Gamma\backslash H$ (~ 1955).

Selberg's analysis of the continuous spectrum left open the question of the discrete spectrum of Δ on $L^2(\Gamma\backslash H)$. About this time, examples of square integrable eigenfunctions of Δ were constructed separately (and by very different means) by *H. Maass* and *C.L. Siegel.* Were these examples isolated anomalies, or did they represent only what was visible of a much richer discrete spectrum?

A decisive answer was provided by the trace formula Selberg created to this end. The Selberg trace formula is an identity

$$\text{(STF)} \qquad \sum_i a_i\, g(u_i) = \sum_j b_j\, \hat{g}(\lambda_j) + e(g),$$

where g is any symmetric test function in $C_c^\infty(\mathbb{R})$, $\{u_i\}$ are essentially[3] the real eigenvalues of conjugacy classes in Γ, and $\{\lambda_i\}$ are essentially[3] the discrete eigenvalues of Δ on $L^2(\Gamma\backslash H)$. The coefficients $\{a_i\}$ and $\{b_j\}$ are explicit nonzero constants, and $e(g)$ is an explicit error term (which contains both geometric and spectral data). The proof of (STF) was a tour de force. The function g gives rise to an operator on $L^2(\Gamma\backslash H)$, but the presence of a continous spectrum means that the operator is not of trace class. Selberg had first to subtract the contribution of this operator to the continuous spectrum, something he could in principle do by virtue of (a). However, the modified operator is quite complicated. It is remarkable that Selberg was able to express its trace by such a relatively simple formula.

Selberg's original application of (STF) came by choosing g so that $\hat{g}$ approximated the characteristic function of a large symmetric interval in $\mathbb{R}$. The result was a sharp asymptotic formula

$$\left|\left\{\Lambda_j = \tfrac{1}{4} - \lambda_j^2 \le T\right\}\right| \sim \frac{\pi}{2} \operatorname{vol}(\Gamma\backslash H)\, T$$

for the number of eigenvalues Λ_j in the discrete spectrum.This is an analogue of Weyl's law (which applies to compact Riemannian manifolds) for the non-compact manifold $\Gamma\backslash H$. In particular, it shows that the congruence arithmetic quotient $\Gamma\backslash H$ has a rich discrete spectrum, something subsequent experience has shown is quite unusual for noncompact Riemannian manifolds.

Ramifications (~ 1955–1960).

(i) Selberg seems to have observed *after* his discovery of (STF) that a similar but simpler formula could be proved for any *compact* Riemann surface $\Gamma'\backslash H$. (and indeed, for any compact, locally symmetric space). For example, one could take the fundamental group Γ' to be a congruence group inside a quaternion algebra Q over $\mathbb{R}$ with $Q(\mathbb{R}) \cong M_2(\mathbb{R})$. The trace formula in this case is similar to (STF), except that the explicit error term $e(g)$ is considerably simpler.

(ii) Selberg also observed that (STF) could be extended to the *Hecke operators*

$$\{\, T_p : p \text{ prime}\}$$

on $L^2(\Gamma\backslash H)$. These operators have turned out to be the most significant of Hecke's many contributions. They are a commuting family of operators, parametrized by prime numbers p, which also commute with Δ. The corresponding family of simultaneous eigenvalues $\{t_{p,j}\}$ carries arithmetic information. They can be regarded as the analytic embodiment of data that govern fundamental arithmetic phenomena. Selberg's generalization of (STF) includes terms on the right hand side that quantify the numbers $\{t_{p,j}\}$. It also holds more generally if $L^2(\Gamma\backslash H)$ is replaced by the space of square integrable sections of a line bundle on $\Gamma\backslash H$. In this form, it can be applied to the space of classical cusp forms of weight $2k$ on $\Gamma\backslash H$. It yields a finite closed formula for the trace of any Hecke operator on this space.

(iii) Selberg also studied generalizations of Eisenstein series and (STF) to some spaces of higher dimension.

II. Langlands

(a) General Eisenstein series (~ 1960–1965).

Motivated by Selberg's results, *R. Langlands* set about constructing continuous spectra for *any* locally symmetric space $\Gamma\backslash X$ of finite volume. Like the special case $\Gamma\backslash H$, the problem is to show that absolutely convergent Eisenstein series have analytic continuation to meromorphic functions, whose values at imaginary arguments exhaust the continuous spectrum. The analytic difficulties were enormous. Langlands was able to overcome them with a remarkable argument based on an interplay between spectral theory and higher residue calculus. The result was a complete description of the continuous spectrum of $L^2(\Gamma\backslash X)$ in terms of discrete spectra for spaces of smaller dimension.

(b) Comparison of trace formulas (~ 1970–1975).

Langlands changed the focus of applications of the trace formula. Instead of taking one formula in isolation, he showed how to establish deep results by comparing two trace formulas with each other. He treated three different kinds of comparison, following special cases that had been studied earlier by *M. Eichler* and *H. Shimizu*, *Y. Ihara*, and *H. Saito* and *T. Shintani*. I shall illustrate each of these in shorthand, with a symbolic correspondence between associated data for which the comparison yields a reciprocity law. In each case, the left hand side represents some form of the trace formula (STF), while the right hand side represents another trace formula.

(i) $$(\Gamma\backslash H) \leftrightarrow (\Gamma'\backslash H)$$
$$\{\lambda_j, t_{p,j}\} \leftrightarrow \{\lambda'_j, t'_{p,j}\}.$$

Here $\Gamma'\backslash H$ represents a compact Riemann surface attached to a congruence quaternion group Γ'. The reciprocity law, established by Langlands in collaboration with *H. Jacquet*, is a remarkable correspondence between spectra of Laplacians on two Riemann surfaces, one noncompact and the other compact, and also a correspondence between eigenvalues of associated Hecke operators.

(ii) $$(\Gamma\backslash H) \leftrightarrow (\Gamma\backslash H)_p$$
$$\{t_{p,j}\} \leftrightarrow \{\Phi_{p,j}\}.$$

Here $(\Gamma\backslash H)_p$ represents an algebraic curve over $\mathbb{F}_p$, obtained by reduction mod p of a $\mathbb{Z}$-scheme associated to $\Gamma\backslash H$. The relevant trace formula is the Grothendieck-Lefschetz fixed point formula, and $\{\Phi_{p,j}\}$ represent eigenvalues of the Frobenius endomorphism on the ℓ-adic cohomology of $(\Gamma\backslash H)_p$. The reciprocity law illustrated in this case gives an idea of the arithmetic significance of eigenvalues $\{t_{p,j}\}$ of Hecke operators

(iii) $$(\Gamma\backslash H) \leftrightarrow (\Gamma_E\backslash H_E)$$
$$\{\lambda_j, t_{p,j}\} \leftrightarrow \{\lambda_{E,j}, t_{\mathfrak{p},j}\}.$$

Here, $(\Gamma_E\backslash H_E)$ is a higher dimensional locally symmetric space attached to a cyclic Galois extension $E/\mathbb{Q}$, and $\mathfrak{p}$ denotes a prime ideal in $\mathcal{O}_E$ over p. The relevant formula is a twisted trace formula, attached to the diffeomorphism of $\Gamma_E\backslash H_E$ defined by a generator of the Galois group of E/F. The reciprocity law it yields (and its generalization with $\mathbb{Q}$ replaced by an arbitrary number field F) is known as cyclic base change. It has had spectacular consequences. It led to the proof of a famous conjecture of *E. Artin* on representations of Galois groups, in the special case of a two dimensional representation of a solvable Galois group. This result, known as the Langlands-Tunnell theorem, was in turn a starting point for the work of *A. Wiles* on the Shimura-Taniyama-Weil conjecture and his proof of Fermat's last theorem.

My impressionistic review of the three kinds of comparison is not to be taken too literally. For example, it is best not to fix the congruence subgroup Γ of $SL(2,\mathbb{R})$. The correspondences are really between a (topological) projective limit

$$\varprojlim_{\Gamma}(\Gamma\backslash H)$$

and its three associated analogues. Moreover, the group $SL(2)$ should actually be replaced by $GL(2)$. Nevertheless, the basic idea is as stated, to compare a formula like (STF) with something else. One deduces relations between data on the spectral sides from a priori relations between data on the geometric sides. We recall that the geometric terms in (STF) are indexed by conjugacy classes in the discrete group Γ.

Before going to the next stage, I need to recall some other foundational ideas of Langlands. To maintain a sense of historical flow, I shall divide these remarks artificially into two time periods.

Between II(a) and II(b) (~ 1965–1970).

During this period, Langlands formulated the conjectures that came to be known as the *Langlands programme*. Many of these are subsumed in his *principle of functoriality*. This grand conjecture consists of a collection of very general, yet quite precise, relations among spectral data $\{\lambda_j, t_{p,j}\}$ attached to arbitrary locally symmetric spaces $(\Gamma\backslash X)$ (of congruence type). It also includes striking relations between these data and arithmetic data attached to finite dimensional, complex representations of Galois groups.

Among other things, Langlands' ideas altered definitively the language of modular forms (and its generalizations). He formulated his conjectures in terms of the adeles, a locally compact ring

$$\mathbb{A} = \mathbb{R} \times \prod_{p}^{\text{rest}} \mathbb{Q}_p,$$

which contains $\mathbb{Q}$ diagonally as a discrete subring. This point of view itself has an interesting history, which went through a series of refinements with *C. Chevalley, J. Tate, I. Gelfand* and *T. Tamagawa*. In the present setting, the basic observation is that there are natural isomorphisms

$$\begin{aligned} L^2\big(SL(2,\mathbb{Z})\backslash H\big) &\cong L^2\big(SL(2,\mathbb{Z})\backslash SL(2,\mathbb{R})/SO(2,\mathbb{R})\big) \\ &\cong L^2\big(SL(2,\mathbb{Q})\backslash SL(2,\mathbb{A})/SO(2,\mathbb{R})K_0\big), \end{aligned}$$

for the compact subgroup

$$K_0 = \prod_p SL(2,\mathbb{Z}_p)$$

of $SL(2,\mathbb{A})$. A removal of K_0 from the last quotient causes the first space to be replaced by a direct limit

$$\varinjlim_{\Gamma} L^2(\Gamma\backslash H) = L^2\Big(\varprojlim_{\Gamma}(\Gamma\backslash H)\Big).$$

If one removes $SO(2,\mathbb{R})$ from the quotient, one obtains a Hilbert space that includes the square integrable sections of line bundles that define classical cusp forms. Thus, the classical objects we have discussed can all be combined together into the single Hilbert space of square integrable functions on $SL(2,\mathbb{Q})\backslash SL(2,\mathbb{A})$.

To treat the general case of spaces of higher dimension, one simply replaces $SL(2)$ by a general reductive algebraic group G over $\mathbb{Q}$. One then studies the irreducible decompositon of the representation of $G(\mathbb{A})$ by right translation on the Hilbert space

$$\mathcal{H} = L^2\big(G(\mathbb{Q})\backslash G(\mathbb{A})\big).$$

Irreducible representations of $G(\mathbb{A})$ obtained in this way are known as *automorphic representations*. They carry all the information contained in the spectral decomposition.

After II(b) (~ 1975–1985).

Having established striking results by comparing the trace formula for $GL(2)$ with three other trace formulas, Langlands gave careful thought to what might happen in general. There was no general trace formula, at least initially, but it was still possible to make predictions. The result was Langlands' conjectural *theory of endoscopy*. This theory offers a general strategy for comparing trace formulas attached to arbitrary reductive groups G. It is founded largely on conjugacy classes, both in $G(\mathbb{Q})$ and any of its completions $G(\mathbb{Q}_v)\in\{G(\mathbb{R}),G(\mathbb{Q}_p)\}$. The theory is based on the critical observation that elements in $G(\mathbb{Q})$ (or $G(\mathbb{Q}_v)$) need not be conjugate even if they are conjugate over the algebraic closure $G(\overline{\mathbb{Q}})$ (or $G(\overline{\mathbb{Q}}_v)$). This phenomenon is absent in the special case $G=GL(2)$, but it would obviously be an essential consideration in any general comparison of geometric terms in trace formulas. The theory of endoscopy represents a precise measure, in both geometric and spectral terms, of the failure of geometric conjugacy to imply conjugacy.

III. Arthur[4]

(a) The general trace formula (~ 1975–1985).

One takes G to be a reductive group over $\mathbb{Q}$, as above. Any function $f \in C_c^\infty(G(\mathbb{A}))$ then provides a convolution operator $R(f)$ on the Hilbert space $\mathcal{H}=L^2\big(G(\mathbb{Q})\backslash G(\mathbb{A})\big)$, which in turn has an orthogonal decomposition

$$R(f)=R_{\text{disc}}(f)\oplus R_{\text{cont}}(f),$$

relative to the discrete and continuous spectra. The general trace formula (GTF) is a formula for the trace[5] of the operator $R_{\text{disc}}(f)$. It can be written as a sum of relatively simple terms, indexed by $\mathbb{Q}$-elliptic conjugacy classes in $G(\mathbb{Q})$, with more complicated "error" terms. The error terms come from hyperbolic conjugacy classes in $G(\mathbb{Q})$, which are parametrized by elliptic conjugacy classes in Levi subgroups M of G, and continuous spectra, which are parametrized by discrete spectra of Levi subgroups.

(b) Endoscopy for classical groups (~ 1995–present).

The problem is to classify automorphic representations of classical groups G (such as the split groups $SO(2n+1)$, $Sp(2n)$ and $SO(2n)$) in terms of automorphic representations of general linear groups $\widetilde{G}=GL(N)$. In the symbolic shorthand of II(b), the comparison takes the form

$$G(\mathbb{Q})\backslash G(\mathbb{A}) \leftrightarrow \widetilde{G}(\mathbb{Q})\backslash\widetilde{G}(\mathbb{A}),$$
$$\{\lambda_j, t_{p,j}\} \leftrightarrow \{\widetilde{\lambda}_j, \widetilde{t}_{p,j}\}.$$

However, the situation here is more subtle than that of II(b). On the left, one has to take the stable trace formula for G, a refinement of the ordinary trace formula that compensates for the failure of geometric conjugacy to imply ordinary conjugacy. One also has to treat several G together, taking appropriate linear combinations of terms in their stable trace formulas. On the right, one takes the twisted trace formula of $\widetilde{G}$, relative to the standard outer automorphism $x \to {}^t x^{-1}$.

Despite the difficulties, it appears that this comparison of trace formulas will lead to precise information about automorphic representations of classical groups. I mention three of what are likely to be many applications.

(i) A classification of the automorphic representations of the split classical groups G ought to lead to a sharp analogue of Weyl's law[6] for the associated noncompact symmetric spaces

$$X_\Gamma=\Gamma\backslash X=\Gamma\backslash G(\mathbb{R})/K_{\mathbb{R}}.$$

(ii) In cases that X_Γ has a complex structure (such as for G=$GSp(2n)$), the classification gives important information about the L^2-cohomology $H^*_{(2)}(X_\Gamma)$. It leads to a decomposition of $H^*_{(2)}(X_\Gamma)$ that clearly exhibits the Hodge structure, the cup product action of a Kähler class, and the action of Hecke operators.

(iii) The theory of endoscopy for classical groups includes some significant cases of functoriality. It also places automorphic L-functions of classical groups on a par with those of $GL(N)$.

IV. The Future

(a) Principle of functoriality (2007–?).

Many cases of the principle of functoriality lie well beyond what is implied by the theory of endoscopy (which itself is still conjectural in general). Langlands has recently proposed a strategy for applying the trace formula (GTF) to the general principle of functoriality. The proposal includes a comparison of trace formulas that is completely different than anything attempted before. It remains highly speculative, and needless to say, is completely open.

(b) Motives and automorphic representations (2007–?).

As conceived by *A. Grothendieck*, motives are the essential building blocks of algebraic geometry. If one thinks of algebraic varieties (say, projective and nonsingular) as the basic objects of everyday life, motives represent the elementary particles. In a far-reaching generalization of the Shimura-Taniyama-Weil conjecture, Langlands has proposed a precise reciprocity law between general motives and automorphic representations. It amounts to a description of arithmetic data that characterize algebraic varieties in terms of eigenvalues $\{t_{p,j}\}$ of Hecke operators attached to general groups G. This conjecture is again completely open. It appears to be irrevocably intertwined with the general principle of functoriality.

Footnotes

1. These dates, like others that follow, are not to be taken too literally. They are my attempt to approximate the relevant period of activity, and to orient the reader to the development of the subject.
2. These results were actually first established by *H. Maass*, whose work was later applied to more general discrete subgroups of $SL(2,\mathbb{R})$ by *W. Roelke*. However, Selberg's techniques have been more influential, having shown themselves to be amenable to considerable generalization.
3. For example, the eigenvalues $\{\Lambda_j\}$ are related to the numbers $\{\lambda_j\}$ by the formula $\Lambda_j = \frac{1}{4} - \lambda_j^2$.
4. I was following a suggestion to divide the history of the trace formula into three periods of development, indexed by three names!
5. The proof that $R_{\text{disc}}(f)$ is of trace class is due to *W. Muller.*
6. A general noncompact form of Weyl's law has been established recently by *E. Lindenstrauss* and *A. Venkatesh*. In the case of classical groups above, the goal would be to establish the strongest possible error term.

Professor James Arthur is regarded as one of two or three leading mathematicians in the world in the central fields of representation theory and automorphic forms. In addition to being an outstanding scientist, Professor Arthur has a distinguished record of service to both the University and the mathematics community.

Dr. Arthur has achieved many distinctions in his career. He became the first recipient of the Synge Award of the Royal Society of Canada in 1987. In 1999 he received the Canada Gold Medal for Science and Engineering from NSERC, making him the only mathematician to have won Canada's top award in science. He is the President of the American Mathematical Society (AMS).

PIMS' collaborative strength lies in its close connections with other centres of mathematical excellence. PIMS holds a place on the world mathematical stage, bringing our six member universities and three affiliated universities to international collaborations with PRIMA, CNRS, CMM, Cinvestav, and IM-UNAM, to name only a few.

We look forward to the next 10 years. PRIMA is growing to becom a global enterprise for training and research in emerging areas of mathematics. With our international connections, PIMS stands as a gateway between the Pacific Rim, the Americas and Europe, bringing different mathematical traditions to study global problems.

The Founding of PIMS – A Taboo-Shattering Experience, But So Many To Thank

By Nassif Ghoussoub, PIMS founding director (1996-2003)

Created in 1996, the Pacific Institute for the Mathematical Sciences (PIMS) has evolved in 10 short years into a unique bi-national scientific partnership involving all of the major universities of Alberta, B.C. and Washington State. PIMS scientists have collectively conceived and built an entity that has galvanized the mathematical community. The institute is now recognized worldwide as an effective new model for the mathematical sciences: one that simultaneously addresses the imperatives of research, education and technology transfer, and one that was able to unite a diverse community of many institutions over a geographically challenging area.

PIMS' early successes reinvigorated the Canadian mathematical science community and stimulated its institutions. The institute's proactive approach to industrial and education outreach, and its use of modern communication and dissemination tools, contributed to changing the culture, to erasing outdated perceptions and to increasing mathematical awareness. PIMS' energetic and vocal efforts on behalf of the mathematical sciences led to a re-affirmation of their key importance, whether in K-12 school programs, or for leading-edge Canadian R&D efforts.

(l to r) Janet Walden, Nigel Lloyd, Nassif Ghoussoub and Isabelle Blain

Through a series of bold national and international initiatives (the MITACS Network of Centres of Excellence, the Banff International Research Station (BIRS), the Pacific Northwest Partnership, the Pacific Rim Initiative (PRIMA)), PIMS has raised the profile of Canadian research throughout the world. By developing key partnerships, PIMS multiplied the opportunities and attracted substantial investments from industrial, provincial, federal and foreign sources in support of Canadian-led research.

NSERC's former President, Tom Brzustowski, stated at the BIRS inaugural that "*the hallmark of a good idea is that so many people find it obvious once it has been mentioned*." On this 10th anniversary of an institution we came to cherish, it is fair to say that many of the ideas behind PIMS and its "offsprings" turned out to be darn good, but obvious to everyone, then? Not really, since for all this to happen, many taboos had to be broken, and for that many people have to be thanked.

- It was said that institutes are about "bricks and mortar" holding a selected few, but PIMS became a distributed institute for anyone who was interested.
- It was said that rivalry is the name of the game between neighbouring universities, but PIMS effectively linked our universities with great results.
- It was said that mathematicians work only in isolation, but PIMS created *Collaborative Research Groups* spanning institutions and crossing boundaries.
- It was said that the West was too isolated to be relevant to the world, but PIMS went on to create BIRS for the world.
- It was said that Canada cannot but follow the lead of its giant neighbor to the south, but PIMS was to be the first bi-national institute, and an equal partner with MSRI in developing BIRS.
- It was said that we were a threat on resources because it was a zero-sum game, but PIMS was to bring about a significant increase to the pie, while revitalizing its sister institutes in central Canada.
- It was said that mathematics was oblivious to real world problems, but PIMS showed otherwise and earned the respect of its partners in the private and industrial sector.
- It was said that the NCE programme was not for mathematics, but PIMS led the way in the Network of Centres of Excellence programme that MITACS so aptly represents.
- It was said that university academics only give lip service to K-12 education, but PIMS reached out to both students and teachers in hundreds of primary and high schools.
- It was said that our science is esoteric and practiced only by a chosen few, but PIMS generated mathematical awareness on buses, magazines and in theatre, exhibiting its omnipresence in matters of everyday life.
- It was said that mathematics is low priority for university senior administrators, but PIMS continues to make universities proud of their support for mathematics.

(l to r) Arvind Gupta, Nassif Ghoussoub and Ed Perkins

- It was said that NSERC's decisions are not to be second-guessed, but PIMS persevered and became a major success story for NSERC's investment in research.

Thanks again Mike Boorman, Tom Brzustowski, Don Dawson, David Eisenbud, Colin Jones, Arvind Gupta, Steve Halperin, Barry McBride, Nigel Lloyd, Robert Moody, Hugh Morris, Ed Perkins, Dick Peter, Indira Samarasekera, Martin Taylor, Luc Vinet and so many others. I surely hope that all those great memories still bring a smile to your faces, the way they do to mine.

CRM-Fields-PIMS Prize 2006: Dr. Joel Feldman

The directors of the Centre de recherches mathématiques (CRM) of l'Université de Montréal - François Lalonde, the Fields Institute - Barbara Keyfitz, and the Pacific Institute for the Mathematical Sciences - Ivar Ekeland, are pleased to announce that Professor Joel S. Feldman (University of British Columbia) is the recipient of the 2007 CRM-Fields-PIMS Prize, in recognition of his exceptional achievement and work in mathematical physics.

Established in 1994, the CRM-Fields Prize recognizes exceptional research in the mathematical sciences. In 2005, PIMS became an equal partner in the prize, and the name was changed to the CRM-Fields-PIMS prize. A committee appointed by the three institutes chooses the recipient. This year's committee consisted of: Niky Kamran (McGill) [Chair], John McKay (Concordia), Catherine Sulem (Toronto), George Elliott (Toronto), Mark Goresky (IAS) and Ed Perkins (UBC).

(l to r) Alejandro Adem (PIMS Deputy Director), Joel Feldman (CRM-Fields-PIMS Prize 2006 winner) and Barbara Keyfitz (Fields Institute Director).

Professor Feldman has risen to a position of international prominence in the world of mathematical physics, with a 30-year record of sustained output of the highest caliber. He has made important contributions to quantum field theory, many-body theory, Schrödinger operator theory, and the theory of infinite genus Riemann surfaces. Many of Professor Feldman's recent results on quantum many-body systems at positive densities and on Fermi liquids and superconductivity have been classed as some of the best research in mathematical physics in the last decade.

Professor Feldman received his B.Sc. from the University of Toronto in 1970, and his A.M. and Ph.D. from Harvard University in 1971 and 1974, respectively. He worked as a Research Fellow at Harvard University from 1974 to 1975, and was a C. L. E. Moore Instructor at the Massachusetts Institute of Technology (MIT) from 1975 to 1977. Since 1977, he has taught at the University of British Columbia, where he is currently a full professor. Professor Feldman was an invited speaker at the International Congress of Mathematicians in Kyoto in 1990. He was a plenary speaker at the XIIth International Congress on Mathematical Physics in Brisbane in 1997, and was an invited speaker at the XIVth International Congress on Mathematical Physics in Lisbon in 2003. He is a fellow of the Royal Society of Canada, and has been awarded the 1996 John L. Synge award and CRM Aisenstadt Chair Lectureship in 1999/2000, as well as the 2004 Jeffery-Williams Prize by the Canadian Mathematical Society for outstanding contributions to mathematical research.

Previous recipients of the prize are H.S.M. (Donald) Coxeter, George A. Elliott, James Arthur, Robert V. Moody, Stephen A. Cook, Israel Michael Sigal, William T. Tutte, John B. Friedlander, John McKay, Edwin Perkins, Donald A. Dawson, David Boyd and Nicole Tomczak-Jaegermann.

CRM-Fields-PIMS Prize 2005: Dr. Nicole Tomczak-Jaegermann

On Dec. 1, 2006, Dr. Nicole Tomczak-Jaegermann (University of Albert), the winner of the CRM-Fields-PIMS 2005 Prize, presented a Distinguished Lecture at UBC on **High dimensional convex bodies: phenomena, intuitions and results**

Abstract: Phenomena in large dimensions appear in a number of fields of mathematics and related fields of science, dealing with functions of infinitely growing number of variables and with objects that are determined by infinitely growing number of parameters. In this talk we trace these phenomena in linear-metric, geometric and some combinatorial structure of high-dimensional convex bodies. We shall concentrate this presentation on very recent results in Asymptotic Geometric Analysis.

A streaming video replay of Dr. Tomczak-Jaegermann's lecture is available on the PIMS website, at http://www.pims.math.ca/Publications_and_Videos/Streaming_Videos/

Photograph by W. Eryk Jaegerman

Mathematical Biology Research at the University of Alberta

Dr. Mark Lewis, the Canada Research Chair in Mathematical Biology at the University of Alberta, presented a 10th Anniversary Lecture at PIMS on Dec. 4, 2006. He gave the PIMS Newsletter an exclusive interview on the field of mathematical biology.

Q. What is mathematical biology?

In mathematical biology, I've found that you have to have a willingness to engage in both the math and the biology sides of the research. It is crucial to spend a lot of time with the different scientists involved in the project, and to gain a real understanding of what they are working on. The payoffs are great: the directions the math takes are astounding, and improves the understanding of the biological aspects of the science. There is a vibrant network of researchers in Mathematical Biology distributed across the PIMS universities, including very active groups at Alberta and UBC.

Q. Tell us a little about your current work in mathematical biology.

At the University of Alberta, there is the Centre for Mathematical Biology. When I joined the university in 2001, part of my role as the Senior Canada Research Chair in Mathematical Biology at UA was to create the Centre. We have functioned informally at the university since 2002, where the Centre has enjoyed support from PIMS as well as other agencies. Recently, the UA has approved the Centre and its financial plan for the next five years.

Q. What occurs at the Centre?

The Centre, which is housed within the Mathematics and Statistics Department at UA, functions as an interactive collaborative resource for researchers. At the core of it, our researchers, be they faculty, postdocs or graduate students, collaborate on interdisciplinary projects that involve both mathematics and biology.

We have many visitors at the centre, usually 20 per year. Some stay for a few days, while others travel to UA for an extended period. The focus we have with all visitors and researchers is on the collaborative nature of our interdisciplinary research, allowing them to use our computing facilities and meeting rooms.

(l to r) Mark Lewis and Ivar Ekeland.

Q. Can you give us some examples of the research that takes place at the Centre?

One example of recent work would be on the issue of the Mountain Pine Beetle. Researchers from several disciplines at UA, including math and stats, biology, and renewable resources (Faculty of Agriculture, Forestry, and Home Economics), are working together to address the threat of the Mountain Pine Beetle, in collaboration with the federal government's Pacific Forestry Centre, based in Victoria, B.C. The issue is very timely, as recently the Mountain Pine Beetle has crossed the border from B.C. and is moving east, threatening trees in the Alberta foothills. We are using mathematical modeling and computer modeling to understand the dispersal of the Mountain Pine Beetle, and how the beetle reacts to various situations. The collaboration allows people of different backgrounds to interact, to bring their own skills to the issue, and allows for communications across disciplines.

Another example is the Centre's work on cancer research. Dr. Thomas Hillen and Dr. Gerda de Vries (both of UA) are leading a group that is collaborating with the Cross Cancer Institute in Alberta, looking at ways of optimizing therapy for tumors, as well as plotting the regression of the cancer. The collaboration involves regular meetings and the presentation of ideas, from the mathematical angle, to the group to solve presented problems.

Q. Where is the Centre going?

We are constantly working on new projects. One such example is the analysis of disease group, looking at West Nile virus. They hope to use the developed models on West Nile and transfer them to work with an international group, on modeling the transmission of malaria in urban regions.

Over the longer term, we plan to continue with the small collaborative groups that we currently use. We find they work efficiently and contain a nice dynamic. We are constantly developing new initiatives and starting new collaborations.

Q. Please explain about the types of collaborations at the Centre.

Our research is not constrained by borders or geography. Some of our programs are funded by the U.S. National Science Foundation, while others receive funding from Canadian granting agencies. Several of our initiatives demonstrate our international collaborations. The Biological Invasion group, which is working on control strategies of invading freshwater species such as zebra mussels, puts together biologists, economists and mathematicians from across Canada and the United States.

More information on our projects and people is available on our website, http://www.math.ualberta.ca/~mathbio/.

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Streaming Videos	PIMS Proceedings	PIMS Logos

PIMS 10th Anniversary Speakers

To celebrate the 10th anniversary of PIMS, five of the six PIMS sites have developed their own series of distinguished lectures in 2006-07. UVic is planning an international-caliber ***Symposium on Kinetic Equations and Methods***, April 27-28, 2007.

The aim of these events is to show the infinite variety of mathematics and the tremendous progress accomplished in the past 10 years. The lectures have been video-taped, and are available on the PIMS website, so that everyone can enjoy these truly remarkable mathematical experiences. I thank the lecturers for some of the best presentations I have ever seen. — *Ivar Ekeland*

SFU

Alexander Razborov (IAS)
Nov. 10, 2006
Feasible Proofs and Computations

Jesper Lutzen (University of Copenhagen)
Feb. 5, 2007

Herbert Wilf (University of Pennsylvania)
May 25, 2007

John Mason (Open University, UK)
June 15, 2007

Craig Evans (UC Berkeley)
Date TBA

George Papanicolaou (Stanford University)
Date TBA

Paul Seymour (Princeton University)
Date TBA

Efim Zelmanov (UC San Diego)
Date TBA

U. Alberta

Alexander Merkurjev (UC Los Angeles)
March 29, 2007

Mark Chaplain (University of Dundee)
Date TBA

V. Kozlov (Steklov Institute, Moscow)
Date TBA

Benoit Perthame (École Normale Supérieure, Paris)
Date TBA

V. Srinivas (Tata Institute)
Date TBA

UBC

Andrei Okounkov (Princeton University)
Oct. 16, 2006
Frozen boundaries and log-fronts

Helmut Hofer (Courant Institute, NYU)
Oct. 23, 2006
New geometric and functional analytic ideas arising from problems in symplectic geometry

Raman Parimala (Tata Institute)
Oct. 30, 2006
Sums of Squares and Pfister forms

James Arthur (University of Toronto)
Nov. 6, 2006
A History of the Trace Formula

Garrett Odell (University of Washington)
Nov. 27, 2006
For making genetic networks operate robustly, unintelligent non-design suffices

Mark Lewis (University of Alberta)
Dec. 4, 2006
Plagued by numbers: the mathematics of disease

Jerry Sacks (National Institute of Statistical Sciences)
Feb. 19 2007

Gary Leal (UC Santa Barbara)
Feb. 26, 2007
Computational Studies of the Motion of a Nematic LCP in a Simple Shear Device

James Berger (Statistical and Applied Mathematics Institute)
March 19, 2007

Nancy Reid (University of Toronto)
March 26, 2007
The interface between Bayesian and frequentist statistics

Gunnar Carlsson (Stanford University)
April 16, 2007
Algebraic Topology and Geometric Pattern Recognition

Darrell Duffie (Stanford University)
May 7, 2007
Frailty Correlated Default

U. Calgary

John Taylor (University of Montreal)
Sept. 28, 2006
The integral geometry of random sets

Robert J. Adler (Technion, Israel)
Oct. 25, 2006
The brain, the universe, and random processes on manifolds

Richard Howitt (UC Davis)
Nov. 10, 2006
A Computational Economics Approach to Policy Models: Applications to Natural Resources

Karlheinz Groechenig (University of Vienna)
Dec. 7, 2006
Time-Frequency Analysis: From Wireless Communications to Abstract Harmonic Analysis

U. Washington

Gregory Lawler (University of Chicago)
Oct. 24, 2006
Conformal Invariance and Two-dimensional Statistical Physics

Peter Bickel (UC Berkeley)
October 30, 2006
Regularized covariance matrix estimation

Bin Yu (UC Berkeley)
November 20, 2006
Feature Selection through Lasso: model selection consistency and the BLasso algorithm

Stephen Smale (Toyota Technological Institute)
January 9, 2007
Topology, data and vision
January 10, 2007
Emergence and Flocking

Klaus Schmidt (University of Vienna)
January 11, 2007
On Some of the Differences Between Z and Z^2 in Dynamics

Jim Zidek (University of British Columbia)
January 29, 2007
Statistical modeling in setting air quality standards

Elliott Lieb (Princeton University)
April 11, 2007

Carlos Kenig (University of Chicago)
April 17, 2007

Leo Kadanoff (University of Chicago)
May 22, 2007

Please see page 24 for information on the Symposium on Kinetic Equations and Methods, to be held at UVic on April 27-28, 2007.

PIMS Events

EQUIPS 2006

The Sixth Canadian Summer School on Quantum Information Processing, University of Calgary

Aug. 7-11 2006

by Peter Høyer, University of Calgary

The Sixth Canadian Summer School on Quantum Information Processing was held at the University of Calgary in August 2006. The goal of the school was to introduce quantum information processing to a general audience of mathematicians, computer scientists and physicists with little or no background in the field.

Quantum information processing lies at the intersection of mathematics, computer science and mathematics, and concerns information processing that depends on quantum mechanical effects. It aims at understanding the principles of quantum mechanics and how they can be used for computations and in communication. It is an interdisciplinary area that brings together theorists and experimentalists.

Equips 2006 features 23 lectures, given by 10 lecturers, gathered from:

Andris Ambainis, University of Waterloo
Richard Cleve, University of Waterloo
David Feder, University of Calgary
Paul Haljan, Simon Fraser University
Peter Høyer, University of Calgary
Ashwin Nayak, University of Waterloo
Alain Tapp, Université de Montréal
Wolfgang Tittel, University of Calgary
John Watrous, University of Waterloo
Gregor Weihs, University of Waterloo

The school had 97 participants. A large majority of the attendees were graduate students, of which almost all were enrolled in programs within computer science, physics, and mathematics. The remaining attendees were professors and from industry and research organizations. The school also hosted a few advanced undergraduate students.

The school is the largest of its kind in the world. Training of highly qualified personel, communication of research, and industrial outreach are important goals of the quantum information society in Canada, and the Canadian summer school constitutes an important collegiate effort in reaching those goals. A significant number of participants at past schools have since been engaged in collaborative work with Canadian researchers. The schools have demonstrated that Canada is a world-leader in research in quantum information processing. This year was the second time the school was held in Calgary.

This year's school was made possible through the generous support by our primary sponsor the Canadian Institute for Advanced Research (CIAR), and additional funding by the Pacific Institute for the Mathematical Sciences (PIMS), the Department of Computer Science at the University of Calgary, and the Institute for Quantum Information Science (IQIS).

Joint UBC/SFU Seminar in Statistics

British Columbia Cancer Research Centre

Nov. 10, 2006

by Leilei Zeng, Simon Fraser University

The fourth Joint UBC/SFU Seminar in Statistics, held on Nov. 10, 2006 at British Columbia Cancer Research Centre, was supported by PIMS, the SFU Department of Statistics and Actuarial Science, and the UBC Department of Statistics. It attracted approximately 60 participants, including SFU and UBC faculty and graduate students, as well as numerous researchers from local medical centres. The seminar comprised two talks concentrating on statistics issues arising from medical and health related research. The success of the seminar was due partly to the lively discussion that followed each talk.

Participants at the Joint UBC/SFU Seminar in Statistics

Dr. Jenny Bryan (UBC) started the proceedings by introducing an alternative platform that is under rapid development in the genetic research: high-throughput studies of phenotype (HTP). As with microarray data, a common goal to use HTP data is to cluster genes. Using a motivating example from a HTP study of intracellular protein transport, Dr. Bryan outlined methods for gene clustering and presented statistical methods for computing the significance of gene clusters obtained with hierarchical clustering.

This was followed by Dr. Joan Hu (SFU) who discussed her work in investigating hospitalization records from administrative databases. She raised a number of interesting statistical issues and explored different model formulations that can be used to address these problems. The example Dr. Hu gave was motivated by the data of childhood cancer of hospitalizations of the cancer survivors over the years.

The next seminar will be held in the winter of 2007. For more information about this series, please contact Leilei Zeng (lzeng@sfu.ca) or Matías Salibián-Barrera (matias@stat.ubc.ca).

The 4th SFU/UBC Statistics and Actuarial Science Graduate Student Workshop

Simon Fraser University

Nov. 18, 2006

by Leilei Zeng

As a semi-annual event, the Graduate Caucus in the department of Statistics and Actuarial Science in Simon Fraser University held a graduate student workshop on Nov. 18, 2006. The workshop was taken place in the Interdisciplinary Research in the Mathematical and Computer Sciences (IRMACS) Centre at the SFU Burnaby campus. The event was supported by Pacific Institute for the Mathematical Sciences (PIMS), the Department of Statistics and Actuarial Science in SFU, and the Department of Statistics in UBC. The address of the website designed for the workshop is http://www.stat.sfu.ca/~sbonner/sfu_ubc_wshp_2006_files/abstracts.html.

We invite two faculties and six graduate students to share their experience and research interest. The faculty from SFU is Thomas M. Loughin, who recently joined the department and has been working in the statistical consulting for more than 17 years. With his tremendous consulting experience, he kindly gave an educative and informative talk titled as "Practicing Statistics – Communication is the Key". The other faculty is Bruce Dunham from UBC. The title of the talk is "So, you're teaching...". During the talk, his valuable teaching experience was shared, some advice was offered on how to approach undergraduate teaching, and suggestions put forward that may help a new instructor. Overall, the talks from the faculties cover the important parts of graduate studies, mainly consulting and teaching.

The student speakers from UBC were Hui Shen, Guohua Yan, and Kenneth Lo. Jean Shin, Elizabeth Juarez-Colunga and Gurbakhshash Singh represented the graduate students in SFU. The areas of the talks are quite comprehensive. They vary from frequency approaches to Bayesian methods, from theoretical studies to applied statistics. For the details such as the title and abstract of the talks, please refer to the website.

Around 43 graduate students registered and participated the workshop. The workshop not only is a good opportunity for the speakers to present their own work, but also it provides a platform for all the graduate students to share and discuss their research. Meanwhile, strong interest was shown in both talks of faculties and a lot of questions were asked and answered. With the funding, the graduate students were able to gather together and chat more over the social dinner. As a consequence, the workshop was a success.

For more information on past and upcoming events at all of the PIMS Universities, please visit the website: http://www.pims.math.ca/wrapper/Activities/

Upcoming Events

Symposium on Kinetic Equations and Methods

University of Victoria

April 27-28, 2007

Please see page 24 for more details on this conference.

2007 Alberta North-South Dialogue on Mathematics and 2007 Alberta College Teachers Conference

University of Alberta

May 3-5, 2007

The North-South Dialogue and the Alberta College Teachers Conference are annual gatherings of post-secondary mathematics researchers and instructors from across Alberta.

The organizing committee are **Gerald Cliff** (U. Alberta), **Manny Estabrooks** (Red Deer College), **Thomas Hillen** (U. Alberta), **Tiina Hohn** (Grant MacEwan CC), **David McLaughlin** (Grant MacEwan CC), and **Eric Woolgar** (U. Alberta).

Combinatorial Models In Geometry And Topology Of Flag Manifolds

University of Regina

June 5 - 14, 2007

The main objective of the school is to provide an interactive environment where interested people (graduate students, postdocs, young researchers) can learn results and understand techniques concerning various aspects of flag manifolds. The subject is an interplay between differential geometry, algebraic geometry, Lie theory, and combinatorics, and the school will focus on combinatorial models and algorithms which have been developed in connection with the study of various geometric and topological aspects of flag manifolds.

Lecturers include **Leonardo Mihalcea** (Duke University), **Matthieu Willems** (U. Toronto), **Catalin Zara** (U. Massachusets-Boston) and **Liviu Mare** (U. Regina).

The conference organizer is **Liviu Mare** (U. Regina).

Applied Inverse Problems 2007: Theoretical and Computational Aspects

University of British Columbia

June 25-29, 2007

The enormous increase in computing power and the development of powerful algorithms has made it possible to apply the techniques of Inverse Problems to real-world problems of growing complexity. Applications include a number of medical as well as other imaging techniques, location of oil and mineral deposits in the Earth's substructure, creation of astrophysical images from telescope data, finding cracks and interfaces within materials, shape optimization, model identification in growth processes and, more recently, modelling in the life sciences.

The series of AIP Conferences aim to provide a primary international forum for academic and industrial researchers working on all aspects of inverse problems, such as mathematical modelling, functional analytic methods, computational approaches, numerical algorithms etc.

continued on page 19

Diversity in Mathematics

by Ivar Ekeland

delivered at the BIRS Women in Mathematics conference by Ulrich Horst

In January of 2005, in an official statement, PIMS declared that "One of the most severe brain drains impeding progress throughout the world, in developed and underdeveloped countries alike, is the fact that women are turning away – or are being turned away – from studies and research in science and technology". We stand by that statement. Society is depriving itself of one-half of its workforce, in an area where it is sorely needed, and PIMS is committed to reverse that trend.

I think it is fair to say that the reasons for this situation are not fully understood, and could be quite subtle. In economic theory, one is used to see small imbalances on the individual scale have major effects on the global scale. For instance, if there are two types of individuals in a city, and if everyone strongly prefers to have neighbours of the same type, it will come as no surprise that eventually the city is split in two homogeneous parts, one of type A and the other of type B. The surprise is that the same effect is observed even if there is only a slight preference to have neighbours of the same type: eventually, the city will be split in two although no one has a strong preference for segregation. A slight discomfort is enough.

Something similar may be at work in the present situation: although most people mean well, and are ready to give girls and women a chance, slightly better opportunities for males (because there are more men in the field, or because one is more used to see them in scientific positions, etc...), and/or slightly more difficult conditions for females (because they do not project themselves in such roles, or because they bear more of a burden in the family life, etc...), adding up over the years and the generations, may result in a stark pattern of exclusion which no one actually wanted. And since no one wanted that result, the danger is that it is seen as "natural", so that people would believe that it arises from large differences in abilities, instead of small differences in social opportunities.

The practical consequence is that details are important. The cure has to be like the illness, a succession of actions, not necessarily major, but consistent, and spread throughout the education years, K-12 and college, and the academic career for those who pursue one. At PIMS we have the issue constantly in mind, and we try to take corrective steps in every of our programs. At the present time, there are 26 PIMS post-doctoral fellows, five of whom are women. Nicole Tomczak-Jaegerman, Pauline van der Driessche, Leah Keshet, Rachel Kuske, have been CRG leaders. We are fortunate in having so many talented female colleagues in our direct environment, and we will try to recruit even more. It used to be the case that at the PIMS board there was no women, but this has now been corrected. We also try to bring the problem to public attention as much as possible. The last issue of the PIMS newsletter has an interview of Ingrid Daubechies, the preceding one an article of Barbara Keyfitz. We are also thinking of ways to address the problem in our K-12 educational problems. For instance, to give role models for girls, a future issue of Pi in the Sky could be devoted to women in mathematics. In short, PIMS is fully committed, and we hope that this workshop will come up with some more suggestions that we can implement.

Let me note that, in seeming contradiction with what I have said up to now, there are natural thresholds (such as entering college, or promotion from associate to full professor), where the amount of women is greatly depleted. This specific problem may have to be addressed by other means. In fact, as I said at the beginning, we do not fully understand the causes of the gender imbalance in mathematics. I hope that the three mathematics institutes, CRM, Fields and PIMS, can show leadership on this issue. Together with the other representatives of the Canadian mathematical community, I hope we can develop a national policy to correct gender imbalance in mathematics at all levels, both in education and in academia. We think the potential rewards are important, and PIMS is ready to participate in such an effort.

The conference organizers are **Gary Margrave** (U. Calgary), **Richard Froese** (UBC) and **Gunther Uhlmann** (U. Washington). More information on the conference, including a list of speakers, can be found at http://pims.math.ca/science/2007/07aip/.

Discrete Simulation of Fluid Dynamics: Micro, Nano and Multiscale Physics for Emerging Technologies

Banff, Canada
July 23-27, 2007

Topics covered at the DSFD series of meetings include lattice gas automata, the lattice Boltzmann equation, dissipative particle dynamics, smoothed-particle hydrodynamics, direct simulation Monte Carlo, stochastic rotation dynamics, molecular dynamics, and hybrid methods. There will be sessions on advances in both theory and computation, on engineering applications of discrete fluid algorithms, and on fundamental issues in statistical mechanics, kinetic theory, and hydrodynamics and their applications in Micro, Nano and Multiscale Physics for emerging technologies. Other topics of interest also include experimental work on interfacial phenomena, droplets, free-surface flow, micro and nanofluidics.

More information can be found at http://nanotech.ucalgary.ca/dsfd2007/.

Canadian Summer School on Communications and Information Theory 2007

Banff, Canada
Aug. 20-22, 2007

The iCORE HCDC Laboratory, U. Alberta, is holding a summer school that will consist of invited talks from leading experts in the areas of Communications and Information theory. The talks will be self-contained and aimed at introducing graduate students and researchers to new areas in Communications and Information theory that are otherwise not covered in a comprehensive and consolidated manner in the literature. Additionally, the summer school will provide a stimulating atmosphere to learn, present, discuss and exchange ideas.

The organizing committee comprises **Christian Schlegel, Dmitri Truhachev, Sumeeth Nagaraj, Lukasz Krzymien** and **Sheehan Khan.**

A Phenomenology of Mathematics in the XXIst Century? The First Elements of a Sketch

by François Lalonde, CRM

I would like to thank Alejandro Adem, the deputy director of PIMS, for encouraging me to write these reflections. I would also like to thank the organizers of the BIRS Workshop "Women in Mathematics" who gave me an opportunity to examine these questions more closely.

Action

Group actions, geometric or analytic transformations, zeta functions of dynamical systems and many other examples bring us constantly back to a tension, one which nonetheless forms part of the integrity and the finality of mathematics, to its definition: mathematics is, above all, an abstraction of our relation to the world, an abstraction of our action on it, whatever form this action may take.

Transcendance

In reflecting on modern mathematics, it is interesting to ask what parts of it are of a transcendental nature, and what parts are not. An algebraic algorithm is not transcendental, for example, no more than an integrable system. This does not mean that integrable systems are uninteresting: it is quite the opposite, as they have been at the heart of some of the most spectacular recent developments. Optimal algorithms may be quite hard to find, discovering the first integrals of a dynamical system in order to prove that it is integrable is often a remarkable tour de force. Once found, however, it only takes a few minutes to give them explicitly. On the contrary, the singularities of moduli spaces of PDEs is certainly transcendental, inasmuch as they require existence theorems based on proofs that present no direct access to explicit comprehension, that is, to understanding related to constructive proofs, the only form of understanding that can immediately persuade. Still, how powerful these proofs are!

I suppose that every mathematician has his or her own definition of what is transcendental and what is not. There are certainly many ways of defining the transcendental in mathematics: the first one, and probably the simplest, is the necessity of the intervention of spaces of infinite dimension; the second one, close to the first one, is the unavoidable occurrence of non-constructive proofs of existence. In symplectic geometry, a field that I know well, Gromov used to make a distinction between "hard" and "soft" symplectic geometry, being understood that what is "soft" is as hard as what is "hard", the difference between the two lies in the fact that "hard" theorems cannot be proven by purely algebro-topological techniques, but require moduli spaces of elliptic PDEs (whence the term "hard" or "rigid" that refers to the rigidity of analytic functions). In the context of these reflections, what is "hard' would be transcendental, while what is "soft" would be algebro-topological. Certainly, the distinction between the transcendental and the algorithmic has a meaning not only in pure mathematics, but in applied mathematics as well (assuming that one insists on distinguishing more or less arbitrarily between pure and applied mathematics).

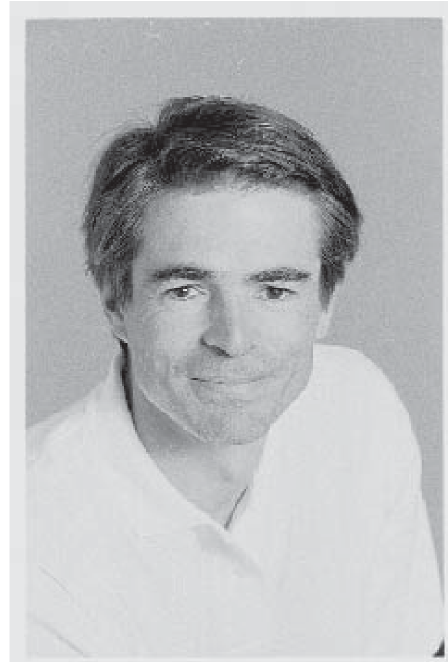
A Paradox

Reflecting on these paragraphs, a troubling question immediately comes to mind: if mathematics is the abstract expression of our action on the world, how could there have been, even in the slightest way, the need to give birth to an artifice which, whatever the form it has taken through the ages, expresses itself through the emergence of infinite dimensional spaces. Naively, these spaces naturally appear as soon as one thinks of spaces of functions, perhaps whose simplest example nowadays is the space of real-valued functions defined on the reals. But even this simple example has its subtleties: the dimension of the space of *continuous* real functions is of a *countable* cardinality, since you can expand them in terms of Fourier series, whereas the space of *all* real functions is of much higher cardinality. Continuity imposes such a strong connection between nearby data of real functions that it constrains them infinitely... What a beautiful thing! and it seems to us, without reason, elementary. It is because the world surpasses us so completely that mathematicians have developed so many transcendental tools.

Nassif Ghoussoub recently published an article that the CRM's Bulletin printed in its full version, explaining the sublime beauty of questions of a transcendental nature, starting from the works of Nicole Tomczak-Jaegermann. Demailly's plenary talk at the ICM 2006 was entitled "Compact Kähler manifolds and transcendental techniques in algebraic geometry."

Culture Shock

As director of the CRM, and even more as a mathematician, I think that over the course of the next century there will be a tension between the algorithmic and the transcendental which will occur in a thousand ways. The problem will not come so much from within mathematics, since,



François Lalonde

for example, nothing is more useful in algebraic combinatorics than the transcendental world of complex analytic geometry, though there are still differences between the two cultures, even among mathematicians. This tension is expressed among physicists in a manner vaguely analogous to the contrast between non-chaotic classical systems and the quantizations of (almost) ergodic systems.

The most virulent problem, however, will come from the difference in cultures between mathematicians and experimentalists: mathematicians resolved the problem of constructivism a long time ago, simply because their objects of study are so real to them that all mathematicians have this confidence, which has been carried across the centuries, and which has seen, over generations, how much these objects are precisely what is needed, how much these methods, however indirect they may be, touch the heart of a problem. How will this tension develop in Canada? We have the chance to live in an environment where universities dominate public research and form a very uniform body (in contrast to the USA, France, Great Britain): all Canadian universities are quasi-public and while there exist differences between the oldest and the youngest ones, they all share the same characteristics and the same philosophy. In addition, sponsored research which, elsewhere, would normally take place in a government laboratory, is often carried out in the universities themselves. Secret or military research is less present in Canada than it is abroad. And this is a good thing because the governments of the western world are progressively divesting from sponsored research in government laboratories in order to invest more in the free, open and competitive research that takes place in universities. These developments are particularly encouraging for Canada. It is also this situation which has permitted MITACS to take shape and to progress: an organization of this kind would never have been thinkable in a society where the transmission of knowledge and its service to civil society is dominated by bureaucracy or by private research which remains undisclosed.

I just discussed very briefly the tension between the algorithmic and the transcendental in mathematics, as well as the tension which persists between free and oriented research, a tension that is all the more interesting in Canada, since here we are evolving towards a model where the two types of research take place in the heart of our universities, in the same departments, and among the same professorial body. This will pose a great number of frictions - but I am convinced that it is preferable to face them than to separate the cultures.

Women and Men in Mathematics

I would now like to address a third question, the presence and the contributions of women in mathematics. I am sensitive to this question for at least three reasons: the first one is that more than half of my collaborators were women. My encounter with Dusa McDuff (and with Michèle Audin before) was certainly a turning point in my scientific life. I am sensitive to this question too because the fields of mathematics that have interested me over the last 15 years - symplectic geometry and topology - are precisely the fields where the contribution of women have been constantly at the highest international level (Noether, Vergne, McDuff, Kirwan, Audin, Jeffrey, Ionel, Tolman, Karshon, Wehrheim...). It proves in the clearest terms that women can be perfectly at ease in fields of research that are the abstraction of our *action on the world* (i.e group actions on manifolds, study of infinite dimensional transformation groups, actions of symmetries on moduli spaces,...). I mean that there is no reason to believe that women could feel more attracted to questions that are the abstraction of phenomena of a less dynamical nature. This must be said. I am finally sensitive to this question because I was the first mathematician, responding to an invitation of NSERC, to set up the rules at the end of the 1980s for the WFA (Women Faculty Award) programme, now changed to UFA.

The question of the representation of women in mathematics in academic positions in Canada is the main issue of the BIRS Workshop of September 2006, to which I was very likely invited as director of the CRM - which is perhaps a little disappointing since I would have liked to have been invited for several other reasons. What follows constitutes my reflections on this issue.

Currently, less than 15 percent of mathematicians in Canada holding an academic position are women. This is unacceptable. So the question is still of the greatest relevance, and I am happy that the organizers reminded us of these issues and the actions to be taken. Reports provided in advance to the participants by the organizers seem to look at the question mainly from a statistical point of view: “If women constitute 50% of the population, how could we continue to deprive ourselves of such a potential for discovery?” Of course, I agree with the organizers about how urgent it is to increase the presence and influence of women at all levels of research and training in universities. It is a pity that no women has yet won the most ‘mediatized’ prize in mathematics, the Fields Medal. However, given the strict and exceptional rules for this prize, with its age constraints, this is perhaps not so surprising - and female mathematicians should not feel more excluded than Canadian mathematicians, who have never won this prize either. What is of a much more immediate concern is that, of a total of 160 invited lectures, there were less than 10 invited women at the last ICM in August 2006, held a month before the BIRS workshop. This will change very quickly!

That being said, I do not think that statistical considerations should be the only considerations to dominate the debates, unless one is willing to concentrate on a purely descriptive and technical way of discussing these questions. For the purpose of these remarks, I would like to discuss three aspects concerning the rate of representation of any group of people in any given body. This brief apparent digression is essential, in my opinion, before addressing the question of women in mathematics. Schematically, we would have:

1- the rate of representation of a group which is rather a curiosity;
2- the rate of representation of a group which is intimately related to politically organized lobby groups, but which is not likely to change the nature of the body in which they want to integrate;
3- the rate of representation of groups that can change the nature of the body.

The first case, the one pertaining to curiosity, is exemplified, say, by the rate of left-handed mathematicians in academic positions. It is a curiosity, which is not uninteresting if one discovered that, say, the rate of left-handed mathematicians in geometry and topology was significantly higher than their global representation in the general population. I do not know if a study relating left-handed people to mathematics has ever been done. For the moment, it does not interest me, but it could be of great interest to experimental psychologists.

The second case, politics, is illustrated in multiple ways: what is the percentage of visible minorities in the US in academic positions in mathematics? What is the percentage of grants awarded by NSERC or the other two Canadian funding organizations obtained by a given region of Canada? Do Francophones receive more or less funding than Anglophones? These are the questions of a political nature that have an importance, but that probably will not affect the course of scientific discovery in the coming century.

Finally, and above all, I would like to express an opinion on the third case, of groups whose contribution goes beyond their political membership. The only significant example that I have in mind is that of women. Contrary to political pressure groups, for example those of a region of Canada, I am convinced that in the century to come, women will bring a new dimension to mathematics. There are several points which I will make in the course of these reflections. First, just so you understand me well, I strongly believe in equal representation of each Canadian region in NSERC’s committees, since this has immense consequences for the various regions and their development - I want to say simply that I do not think that professors from Ontario or Quebec, for example, have characteristics that are so different that they conceive of mathematics in a different manner.

As I am convinced that women will soon occupy as many important positions in all spheres of public life as men, the question that interests me most is the following: what can we expect from this change, in what manner will the presence of women in mathematics change the nature of research and the milieu in which it takes place?

In order to respond to this question, I would ask that you grant me the liberty simply to describe what I have observed over the course of my 20 years’ teaching at the bachelor’s and post-graduate levels. My experience has shown

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me that there is a difference between the manner in which most men and women learn mathematics. It is as though, bizarrely, men were "defined" a priori, that is to say, as though they perceived their identity as given once and for all, and as though their interaction with the objects of the world was an experience which, however fascinating it might be, stayed a game which never called into question their identity. This is evidently a difficult thing to understand, since it is an attitude which can seem coarse, basic. From their youngest childhood, most boys that I have known break into pieces all the things with which they are presented: not only to destroy them, but also to reconstruct them in their own manner. Most girls that I have known act in another manner entirely, as if their identity evolved with the objects that they encounter, or more exactly, as if each encounter defined their identity more - it is no longer an abstract game of disassembly and reconstruction. Whatever the origin of this difference, it exists - with of course a large number of exceptions - and it convinces me that the participation of many more women in mathematics, at the highest level, is something which surpasses political or statistical considerations. It is a question of an infinitely more important nature. It is possible that this difference will fade rapidly with time in the next century, but it is also possible that it will persist.

A Relation Between the Two Main Subjects of This Note?

Could there be a relation between the algorithmic-transcendental tension and the difference in the sexes in mathematical research? As I said above, the transcendental is virtually impossible to reconstruct and women could very well excel here more than men. We probably cannot do transcendental mathematics while being naively constructivist, and the toys (cement trucks, tractors, etc.) that boys will have taken apart during their childhood will perhaps not prepare them to understand this world better than women, even more now, since today's toys are almost all electronic and taking them apart will not teach much to a five-year old! This relative ease of women in the transcendental objects of mathematics seems to me to be confirmed by three other observations: (1) the more transcendental the mathematics, the more they bring into play large bodies of knowledge, and it has seemed to me, in the course of my 20 years' teaching, that young women are often more adept than young men at assimilating a large number of things in a small amount of time; (2) the second confirmation of this hypothesis is that it is not in mathematics that women are the least represented, but in engineering, which is the field par excellence of the algorithmic and of the constructivist (professional women engineers form barely five percent of all engineers!); (3) the third confirmation is that, in making a cursory count of the women who have contributed the most to the highest levels of mathematical research in the 20th century, one observes the following: in fields like algebraic topology and the theory of homotopy which dominated mathematics during a good quarter of a century, which are constructive disciplines (nothing is more constructive than simplicial homology which seems like a Lego-techno game), there are very few women, except where the field became coupled to questions frankly transcendental. There are a certain number of exceptions of course. This is to be understood as a tendency, not a theory, but all seems to indicate that the representation of women at the highest level increases (as at all the other levels) the more distant one is from engineering and the more one approaches the more transcendental fields of mathematics. Supposing that these remarks might have some interest, they are only based on my personal observation which extends between 1985 and 2005, and they do not contain anything that is determinate and even less which reflects anything innate. With a note of humour, one of the organizers of the BIRS workshop on "Women in Mathematics" confided to me in the minutes before the opening of the Workshop that the workshop would be much too algorithmic to give any real attention to these transcendental reflections! I would respond with pleasure that it is very plausible that these reflections tell much more about me than about women in mathematics.

Some mathematicians will find these reflections "dépassées." Why should we go back to the differences between women and men in mathematics? Is it of any interest? The fact that this question has apparently been resolved (and would therefore not need any further thought) is exactly what I spontaneously felt when I began to write this article for the BIRS workshop. But the more I worked on this contribution, the more I felt that I should say where my reflections led me.

I would like to end this paragraph by insisting on the distance in point of view which exists between this article and some common ideas which we find over the ages about the differences between men and women: for example, even though most young boys play by dissembling and reassembling their toys, most young girls play as well by reinventing the theater of life, by creating all forms of situations - this corresponds to my observation. Whether this is innate or cultural I do not know, only that it seems to appear very early in life. The second: in Madrid, while learning the history of Plaza Mayor, where I am writing this article, I have realized once more how harsh the lives were of people in the centuries before ours. Even considering the lives of the most privileged, the kings and queens of the 17th century, we find the same: they died at 30 or 40 years of age, queens earlier than kings. Nothing prevents us from imagining that women, who now live longer than men, will finish by pushing back menopause to the same moment as that of men, especially since they will soon be in the majority in medical research. This would be enough by itself to change a great number of parameters! The third: according to a common idea, women, from their youngest age are more attracted by people and life, while boys are more fascinated by objects, technology, and construction. This could be explained by motherhood, by their different relation to life itself, and this may explain why women have entered the medical disciplines at a faster rate than the physical sciences and engineering. Even if this common idea does not seem to be contradicted by my experience, it is of limited value. It is certain that whoever believes in this common idea will be able to establish a relation between it and what I have written here: such a person would consider the most transcendental mathematical concepts as objects that are so complex that one should consider them more as subjects than objects and would then conclude that a woman's mode of learning is more appropriate there than a man's approach of appropriation and reconstruction. Extrapolations such as these, however, go beyond the subject of my remarks.

There is nonetheless an observation here which, to my knowledge, has never been made, and which tells us something that has nothing to do with the question of the sexes in mathematics: women, supposing that they are, for the moment, more readily at ease or interested in the world of living subjects than in that of objects, would naturally dominate the fields of languages. This is effectively the case in the natural languages. If, as many people continue to believe, mathematics were a language, albeit that of nature, I am convinced that women would have more quickly entered the mathematical world. What is important here is that this situation simply underlines my profound conviction that mathematics is not a language and it will never be one; mathematics is a science which studies objects, certainly objects which are abstract, but objects which are imposed on the mathematician with the same power, the same troubling reality as those objects of a physicist or a chemist. After all, when physicists make an appeal to mathematics, as in general relativity, in string theory, or in statistical mechanics, it is not to look for a language, but to find - and to develop - the right objects and the right ideas.

The Title Revisited

Looking back at the title of these notes, the reader may feel deceived, since there are so many other interesting aspects to explore: one could study the rise of probabilistic methods that have had such an impact on all aspects of science at the beginning of this century, the evolution of each very recent field of mathematics that starts so often with simple, but very original, geometric ideas, and then goes through a period of explosion in its (often unexpected, even spectacular) relations with different fields where analysis plays a crucial role, and finally reaches a extremely sophisticated level where algebra takes over. Algebra is the only way to make all of these discoveries digestible, transmissible. I remember how disappointed I was when the enumerative “Gromov-Witten” invariants were introduced in Symplectic Topology. It was such a reduction of such a rich world! But I realize, 10 years later, that this algebraization was essential. When Kontsevich pronounced his inaugural speech at the IHES, he insisted that Algebra should now be as much respected as Geometry in the Institute where Geometry, with Thom and Gromov, had had such an influence, for such a long time. He had in mind his recent results about quantization. Algebraic and Analytic Number theories are still very far apart: the latter is very close to probablistic methods while the former is still deeply anchored in arithmetic geometry. That is to say: numbers are geometric objects, that are simple enough to be studied by probabilistic methods, like graphs. An interesting question is: will there be a necessity to apply probability theory to much more complicated objects, like Lagrangian or complex submanifolds, in a way that would result in theorems about these objects that would tell something only within a certain range of probability, while being certain that the same theorems are unprovable by non-probabilistic methods? This is a very different question than the well-known genericity assumption. It would be a pleasure to write on these subjects.

On a more practical level, one which is more in line with the spirit and the objectives of the BIRS workshop, what are the means at our disposal for increasing the presence of women in mathematics? Regarding our current programs, Isabelle Blain, vice-president of NSERC, confided to me recently that the University Faculty Award program, after 15 years in existence, has not been able to increase the proportion of women in faculty positions in science and engineering. As this fact is of a public nature, I did not think it necessary to ask her permission to mention it here. In my opinion, and also since I participated in the conception of this program, it no longer seems adapted to either reality or necessity. In the beginning, the program sought to compensate for a certain prejudice against the hiring of women in university positions in science, since many of the hiring committees in the 1970s and 1980s were largely dominated by men, some of whom were still part of a generation that did not imagine that women could have their place in the academic world. However, since these prejudices have fallen, the program has become outdated. To make things clear: a woman now hired via the UFA program in a given university is either effectively the best candidate and we do not need the program, or else she is not the best candidate and in this case the program does a disservice to Canadian universities. It seems to me that NSERC should end this program and that we need to create a program with a different angle. The goal is that there be no obstacles based solely on sex preventing women from pursuing careers in mathematics. Any woman, no matter at what stage she might be in her life, should feel welcome and supported in the mathematical world. This is particularly important for women between 20 and 35 years old, a critical period in a woman’s life which will continue to be so for a long time, even if all other obstacles (prejudice, relative inertia of the academy, etc) are removed. Women who enter into an academic career must achieve everything in a very short period of time: establish a scientific career and start a family (for those who want to) at the same time. Men, even the most liberal who rigorously share all domestic tasks with their spouses, still have a longer horizon: they can very well give themselves completely to research for 15 years, and start a family afterward. At the age of 25, the critical age for seriously considering a postdoctoral position, women have their life on their shoulders, whereas men still have their lives in front of them! Men and women live in different scales of time.

There are, in the short term, many ways to break down the barriers that often prevent women from feeling at ease in mathematics. However, these are to be found more in civil society in general than at NSERC or the three Canadian mathematical institutes. We must place daycare and parental support which is accessible and of the highest quality at the disposition of families. In this way women active in the sciences can devote as much time as they desire to their research. These programs exist in Quebec and should be extended to the rest of Canada. By the same token, we must recognize that the scales of time play in a different manner in women than in men. As a mathematician and as director of the CRM, I think that this is a crucial issue: it seems altogether reasonable to hire a female mathematician at a more advanced age, say 35, in any top-level research oriented university. This could apply to the CRM postdoctoral programmes soon.

I would like to end this contribution by mentioning that I have never witnessed in any selection committee at NSERC, FQRNT or in my university, a single occurrence of discrimination against the hiring of women. All the talented women that I know have found positions, whether they be Canadians, Americans, or Europeans. I think that we should be clear and take a position for a genuine policy of recognition and support for women: the UFA program is no longer appropriate, but civil society has genuine responsibilities that the BIRS workshop and its follow-up should identify and promote. The CRM is ready to participate vigorously in this endeavor. The CRM, which did not have a single women on its Scientific Advisory Panel two years ago, now has four female members in 2007. The same applies to the direction of the CRM: half of the deputy directors are women. This is not the result of a “proactive action” - it is simply the consequence of the beauty of mathematics, with no concession, with no discrimination of any sort.

A mathematician and physicist by training, François Lalonde holds a Doctorat d’État (1985) from the Université de Paris-Sud Orsay in the field of differential topology. His fields of interests include symplectic topology, Hamiltonian dynamics and the study of infinite-dimensional groups of transformations. He is member of the Royal Society of Canada since 1997 and was a Killam Research Fellowship recipient in 2000-2002. He holds the Canada Research Chair in the field of Symplectic Geometry and Topology at the Department of Mathematics and Statistics of Université de Montréal. Plenary speaker at the First Canada-China congress in 1997, his joint works in collaboration with Dusa McDuff were presented in her plenary address at the ICM 1998 in Berlin. Over the last year, he gave the Stanford 2005 Distinguished Lecture series, the 2005 Floer Memorial Lecture at Berkeley, and was invited speaker at the ICM 2006 in Madrid. The IAS organized recently a workshop on the relations between the Cornea-Lalonde cluster homology and the Hofer-Wysocki-Zenhder polyfold theory funded by the Clay Institute. He is director of the Centre de Recherches Mathématiques (CRM) since 2004. He currently supervises nine graduate students and postdoctoral fellows.

Symposium on Kinetic Equations and Methods

University of Victoria, April 27-28, 2007

A conference in honour of the 10th anniversary of PIMS

World leaders from diverse branches of kinetic theory will gather for an intense two-day workshop at the University of Victoria in April, 2007. Ten invited speakers will deliver hour-long lectures on recent work in kinetic equations. The organizers expect that this format will attract may participants in addition to the speakers. The structure of the meeting represents a unique opportunity to hear up-to-date reports from leaders in many branches of the field at one meeting. Students especially would benefit from this opportunity.

Scientific Background: Kinetic theory has seen much and dramatic activity in the last two decades; the best advertised event was the award of the Fields medal to Pierre-Louis Lions and his work on the Boltzmann equation was explicitly cited in this award. However, there have been many other profound results and trends, such as:

• the satisfactory treatment of fluid-dynamic limits of the Boltzmann equation, completing a program which was started in the late eighties by Bardos, Golse and Levermore, and separately by Esposito, Lebowitz and De Masi. The relatively recent completion of the program is attributed to L. St-Raymond, Paris.

• qualitative results for the spatially homogeneous Boltzmann equation for different types of interactions, including grazing collisions. Many distinguished mathematicians have contributed to this among others C. Villani, G. Toscani, and B. Wennberg.

• analytical studies of nonlinear kinetic equations arising in quantum physics, for example for the description of electron motions in semiconductors, or in Bose-Einstein condensates. A prominent representative of such work is Peter Markowich in Vienna, who won the Wittgenstein prize for his scientific achievement.

• work on other kinetic equations, for example the Vlasov-Maxwell system, which in spite of its importance in plasma simulation still offers deep mysteries. Much analytical effort into this system has been invested by W. Strauss, R. Glassey and G. Rein, and more recently by F. Golse, S. Klainerman and Staffilani.

• results on statistical foundations of kinetic and fluid dynamical equations as pioneered by R. Varadhan and his school. A prominent member of this school is F. Rezakhanlou in Berkeley, who is applying probabilistic machinery to obtain rigorous derivations of kinetic equations.

• the spread of kinetic equations and methodology in applied science, for example in traffic flow studies, in biological contexts, even in sociology.

• finally (and this does by no means complete the list) the use of modern methodology (such as mass transportation methods) and their impact in kinetic theory.

Organizers: **Chris Bose** (UVic), **Reinhard Illner** (UVic), **Robert McCann** (U. Toronto).

http://pims.math.ca/science/2007/07kin/

Clarification: *Accromath*, the sister publication of *Pi in the Sky*, is published by the CRM and by the Institut des sciences mathématiques (ISM) which is directed by Octav Cornea. (http://www.math.uqam.ca/ism/index_en.html?intro_en.html). Incorrect information appeared in the PIMS Newsletter, Vol. 10, Issue 1.

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