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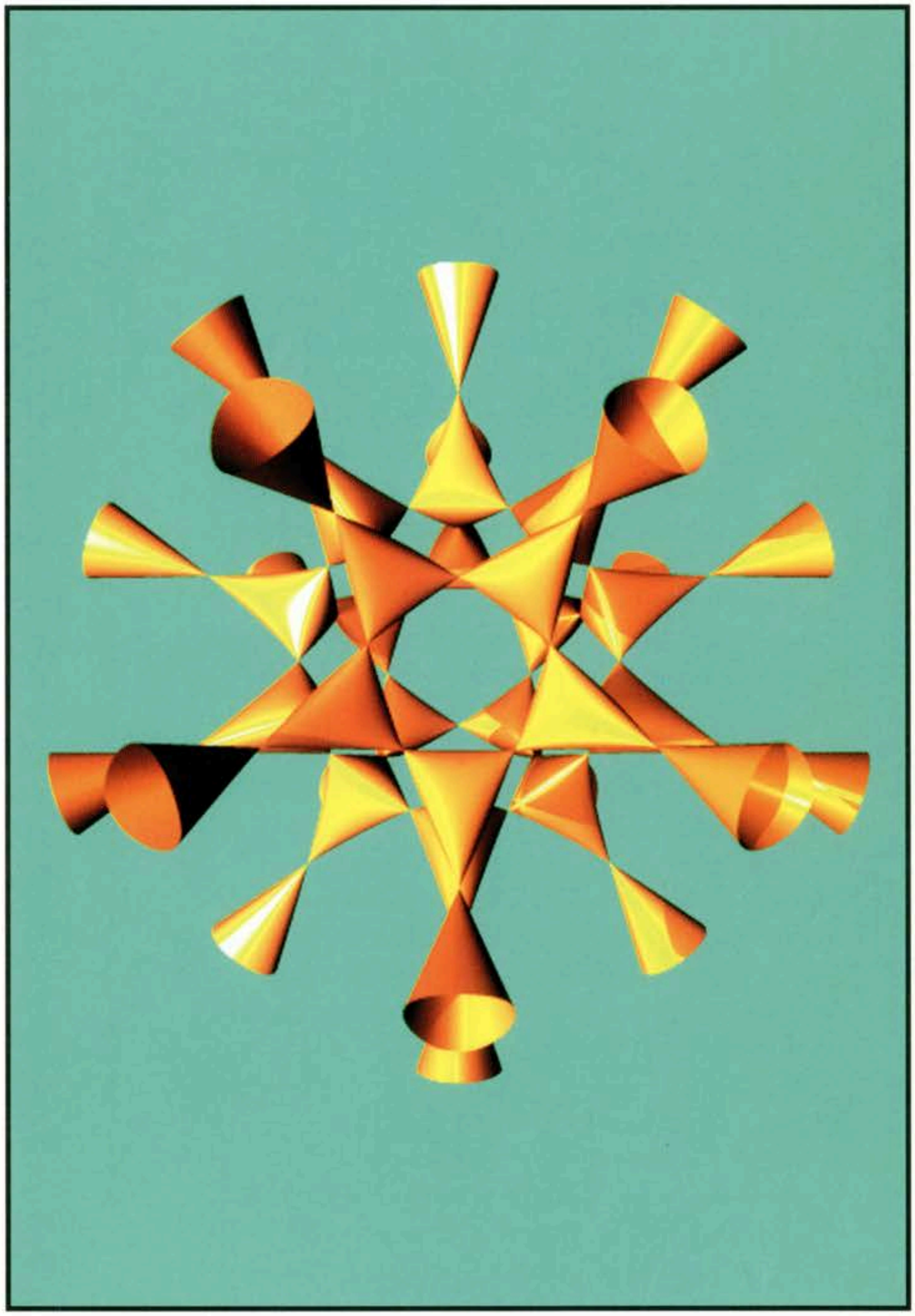
Notices

of the American Mathematical Society

March 1999

Volume 46, Number 3



A Very Singular Surface (See page 318)

American Mathematical Society

New Titles from the AMS

Higher Category Theory

Ezra Getzler and **Mikhail Kapranov**, *Northwestern University, Evanston, IL*, Editors

This volume presents the proceedings of the workshop on higher category theory and mathematical physics held at Northwestern University. Exciting new developments were presented with the aim of making them better known outside the community of experts. In particular, presentations in the style, "Higher Categories for the Working Mathematician", were encouraged. The volume is the first to bring together developments in higher category theory with applications. This collection is a valuable introduction to this topic—one that holds great promise for future developments in mathematics.

Contemporary Mathematics, Volume 230; 1998; 134 pages; Softcover; ISBN 0-8218-1056-1; List $34; Individual member $20; Order code CONM/230NT93

Trends in the Representation Theory of Finite Dimensional Algebras

Edward L. Green, *Virginia Polytechnic Institute and State University, Blacksburg*, and **Birge Huisgen-Zimmermann**, *University of California, Santa Barbara*, Editors

This refereed collection of research papers and survey articles reflects the interplay of finite-dimensional algebras with other areas (algebraic geometry, homological algebra, and the theory of quantum groups). Current trends are presented from the discussions at the AMS-IMS-SIAM Joint Summer Research Conference at the University of Washington (Seattle).

The volume features several excellent expository articles which will introduce the beginning researcher to cutting-edge topics in representation theory. The book will also provide inspiration to researchers in related areas, as it includes original papers spanning a broad spectrum of representation theory.

Features:

- Work outlining significant progress on long-standing open problems.
- Survey articles offering both overviews and introductions to various subfields of the topic.
- Expositions reflecting the interplay between the representation theory of algebras and other fields.

Contemporary Mathematics, Volume 229; 1998; 356 pages; Softcover; ISBN 0-8218-0928-8; List $75; Individual member $45; Order code CONM/229NT93

Symmetries and Conservation Laws for Differential Equations of Mathematical Physics

I. S. Krasil'shchik, *Moscow Institute for Municipal Economy, Russia*, and **A. M. Vinogradov**, *University of Salerno, Italy*, Editors

This book presents developments in the geometric approach to nonlinear partial differential equations (PDEs). The expositions discuss the main features of the approach, and the theory of symmetries and the conservation laws based on it. The book combines rigorous mathematics with concrete examples. Nontraditional topics, such as the theory of nonlocal symmetries and cohomological theory of conservation laws, are also included.

The volume is largely self-contained and includes detailed motivations, extensive examples and exercises, and careful proofs of all results. Readers interested in learning the basics of applications of symmetry methods to differential equations of mathematical physics will find the text useful. Experts will also find it useful as it gathers many results previously only available in journals.

Translations of Mathematical Monographs, Volume 182; 1999; approximately 347 pages; Hardcover; ISBN 0-8218-0958-X; List $129; Individual member $77; Order code MMONO/182NT93

Proceedings of the International Congress of Mathematicians, Berlin 1998

Gerd Fischer, *University of Dusseldorf, Germany*, and **Ulf Rehmann**, *University of Bielefeld, Germany*, Editors

A publication of DOCUMENTA MATHEMATICA.

Each International Congress brings together mathematicians from all over the world to discuss recent developments in all areas of mathematics. It is one of the most exciting gatherings of mathematicians. The 1998 Congress in Berlin was no exception.

The invited speakers at the ICM have been recognized by their colleagues as important leaders in their fields, with their work representing some of the most significant recent research in mathematics. The twenty-one plenary speakers are asked to address the whole congress on recent results and trends that are shaping mathematics today. All plenary and invited lectures are published in these proceedings.

The announcement of the Fields Medalists and the Nevanlinna Prize Winner is a particular highlight of each International Congress. Volume I of the proceedings includes a short description of their work and the text of the lectures presented by the Medalists and Prize Winner at the Congress. This year, the Fields Medal Committee also paid special tribute to Andrew Wiles for his proof of Fermat's Last Theorem.

The *Proceedings of an International Congress of Mathematicians* provides a snapshot of mathematics at a given time. The articles for ICM '98 are guideposts to the significant developments in mathematical research at the end of the millenium.

Members of the DMV (Deutschen Mathematiker-Vereinigung) may order at the AMS member price.

1998; 2374 pages; Hardcover; List $140; Individual member $105; Order code PICM/98NT93

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A. Filippov, *Joint Institute for Nuclear Research (JINR), Dubna, Russia*

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April 1999 Approx. 250 pp., 75 illus. Hardcover ISBN 0-8176-3635-8
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H. Bass, *Columbia University, New York* & **A. Lubotzky,** *Hebrew University, Jerusalem, Israel*

This monograph is a coherent survey of the results on uniform tree lattices, and a (previously unpublished) development of the theory of non-uniform tree lattices. Important connections to Lie group theory are drawn, and a number of applications to combinatorics and number theory are also presented. A good deal of attention is given to the construction and study of diverse examples throughout the text, making this a useful resource for self-study or graduate courses.

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Editorial

Public Awareness

In recent years the mathematical community has become increasingly concerned about public awareness of mathematics. Among the tangible expressions of this concern is the establishment by the AMS of a small public relations effort that includes mailings of occasional press releases and a Web site aimed at the general public and science journalists. Another indication is the organization of a conference, held last October by the Mathematical Sciences Research Institute (MSRI), which brought mathematicians together with science editors and reporters.

At the MSRI conference, entitled "Mathematics and the Media", one of the participants claimed that the present time is a "golden age" for popularizations of mathematics. There is indeed some evidence for this claim. For example, in looking at the print media in the past couple of years, one finds that a large number of well-received popular books on mathematics have appeared. Many of these are found in the "Book List", a newly established *Notices* feature, and some have been reviewed in the *Notices*. The quintessential example is Simon Singh's book *Fermat's Enigma*, which told the dramatic story of Andew Wiles's proof of the famous conjecture and which became an international bestseller. Singh has recently written about mathematics for the *New York Times* and some British newspapers. He joins an increasing number of prominent reporters whose specialties include mathematics. Among these are Barry Cipra, Dana Mackenzie, and Gary Taubes at *Science* magazine; K. C. Cole at the *Los Angeles Times*; Brian Hayes at *American Scientist*; Gina Kolata at the *New York Times*; and Ivars Peterson at *Science News*.

In fact, the MSRI conference made it clear that science journalists are very interested in writing about mathematics. The problem is that most of them simply do not hear about mathematics stories. NASA projects and the Hubble Space Telescope routinely land on the front pages of newspapers, partly because there is something inherently fascinating about space exploration, but also because NASA and the Hubble Telescope have public relations machines that feed stories and information to the press.

The AMS is, in small steps, establishing a public relations effort to help reporters find out about stories in mathematics. The AMS Web site "What's New in Mathematics" (www.ams.org/new-in-math/) has a special section devoted to this effort. Another section of the site, called "Math Digest", tracks mathematics coverage in magazines and newspapers. In addition, the Society sends out to a database of science reporters occasional press releases about mathematical developments. Most of these are linked to *Notices* articles and are accompanied by advance copies of the articles. Some of these press releases have generated coverage. Examples include the many articles about the "Beal Conjecture" (see *Notices*, December 1997) and the articles in *Science* and in *Science News* on the use of fractals in modeling Internet traffic (*Notices*, September 1998).

One problem with the existing coverage of mathematics is that it often focuses on developments that happen to be easily explainable rather than on the advances that mathematicians consider to be truly important. For example, the work for which Borcherds, Gowers, Kontsevich, and McMullen received Fields Medals was done in the five to ten years before they received this honor last August, and yet none of their work had been written up in the popular press before they received their medals. The difficulty of inspiring coverage of the truly significant advances in the field derives partly from reporters' lack of mathematical background and partly from mathematicians' lack of experience in explaining in nontechnical terms just what these advances are about.

During the MSRI conference, Sharon Begley, science editor for *Newsweek*, posed an intriguing question: What do mathematicians expect to get out of press coverage of their field? Increased research funding? Fame and glory? A society better informed about mathematics? Answering this fundamental question may be the first step in developing strategies for raising public awareness of mathematics.

—*Allyn Jackson*

Commentary

Another Opinion

Statistical Methods in the Census

Rarely has an application of accepted techniques from the mathematical sciences caused as much discussion among politicians and in the media as the Census Bureau's proposal to use estimation based on statistically designed samples to supplement direct counting in arriving at final counts from the year 2000 Census. Congressional Republicans in particular have strongly opposed this plan, reasoning that increasing the tally of groups undercounted by traditional methods might tilt the reapportionment that follows each census in favor of the Democrats. In response to a suit filed by House Republicans, a federal court panel ruled in August 1998 that the use of statistical sampling for congressional apportionment violates the Census Act.

Here are a statistician's comments on this public controversy. I will ignore the legal and political issues and also will avoid a critique of the specific (and complex) proposal put forward by the Census Bureau. I am mainly concerned about the effects that unrestrained and inaccurate comments made by politicians and commentators during the debate may have on public attitudes toward statistics and toward science in general.

First, estimation based on statistically designed samples is a standard and widely used method for obtaining information about large human populations. The mathematical theory has reached an advanced state, and the practical difficulties that the theory does not deal with are understood, along with methods for at least partially coping with them. Almost all government economic and social data—think of the monthly unemployment rate—are produced by sampling. In fact, most of the data produced by the decennial census come from a "long form" sent to only a statistically selected sample of the population. Even the plaintiffs in the recent court case agree that existing laws "encourage, if not require, the extensive use of sampling" for census responsibilities. The court ruling is based, not on any deficiencies in sampling, but on language in the Census Act that makes a specific exception for its use in apportioning Congress. Broad attacks on sampling as a scientific method are either uninformed or malicious.

In the light of the accepted scientific status of statistical sampling, it is not surprising that two National Research Council panels and a Blue Ribbon Panel of the American Statistical Association concluded that (in the words of the latter) "sampling has the potential to increase the quality and accuracy of the count and to reduce costs" in the 2000 Census. Professionals generally see sampling as another in the long series of innovations in census methods since the first enumerators went out on horseback in 1790.

Second, and perhaps even more important, the nonpartisan professional status of government statistical offices is a national asset that deserves protection. We do not expect to read that, as recently happened in Russia, our chief government statisticians have been arrested for manipulating data to help businesses avoid taxation. We do not expect an unfavorable unemployment report to be withheld because an election is imminent. And we do not expect Census Bureau plans for the 2000 Census to have any motivation other than a desire for the most accurate count possible. I am convinced that the Bureau's plans have no other motivation, and this conviction is reinforced by the fact that planning began on the basis of expert recommendations from the NRC and other groups.

Some respected national columnists have attacked the Census Bureau in language that damages the public interest. William Safire implied that government statisticians are both politicized and lazy. He characterized Census Bureau plans as "having a statistician put a thumb on the scale." George Will took a more subtle approach: this administration, with its "remarkable record of lawlessness," will manipulate the sample selection. Government statisticians are not explicitly accused but are presumably too weak to resist blatant political interference.

Repeated accusations of political motivations in Census Bureau planning, combined with the impressive level of distrust of government that characterizes American public opinion, will lead to distrust of government statistics in general. If the census is politicized, why not the unemployment rate? A conspiracy lurks behind every weighted mean. The distrust of national statistics may grow worse: the continuing debate is hindering the immensely detailed logistical preparation required for a successful census, with or without sampling. The 2000 Census may well be seen by the public as a failure.

Public debate in the age of the sound bite inevitably oversimplifies complex issues. The proposal to use statistical sampling in the 2000 Census combines arcane mathematical science with potentially substantial political implications. It is not surprising that oversimplification has predominated among politicians and commentators and also in how more careful statements, such as those of the NRC and the ASA, are heard. The fallout from oversimplified and sometimes irresponsible claims will damage statistics as a discipline and will damage government statistical offices and public trust in important national data.

—*David S. Moore*

David S. Moore is S. S. Gupta Distinguished Professor of Statistics at Purdue University and 1998 President of the American Statistical Association. He emphasizes that his opinions are his own.

Letters to the Editor

Authors Can Publicize History of Papers on Web

Authors submit papers to journals. Journals need authors, but they give little or no opportunity to authors to complain about poor service. Journals publish submission dates (largely for their own protection perhaps), but would hardly publish any history of long delays in publication, of the frequently inane referee's reports, or of rejection of the excellent paper by other journals for idiotic reasons.

Web technology has given authors a tool to deal with the above problems; I suggest using it. Readers interested in background history can be provided with the record of the refereeing process, including referee's comments. On the positive side, this might provide insights into the paper, especially if the refereeing was effective, but it can also provide an often needed outlet for the author's frustrations with the referees and with the real reason for the long gap between submission and publication. Maybe few readers will be interested in such history, but it would make me feel that I have levelled the playing field a little by providing it, and I shall—oh yes, I shall!

—*Larry Shepp*
Rutgers University

(Received November 10, 1998)

Achievements of Chaos Theory

The commentary "See No Evil, Hear No Evil, Speak No Evil" by S. G. Krantz (October issue of the *Notices*) has just come to my notice. While I sympathize with Krantz's desire to challenge the conformism of the mathematical community, I regret that lack of caution weakens his argument considerably. He claims that "there is not one example of any scientific problem that has been solved (not just described)" using chaos theory. In fact, the only "explanations" that physics provides are through theories that accurately "describe" reality. This has been achieved by relativity, quantum mechanics, and, I believe, chaos theory. (For details on the latter I must refer, for example, to my review "Where can one hope to profitably apply the ideas of chaos", *Physics Today* **47**, no. 7, (1994), 24–30.) The problem is that any successful idea produces an explosion of papers by people who want to invest in the success. This leads to inflated claims, particularly visible at the level of popular science, and then to counterclaims that this is all baloney. (This has happened before with relativity, quantum mechanics, and Gödel's theorem.) Professionals have, of course, a duty to try to set things straight. To return to the general issue of challenging conformism in the scientific community, I think that this has to be done in a careful and responsible way to be effective. As a positive example, I would mention the paper of A. Jaffe and F. Quinn "Theoretical mathematics: Towards a cultural synthesis of mathematics and theoretical physics", *Bull. Amer. Math. Soc. (N.S.)* **29** (1993), 1–13. Even those who did not like this paper will admit that it was useful in prompting the beautiful response of W. Thurston, "On proof and progress in mathematics", *Bull. Amer. Math. Soc. (N.S.)* **30** (1994), 161–177 .

—*David Ruelle*
I.H.É.S., France

(Received December 8, 1998)

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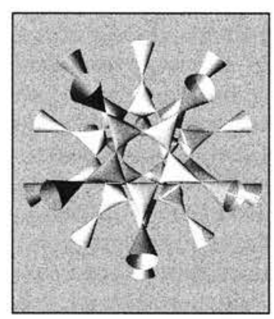
About the Cover

The computer-generated image was provided by Paolo Dominici, who lives in Todi, Italy, and is now elaborating new visualizing styles for rendering mathematical objects and ideas more attractive and understandable.

Dominici writes, "This balanced assemblage of curved tetrahedra and carved cones is the spherical neighborhood, of radius 5/2 around the origin, of the algebraic surface with affine equation

$$4(\tau^2x^2 - y^2)(\tau^2y^2 - z^2)(\tau^2z^2 - x^2) - (1 + 2\tau)(x^2 + y^2 + z^2 - 1)^2 = 0$$

where $\tau = (\sqrt{5} + 1)/2$ is the golden section. It was discovered by Wolf Barth (Erlangen University, Germany) in 1994. The surface has 20 nodes at the vertices of a regular dodecahedron of edge $2/\tau$ and 30 nodes at the midpoints of the edges of a concentric dodecahedron of edge $2/\tau^2$. Its projective completion is of degree 6 and has 15 additional nodes, thus obtaining a total of 65 nodes, the maximum for a sextic surface. Beyond its intrinsic beauty, the surface has the rare gift of enclosing in its symmetric frame many hundred years of geometrical insight and skill."



Resonances in Physics and Geometry

Maciej Zworski

Resonances are most readily associated with musical instruments or with the Tacoma bridge disaster. The latter is described in many physics and ODE books, and at the Ontario Science Center one can even find a model allowing one to find the destructive resonant frequency. The resonances I would like to write about are closely related but have their origins in quantum or electromagnetic scattering. To introduce them in a rough way, let us first recall the notion of *eigenvalues*. Eigenvalues of self-adjoint operators describe, among other things, the energies of bound states, states that exist forever if unperturbed. These do exist in real life; for instance, we can tell the composition of stars from our knowledge of atomic spectra. In most situations, however, states do not exist forever, and a more accurate model is given by a decaying state that oscillates at some rate. The decay might be caused by damping or by a possibility of escape to infinity. To describe these more realistic states, we use resonances. They have a very long tradition in mathematical physics, but they also appear naturally in pure mathematics. The last ten years brought many new ideas and new results into the subject. Old problems concerning the proximity of resonances to the real axis, their relation to quasi-modes, and their distribution for scattering by convex bodies have been solved. Upper bounds for counting functions of resonances have become well understood, and the new area of lower bounds has become active. New directions were opened by considering resonances in geometry, where in fact they make a very natural appearance. The purpose of this article is to motivate the study of resonances and to survey the recent advances.

The focus of the presentation is very personal, and many aspects of the enormous subject of resonances are bound to be neglected. Allusion to some other aspects of the subject is made at various places in the text, and some references, or pointers to lists of references, are included.

Maciej Zworski is professor of mathematics at the University of California at Berkeley. His e-mail address is `zworski@math.berkeley.edu`.

Eigenvalues

To introduce resonances we first need to talk about eigenvalues. Perhaps the simplest case in which they arise is that of an oscillating string. Let $X = [0, \pi]$, and let $P = -\partial_x^2$ be the Laplacian on X acting on functions satisfying the Dirichlet boundary condition $u(0) = u(\pi) = 0$. The position at time t of the string fixed at the end points $u(t, x)$ is given by solutions of the wave equation

$$(1) \quad (-\partial_t^2 - P)u(t,x) = 0, \qquad u(t,0) = u(t,\pi) = 0.$$

To solve this, the initial values of the position and velocity of the string are needed—$u(0,x)$, $\partial_t u(0,x)$. It is therefore advantageous to consider a system where instead of $u(t,x)$ we take

$$U(t,x) = \begin{pmatrix} u(t,x) \\ -i\partial_t u(t,x) \end{pmatrix}.$$

The wave equation (1) becomes

$$(2) \quad \begin{aligned} &\frac{1}{i}\partial_t U = \mathcal{P}U, \qquad U(0,x) = \begin{pmatrix} u(0,x) \\ -i\partial_t u(0,x) \end{pmatrix}, \\ &\mathcal{P} = \begin{pmatrix} 0 & 1 \\ P & 0 \end{pmatrix}, \qquad U(t,0) = U(t,\pi) = \begin{pmatrix} 0 \\ 0 \end{pmatrix}. \end{aligned}$$

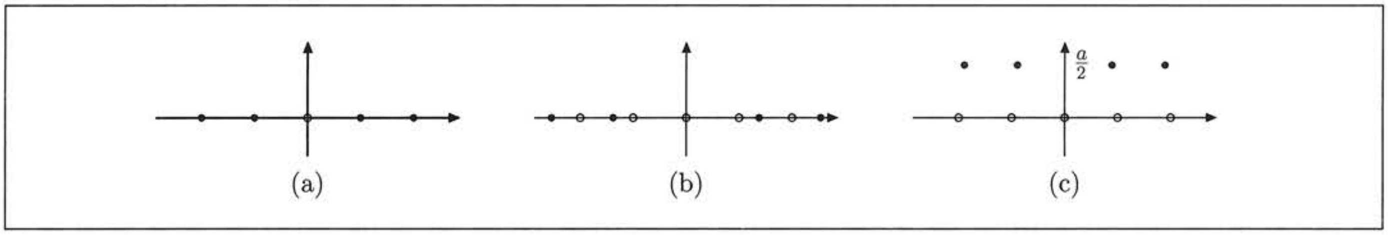


Figure 1. (a) The spectrum of $\mathcal{P}$ corresponding to $-\partial_x^2$. (b) The spectrum (•) of $\mathcal{P}$ corresponding to $-\partial_x^2 + V(x)$ (points ∘ show the spectrum in the unperturbed case $V = 0$). (c) The spectrum of $\mathcal{P}_a$ corresponding to the damped wave equation obtained by adding a term $-a\partial_t$, $a > 0$, constant, hence the constant imaginary part corresponding to the constant rate of damping.

At least formally the solution is simply given by putting $U(t,x) = \exp(it\mathcal{P})U(0,\cdot)(x)$. To actually write down the solution, we use the eigenvalues and the eigenfunctions of $\mathcal{P}$:

$$\text{(3)} \qquad \mathcal{P}W = \lambda W, \qquad W|_{\partial X} = 0.$$

We say that λ is an *eigenvalue* of $\mathcal{P}$ or that $\lambda \in \sigma(\mathcal{P})$, where $\sigma(\mathcal{P})$ is the *spectrum* of $\mathcal{P}$. The solutions of (2) are known to be given by superpositions of $\exp(i\lambda t)W(x)$ where λ and W are as in (3). In the case of the string, we have $\lambda = n \in \mathbb{Z} \setminus \{0\}$, and $\sigma(\mathcal{P})$ is shown in Figure 1a. Nothing much changes when we consider a more general operator on $X : P = \partial_x^2 + V(x)$, $V(x) \geq 0$, $V \in C^\infty(X)$ (positivity and smoothness are assumed to avoid technical difficulties). The spectrum shifts due to the presence of V, and it is shown in Figure 1b. The eigenvalues stay real because P with the Dirichlet boundary condition is an unbounded self-adjoint operator on a suitable space. So is $\mathcal{P}$ when we take $\mathcal{H}$ to be the closure of $C_c^\infty(X) \times C_c^\infty(X)$ with respect to the inner product

$$\langle U, V\rangle_{\mathcal{H}} = \langle Pu_0, v_0\rangle + \langle u_1, v_1\rangle,$$
$$U = \begin{pmatrix} u_0 \\ u_1 \end{pmatrix}, \qquad V = \begin{pmatrix} v_0 \\ v_1 \end{pmatrix}.$$

Checking the Hermitian property $\langle \mathcal{P}W, V\rangle_{\mathcal{H}} = \langle W, \mathcal{P}V\rangle_{\mathcal{H}}$ is straightforward. Then we argue as we do in the case of matrices, and consequently $\lambda \in \mathbb{R}$. In these examples eigenvalues can also be characterized by saying that

$$\lambda \in \sigma(\mathcal{P}) \iff \lambda \text{ is a pole of } (\mathcal{P} - z)^{-1} : \mathcal{H} \to \mathcal{H}.$$

The *multiplicity* is defined as the rank of the residue.

We conclude this brief discussion by quoting perhaps the most famous general result about eigenvalues of operators on compact manifolds, the Weyl asymptotics:

$$\text{(4)} \quad \#\{\lambda \in \sigma(\mathcal{P}) : |\lambda| \leq r\} \sim 2\frac{\mathrm{vol}(\mathbb{B}^n)}{(2\pi)^n}\mathrm{vol}(X)r^n,$$

where $\mathbb{B}^n$ is the unit n-ball and in our case $n = 1$. The improvement of Weyl asymptotics and deeper understanding of the distribution of eigenvalues at high energies remain fascinating subjects closely related to such issues as "quantum chaos". In the last thirty years great breakthroughs were achieved by Lars Hörmander, J. J. Duistermaat, Victor Guillemin, and Victor Ivrii.

All this said, we remember that no string oscillates forever! This failure is of course due to some form of damping. Mathematically it can be introduced by adding a term $q(x)\partial_x$ to the operator P, as is done in standard ODE courses, or by adding a dissipative term $a(x)\partial_t$ in the wave equation. In each case the self-adjointness of P is destroyed. For the purposes of this discussion let us keep $P = -\partial_x^2 + V(x), V(x) \geq 0$, $X = [0, \pi]$, and the Dirichlet boundary conditions. Let us change the wave equation to:

$$\text{(5)} \quad (-\partial_t^2 + a(x)\partial_t - P)u(t,x), \qquad u|_{(0,\infty)\times\partial X} = 0, \quad t > 0,$$

where $a(x) \geq 0$. We can again conveniently rewrite this as a system

$$\text{(6)} \qquad \frac{1}{i}\partial_t U = \mathcal{P}_a U, \qquad \mathcal{P}_a = \begin{pmatrix} 0 & 1 \\ P & ia(x) \end{pmatrix}.$$

Now, however, $\mathcal{P}_a$ is not self-adjoint on $\mathcal{H}$ unless $a(x) \equiv 0$. Nevertheless, the general picture remains the same: the eigenvalues and eigenfunctions of $\mathcal{P}_a$ are defined by:

$$\mathcal{P}_a W = \lambda W, \qquad W|_{\partial X} = 0,$$

and the solutions of (6) are given by superpositions of solutions of the form $U(t,x) = \exp(it\lambda)W(x)$. The rate of oscillations of U is given by the real part of λ, and the rate of decay by the imaginary part. In the simplest case $a(x) \equiv a > 0$

$$\lambda \in \sigma(\mathcal{P}_a) \iff \lambda(\lambda - ia) \in (\sigma(\mathcal{P}))^2.$$

The qualitative picture is very close to this one also in the variable $a(x)$ case (see Figure 1c), and in particular the Weyl asymptotics remain valid.

These types of non-self-adjoint perturbations corresponding to some dissipative effects have been successfully studied, most recently in spectacular work of Gilles Lebeau. To learn more, the reader may consult [6] and references given there. The damped wave equation is mentioned here to illustrate the following important point:

Solutions are described as superpositions of states corresponding to complex numbers, where the real part describes the rate of oscillations and the imaginary part the rate of exponential decay. They are eigenvalues of the non-self-adjoint operator $\mathcal{P}_a$ or, equivalently, poles of $(\mathcal{P}_a - z)^{-1} : \mathcal{H} \to \mathcal{H}$.

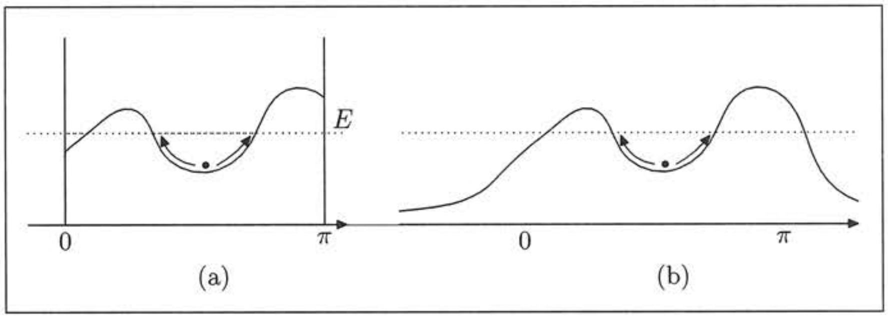


Figure 2. (a) A potential well on a finite interval. (b) A potential on $\mathbb{R}$: same classical picture, but a very different quantum picture.

The notion of resonance mentioned in the opening of this article is closely related to this. Suppose we solve $(\mathcal{P}_a - \mathrm{Re}\lambda)u = f$ where λ is an eigenvalue of $\mathcal{P}_a$ with $\mathrm{Im}\lambda$ small. This can be done, since $\mathrm{Re}\lambda$ is not an eigenvalue. However, with the right choice of the forcing term f, $(\mathcal{P}_a - \mathrm{Re}\lambda)^{-1}f$ can be enormous, as $(\mathcal{P}_a - z)^{-1}$ has a pole nearby. So, with the resonant frequency $\mathrm{Re}\lambda$ we hit a *resonance* which decays at a rate given by $\mathrm{Im}\lambda$.

Resonances

A more dramatic change of the situation occurs when, instead of damping, some escape to infinity is allowed. Mathematically that means that instead of considering $P = -\partial_x^2 + V(x)$ on $X = [0, \pi]$, we will consider it on $X = \mathbb{R}$. We will take $V(x) \geq 0$ and assume that $V \in C_c^\infty(\mathbb{R})$. See Figure 2 for a meaningful example. When we consider the corresponding wave equations, we cannot describe the solutions as sums of solutions coming from propagating eigenfunctions of P. In fact, we can easily see that P cannot have any square integrable eigenfunctions: if $Pu = Eu$, then we have

$$E \int |u(x)|^2 dx = \int (-\partial_x^2 + V(x))u(x)\overline{u(x)}\, dx$$
$$= \int (|\partial_x u(x)|^2 + V(x)|u(x)|^2)\, dx > 0,$$

and hence $E > 0$. But then, outside of the support of $V(x)$, $u(x)$ has to be a combination of $\exp(\pm i\sqrt{E}x)$. It is square integrable only when it is identically zero, and hence, by the uniqueness theorem for ODEs, $u(x)$ is itself identically zero.

Why should we expect any similarity with the picture involving eigenvalues? To answer this in a somewhat fuzzy way, we have to enter the fuzzy world of quantum mechanics. Classical mechanics describes a particle by specifying its position x and its momentum ξ. The motion is then governed by the classical equations of motions, such as conservation of energy:

$$\text{(7)} \qquad \textbf{Classical:} \quad \xi^2 + V(x) = E,$$

as we see in the rolling ball of Figure 2. Quantum mechanics describes a particle in a stationary state by a *wave function*, $u(x)$, and $|u(x)|^2 dx$ gives the probability density of finding the particle in a given region. In particular, $u(x)$ should be square integrable. The wave function should satisfy the quantized version of (7):

$$\text{(8)} \quad \textbf{Quantum:} \quad \left(\left(\frac{h}{i}\partial_x\right)^2 + V(x)\right)u(x) = Eu(x),$$

obtained by replacing ξ with $(h/i)\partial_x$. Here h is the Planck constant. When h is very small compared to everything else (so to speak!), we expect the quantum picture to be close to the classical picture: that is, we take the *semiclassical* view of the world. Previously, in P, the Planck constant was 1, but that of course means that everything else had to be appropriately large to justify the semiclassical approximation. When confined to $X = [0, \pi]$, the set of E's corresponding to eigenvalues of P is discrete: the energy levels are quantized. As h gets smaller, the levels get denser, and the classical situation of having every energy level allowed is approached.

When we are on $X = \mathbb{R}$ and the energy is at the level shown in Figure 2b, the classical picture remains unchanged from the case $X = [0, \pi]$. The rolling ball does not know about the world behind the "mountains". Thinking semiclassically, we expect a corresponding quantum state to exist. However, we have seen that the quantized equation (8) does not have any square integrable solutions. Hence, that state cannot be a usual wave function. The trouble is due to "tunneling" through the barrier created by the mountains. The particle bounces back and forth at some frequency, but it decays at some rate due to tunneling and the consequent escape to infinity. Here *tunneling* means interaction between the well and infinity and is measured by the rate of decay.[1] Any understanding of this has to be in a fundamental way dynamical: that is, it has to involve evolution in time. We moved from a spectral problem to a "scattering problem", with the potential as the "scatterer".

Although the situation discussed above might sound frighteningly fuzzy, it has a very elegant

[1] *The mathematical theory of tunneling is rather well understood, especially in the context of symmetry breaking for low-lying states. The article of Barry Simon [8] and the references in [3] describe this theory. There tunneling refers to interactions between different potential wells and to the way the exponentially small effects of those interactions are measured.*

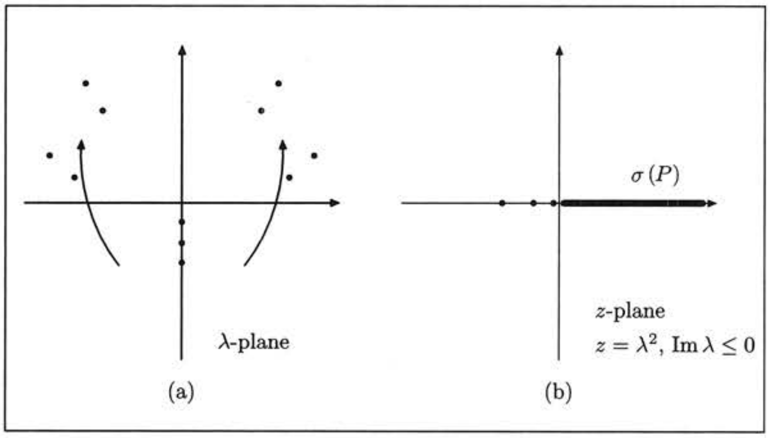


Figure 3. (a) Meromorphic continuation of the resolvents $\mathcal{R}(\lambda) = (\mathcal{P} - \lambda)^{-1}$ and $R(\lambda) = (P - \lambda^2)^{-1}$; the poles in the lower half-plane correspond to negative eigenvalues of P. (b) The spectrum of P: the z-plane, $z = \lambda^2$.

mathematical description valid in many interesting cases. Let us leave quantum mechanics for the moment and, rather than study the Schrödinger equation, go back to the wave equation. Thus we consider the operator $\mathcal{P}$ given by (2), now on $X = \mathbb{R}$. Since the eigenvalues appeared as poles of the resolvent, then to seek analogous objects it is natural to consider the *resolvent* of $\mathcal{P}$, $\mathcal{R}(z) = (\mathcal{P} - z)^{-1}$. As an operator on $\mathcal{H}$ it is bounded at each $z \in \mathbb{C} \setminus \mathbb{R}$ and makes no sense on $\mathbb{R}$, which is the continuous spectrum of $\mathcal{P}$. If the source space is made smaller and the target space bigger, much more than boundedness on $\mathbb{R}$ can be achieved:

> As an operator $\mathcal{R}(z) = (\mathcal{P} - z)^{-1}$ from $\mathcal{H}_c$ to $\mathcal{H}_{\text{loc}}$, $\mathcal{R}(z)$ continues meromorphically from $\text{Im}\, z < 0$ to $\mathbb{C}$.

Here by $\mathcal{H}_c$ we mean the elements of $\mathcal{H}$ that are zero outside some compact set, and by $\mathcal{H}_{\text{loc}}$, functions that are locally in $\mathcal{H}$. The meromorphic continuation has poles, and by the analogy with the characterization of eigenvalues, we would like to consider those poles as the replacement of discrete spectral data for problems on noncompact domains (in this discussion $\mathbb{R}$). We denote the set of poles of $\mathcal{R}(z)$ by $\text{Res}(P)$, where P is the original operator from which $\mathcal{P}$ was constructed (here it is $P = -\partial_x^2 + V(x)$, $V \in C_c^\infty$, $V \ge 0$). See Figure 3.

That the elements of $\text{Res}(P)$ are what we are looking for is shown by their appearance in the solutions of the wave equation: if

$$(-\partial_t^2 - P)u = 0, \qquad u|_{t=0}, \qquad \partial_t u|_{t=0} \in C_c^\infty,$$

then for any fixed compact set $K \subset X$,

$$u(t,x) \sim \sum_{\lambda \in \text{Res}(P)} e^{it\lambda} w_\lambda(x), \qquad x \in K, \qquad t \longrightarrow \infty. \tag{9}$$

Hence, in a fuzzy way we have a similarity with the case of eigenvalues, in which the solutions are given by superpositions of propagated eigenfunctions. We see that in (9)

$\text{Re}\lambda$ corresponds to the rate of oscillations,

$\text{Im}\lambda$ corresponds to the rate of decay.

The assumption that $V(x) \ge 0$ can be eliminated quite easily.The only complication comes from the possible presence of (honest) negative eigenvalues of P which then produce imaginary eigenvalues of $\mathcal{P}$ (the definition of $\mathcal{H}$ has to be modified, and $\mathcal{P}$ is no longer self-adjoint). The meromorphic continuation can also be described purely in terms of the resolvent of P. We consider

$$R(\lambda) = (P - \lambda^2)^{-1} \ : \ L^2_c \longrightarrow L^2_{\text{loc}},$$

so that it coincides with the resolvent bounded on L^2 for $\text{Im}\lambda < 0$ (except at poles corresponding to $\lambda^2 \in \sigma(P)$). It then continues meromorphically to $\mathbb{C}$ as shown on Figure 3a. In Figure 3b we exhibit also the "honest" spectrum of P in the z-plane, $z = \lambda^2$.

The definition of resonances as poles of the meromorphically continued resolvent remains valid, with various modifications, in many situations. It is valid in the exact same way as described above for compactly supported perturbations of the Laplacian in $\mathbb{R}^n$, n odd. It is valid also for n even, but then we have to continue $\mathcal{R}(z)$ to the Riemann surface for $\log z$ rather than $\mathbb{C}$. Perhaps the most interesting class of compactly supported perturbations comes from considering scattering by compact obstacles. In that case the wave-equation point of view towards resonances was introduced in the seminal work of Peter Lax and Ralph Phillips [5] in the 1960s. Many general results can now be formulated in an abstract notion of "black box scattering", in which one does not have to consider specific aspects of the perturbation. That formalism was introduced by Johannes Sjöstrand and the author and has now been extended to include classes of long-range perturbations. References and a review of results are provided in [9] and [11].

As in the case of eigenvalues, it is natural to study *large-energy asymptotics*, that is, to look for analogues of the Weyl law (4). Since the resonances are distributed in the complex plane, it is not clear what is the most appropriate way of counting them; the issues involved in that will hopefully become clearer below. The study of global upper bounds on the number of resonances—that is, of counting them in discs $\{z \in \mathbb{C} : |z| \le r\}$—was initiated by Richard Melrose, who proved the sharp polynomial bound $\mathcal{O}(r^n)$ in the case of obstacle scattering in $\mathbb{R}^n$, n odd. In the last ten years, that work inspired many results on global and local, upper and lower bounds on the number of resonances. The main results were obtained by Johannes Sjöstrand, Georgi Vodev, Laurent Guillopé, and the author. See [7], [2], [9], and [11] for discussion and references.

Despite significant advances, the state of knowledge is hardly satisfactory. In standard Euclidean scattering, asymptotics for the counting function of resonances are known only in dimension one and in some specific radial cases such as scattering by the sphere (see Figure 8).

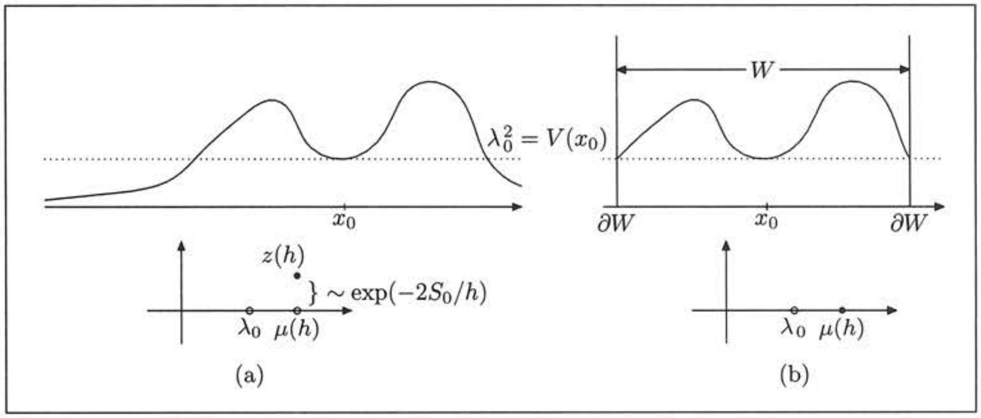


Figure 4. (a) A potential well and a resonance generated by the eigenvalue of a reference Dirichlet boundary problem. (b) A reference problem and its eigenvalue close to the ground state of the well.

Two Examples

So far we have discussed in some detail the simplest but already nontrivial example of potential scattering on the line. Let us now give two more involved examples that have long traditions in mathematical physics and in geometric analysis.

The first example is a semiclassical potential well in $\mathbb{R}^n$. Let $V(x)$ be an analytic potential which looks like the potential shown in Figure 4; we skip here a detailed description of the technical assumptions on V. Roughly speaking, it is supposed to have a nondegenerate local minimum at x_0, and that point should be the only place where a particle moving according to the classical equation, $|\xi|^2 + V(x) = E$, could be trapped. We are then interested in resonances of the semiclassical Schrödinger operator

$$P(h) = -h^2\Delta + V(x), \qquad \Delta = \sum_{i=1}^{n} \partial_{x_i}^2,$$

near λ_0 with $\lambda_0^2 = V(x_0)$, that is, near the energy corresponding to the bottom of the well. Under further assumptions a typical resonance is given by

$$z(h) = \mu(h) + \mathcal{O}(1)\exp(-2S_0/h),$$
$$\operatorname{Im} z(h) = r(h)\exp(-2S_0/h), \qquad r(h) \sim h^{C_1},$$

where $\mu(h) \to \lambda_0$ is an eigenvalue of the operator $P(h)$ restricted to W, shown in Figure 4b, with zero boundary conditions at ∂W and S_0 is the "Agmon width" of the barrier. The latter measures the rate of tunneling through a potential barrier and is closely related to weights appearing in "Carleman estimates" that are used to show unique continuation of solutions to PDEs. In fact, unique continuation is due to tunneling, or depending on one's perspective, tunneling is a quantitative form of unique continuation: a solution cannot be completely localized to a compact set.

In this example the resonances can be defined through meromorphic continuation of the resolvent. Typically, however, we can continue only to a neighborhood of the real axis. That is done using the method of "complex scaling" introduced by Jacques Aguilar, Jean-Michel Combes, and Eric Balslev in the early 1970s: through a deformation of the operator, the resonances become eigenvalues of a non-self-adjoint problem.[2] This method was developed by many authors, and it was raised to the level of high art through the use of analytic microlocal analysis by Bernard Helffer and Johannes Sjöstrand [3]. The example described above has been extensively studied, and [3], [4] can be consulted for the history and results.

The second example is pure "pure mathematics". Let X be the modular surface obtained as the quotient of the hyperbolic upper half-plane by the modular group: $X = \mathrm{SL}(2,\mathbb{Z})\backslash\mathbb{H}^2$, where $\mathbb{H}^2 = \mathrm{SL}(2,\mathbb{R})/SO(2)$. The famous fundamental domain of $\mathrm{SL}(2,\mathbb{Z})$ is shown in Figure 5. The quotient, X, is a noncompact surface with a cusp at infinity and two conic singularities. It inherits the hyperbolic metric from $\mathbb{H}^2$, and consequently we have a natural Laplace operator, Δ_X. The resolvent $(-\Delta_X - \zeta)^{-1}$ turns out to be bounded on $\mathbb{C} \setminus (\{0\} \cup [1/4, \infty))$, and we then consider

$$R(\lambda) = (P - \lambda^2)^{-1}, \qquad P = -\Delta_X - \frac{1}{4},$$
$$\operatorname{Im}\lambda < 0, \qquad \lambda \neq -\frac{i}{2}.$$

As before, $R(\lambda)$ continues meromorphically to $\mathbb{C}$, and its poles, which are eigenvalues and resonances, have a classical interpretation; most of the poles lie exactly on $\mathbb{R}$ and are honest L^2 eigenvalues embedded in the continuous spectrum. See Figure 5. They correspond to "cusp forms" of analytic number theory. The remaining poles are honest resonances (that is, they have nonzero imaginary parts), and they are given by the solutions of

[2] *The operator-theoretical approach to complex scaling is comprehensively reviewed by Peter Hislop and I. Michael Sigal, themselves important contributors to the subject, in [4]. For a brief exposition of the geometrical approach in the spirit of Helffer-Sjöstrand, the reader may consult Sec. 5b of [11].*

$$\zeta(1+2i\lambda) = 0, \qquad \lambda \notin i\mathbb{R},$$

where ζ is the Riemann zeta function, $\zeta(s) = \sum_{n=1}^{\infty} n^{-s}$. The reason for this comes from another characterization of resonances: they are the poles of the meromorphic continuation of the "scattering matrix". In the case of modular surface, the scattering matrix can be expressed explicitly in terms of the zeta function.

The scattering-theoretical interpretation of the theory of automorphic forms was initiated by Ludvig Faddeev and continued by Peter Lax and Ralph Phillips. Their insight has been useful in more complicated situations, as shown by the work of Werner Müller and then of Lizhen Ji on the trace class conjecture. It also inspired Yves Colin de Verdière to show that a generic C_c^∞ perturbation of the metric on X will destroy all embedded eigenvalues and turn them into resonances. That motivated the work of Ralph Phillips and Peter Sarnak on dissolving embedding eigenvalues when an arithmetic surface is deformed to another surface of constant curvature (which cannot be done for our X, but is possible in other situations). It is now believed that most of the eigenvalues become resonances under such deformations.

Classical Dynamical Structure and Distribution of Resonances

Our quantum mechanical motivation for introducing resonances rested on the semiclassical assumption that the existence of classical states should imply the existence of corresponding quantum states. That classical-quantum correspondence is very subtle and is one of the central issues of spectral and scattering theories. In the crudest form it already manifests itself in the Weyl law (4). If we are interested in eigenvalues of an operator $P = -\Delta + V(x)$ that is the quantization of $p = |\xi|^2 + V(x)$, then, very roughly speaking,

$$\#\{\lambda^2 \in \sigma(P) : |\lambda| \le r\} \sim \mathrm{vol}\{(x,\xi) \in T^*X : p(x,\xi) \le r^2\},$$

as we have seen in (4) for Schrödinger operators on compact manifolds.

In the case of resonances a new wealth of phenomena is seen. In addition to situations in which resonances behave as perturbed eigenvalues (see Figure 4), there are many situations in which there is no eigenvalue analogue. In particular, the dynamical structure of the scatterer may manifest itself directly in the counting function for resonances. Since resonances are supposed to correspond to states that eventually escape and since their lifespan (which is the inverse of the rate of decay) should be related to the inverse of their imaginary parts, a very heuristic and in fact not quite correct analogue of the Weyl law is

$$\#\left\{\lambda \in \mathrm{Res}\,(P) : r \le |\lambda| \le 2r, 0 \le \mathrm{Im}\,\lambda \le \frac{r}{T}\right\} \tag{10}$$

$$\sim \mathrm{vol}\left\{\begin{array}{l}(x,\xi) \in T^*X \text{ such that } r^2 \le p(x,\xi) \le (2r)^2 \\ \text{and a trajectory through } (x,\xi) \text{ of the flow of} \\ \text{the Hamiltonian } p \text{ spends time } T \text{ near the} \\ \text{perturbation}\end{array}\right\},$$

where r and T are supposed to be large and where T can depend on r. Since this is appallingly vague, let us mention that a better formulation is obtained in the semiclassical, small h regime with the use of the "escape function" of Helffer-Sjöstrand, which is also known as the "Lyapunoff function". In fact, Johannes Sjöstrand obtained related upper bounds for analytic semiclassical operators in $\mathbb{R}^n$, and that discovery was followed by some similar bounds for hyperbolic surfaces that are illustrated in Figure 6b. References can be found in [9] and [2].

From the dynamical interpretation of the imaginary parts as the rates of decay of the corresponding states, we see that only resonances near the real axis are truly meaningful. How "near" is of course dependent on the problem, but as indicated already in (10), small conic neighborhoods are really the farthest we should look for detailed information. Knowing what happens farther away can, however, be important; in particular, it can be useful to know that there are not too many resonances far from the axis (so that they do not

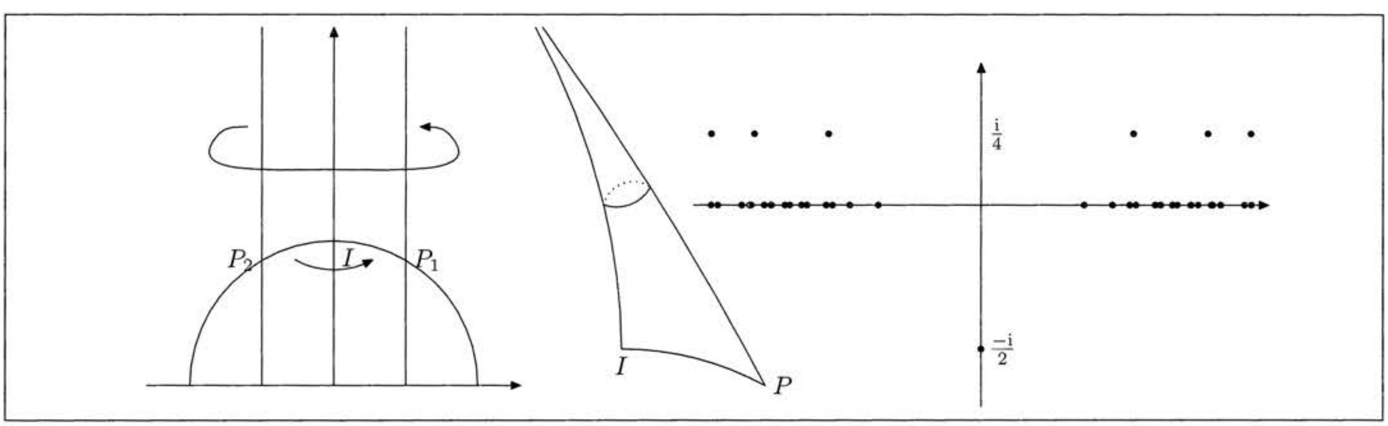


Figure 5. The fundamental domain of the modular group and the resonances of the modular surface.

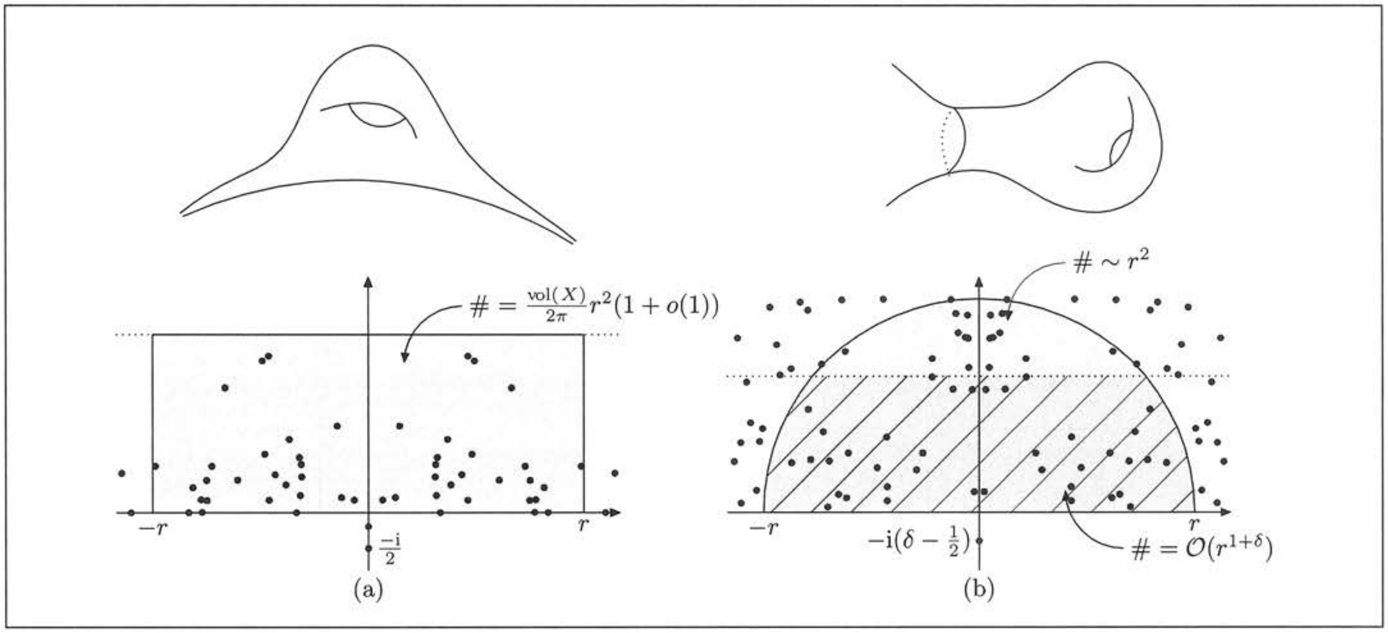


Figure 6. (a) Resonances for a finite volume hyperbolic surface: they are confined to a horizontal strip and satisfy the usual Weyl law. (b) Resonances for an infinite volume surface with no cusps: they are scattered all over the upper half-plane; the counting function in a disc of radius r is bounded from above and below by multiples of r^2; when we count only in a strip the number of resonances is bounded by a multiple of $r^{1+\delta}$, where δ is a number less than one with a dynamical intepretation.

affect the behavior on the real axis). Also, for low-energy resonances, a restriction to conic neighborhoods is irrelevant.

In the opposite direction, we can ask how near the resonances can approach the real axis. In situations where infinity is "small" (see Figures 5 and 6a) there are no restrictions, and resonances can mix with embedded eigenvalues. When infinity is "large", as in Euclidean obstacle problems or as in Figure 6b, the resonances have to be separated from the real axis. A fundamental result obtained very recently by Nicolas Burq [1] says that for $|\mathrm{Re}\lambda| > C_0$, the resonances have to satisfy $\mathrm{Im}\lambda > \exp(-C_1|\mathrm{Re}\lambda|)$ for some constants C_0 and C_1. The proof is based on "Carleman estimates", that is, on quantitative understanding of tunneling (see the discussion of the example shown in Figure 4 above). One could say that not only can states not live forever, but they cannot live for an arbitrarily long time. Of course, a lifespan that is exponential in energy is more than any one of us can hope for!

Figure 6 illustrates some of the issues discussed above in the case of two-dimensional hyperbolic surfaces, $X = \Gamma\backslash\mathbb{H}^2$. In Figure 6a we look at the finite-volume case where the resonances are confined to a strip. Most of them lie very close to the real axis, and they satisfy the usual Weyl law (4), with $n = 2$. This is now classical and was established by Atle Selberg in the 1950s. In Figure 6b we take X to be an infinite volume surface with no cusps. The resonances are now scattered through the entire half-plane, and we have global bounds

$$r^2/C - C \leq \{\lambda \in \mathrm{Res}(-\Delta_X - 1/4) : |\lambda| \leq r\} \leq Cr^2 + C, \tag{11}$$

which are a special case of bounds obtained in [2] for a more general class of surfaces. It is the existence of the lower bound that makes this particularly interesting, as these are rarely known when infinity is "large". In strips parallel to the real axis the number of resonances is much smaller. The author has recently shown that in a strip the number of resonances with $|\lambda| \leq r$ is bounded by $Cr^{1+\delta}$, where δ is the dimension of the "limit set" of the Γ. This is related to the dynamical interpretation of δ given by Dennis Sullivan and is an indication of the validity of (a modified version of) (10). We should also note that in the case of exact quotients, such as shown in Figure 6b, the resonances have an interesting reinterpretation as zeros of the meromorphic continuation of the dynamical zeta function, and that has been recently studied by S. J. Patterson and Peter Perry.

We conclude with the description of two important results in obstacle scattering. In both of them, resonances behave in ways that do not have eigenvalue analogues.

If we consider a scatterer consisting of two strictly convex bodies, then the dynamical structure is very simple. The only trapped orbit coming from reflections is the hyperbolic trajectory obtained by bouncing along the ray, minimizing the distance between the two bodies. See Figure 7. It is hyperbolic, since any small perturbation will result in fast escape to infinity. Mitsuru Ikawa has shown that this closed hyperbolic orbit generates

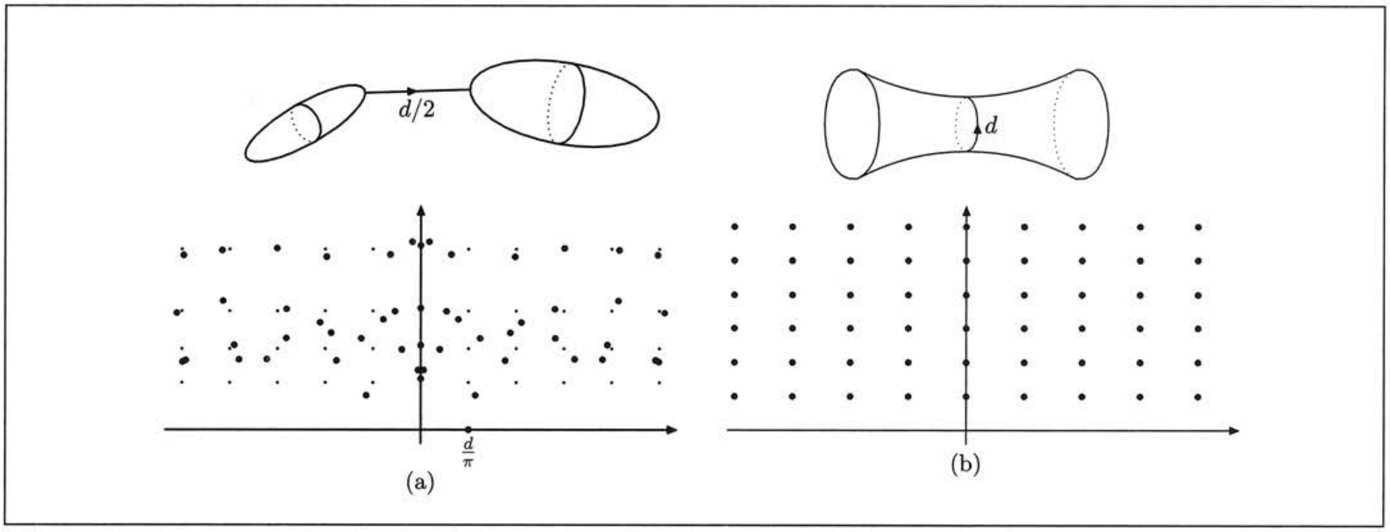


Figure 7. (a) Resonances associated to two strictly convex bodies: in every fixed strip, the resonances become closer to points on the lattice as the real part increases. (b) Resonances for a hyperbolic cylinder: all resonances lie exactly on a lattice. The underlying dynamical structure, exactly one hyperbolic closed orbit, is the same in the two examples.

a string of resonances parallel to the real axis with no other resonances below them. That was later extended by Christian Gérard, who described all resonances in a strip. The great significance of this result lies in the fact that it described quantum objects (a lattice of resonances) associated to a single hyperbolic orbit. Later, a simpler and exact model for this classical-quantum correspondence, based on the hyperbolic cylinder, was given by Charles Epstein and Laurent Guillopé (see Figure 7b), while a physically more relevant semiclassical version was developed by Gérard-Sjöstrand. The point is that the presence of a single hyperbolic periodic orbit generates a lattice of resonances no matter what situation we are in.

Another significance of Ikawa's result lies in the fact that it disproves the *Lax-Phillips conjecture*,[3] which stated that in case of any classical trapping (such as existence of one closed orbit) there should exist a sequence of resonances converging to the real axis. The conjecture was consequently modified; and, in particular, when one assumed the existence of an *elliptic* closed orbit, it was proved by Plamen Stefanov and Georgi Vodev. A quantitative version was then found by Siu-Hung Tang and the author, and in 1998 that was improved further by Stefanov; see [10] and references given there. Ideally, we should finally reach a statement resembling the modified Weyl law (10). At the moment, these results are based on the understanding of the relation between resonances and "quasimodes", which are approximate eigenvalues.

Let us also mention that the first result on the existence of resonances associated to two convex bodies was obtained by Claude Bardos, Jean-Claude Guillot, and James Ralston in 1982 using their "Poisson formula" for resonances. That formula, improved and extended to other settings, has since become one of the most powerful tools for proving existence of resonances; further information may be found in [9] and references given there.

The second result, recently obtained by Johannes Sjöstrand and the author, describes resonances for scattering by strictly convex obstacles. This is illustrated in Figure 8: the curves are of the form $\mathrm{Im}\lambda = K_j^{\mp} |\mathrm{Re}\lambda|^{1/3} \pm C$, and the pinching condition that guarantees the existence of j bands is

$$\frac{\max_{S\partial\mathcal{O}} Q}{\min_{S\partial\mathcal{O}} Q} < \gamma(j), \qquad \gamma(1) = 2.31186\cdots,$$
$$\gamma(j) \to 1, \qquad j \to \infty,$$

where Q is the second fundamental form and $S\partial\mathcal{O}$ is the unit tangent bundle of $\partial\mathcal{O}$.

The association of cubic curves with resonances of convex bodies has a long tradition originating in diffraction theory. Our result has been preceded by many related results in applied mathematics and in microlocal analysis, in particular by Lebeau's work on propagation of Gevrey singularities. Heuristically, the resonances for convex bodies are created by waves creeping along the geodesics on the boundary and losing energy at a rate depending on the curvature. Consequently, the precise distribution depends in a subtle way on the dynamics of the geodesic flow of the surface and its relation to the curvature. However, those subtle effects are mostly present in the distribution

[3]*More like a suspicion than a conjecture, to be quite fair (see the end of Sec. V.3 of [5]). A statement made more clearly as a conjecture concerned propagation of singularities for boundary value problems (see (A) and (B) in Sec. V.3 of [5]), and it was proved in the works of Andersson, Melrose, Sjöstrand, and Taylor in the late 1970s. It was also motivated by the study of resonances, as it implied that logarithmic neighborhoods of $\mathbb{R}$ are free of resonances for nontrapping obstacles.*

of imaginary parts of the resonances. The crude heuristic picture suggests that as far as the real parts are concerned, the distribution should be governed by the same rules as those for eigenvalues of the surface. Our result justifies this claim. The pinching condition for the curvature needs to be imposed to eliminate interference between different bands.

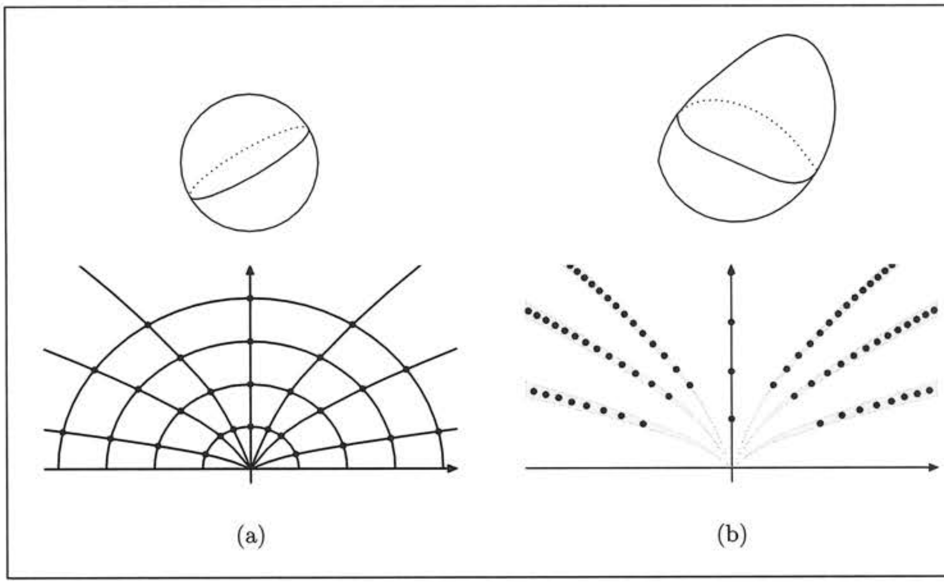


Figure 8. (a) Resonances for the sphere; the resonances on the lth ring have multiplicity $2l+1$. (b) Resonances for a convex body $\mathcal{O}$ satisfying the pinched curvature assumption. The resonances in each band (on a cubic curve in case of the sphere) satisfy the same Weyl law as the eigenvalues of the Laplacian on $\partial\mathcal{O}$.

Open Problems

In this article introduction of technical terminology was rather systematically avoided, and therefore a precise formulation of open problems is a somewhat difficult task. The existence of many problems should, however, already be clear. Continuing in the same spirit of vagueness, we can make them a little bit more precise. Some of them are present already in most basic settings, and their solutions may be elementary. Other problems involve extending the existing knowledge to more complicated situations. We may ask for:

- Global lower bounds of the form (11) on the number of resonances; at the moment very few unconditional bounds are known. To put this in perspective, until the work of Plamen Stefanov in 1998, the sphere was the only obstacle for which the optimal lower bound was known; it is still unknown for an arbitrary obstacle.
- Local lower bounds related to finer aspects of the dynamical structure: a modification of (10). At present only the "one hyperbolic orbit" examples and their extensions provide lower bounds corresponding to finer upper bounds.
- The modified Lax-Phillips conjecture of Ikawa stating that there should be a strip with infinitely many resonances for the Dirichlet Laplacian on the exterior of several convex bodies. Ikawa proved this for the Neumann Laplacian.
- Understanding of meromorphic continuation of the resolvent on manifolds. In addition to manifolds with simple structure at infinity (some of which were discussed above), the best understood general class consists of "conformally compact manifolds" studied by Rafe Mazzeo and Richard Melrose. They generalize surfaces of the type shown in Figure 6. Even there, the method of complex scaling is not properly understood, nor are the upper bounds. For other natural classes of manifolds the situation is even less clear.
- Generalization of existing methods and results (upper bounds, Poisson formulæ) to situations where there are singularities at infinity. The natural directions are provided by higher-rank symmetric spaces and by the quantum N-body problem.

The Riemann hypothesis could also have been added, since it can be formulated in terms of resonances (see Figure 5). It should, however, be remembered that in their book on automorphic scattering, Lax and Phillips had a chapter titled "How Not to Prove the Riemann Hypothesis". So it is better to leave it out.

Acknowledgments

I would like to dedicate this article to the memory of Professor Ralph Phillips, 1913–1998.

The article originated from a discussion after a talk on resonances for convex bodies I gave at a seminar in Berlin in May 1998. By chance, two editors of these *Notices* were in the audience—Beth Ruskai and Victor Guillemin. I learned most of what I know about eigenvalues from Victor, and to be mischievous, I made a statement that "eigenvalues are yet another expression of humanity's narcissistic desire for immortality." That led to a lively discussion in which it was suggested that I write an article on "Narcissism and self-adjointness". What I could write is, of course, much more prosaic.

I would like to thank Tanya Christiansen, Laurent Guillopé, Anders Holst, John Lott, Andras Vasy, and in particular Jared Wunsch and Steve

Zelditch for their most helpful comments on earlier versions of this article. I am also very grateful for the detailed comments and suggestions I received from Tony Knapp and the referees. The figures were conceived and executed by Laurent Guillopé. His generous help is very much appreciated.

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The IHÉS at Forty

Allyn Jackson

Not far outside Paris, in a small village, along a busy road, there is a gate leading into a park. The sound of the traffic dissipates as one follows the footpath. The trees are abundant enough to give the impression that one is simply walking through a serene wood, which has a slight incline that amplifies the rustle of the breeze through the treetops. But soon one reaches a small parking lot, and beyond it a summer house that has been fitted with windows and turned into a library. Next to the summer house there is a nondescript two-story building, and down a lawn of trimmed grass, a low one-story building. This is no ordinary park. It is the Bois-Marie, grounds of one of the world's leading research institutes in mathematics, the Institut des Hautes Études Scientifiques (IHÉS).

Now forty years old, the IHÉS has spent nearly its entire lifetime in the Bois-Marie, in the Paris suburb of Bures-sur-Yvette. A special event was held last October to celebrate four decades of research at the IHÉS. Over this period, the institute has provided mathematicians with an idyllic, and in many ways ideal, setting for research. The story of the IHÉS, as befits its French heritage, is a story with a little of everything—romance, madness, tragedy, as well as triumphal intellectual achievements. It is also the story of a small, hardy institute that has survived, despite perpetual financial uncertainties, to become home to an illustrious permanent faculty and a major visiting center for researchers from all over the world.

The Founding of the IHÉS

The IHÉS was founded in 1958 by Léon Motchane. He was born in St. Petersburg in 1900 to Swiss parents. After the Russian revolution, Motchane moved to Switzerland with his family. He had studied mathematics and physics in Russia and served for a time as a physics assistant in Lausanne. However, he had to give up his studies to earn money for his family and went into banking and insurance. He settled in France in 1924. After World War II he continued to work in industry, but maintained an interest in scholarly work and published a few papers. Encouraged by the French mathematician Paul Montel, Motchane eventually received, at age fifty-four, a doctorate in mathematics.

In 1949 through his brother, who was an engineer in New Jersey, Motchane met the physicist Robert Oppenheimer, then director of the Institute for Advanced Study (IAS) in Princeton. It was around this time that Motchane conceived his idea of establishing in France an institute akin to the IAS. Until his death in 1967, Oppenheimer remained an important advisor to Motchane as the IHÉS developed. Motchane's original plan was to establish an institute dedicated to fundamental research in three areas: mathematics, theoretical physics, and the methodology of human sciences (the latter area never really took root at the IHÉS). The institute was to be an entirely private enterprise, supported through donations from French companies, and the researchers would have complete freedom in choosing whatever directions they wanted to pursue. Motchane's vision was highly unusual in France, where the government was the dominant force in the economy, in higher education, and in support of scientific research.

Unfortunately, the goodwill of industry did not last long. Some of the corporate sponsors pressed Motchane for more say in the directions pursued by IHÉS researchers, and when he held fast to his original concept of unfettered research, they withdrew their support. By the late 1960s industrial support had diminished considerably, but the IHÉS was able to secure funding from the French government, which became, and remains today, the major source of support. As this shift in funding sources took place, the financial situation of the IHÉS remained precarious and did not stabilize until the early 1970s. It was Motchane's business savvy, as well as his detailed understanding of the French system, that helped the IHÉS survive. For example, in 1962 he purchased at a very favorable price the Bois-Marie, which had come under state ownership after World War II. Later on, when the state laid plans for a new highway that would cut across an edge of the Bois-Marie, it recompensated the IHÉS for the loss. This recompensation was larger than the price Motchane had paid for the whole property.

Prior to the purchase of the Bois-Marie, the IHÉS occupied a couple of offices in the Fondation Thiers in Paris, where Motchane and the IHÉS secretary, Annie Rolland, worked. Despite the meager facilities, the IHÉS succeeded brilliantly in its first

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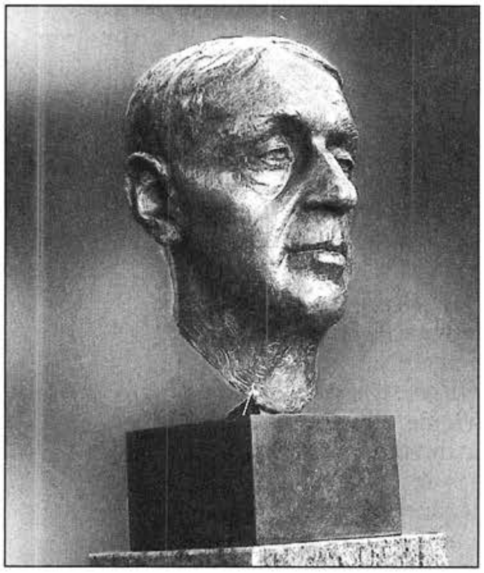
All photographs for this article were provided courtesy of the IHÉS.



Bust of IHÉS founder Léon Motchane, installed during the IHÉS 40th anniversary celebration in October 1998.

two appointments in mathematics: Jean Dieudonné and Alexandre Grothendieck. The two worked at their homes and presented seminars in a room lent by the Fondation Thiers or at one of the universities nearby. Even at this time the IHÉS managed to attract as visitors some of the top mathematicians of the day, including Michael Atiyah, S. S. Chern, Friedrich Hirzebruch, and André Weil. In 1960 the IHÉS launched its now famous series of blue-covered books, Les Publications de l'IHÉS. The series emphasizes long articles of fundamental character and has carried some of the most important work to issue from the institute. Dieudonné was the original editor of the series, and since 1979 Jacques Tits has been the editor in chief.

Over the years, Motchane came increasingly to depend upon Rolland, and she wielded considerable influence. Upon his retirement in 1970, Motchane divorced his wife and married Rolland. Still devoted to the IHÉS, he maintained an involvement in administrative and financial matters even after his successor, the Dutch mathematician Nicolaas Kuiper, had taken over as director. Motchane died in 1990, and a few years later Rolland committed suicide by throwing herself into the Seine River. One observer saw a link between Rolland's tragic death and the IHÉS, saying that she never got over her loss of influence at the institute. She is not the only secretary who was deeply affected by her time at the IHÉS. Kuiper's secretary, Nicole Gaume, was ousted after Kuiper's retirement, and she took her revenge by writing a novel about the IHÉS. Entitled *Dis-moi qui tu aimes (je te dirai qui tu hais) (Tell me whom you love (I'll tell you whom you hate))*, and written under the nom de plume Margot Bruyère, the book was ostensibly a murder mystery, but in fact attempted a thinly veiled exposé of life at the institute.

It was Kuiper who persuaded scientific societies from other countries to contribute funds to the IHÉS, and today such contributions remain a small but important part of the institute's budget. However, he never really understood the intricacies of obtaining support through the French system in the way that Motchane did. Rather, Kuiper excelled on the scientific side. According to David Ruelle, who has been a permanent professor at the IHÉS since 1964, Kuiper understood that in-depth discussion of research matters was the best way to make decisions about whom to invite. These discussions, says Ruelle, "were more interesting and effective than a case-by-case discussion of individual applications, with the usual guesswork of how to read between the lines of letters of recommendation." Still, there was dissatisfaction over Kuiper's lack of attention to physics and his inability to penetrate the workings of the French bureaucracy. The two directors who came after Kuiper are both French: Marcel Berger, who served from 1985 until 1994, and the present director, Jean-Pierre Bourguignon. Interestingly, the three directors succeeding Motchane all worked in differential geometry, an area that fell somewhat out of fashion as the world of French mathematics came to be dominated by Grothendieck and Bourbaki.

The Early Golden Years

The creation of the IHÉS took place at a time when the Bourbakists were exerting a deep influence on mathematics, particularly in France. Dieudonné was one of the founding fathers of Bourbaki, and Grothendieck was one of its members. Many other Bourbaki members, such as Claude Chevalley, Jean-Pierre Serre, and Armand Borel, attended Grothendieck's seminars at the IHÉS. And in 1971 Pierre Cartier, another Bourbakist, began his long association with the IHÉS as a visitor. Thus, as Cartier puts it, in the first ten years of the IHÉS, "the Bourbaki spirit was there, if not the institution of Bourbaki."

The Bourbaki spirit was also reflected in what is arguably the most famous work to be published in the IHÉS blue series, the collection of six volumes that make up *Éléments de Géométrie Algébrique*, written by Grothendieck in collaboration with Dieudonné. According to Cartier, there was an explicit agreement between Grothendieck and Bourbaki that the books by Bourbaki on commutative algebra would leave off exactly where EGA began. All told, Grothendieck was the sole author or a coauthor on some thirty volumes in the IHÉS blue series, most of which ran over 150 pages. He also wrote *Séminaire de Géométrie Algébrique*, which ran twelve volumes, ten of which were published by Springer-Verlag. EGA and SGA total approximately 10,000 pages, and the rest of his works run a couple of thousand more. There was a sense of a revolution under way as Grothendieck, through his writings and his lectures at the IHÉS, transformed the landscape of a wide swath of mathematics. He was not merely boasting when he replied to a visitor's complaint about the inadequacy of the IHÉS library, "We do not read books, we write them." His prodigious output was cut short in 1970, when he abruptly resigned from the IHÉS [see sidebar].

Bourbaki and Grothendieck brought a new viewpoint to mathematics that emphasized the power of general structures, especially category theory. In particular, Grothendieck found a way of introducing general structures to unify commutative algebra and number theory. Through the language of categories and schemes, many important mathematical problems could be recast in such a way as to elucidate their main features. In his book *Undergraduate Algebraic Geometry*, Miles Reid notes that the period from about 1955 to 1970 was one "in which tremendous conceptual and technical advances were made, and thanks to the systematic notion of a scheme ..., algebraic geometry was able to absorb practically all the advances made in topology, homological algebra, number theory, etc." Grothendieck's influence on algebraic geometry is perhaps the most clear. In the past one could make a living in that field by doing calculations with particular equations. With the advent of Grothendieck's ideas, algebraic geometry evolved into one of the most abstract and technical fields in mathematics.

That for twelve years Grothendieck kept a loosely knit group of mathematicians focused on developing his vision testifies to the forcefulness of his personality. His influence extended well beyond this group and had a major impact on an entire generation of French mathematicians. As Reid points out, this influence was not always positive, for the "Grothendieck personality cult," as Reid calls it, induced many mathematicians to pursue a rather sterile elaboration of Grothendieck's theories and to ignore their use in important problems. The mathematicians who put these theories to the most fruitful uses were those such as David Mumford and Michael Artin, who visited the IHÉS but had some distance from the Grothendieck school.

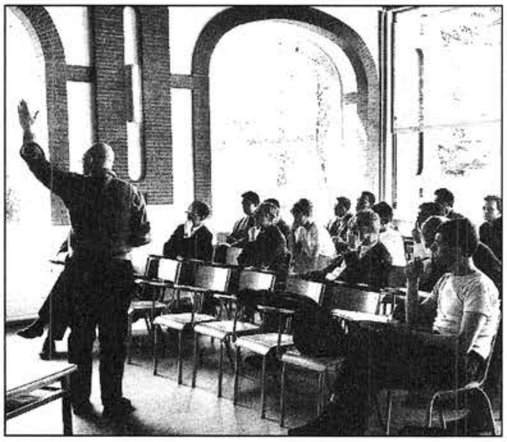
Despite the influence of Dieudonné and Grothendieck, the IHÉS was no Bourbaki stronghold: in 1963 René Thom accepted a professorship at the institute. Grothendieck and Thom, each brilliant in his own way, embodied the yin and yang of research. For Grothendieck a theorem had to be exactly right, with every detail accounted for. Thom, who had been educated in the Bourbaki tradition, nevertheless had a much more qualitative and intuitive approach to mathematics. Ruelle recalls one session in Thom's seminar in which Thom stated a theorem. Adrien Douady, who was in the audience, asked "Have you proved this theorem?" "Non, mais j'en mettrais ma tête à couper," Thom replied ("I will put my head to be cut off if it's not true"). "Avec toutes les têtes de Thom qu'on a déjà coupées," Douady murmured ("Just like all his other heads that have already been cut off"). Someone of lower caliber than Thom would likely have produced nonsense with such an imprecise approach. As Ruelle notes, Thom "did produce excellent mathematics, but in this sort of lazy style, which was not at all fashionable then."

When he arrived at the IHÉS, Thom already had in hand his 1958 Fields Medal. During the 1950s he did foundational work in differential topology and in particular invented cobordism theory. In his famous IHÉS seminar, which, like Grothendieck's, attracted many participants from Paris and beyond, Thom began developing the theory for which he is probably most famous, that of the classification of singularities of smooth maps. This forms the heart of what is known as catastrophe theory, which attempted to elucidate the mechanisms involved in sudden changes in smoothly varying systems, such as when an eroding cliff disintegrates or a cell divides to become two. Thom's 1972 book *Stabilité Structurelle et Morphogenèse* (*Structural Stability and Morphogenesis*) became the bible of catastrophe theory. In it he presents his views on a tremendous variety of subjects, including embryology, linguistics, and evolution. At times philosophical and highly speculative, the book nevertheless testifies to Thom's striking originality and his deep intuition about the nature of things. That he was aware of the imprecise nature of his work is clear in many passages of the book. "Many of my assertions depend on pure speculation and may be treated as day-dreams, and I accept this qualification," he writes near the end of the book. "At a time when so many scholars in the world are calculating, is it not desirable that some, who can, dream?"

Nowadays the term catastrophe theory inevitably calls to mind the controversy that surrounded attempts to apply the theory in a wide range of scientific fields. At the center of the controversy was the British mathematician Christopher Zeeman, who was a frequent visitor to the IHÉS in the 1960s and 1970s and an enthusiastic proponent of Thom's ideas. It was Zeeman who went the furthest in attempting to apply catastrophe theory in physics and biology, and even in sociology and politics. These applications were enthusiastically taken up by practitioners in other sciences and heralded in the press. What ended up happening was that the unsuccessful attempts were labeled applications of catastrophe theory, and the successful attempts were labeled more neutrally, as applications of singularity theory. Indeed, many of the ideas that originally came under the rubric of catastrophe theory are still alive in singularity theory, which remains today an active area of mathematical research. In his 1998 doctoral thesis entitled *A Cultural History of Catastrophes and Chaos: Around the Institut des Hautes Études Scientifiques, France,* mathematical historian David Aubin argues that Thom's work in general, and catastrophe theory in particular, had an important impact on the development of new ideas for mathematical modeling, especially chaos theory. Thom's work also had a major influence on Ruelle, who before coming to the IHÉS had worked in statistical me-

Grothendieck: The Genie of the Bois-Marie

Though he left the IHÉS nearly thirty years ago, Alexandre Grothendieck remains an eerily strong presence at the institute. His name surfaces frequently in conversations with IHÉS visitors and professors, even when one is talking to those who never knew him. His viewpoint profoundly changed mathematics and had a deep influence on mathematicians in France and beyond. The potency of his ideas and the forcefulness of his personality have left a lasting mark on the institute.



Grothendieck lecturing at the IHÉS.

Grothendieck's father was an ally of Lenin and took part in some of the major political upheavals in Europe in the early part of this century. In the 1920s he lived in Germany, where he worked with groups opposed to the Nazis and also met Hanka Grothendieck, who gave birth to their son in 1928. The parents did not remain together long, as the father left to take part in the Spanish Civil War and in 1943 perished in the concentration camp at Dachau. Though Alexandre Grothendieck never knew his father, he held him in great esteem. Grothendieck's office at the IHÉS had no decoration except an oil painting of his father.

During World War II Grothendieck and his mother lived in a detention camp in France, but he was able to attend a school organized by a group of Protestant resistors of the Nazis. In 1948 he went to Paris carrying a letter that the school had written for him as an introduction to Henri Cartan. Later he went to Nancy, where he received his doctoral degree under the direction of Jean Dieudonné. Grothendieck then spent a number of years traveling in Brazil and in the United States. In 1958 he and Dieudonné accepted appointments as permanent professors in the newly established IHÉS.

After twelve years at the institute, in which he ran a celebrated seminar that reshaped the foundations of algebraic geometry, Grothendieck suddenly resigned. One reason was a dispute with the director, Léon Motchane, over the fact that a small proportion of the IHÉS budget had come from military sources. There had been earlier indications of Grothendieck's strongly held political views. For example, in 1966 Motchane traveled to Moscow to collect Grothendieck's Fields Medal because Grothendieck himself refused to attend for political reasons. Three years later Grothendieck's insistence that the IHÉS refuse military funding infuriated Motchane, who had always maintained a clear division between scientific matters, which were left up to the permanent professors, and financial ones, which were the director's domain. Grothendieck's stance found some sympathy among the other IHÉS professors, who at one point told Motchane they would rather do without military funding than lose Grothendieck. However, his naiveté must have been vexing. Retired IHÉS physics professor Louis Michel recalls that around this time he showed Grothendieck a poster advertising a conference in which he, Grothendieck, was the main speaker. Michel pointed out that the talks were sponsored by NATO and asked him if he knew what NATO was. No, Grothendieck replied. Michel explained it to him and recalls Grothendieck saying, "They never told me!" True to his convictions, Grothendieck wrote to the conference organizers, who refused the NATO support and kept Grothendieck as a speaker.

While the issue of military funding was perhaps the most obvious explanation for Grothendieck's departure, those who knew him say that the causes of the rupture ran deeper. Pierre Cartier, a *visiteur de longue durée* at the IHÉS, wrote a piece about Grothendieck for a special volume published on the occasion of the IHÉS's fortieth anniversary. In it Cartier notes that, as the son of an antimilitary anarchist and one who grew up among the disenfranchised, Grothendieck always had a deep compassion for the poor and the downtrodden. As Cartier puts it, Grothendieck came to find Bures-sur-Yvette *"une cage dorée"* ("a golden cage"). While Grothendieck was at the IHÉS, opposition to the Vietnam War was heating up, and Cartier suggests that this also reinforced Grothendieck's distaste at having become a mandarin of the scientific world.

In addition, after several years at the IHÉS Grothendieck seemed to cast about for new intellectual interests. By the late 1960s he had started to become interested in scientific areas outside of mathematics. David Ruelle, a physicist who joined the IHÉS faculty in 1964, said that Grothendieck came to talk to him a few times about physics. Biology interested Grothendieck more than physics, and he organized some seminars on biological topics. Ruelle suggests that Grothendieck's interests were changing because he was starting to believe he would never finish the mathematical edifice he had started. "Grothendieck was working on the foundations of algebraic geometry 7 days a week, 12 hours a day, for 10 years," Ruelle notes. "He had achieved level -1 and was working on level 0 of something that must be 10 levels high. At a certain age, it becomes clear that you will never be able to finish the building."

After leaving the IHÉS, Grothendieck tried and failed to get a position at the Collège de France. He then went to Université de Montpellier, where he became increasingly estranged from the mathematical community. Around this time, he founded a group called Survivre, which was dedicated to antimilitary and ecological issues. His mathematical career, for the most part, ended when he left the IHÉS. In 1984 he wrote a proposal to get a position through the Centre National de la Recherche Scientifique. The proposal, entitled *Esquisse d'un Programme* (*Sketch of a Program*) describes new ideas for studying the moduli space of complex curves. Although Grothendieck himself never published his work in this area, the proposal became the inspiration for work by other mathematicians and the source of the theory of *dessins d'enfants* (children's drawings). *Esquisse d'un Programme* was published in the two-volume proceedings *Geometric Galois Actions* (Cambridge University Press, 1997).

In 1985 Grothendieck produced his notorious *Récoltes et Semailles* (*Harvests and Seeds*), a beautifully written but bitter treatise of some 1,000 pages in which he lays out his dissatisfactions with the mathematical world. Grothendieck deeply resented the fact that, after he left the IHÉS, other mathematicians took up his ideas and carried them forward, adding their own imprint along the way. This resentment eventually metamorphosed into a paranoia which is evident in the pages of *Récoltes et Semailles.*

Grothendieck, who turns seventy-one years old in March 1999, lives in a remote hamlet in the Pyrenées. Some reports hold that his psychological condition has deteriorated over the years. For example, Cartier writes that according to two mathematicians who visited Grothendieck in the last couple of years, he is "obsessed by the devil, which he sees at work everywhere in the world, destroying the divine harmony, and replacing 300,000 km/sec by 299,887 km/sec for the speed of light!" The severance of his ties to the mathematical world is nearly complete, and he has made it clear that he does not wish to renew them. However, nothing can expunge Alexandre Grothendieck from the IHÉS, where his spirit and his genius continue to haunt the Bois-Marie.

—A. J.

chanics and afterward became a leading figure in the burgeoning area of dynamical systems. In the 1970s Ruelle and the Dutch mathematician Floris Takens produced a new model for turbulence, and it was Ruelle who invented the concept of a strange attractor in a dynamical system.

Still Golden after All These Years

Some things have changed at the IHÉS since its early golden years. For one thing, there are no longer seminars in the style of Grothendieck and Thom, in which each was the main speaker. However, there is much that has not changed, such as the quality of the IHÉS mathematics faculty, which has remained extremely high. Of the nine people who have been permanent mathematics professors at the IHÉS, six of them—Grothendieck, Thom, Jean Bourgain, Alain Connes, Pierre Deligne, and Maxim Kontsevich—have received Fields Medals; two others, Dennis Sullivan and Mikhael Gromov, are often counted among those who should have received Fields Medals but by some fluke did not. At present there are three mathematics professors at the IHÉS: Connes, Gromov, and Kontsevich. (Connes is the Léon Motchane Professor at the IHÉS, where he spends a good deal of his time, and is also a professor at the Collège de France, which pays his salary.) Bourgain and Deligne are now at the Institute for Advanced Study in Princeton, and Sullivan is now half time at the State University of New York, Stony Brook, and half time at the City University of New York. Some of the mathematical themes of the early years of the IHÉS have been carried forward in the interests of faculty appointed in later years. This can be seen most clearly in the work of Pierre Deligne, who developed and extended many of Grothendieck's ideas. It can also be seen in the research of Sullivan, who like Thom has worked in geometry, topology, and dynamical systems theory. Sometimes these themes merge to produce new results, as can be seen in the application of rational homotopy theory to the topology of algebraic varieties, which uses ideas from the work of both Deligne and Sullivan.

Another attribute of the IHÉS that continues to this day is the way in which the scientific life at the IHÉS carries the imprint of the faculty. "The way the institute runs is very much determined by the people who are here," Gromov remarks. "The personalities shape the place to a great extent." In particular, Sullivan, an ebullient Texan, was a master at orchestrating activity and interest among visitors and was especially effective with young people. Recent Fields Medalist Curtis McMullen is a good example of Sullivan's influence: Although McMullen received his Ph.D. from Harvard, he was really Sullivan's student, and it was while visiting the IHÉS that McMullen got the idea for his thesis problem. Another example is Gromov himself: It was Sullivan's invitation that first brought Gromov to the IHÉS as a visitor in 1977, three years after Gromov had gotten out of the Soviet Union. He became a permanent professor at the IHÉS in 1982, and in 1986 his book *Partial Differential Relations* was published. The book contains elaborations on many of the ideas from his doctoral thesis. In the introduction Gromov thanks Kuiper, who was director of the IHÉS during Gromov's early years at the institute, for his "unrelenting criticism" of early drafts. Gromov is best known for his work in differential geometry, especially Riemannian geometry, and he has also had a large influence on symplectic geometry. His interests are very wide ranging and most recently have centered on complexity theory, particularly as it connects to biological systems, and on DNA nanotechnology, which may hold the key to new ways of organizing complex processes.

That two Russians, Gromov and Kontsevich, are permanent professors at the IHÉS testifies to the strength of Russian mathematics. This strength can also be seen in the seminar run by I. M. Gelfand, which takes place at the IHÉS over about a month during the summer. Gelfand brings to the IHÉS the same style that made his Moscow seminar famous. Rather than allowing a speaker to drone on as the audience sits impassively, understanding little, Gelfand constantly asks questions and presents ideas, with the aim of insuring that communication really takes place. Views differ on the successfulness of this style. Some contend that Gelfand does not allow speakers to have their say, and some are offended by what they see as his combative style. Another drawback is the fact that the eighty-five-year-old Gelfand has developed hearing problems. On the other hand, many appreciate Gelfand's approach. Gromov, who witnessed sessions of Gelfand's seminar in Moscow, says the IHÉS version is not the same, but still believes the approach has merit. "Mathematicians' talks are often extremely bad," says Gromov. "They get carried away by a desire to say something, with very little regard for the audience...Gelfand tries to break this, to make talks more comprehensible."

As befits a research institute devoted to mathematics and theoretical physics, two of the current mathematics professors at the IHÉS, Connes and Kontsevich, work in areas with deep ties to physics. Last year Kontsevich received his Fields Medal for work centered on a variety of ideas from the frontiers of mathematical physics, including mirror symmetry and deformation quantization. Connes created noncommutative geometry, and lately he has studied its relations to quantum chromodynamics, the so-called standard model of particle physics. He has also explored mysterious connections between physics and the Riemann Hypothesis. From the beginning the IHÉS has had a component in theoretical physics, but it has always been outshone by the mathematics. This points not to a lack of quality within the physics faculty but to the fact that the mathematics faculty has been so outstanding.

In the early years of the IHÉS, Motchane, using the intuition that served him so well in his first appointments in mathematics, made an offer to the young physicist Murray Gell-Mann, who was later to receive a Nobel Prize. Gell-Mann, after much consideration, turned down the offer and remained at the California Institute of Technology. Harry Lehmann, who had been important in reviving theoretical physics in postwar Germany, was offered a permanent professorship at the IHÉS and spent a few years there in the early 1960s but eventually returned to his home institution of the University of Hamburg. In 1962 elementary particle physicist Louis Michel became the first IHÉS appointment in physics, and David Ruelle became the second in 1964. During the late 1970s and early 1980s, Oscar Lanford III and Jürg Fröhlich both held permanent appointments in physics, and both eventually left to take positions in Switzerland. Today there are two permanent professors in physics, Ruelle and Thibault Damour, who works in cosmology and general relativity. String theorist Michael Douglas is listed on the IHÉS faculty as a permanent professor in physics, but as late as the fall of 1998 it was not entirely certain that he would leave Rutgers University to move to the IHÉS. The offer to Douglas is one indication of the priority the IHÉS is now placing on strengthening theoretical physics.

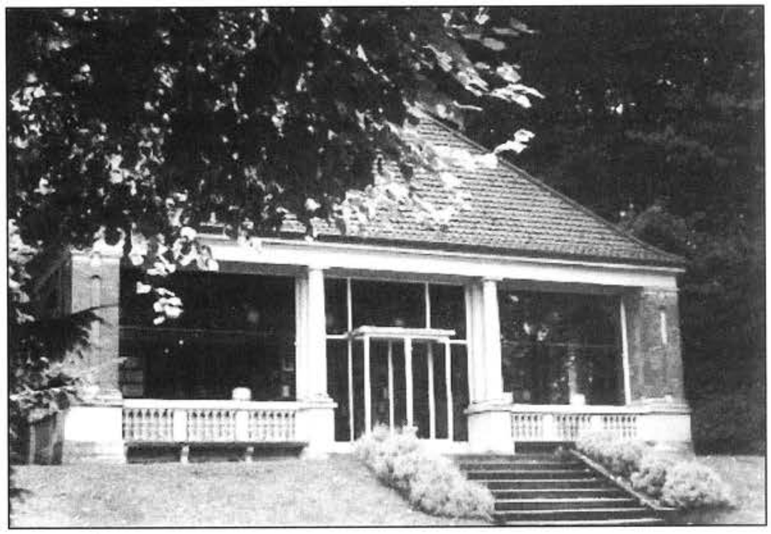
The IHÉS is able to attract and retain excellent mathematicians despite the fact that it does not pay especially well: all the professors have the same salary, which does not increase over time except for adjustments for inflation. The pay is equivalent to the top salary for mathematics professors in France, which is quite a bit less than the corresponding salary would be in the U.S. They are required to spend at least six months a year in residence at the institute. Dennis Sullivan was the first IHÉS professor to supplement his paycheck with a permanent position in the U.S.; for years he had a second job holding the Einstein Chair at the City University of New York. For a number of years Gromov held a part-time position at the University of Maryland, and he has recently shifted to the Courant Institute at New York University, where he spends the spring each year. Kontsevich has a similar arrangement with Rutgers University. Of course, mathematicians of this caliber could easily get highly paid jobs elsewhere. What keeps them at the IHÉS? Kontsevich puts it simply: "It's a place with the maximum amount of freedom." He appreciates the absence of teaching, the ability to invite many visitors, the lack of bureaucracy, and even the fact that there are no concerns about promotions or salary raises. "In my profession, these are the best possible conditions," he says.

Life for the IHÉS Visitor

As an institute, the IHÉS bears more resemblance to, for example, the Max Planck Institute for Mathematics (MPI) in Bonn than to, say, the Mathematical Sciences Research Institute (MSRI) in Berkeley. Like the MPI, the IHÉS is organized around a core of permanent faculty who make decisions about which visitors to invite, either based on their own interests or on applications received. By contrast, thematic programs and conferences form the main part of the activity at institutes like MSRI, and individuals apply to participate in these events. Generally, the IHÉS has a more rarefied atmosphere than an institute like MSRI. This is due in part to the high level of the IHÉS permanent faculty, but also to the fact that there is a cadre of people who have been visiting the IHÉS regularly for years. There are advantages and disadvantages to having the same people visit regularly. On the one hand, if a certain researcher is of high caliber, it is advantageous to have his or her visits continue over the years, and these regular visits establish a certain tradition. On the other hand, it has sometimes happened that regular visitors are offended when, for one reason or another, a request to visit is turned down.

The IHÉS hosts around two hundred visitors per year, with no more than about forty in residence at any one time. In the past it was common for visitors to come to the IHÉS for an entire sabbatical year and bring their families along. However, with the increase in the number of families in which both parents work, such arrangements are less common. Today IHÉS visitors stay an average of about three months. Visitors from the U.S. predominate, accounting for more than one-third of the total. The majority of visitors are housed in the Résidence de l'Ormaille, which is a set of small houses and apartments a short walk from the Bois-Marie. The houses and the studio apartments are neat and pleasant, and each has a full bath and kitchen. However, visitors have complained about the Ormaille's shared quarters, in which several visitors have single rooms and share bathroom and kitchen facilities. Those in the know request apartments in another nearby residence called the Gratien, where some of the IHÉS permanent faculty live and where the IHÉS owns a number of units (plans are under way for the IHÉS to sell all but one of these). Staying in Paris means a commuter rail trip of about forty minutes to reach the IHÉS.

When it comes to the facilities at the IHÉS itself, there are pluses and minuses. One of the biggest drawbacks is the inadequacy of its library; indeed,



The IHÉS library.

some visitors report being rather shocked at the fact that it lacks even the most important journals. The IHÉS relies on the excellent mathematics library at the Université de Paris-Sud in Orsay, which is a twenty-minute walk from the institute. One of the aspects visitors appreciate most is that, unlike at many other institutes where one must share an office, the IHÉS gives everyone an individual office. Each is equipped with its own workstation, a relatively new development at the IHÉS; indeed, it was only a couple of years ago that computers were available only in a common computer room. Some visitors note that the IHÉS computer systems did not always work properly and lacked some standard features. Reports varied on the helpfulness of the IHÉS staff: some found it exasperating that the secretaries, rather than revealing that they spoke English, would let visitors stumble along in broken French; others said these same secretaries went out of their way to be helpful, even booking airline tickets and helping with translating letters into French.

The informality and lack of regulation are among the attributes that IHÉS visitors appreciate the most. However, these same attributes have sometimes left visitors without basic information, such as how to check books out of the library or the time at which afternoon tea is served. One of the most notable expressions of the IHÉS informality is the communal lunch, where postdocs and professors, visitors and permanent faculty sit down together to enjoy food and conversation. The canonical outcome of a group of mathematicians having lunch is several paper napkins filled with pictures and equations. At the IHÉS the napkins are cloth, but paper and pens are available on all the tables. In fact, the lunchtime conversation, helped along by carafes of wine, might as easily be about politics as about mathematics. The IHÉS lunch is probably the tradition that inspires the fondest memories among visitors. Not only does it foster a community spirit, but it also serves the practical purpose of making it convenient for visitors to remain at the institute all day.

The usual rate at which visitors' expenses are reimbursed is 200 FF (approximately $35) per day. The amount is quite meager, even given the fact that visitors usually receive free lunch and housing. Some senior visitors, especially those who want to live in Paris and not at the Ormaille, have complained about the low pay, and such cases are handled individually by the director, who can increase the pay at his discretion. Bourguignon says that usually such exceptions are made in cases where visitors come from poor countries and cannot cover their own travel expenses, which are generally not paid by the IHÉS, or in the case of postdocs without another source of income. One of the things visitors often find surprising is that they are paid in cash. Visitors are told in advance the amount they are to be paid, but some report being uncertain about how and when they would be paid, only to be suddenly handed an envelope stuffed with hundreds of francs. Once they get over the sense of surprise, most visitors find the cash payments a great convenience over setting up a French bank account.

In addition to the visitors who come from outside the IHÉS, there are also a number of *visiteurs de longue durée* (long-term visitors). The long-term visits are open-ended in duration and in some cases have lasted twenty years or more. Usually, these *visiteurs de longue durée* have come into their positions through having a sustained association with the IHÉS, perhaps through collaboration with one of the permanent professors. Until recently there were six such visitors: Jean-Benoît Bost, Ofer Gabber, Christophe Soulé, and Shih Weishu in mathematics, and Henri Epstein and Krzysztof Gawedzki in physics. At the present time there are only three, since Epstein retired, Shih passed away, and Bost left to take a position at the Université de Paris-Sud. The long-term visitors' salaries are paid through the Centre National de la Recherche Scientifique (CNRS), the principal science funding agency of the French government. Such CNRS positions are lifetime appointments that require no teaching and are tenable at institutions where there is a CNRS unit, which for mathematics is usually within a teaching institution. Pierre Cartier holds such a CNRS position attached to the École Normale Supérieure, and he has a longstanding "gentleman's agreement" with the IHÉS that allows him to have an office at the institute, where he has spent a good deal of time over the last twenty-five years.

Although CNRS positions might sound like a mathematician's dream come true, one must bear in mind that, like most positions in the French public sector, the pay is fairly small. Throughout France, there are many excellent mathematicians in CNRS positions. However, the system bears the stamp of French socialism, and in a few cases these positions have become sinecures for people who are no longer productive.

For many years the status of the long-term CNRS visitors at the IHÉS was unclear because the institute had no CNRS unit with which such positions could be officially affiliated. Director Jean-Pierre Bourguignon has sought to regularize the status of these positions. There is now a special agreement between the CNRS and the IHÉS whereby such long-term visitors can be officially affiliated with the IHÉS. Bourguignon has also made efforts to integrate the long-term visitors into some of the scientific decision-making of the IHÉS. They now attend meetings of the Scientific Committee—consisting of the director, the permanent professors, and a number of mathematicians and physicists from outside the IHÉS—and provide input into decisions about which visitors to invite. The long-term visitors do not take part in decisions about appointments of new permanent professors. Although there are good relations between the long-term visitors and the IHÉS permanent faculty, there is some uneasiness too. Within the Scientific Committee there is some feeling that it would be preferable to have specified durations for all CNRS visitors rather than indefinite stays that can essentially become lifetime appointments. And generally there is the worry that the IHÉS, a small private foundation, could be swallowed up by the much larger CNRS.

Raising the Visibility of the IHÉS

In addition to regular seminars in mathematics and theoretical physics, the IHÉS has a series of lectures entitled "Les Vendredis de l'IHÉS" ("Fridays at the IHÉS"), which features a pair of lectures on related mathematical themes. In the nearby Paris area there are hundreds of seminars and lectures given throughout the academic year. Some IHÉS visitors take part in the especially French tradition of *groupes de travail*, which are small working groups that meet to study the details of specific books or papers. The IHÉS does not run conferences on a regular basis, but in the past few years, under the directorship of Jean-Pierre Bourguignon, there have been a few such events. In particular, the IHÉS is establishing a series of conferences called "Entretiens de Bures" ("Bures Discussions"). The first one, held in December 1997, focused on pattern formation and brought together biologists, physicists, computer scientists, and mathematicians. According to Bourguignon, many of the participants had never even heard of the IHÉS before coming to the conference.

Holding such conferences is one of the ways in which Bourguignon is trying to enhance the visibility of the IHÉS. For many years he has been involved in popularizations of mathematics, and these efforts have continued in his time at the

IHÉS. For example, he organized a public event called "Les Mathématiques dans La Ville" ("Mathematics in the City") together with the cultural center in Bures-sur-Yvette. A fifteen-minute informational videotape program about the IHÉS was produced last year, and there are plans to produce another, longer program about the scientific work done at the institute. In addition, the IHÉS will be involved in an international science film festival this year. The IHÉS fortieth anniversary celebration, held in early October 1998, featured not only talks about mathematics, physics, and the history of the IHÉS but also an open house for the general public.

One purpose of all of these outreach efforts is fundraising. The IHÉS has the status of a private foundation in France, and its budget is about 25 million FF (about $4.4 million) per year. The Education Ministry of the French government is the major supporter, accounting for about 60 percent of the total. Foreign scientific institutions—including Germany's Max Planck Society, the Swiss Academy of Sciences, and the Engineering and Physical Sciences Research Council of the UK—together contribute funds comprising about 10 percent of the IHÉS's budget, on the grounds that many researchers from these countries visit the IHÉS. Based on its large number of visitors from the U.S., the IHÉS holds a grant of about $80,000 from the U.S. National Science Foundation (there was also a small grant from the Foundation to support the conference on pattern formation). Recently, some U.S. companies have made donations to the IHÉS. About 7 percent of the IHÉS budget comes from French companies, and a small amount comes from the European Union.

It is sobering to realize that the IHÉS has managed to survive for forty years by patching together funds from different sources. It has about 10 million FF saved in the bank but essentially no endowment. (There is a small endowment from the Sackler Foundation that supports one Sackler Fellow each year at the IHÉS.) Unlike, for example, the IAS in Princeton, which could continue operations using income from its endowment should outside sources dry up, the IHÉS would have to close down. Indeed, the financial history of the IHÉS has been rocky—in some years it has had to borrow money from banks to stay afloat; in other years professors actually gave up their salaries to ease financial strains. A recent indication of the ups and downs of its fortunes is the fact that the director has resumed his CNRS civil servant position. With the fortieth anniversary, the IHÉS started a donor group called Les Amis de l'IHÉS (Friends of the IHÉS), and Bourguignon says that he has been surprised to find that many former IHÉS visitors were willing to donate substantial amounts of money. A U.S. subsidiary of Les Amis de l'IHÉS is in the works. "We are really fragile," says Bourguignon. On the other hand, "maybe being fragile is a virtue."

Despite these difficulties, the IHÉS managed last year to purchase the Résidence de l'Ormaille, which it had leased for thirty-one years (the purchase has necessitated the sale of four of the five Gratien units owned by the IHÉS). In addition, it has secured funding from the French government for the construction of a new wing to its main building. The library will be moved to the new wing from the summerhouse, where the weight of the books has taken a toll on the old building. The summerhouse will then revert to being a lecture room, as it was in the days of the seminars of Grothendieck and Thom. In this way, these changes represent not only a step into the future but also a hearkening back to the greatness that took root early at the IHÉS. Like the trees of the Bois-Marie, this institute is here to stay.

Henri Cartan, age 94, was one of the attendees at the 40th anniversary celebration of the IHÉS.

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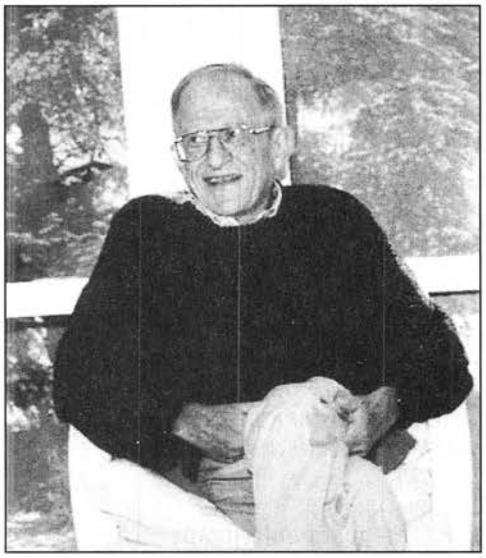
Bernard Dwork (1923–1998)

Nicholas M. Katz and John Tate



All photographs courtesy of Shirley Dwork.

Bernard Dwork, May 27, 1996.

Bernard Morris Dwork, "Bernie" to those who had the privilege of knowing him, died on May 9, 1998, just weeks short of his seventy-fifth birthday. He is survived by his wife of fifty years, Shirley; his three children, Andrew, Deborah, and Cynthia; his four granddaughters; his brothers Julius and Leo; and his sister, Elaine Chanley.

We mention family early in this article, both because it was such a fundamental anchor of Bernie's life and because so many of his mathematical associates found themselves to be part of Bernie's extended family. The authors of this article, although not family by blood, felt themselves to be son and older brother to him.

Bernie was perhaps the world's greatest p-adic analyst. His proof of the rationality of the zeta function of varieties over finite fields, for which he was awarded the AMS Cole Prize in Number Theory, is one of the most unexpected combinations of ideas we know of. In this article we will try to describe that proof and sketch Bernie's other main contributions to mathematics.

But let us start at the beginning. Bernie was born on May 27, 1923, in the Bronx. In 1943 he graduated from the City College of New York with a bachelor's degree in electrical engineering. He served in the United States Army from March 30, 1944, to April 14, 1946. After eight months of training as repeaterman at the Central Signal Corps School, he served in the Asiatic Pacific campaign with the Headquarters Army Service Command. He was stationed in Seoul, Korea, which, according to reliable sources, he once deprived of electricity for twenty-four hours by "getting his wires crossed". This is among the first of many "Bernie stories", some of which are so well known that they are referred to with warm affection in shorthand or code. For instance, "Wrong Plane" refers to the time Bernie put his ninety-year-old mother on the wrong airplane. "Wrong Year" refers to the time Bernie was prevented from flying to Bombay in January 1967 by the fact that his last-minute request for a visa to attend a conference at the Tata Institute was denied on the grounds that the conference was to be held the following year, in 1968.

After his discharge from the army, Bernie worked as an electrical engineer by day and went to school by night, getting his master's degree in electrical engineering from Brooklyn Polytechnic Institute in 1948. Bernie and Shirley Kessler were married on October 26, 1947. He worked successively for I.T.T. (1943–48, minus his army years), the Atomic Energy Commission (1948–50), and the Radiological Research Laboratory of Columbia Medical Center (1950–52). During these years he

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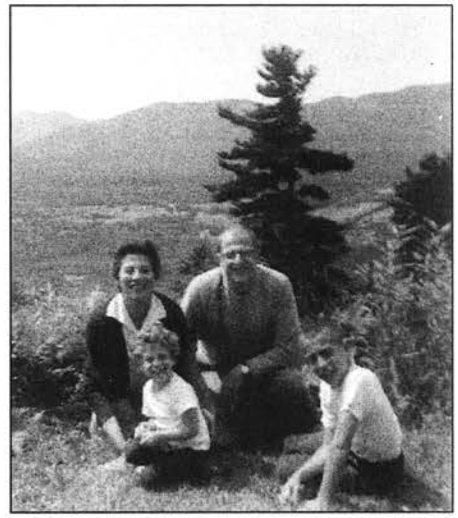
wrote a number of technical reports and published a few papers, including the earliest paper of his listed by *MathSciNet*, "Detection of a pulse superimposed on fluctuation noise", dating from 1950. In view of Bernie's later interest in differential equations (albeit from a p-adic point of view), it is interesting to note that this paper was reviewed by Norman Levinson.

In the summer of 1947 Bernie, encouraged by his brother, took an evening math course at New York University (NYU) with Emil Artin. The course was Higher Modern Algebra Part I: Galois Theory. The course notes, taken by Albert A. Blank, are still one of the best "textbooks" on Galois theory available. The following summer Bernie was back, to take Higher Modern Algebra Part II: Algebraic Number Theory, again with Artin. In the summer of 1949 Bernie took a course from Harold Shapiro on Selected Topics in Additive Number Theory, and in the summer of 1950 he took a course from Artin which was the precursor of Artin's 1950–51 Princeton course Algebraic Numbers and Algebraic Functions.[1]

Bernie was hooked.[2] He continued taking evening courses, both at NYU and at Columbia. He tried to enter NYU as a graduate student in mathematics, but NYU found his educational background wanting. Fortunately for us, Columbia was less picky: in February 1952 Columbia admitted him as a math graduate student, with a scholarship for the year 1952–53. He quit his job and took up full-time study in September of 1952. This was hardly a light decision. He was walking away from a secure career as an engineer, and he had a wife and son to support. Years later he wrote, "Imagine my horror when I found that the scholarship was only for tuition." The family savings soon dwindled, and to make ends meet, Bernie taught night courses at Brooklyn Polytechnic from February 1953 to June 1954.

Bernie had intended, once at Columbia, to study under Chevalley. But Chevalley returned to France that year, so he turned to Artin for advice.[3] Artin gave Bernie a thesis problem and introduced him to the second author of this article, then a young instructor at Princeton who later became Bernie's formal thesis adviser (despite being two years Bernie's junior) when he spent 1953–54 visiting Columbia.



In Europe, en route to 1962 ICM in Stockholm. Shirley and Bernie Dwork with children Cynthia (left) and Andrew.

Bernie received his Ph.D. from Columbia in 1954, with a thesis entitled "On the root number in the functional equation of the Artin-Weil L-series", about the possibility of defining "local root numbers" for nonabelian Artin L-functions, whose product would be the global root number (:= constant in the functional equation connecting $L(s,\chi)$ and $L(1-s,\bar{\chi})$). Bernie solved this problem up to sign; Langlands (unpublished) solved it definitively in 1968, and soon after, Deligne, inspired by the work of Langlands, found a more conceptual solution.

Before we discuss Bernie's later work, let us record the key dates of his professional career as a mathematician. He spent 1954–57 at Harvard as a Peirce Instructor, then 1957–64 at Johns Hopkins (1957–60 as assistant professor, 1960–61 as associate professor, 1961–64 as professor). In 1964 he moved to Princeton, where in 1978 he was named Eugene Higgins Professor of Mathematics. During this time, Bernie spent numerous sabbatical years in France and Italy. In 1992 he was named Professore di Chiara Fama by the Italian government and was awarded a special chair at the University of Padua, which he occupied until his death.

We now return to Bernie's work. In 1959 he electrified the mathematical community when he proved the first part of the Weil conjecture in a strong form, namely, that the zeta function of *any* algebraic variety ("separated scheme of finite type" in the modern terminology) over a finite field was a rational function. What's more, his proof did not at all conform to the then widespread idea that the Weil conjectures would, and should, be solved by the construction of a suitable cohomology theory for varieties over finite fields (a "Weil cohomology" in later terminology) with a plethora of marvelous properties.[4]

Bernie's proof of rationality was an incredible tour de force, making use of a number of new and

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[1] *Artin was in those years professor of mathematics at Princeton University, but he regularly taught evening courses at NYU in algebra and number theory.*

[2] *Strictly speaking, he was "rehooked", because he had been very drawn to mathematics in high school and college, but his parents convinced him that he would never earn a living as a mathematician and that engineering would be an adequate outlet for his mathematical enthusiasm. Parents are not always right.*

[3] *The (alphabetically) first author of this article, who was Bernie's thesis student in 1964–66, has fond memories of Bernie's describing his anxieties and his car troubles, which included once breaking down on the George Washington Bridge, on his early trips to Princeton to see Artin.*

[4] *We should point out, however, that by 1964 the ℓ-adic étale cohomology with compact supports of M. Artin and Grothendieck had caught up with Bernie and provided an alternate proof not only of Bernie's rationality result but also of most of the rest of the Weil conjecture for projective smooth varieties over finite fields, all but the "Riemann Hypothesis", which Deligne proved in 1973.*

Shirley and Bernie Dwork with grandchildren at Bernie's retirement party, October 1993.

unexpected ideas. We will describe it in some detail, because even after nearly forty years it remains strikingly fresh and original and gives a good idea of the way Bernie thought. But before we say more about Bernie's proof, we must digress to say a few words about zeta functions of varieties over finite fields.

Thus, we begin with a finite field k—e.g., k might be $\mathbf{Z}/p\mathbf{Z}$ for p a prime number—and an algebraic variety X/k—e.g., X might be an "affine variety", namely, the common zeroes of a finite collection of polynomials $f_i(X_1, \ldots, X_n)$ in some finite number n of variables with coefficients in the field k. In this affine example, by a k-valued point of X we mean an n-tuple $(a_1, \ldots, a_n)$ in k^n such that $f_i(a_1, \ldots, a_n) = 0$ in k for each defining equation f_i. In any case, for any algebraic variety X/k we have the notion of a k-valued point of X, and an easy but essential observation is that the set $X(k)$ of k-valued points of X/k is a finite set. It is known that inside a given algebraic closure $\bar{k}$ of k there is one and only one field extension k_d/k of each degree $d \geq 1$. Each field k_d is itself finite, so the sets $X(k_d)$ are finite for all $d \geq 1$. We denote by $N_d \geq 0$ the integer

$$N_d := \text{Card}\,(X(k_d)).$$

The integers N_d are fundamental diophantine invariants of X/k. The zeta function of X/k, $\text{Zeta}(X/k, T)$, is simply a convenient packaging of these integers: it is defined as the formal series in T with coefficients in $\mathbf{Q}$ and constant term 1 by

$$\text{Zeta}(X/k, T) := \exp\left(\sum_{d\geq 1} N_d T^d/d\right).$$

An important fact is that $\text{Zeta}(X/k, T)$ has integer coefficients. To see this, let us define a *closed point* $\wp$ of X/k to be an orbit of the Galois group $\text{Gal}(\bar{k}/k)$ on the set $X(\bar{k})$, and let us define the degree of $\wp$ to be the cardinality of the orbit which $\wp$ "is". If we denote by B_d the number of closed points of degree d, we have the relation

$$N_d = \sum_{r|d} rB_r,$$

hence the Euler product expansion

$$\text{Zeta}(X/k, T) = \prod_{r\geq 1}(1 - T^r)^{-B_r} = \prod_{\wp}(1 - T^{\deg(\wp)})^{-1}.$$

This last formula makes clear that $\text{Zeta}(X/k, T)$ as power series has integer coefficients.

Let us interpret what it means for $\text{Zeta}(X/k, T)$ to be a rational function of T, say

$$\text{Zeta}(X/k, T) = \prod_i (1 - \alpha_i T) \Big/ \prod_j (1 - \beta_j T)\,.$$

Taking logarithms of both sides and equating coefficients of like powers of T, we see that rationality means precisely that all the integers N_d are determined by the finitely many numbers α_i and β_j by the rule

$$N_d = \sum_j \beta_j^d - \sum_i \alpha_i^d\,.$$

This has the striking consequence that all the N_d are determined by the first few of them. More precisely, once we know upper bounds, say A and B, for the degrees of the numerator and denominator of Zeta, then *all* the integers N_d are determined by the N_d for $d \leq A + B$.

Let us now describe Bernie's proof of the rationality of $\text{Zeta}(X/k, T)$. By an elementary inclusion-exclusion argument, he reduces first to the case when X/k is affine, then to the case when X/k is defined by one equation $f = 0$ for some polynomial f in $k[X_1, \ldots, X_n]$, and finally to the case when X/k is the open subset of $f = 0$ where all the coordinates x_i are nonzero. To count points over k, he then uses a nontrivial additive character ψ of k with values in a field K of characteristic zero. For a while in the argument, K could be $\mathbf{C}$, but a different choice of K will be handy in a moment. Bernie exploits the classical orthogonality relation: for $a \in k$, we have, in K,

$$\sum_{y\in k}\psi(ya) = \begin{cases} 0\,, & \text{if } a \neq 0 \\ q := \text{Card}\,(k)\,, & \text{if } a = 0\,. \end{cases}$$

Taking for a the value $f(x)$ at a point x in k^n, we get

$$\sum_{y\in k}\psi(yf(x)) = \begin{cases} 0\,, & \text{if } f(x) \neq 0 \\ q\,, & \text{if } f(x) = 0\,. \end{cases}$$

Papers and Books by Bernie

Under Dwork, B., *MathSciNet* lists over seventy items, including three books. Bernie also wrote two papers as Maurizio Boyarsky. Rather than recopy his complete list of publications, we give a complete alphabetical list of Bernie's coauthors, from which the reader can correctly infer Bernie's delight and enthusiasm in sharing ideas with colleagues around the world.

A. Adolphson	F. Loeser
F. Baldassarri	A. Ogus
S. Bosch	P. Robba
S. Chowla	S. Sperber
G. Christol	F. J. Sullivan
R. Evans	F. Tovena
G. Gerotto	A. J. van der Poorten

Ph.D. Students of Bernard Dwork

Kenneth Ireland (1964)
Alvin Thaler (1966)
Nicholas Katz (1966)
Daniel Reich (1967)
Stefan Burr (1968)
Philippe Robba* (c. 1972)
Steven Sperber* (1975)
Edith Stevenson (1975)
Jack Diamond (1975)
Alan Adolphson (1976)
Mark Heiligman (1982)

*Unofficial students of Bernie

Letting $k^* = k \smallsetminus \{0\}$ we get

$$\sum_{\substack{y \in k \\ x \in k^{*n}}} \psi(yf(x)) = qN_1 .$$

The terms with $y = 0$ in the above sum are each 1, so we get

$$\sum_{\substack{y \in k^* \\ x \in k^{*n}}} \psi(yf(x)) = qN_1 - (q-1)^n .$$

So far, nothing too exciting. But now come the fireworks, in three new ideas. The first is to express analytically a nontrivial additive character of k in a way well adapted to the passage from k to k_d. For this, Bernie now takes for K a large p-adic field (large enough to contain the p-th roots of unity and all roots of unity of order prime to p) and introduces the concept of a *splitting function*, i.e., a power series in one variable over K, say $\Theta(T)$, that converges in a disc $|T| < r$ for some $r > 1$ such that the following two conditions hold:

1) For a in k ($= \mathbf{F}_q$), denote by Teich(a) its *Teichmuller representative*, the unique solution of $X^q = X$ in the ring O_K of integers in K that reduces to a in the residue field. Then $a \mapsto \Theta(\text{Teich}(a))$ is a nontrivial additive character ψ of k, with values in K.

2) For each $d \geq 1$, the nontrivial additive character ψ_d of k_d obtained by composing ψ with the trace from k_d to k is given as follows. For a in k_d, denote by Teich(a) the unique solution of $X^{q^d} = X$ in O_K which reduces to a in the residue field. Then we have

$$\psi_d(a) = \prod_{i=0}^{d-1} \Theta(\text{Teich}(a)^{q^i}).$$

The simplest example of a splitting function $\Theta(T)$ relative to $\mathbf{F}_q$ is $\exp(\pi(T - T^q))$, where $\pi^{p-1} = -p$, although the fact that this is a splitting function is nontrivial.

To see what this has bought us, lift the polynomial $f(X)$ over k to a polynomial over O_K by lifting each coefficient to its Teichmuller lifting, say to $\sum A_w X^w$, with each A_w its own q-th power. The series

$$F(Y, X) := \prod_w \Theta(A_w Y X^w)$$

has the property that for any point (y, x) in k^{n+1}, we have

$$\psi(yf(x)) = F(\text{Teich}(y, x)).$$

More generally, for any $d \geq 1$, if we define

$$F_d(Y, X) := \prod_{i=0}^{d-1} F(Y^{q^i}, X^{q^i}),$$

then for any point (y, x) in $(k_d)^{n+1}$, we have

$$\psi_d(yf(x)) = F_d(\text{Teich}(y, x)).$$

Let us recall how this relates to counting points. We have

$$\sum_{\substack{y \in k^* \\ x \in k^{*n}}} F(\text{Teich}(y, x)) = qN_1 - (q-1)^n,$$

and, more generally, for each $d \geq 1$ we have

$$\sum_{\substack{y \in k_d^* \\ x \in k_d^{*n}}} F_d(\text{Teich}(y, x)) = q^d N_d - (q^d - 1)^n.$$

The second new idea is to express a sum of that form as the trace of a completely continuous operator on a p-adic Banach space. On the space of formal series over K in $n+1$ variables, Bernie defines an operator Ψ_q by

Prizes and Fellowships Awarded to Bernie

Sloan Fellowship, 1961
Cole Prize in Number Theory, 1962
Guggenheim Fellowship, 1964
Townsend Harris Medal, 1969 (from the Alumni Association of the City College of New York)
Guggenheim Fellowship, 1975

$$\Psi_q\left(\sum B_w X^w\right) := \sum B_{qw} X^w.$$

Arguing heuristically, one sees that for any formal series $F = \sum C_w X^w$ in the $n+1$ variables $X_0 := Y$ and X_i for $i = 1$ to n, the composition of Ψ_q with multiplication by F has a trace, given by

$$\begin{aligned}\operatorname{Trace}(\Psi_q \circ F) &= \operatorname{Trace}\left(\Psi_q \circ \sum C_w X^w\right)\\ &= \sum C_w \operatorname{Trace}(\Psi_q \circ X^w)\\ &= \sum C_{(q-1)w}\ .\end{aligned}$$

The last equality is valid because in the "basis" given by all monomials, the "matrix" of $\Psi_q \circ X^w$ has no nonzero terms on the diagonal unless w is $(q-1)v$ for some v, in which case the (v, v) entry is 1 and all other diagonal entries vanish. Still arguing heuristically, we interpret $\sum C_{(q-1)w}$ in terms of values of $F = \sum C_w X^w$ at $(n+1)$-tuples of $(q-1)$-th roots of unity in K by the identity

$$\begin{aligned}(q-1)^{n+1} \sum C_{(q-1)w} &= \sum_{a \in (\mu_{q-1}(K))^{n+1}} F(a)\\ &= \sum_{\substack{y \in k^* \\ x \in k^{*n}}} F(\operatorname{Teich}(y, x))\ ,\end{aligned}$$

an identity that does hold, in fact, when F is a single monomial X^w or when F has coefficients tending to zero. Thus we get a heuristic identity, using now the particular choice of F

$$F(Y, X) := \prod_w \Theta(A_w Y X^w),$$

namely,

$$\begin{aligned}(q-1)^{n+1}\operatorname{Trace}(\Psi_q \circ F) &= \sum_{\substack{y \in k^* \\ x \in k^{*n}}} F(\operatorname{Teich}(y, x))\\ &= qN_1 - (q-1)^n.\end{aligned}$$

The d-th iterate of $\Psi_q \circ F$ is easily checked to be $\Psi_{q^d} \circ F_d$, so for each $d \geq 1$ we have a heuristic identity

$$(q^d - 1)^{n+1}\operatorname{Trace}((\Psi_q \circ F)^d) = q^d N_d - (q^d - 1)^n.$$

Because $\Theta(T)$ converges in a disc strictly bigger than the unit disc, F has good convergence properties. By restricting the action of $\Psi_q \circ F$ to a space of series with suitable growth conditions, one can make sense of $\Psi_q \circ F$ as a completely continuous endomorphism of a p-adic Banach space. The Fredholm characteristic series $\det(1 - T\Psi_q \circ F)$ is an entire function of T, which as a formal power series is given by

$$\begin{aligned}&\det(1 - T\Psi_q \circ F)\\ &\quad = \exp\left(-\sum_{d \geq 1} \operatorname{Trace}((\Psi_q \circ F)^d) T^d / d\right).\end{aligned}$$

Denote by $\Delta(T)$ the entire function $\det(1 - T\Psi_q \circ F)$. Then from the identities

$$(q^d - 1)^{n+1}\operatorname{Trace}((\Psi_q \circ F)^d) = q^d N_d - (q^d - 1)^n$$

for $d \geq 1$ we get the identity of series

$$\begin{aligned}&\prod_{i=0}^{n+1} \Delta(q^i T)^{(-1)^{n-i}\binom{n+1}{i}}\\ &\quad = \operatorname{Zeta}(X/k, qT) \prod_{i=0}^{n} (1 - q^i T)^{(-1)^{n-i}\binom{n}{i}}.\end{aligned}$$

Since $\Delta(T)$ is p-adically entire, we see that the zeta function is the ratio of two p-adically entire functions.

To recapitulate, we now know that the zeta function as power series has integer coefficients and that it is the ratio of two p-adically entire functions. We also know the zeta function has a nonzero radius of archimedean convergence (since we have the trivial archimedean bound $N_d \leq (q^d - 1)^n$). Bernie's third new idea is to generalize a classical but largely forgotten result of E. Borel to show that *any* power series with these three properties is a rational function. Thus he proves the rationality of the zeta function.

Bernie then further developed his p-adic approach and applied it to study in detail the zeta function in the special case of a projective smooth hypersurface X/k, say of dimension n and degree d. The Weil conjectures predicted that its zeta function should look like

$$P(T)^{(-1)^{n+1}} \Big/ \prod_{i=0}^{n} (1 - q^i T),$$

with P a polynomial of known degree (namely, the middle "primitive" Betti number of any smooth projective hypersurface $H_{n,d}$ over the complex numbers, of the same degree d and dimension n as X) and that $P(T)$ should satisfy a certain functional equation. Bernie's theory allowed him to confirm these predictions and to study the p-adic valuations of the reciprocal zeros of $P(T)$. He proved, for instance, that, provided p does not divide d, the Newton polygon of $P(T)$ always lies above the middle dimensional primitive "Hodge polygon" of $H_{n,d}$; cf. his Stockholm ICM talk, p. 259. This is the first instance we know of a nontrivial relation between Newton and Hodge polygons. Such relations were later established in great generality by Mazur.

Bernie also studied the way his p-adic construction varied when the projective smooth hypersurface varied in a family. The rich structure he discovered was the first nontrivial instance of what later came to be called an F-crystal. Roughly speaking, an F-crystal is a differential equation upon which a "Frobenius" operates. Bernie correctly conjectured that the underlying differential equation to his F-crystal was the relative (primitive, middle dimensional) de Rham cohomology of the family, endowed with its Gauss-Manin connection, i.e., the classical Picard-Fuchs equations attached to the family. He also studied the variation in a family of the Newton polygon attached to an F-crystal, which led him to discover the "slope filtration" of an F-crystal. It seems fair to say that a desire to understand Bernie's results in a more cohomological context was one of the main motivations for the development, by Grothendieck and Berthelot in the late 1960s, of crystalline cohomology.

One of Bernie's key discoveries was that those differential equations that "admit a Frobenius", i.e., that underlie an F-crystal, have very special properties as p-adic differential equations (for instance, solutions have p-adic radius of convergence 1 in generic discs). By crystalline theory, any Picard-Fuchs equation underlies an F-crystal and hence has these special properties for almost all primes p. One enduring fascination of Bernie's was the still open problem of characterizing, by p-adic conditions for almost all p, those differential equations over, say, number fields, that "come from geometry" (or "are motivic", in the new terminology) in the sense, say, that they are successive extensions of pieces, each of which is a subquotient of a Picard-Fuchs equation.

Another of Bernie's fundamental and iconoclastic discoveries concerns the arithmetic significance of equations with irregular singular points. Picard-Fuchs equations are known to have regular singular points, and for a long time it was generally believed that the only differential equations relevant to algebraic geometry were those with regular singular points. But in the early 1970s Bernie achieved the remarkable insight that equations with irregular singular points (e.g., those for the hypergeometric function ${}_pF_q$ for arbitrary p and q, $q \neq p-1$) were not only not to be regarded as pathological, but they were in fact a fundamental feature of the p-adic algebro-geometric landscape, playing the same role for exponential sums in families as regular singular equations play for counting points in families.

Pursuing these ideas led Bernie to a long and deep study of the p-adic and arithmetic properties of differential equations, both for their own sake and for their interaction with the arithmetic of varieties over finite fields and with the algebraic geometry of families over $\mathbf{C}$. He remained actively engaged in this study right up to his death.

This is perhaps an appropriate point to comment on three early mathematical influences on Bernie.

1. We have already explained how it was an NYU evening course taught by Emil Artin in 1947 which hooked Bernie on mathematics.
2. His interest in mod p and p-adic properties of Picard-Fuchs equations probably dates from the late 1950s at Johns Hopkins, when he learned from Igusa that the Hasse invariant for the Legendre family of elliptic curves

$$y^2 = x(x-1)(x-\lambda)$$

   in any odd characteristic p is a mod p solution of the Picard-Fuchs equation for that family (explicitly, the differential equation for the hypergeometric function $F(1/2, 1/2, 1; \lambda)$).
3. Where did Bernie get the idea that there could be a connection between p-adic analysis and zeta functions? It grew out of a letter from the second author of this article to Bernie, dated February 13, 1958, an extract of which is quoted on page 257 of Bernie's ICM Stockholm talk. The letter contained a result on the "unit root" of an ordinary elliptic curve, which could be proved by using work of Michel Lazard on formal groups to show that certain p-adic power series have integral coefficients. The letter writer, considering Bernie to be the world's leading expert in such matters, challenged him to prove those results by p-adic analysis. Bernie met the challenge almost by return mail and, going further, discovered the "close connection" that he mentions in the following quote from loc. cit., p. 250, "...but using unpublished results of Tate and Lazard, we give indications of the existence of a deformation theory, involving a close connection between hypergeometric series and the zeros of the zeta functions of elliptic curves. We became aware of this connection in 1958; it was the first suggestion of a connection between p-adic analysis and the theory of zeta functions."

Nurtured in Dwork's amazingly original mind, what marvelous fruit these three seeds bore.

Interview with AMS President Felix Browder

On February 1, 1999, Felix Browder started his term as president of the AMS. In this interview with *Notices* deputy editor and senior writer Allyn Jackson, Browder reflects on some of the important issues facing the AMS and discusses some of the projects he plans to pursue as president. An interview with the past president, Arthur Jaffe, appeared in the February 1999 issue of the *Notices.*

Notices: *In your election statement in the* Notices *you said, "Mathematical research flourishes, and its applications have never been more essential to the survival of civilization as we know it. Yet the institutions that support mathematical research are under unprecedented attack." What did you mean by that?*

Browder: Maybe "attack" is not exactly the word, but I think it reflects, for example, the famous incident at Rochester[1]. Institutions that support mathematics are under great stress; there is no doubt of that. The bulk of mathematical research, even applied mathematical research, is done in academic institutions, and yet mathematics departments are not expanding—in fact, they are contracting. Young mathematicians, even gifted ones, are finding it difficult to get good jobs, and some are finding it difficult to get jobs that are at all reasonable. This is a fact of life which is actually damaging the entire mathematical community.

Another problem is that of maintaining the élan of mathematical research if we don't get a recruitment of a sufficient body of very talented young people. There are relatively few mathematically talented young people of American origin going into mathematics. By "American origin" I mean people who have gotten their undergraduate degrees in the United States. This is a very serious problem for the future of American mathematics. The two international benchmarking surveys, one done by the National Research Council and the other by the National Science Foundation, pointed to the fact that this is the central problem for the future of American mathematics. The only reason we are not having these serious problems now is we're importing graduate students and faculty from other countries. How long we can continue to do this depends on the relative attractiveness of the situation in American academic institutions as compared to other countries. I hesitate to believe that this is a very secure gamble.

Notices: *Why aren't young Americans going into mathematics?*

Browder: There are a number of reasons. First of all, the job market is very bad, and it's perceived as bad, perhaps perceived as worse than it actually is. There is an enormous amount of dissatisfaction and unhappiness, which is expressed often very openly in a public way. You certainly can't object to the truth being told, but it doesn't have a positive influence on people's decisions. Second of all, young people see that there is a certain lack of public esteem not only for mathematics but for science and scholarship. At least until recently there has been a tremendous veneration of the commercial sector, particularly banking and so on. Very talented young people know that people earn much more money in such occupations or in the professions of law and medicine. There is also a much greater sense of peer esteem for moneymaking than there used to be.

Many young mathematicians face the prospect of an endless series of temporary academic jobs. In such cases they would be well advised to do something else. There is no possibility of having a constructive career as a research mathematician—or having a constructive career, period—in such occupations, and the best thing to do is to find an alternative occupation. There are figures showing a gradual decrease in the percentage of mathematicians going into academic employment and an increase in the percentage going into nonacademic employment. Mathematical training is a very strong preparation for many jobs, assuming that you don't take mathematical training as scholastics and that you don't insist on doing what your specialty may have been.

Notices: *Do you think that attitudes about nonacademic employment are changing?*

Browder: Yes, I think they are changing very drastically, particularly, for example, with respect to jobs in finance, which are now regarded as a very reasonable alternative for many people. Many

[1] *The incident referred to is the attempt by the University of Rochester to abolish its doctoral program in mathematics. The* Notices *carried reporting on the Rochester incident in the March 1996, April 1996, and June 1996 issues.*

young Ph.D.s from very fancy departments—particularly Princeton, I gather—are moving into that realm, and that's fine. I don't particularly advocate it as an alternative to doing research mathematics, but if you don't find a reasonable position in academia, why not? I trust this will continue, despite the present crisis in the whole area of finance. Banks are not going to abandon mathematics. They can't. Their whole system is now geared to mathematically sophisticated activities.

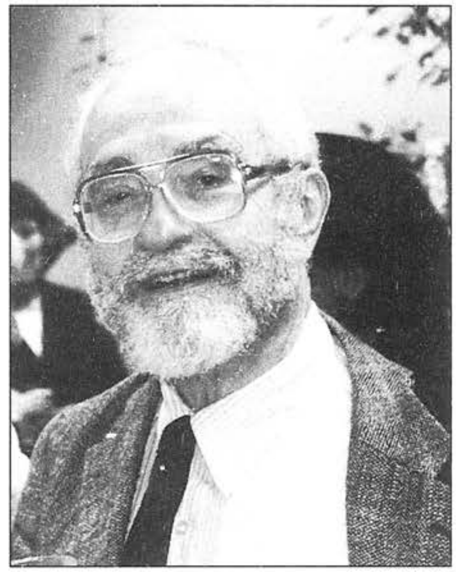
Notices: *Have young people's attitudes been affected by talk about abolishing tenure?*

Browder: Yes. And I'm very much against abolishing tenure, because essentially what you are abolishing is the central nucleus, the whole idea of intellectual responsibility and independence. Having been a university administrator myself, as vice president at Rutgers, and a keen observer of the administrative atmosphere around me, I wouldn't trust the future of intellectual activity of universities to administrators—I mean the people who actually run the universities from the top down and especially boards of trustees, who often don't know very much about academic activities and don't always sympathize with traditional academic values.

I wasn't directly and personally involved in talking to the administrators at Rochester, but I read the internal documents. I had the strong impression that this was the beginning of a process by which they would simply abolish all intellectual activities at Rochester, period. At the same time, they said they wanted to get better students and have better training in science. There were massive contradictions. I think Rochester was a very important incident in waking up the American mathematical community from its pipe dream that somehow, automatically, the routine process of academic administration would always take their concerns seriously. It was very important to make an appropriate response to that, and I think that Arthur Jaffe in particular, who orchestrated the response, should be given a high degree of commendation for his efforts. It was very important symbolically, and administrators all over the country noticed. It was a Rubicon that somebody was trying to cross, and if this had been allowed to pass unchallenged, it would have been a major catastrophe not only for American mathematics but for the whole notion of intellectual competence in American academia. Mathematicians were only the scapegoats for everybody else, and a lot of people realized this. It's one of the reasons Arthur was able to get such strong support from people in physics, chemistry, economics, and so on.

Notices: *What can the AMS do in the area of graduate education?*

Browder: Mathematics over the last fifty years has become highly specialized, and unfortunately the specialties are so divorced from each other that sometimes they don't have the appropriate degree of mutual understanding and interaction. This is a very serious question that concerns graduate education. Everybody is conscious of it, but nobody knows what to do about it. We are training people following the principle enunciated by Carl Becker, who said that a specialist is one who knows more and more about less and less until he knows everything about nothing. Unfortunately, this is a principle which, in order to survive, people have to practice.



AMS president Felix Browder

Nobody besides the AMS is going to be concerned with graduate education in mathematics, and certainly the AMS should pay attention to it. And it does, to some degree. But it's very difficult, because everybody is a self-proclaimed expert on graduate education. Different departments have different styles, different ways of doing things, and you can't prescribe to them. But you can say that they ought to make an effort to make sure that everybody has a broad background of knowledge of both pure and applied mathematics. And—this is perhaps the most utopian prescription, and I don't know a single department in the country that is doing this—they ought to make some effort to have their students learn something on an informal basis about the history of mathematics. Without a sense of where you come from, you have no sense of where you're going. The question of perspective depends on one's sense of the past.

I think there is a growing realization in the mathematical community that specialization and insularity are big problems. For example, I am on the Task Force on Membership for the Society, a group commissioned by Arthur Jaffe. One thing to come out of some surveys done for the Task Force is the need to emphasize the perspectives of mathematical research in the future and try to focus attention on certain major areas of activity, major problems. This is something I and others are trying to do through, for example, the AMS meeting in the summer of the year 2000. I was rather surprised to see this coming out so strongly in the surveys and in people's comments, which were not, as far as I know, related to the year 2000 meeting. We have to bring the attention of both the mathematical community and the external publics—other scientific disciplines, as well as the intellectual public and the general public—to the fact that mathematics is an enterprise with enormous perspectives, in terms of its own objectives and its impact on other forms of knowledge. There has been an enormous growth in the practical importance of mathematics in the world, as represented by the computer revolution and the necessity of analysis of complex systems, which are everywhere around us. We see this in the genome project, in the mathematics of finance, in the enormous growth in mathematical sophistication and interaction in all the realms of theoretical physics, or even practical physics for that matter. What we have to emphasize is that these are not just applications of known mathematics. They are enormous growing points for mathematics.

Mathematics does no good by trying to pretend it is insulated from these things, because these are where the vital areas of activity are. And this is not surprising. It's a reversion to what has been true in the past. It was just a short period of about twenty or thirty years in which mathematicians had the delusion that mathematics could be totally separated from other fields of human knowledge and activity.

Another point that came out of the Task Force surveys is that we have to pay greater attention than in the past to a very explicit role for the AMS, and mathematicians in general, in trying to influence policies on subjects related to the mathematical and scientific interests in Washington. People don't realize that this is exactly what has been attempted in the last two years, particularly under Arthur Jaffe, and I think it is starting to be successful. Perhaps the most important contribution that Jaffe has made is to point out that when you try to influence policy in Washington, you can't do it by just representing mathematical interests. You have to try to join forces with other scientific fields—particularly with physics and chemistry, but also the biological sciences and engineering. This involves an attention to common interests, which are often at a certain distance from mathematical concerns.

The common interest is to see science promoted and scientific research acknowledged as a major contributing factor in national growth. We are now in a very good position as far as congressional attitudes are concerned, and it's very likely that budgets for scientific research will increase. There is a question of exactly how such increases can be organized, and that gets into rather difficult problems. My view is that this is not a matter the AMS should take positions on. For example, increases in the number of individual grants, versus larger grants, versus new institutes, versus postdoctoral fellowships—I don't think the AMS should take positions on these things. We can speak to the value of all these things and try to get a consensus, but we should not take controversial positions which divide the community.

***Notices:** You mentioned the AMS meeting in August of the year 2000. You have been deeply involved in the planning for this meeting.*[2]

Browder: This meeting will be a central part of my mission as AMS president; it was a central part of my mission before I became president. The function of this meeting is to focus the attention of the AMS and the international mathematical community on the major problems and prospects for achievement in mathematics in terms of the development of fields of mathematics and in terms of its applications to other major areas of the sciences and to practical areas such as the computer and finance. The meeting will cover a very broad range. We will have talks about algebraic number theory and the Riemann hypothesis on one side, and on the other side applications to fundamental physics, high-energy physics, condensed matter physics, biology, and last, but certainly not the least, computer science and computational science. The Mathfest meeting of the MAA in 2000 will be held the week preceding the AMS meeting, and I am told it may well be held at UCLA, though that hasn't been formally decided yet. We are planning to hold some joint activities with the MAA.

***Notices:** Is the AMS meeting part of the World Mathematical Year 2000 that is being organized by the International Mathematical Union?*

Browder: Yes, the IMU has designated the meeting as part of World Mathematical Year 2000. This touches on an important point. Although the AMS is an American-run society based in the U.S., we are trying very hard to broaden the involvement of non-American mathematicians. One-third of the membership is outside the U.S., after all. It's really an international mathematical society, although some of the leading figures of the European Mathematical Society, including my dear friend Jean-Pierre Bourguignon, might quarrel with the description! But fundamentally we should have in mind the interests of the international mathematical community, not just of the American mathematical community. The AMS is the richest society, the biggest society, the most active society. No other mathematical society is a major mathematical publisher. We have a major responsibility to the international mathematical community, and we ought to recognize it—and we have begun to recognize it, for example, by having international meetings. There is a common interest of the mathematical community, national and international, and mathematicians should take actions which further this common interest. If we can do that—promote the vitality and quality of mathematical research and education—then we will have done what we need to do.

[2] *For further information about this meeting, see the article, "AMS Meeting in August 2000" in this issue of the* Notices.

Smoothing the Transition to Graduate Education

Sylvia T. Bozeman and Rhonda J. Hughes

It is widely accepted that the mathematics community has led the sciences in the reform of undergraduate and K–12 education. As part of the extensive reform efforts of the past fifteen years, many successful programs were designed to encourage undergraduate students to go on in mathematics, often by introducing them to the excitement of mathematics research.

For four years, from 1992–95, we conducted such a program, the Spelman-Bryn Mawr Summer Mathematics Program. Funded by the National Science Foundation, this program was designed to identify and encourage talented freshman and sophomore women to pursue careers in the mathematical sciences. These programs, ours included, have created a core of students eager to pursue graduate work in mathematics.

On the other hand, it is our perception that graduate education has changed little in the past several decades. Despite some notable exceptions, many graduate programs still operate much as they did in the sixties, when the climate and prospects for mathematicians were very different. All too often, such programs provide students, particularly women and those from small or minority-serving institutions, with their first real taste of failure. Students who may have been superstars in high school and college are often overwhelmed by the abrupt change of status they experience in graduate school, and are discouraged by their inability to achieve their usual levels of academic success. They quickly find themselves struggling with the increased demands of graduate work, and may lack the self-confidence needed to sustain them. Students from small colleges may be accustomed to close relationships with faculty and peers, and often feel isolated in the less nurturing atmosphere of graduate school; moreover, they are usually unaware that their difficulties are shared by other students. Initial setbacks, if unchecked by encouragement and support, all too often escalate into complete failure. Students conclude that they lack sufficient talent to succeed in mathematics, and, if no one intervenes, they may leave graduate school. Not only do they drop out, but they do so with severely diminished self-esteem; discouraged and disillusioned, they are convinced that they are not capable of the work expected of them, and often leave mathematics altogether.

Departments also feel cheated and disappointed by this familiar scenario. They feel misled by the strong records and recommendations that convinced their admissions committees to admit these students, and sometimes conclude that certain types of students, or students from certain kinds of institutions, are poor candidates for their programs. Unfortunately, students who may merely be lacking in confidence or broad preparation are often deemed unfit for graduate work, not cut out for a career in mathematics. Even well-meaning departments give up on these students without realizing their real capabilities and potential. Consequently, talented students who have been shining stars until they hit graduate school, who have been the recipients of considerable effort and dedication from their teachers and families, are suddenly failures, lost to further work in mathematics.

Our own growing sense of frustration with what we perceive to be an unnecessary waste of talent led us to reassess our activities on behalf of women and minority students. Instead of continuing to contribute to the growing pool of students coming out of REU's and other enrichment and intervention programs, we decided to focus our efforts on the difficult transition from undergraduate to graduate education. The result is the EDGE program (Enhancing Diversity in Graduate Education: A Transition Program for Women in the Mathematical Sciences), now ending its first year of operation. With primary funding from the National Science Foundation, as well as support from the National Security Agency, the Andrew W. Mellon Foundation, and Bryn Mawr and Spelman Colleges,

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we have embarked on a project intended to stem the loss of talent from our graduate programs by strengthening the ability of women and minority students to successfully negotiate the transition from undergraduate to graduate education, by empowering students to succeed in a chosen program, and by helping students redirect or refocus their energy when a program is inappropriate or unsuitable. In the process, we hope to identify the growing number of programs that are committed to the support, encouragement, and ultimate success of their graduate students. We also hope that, in concert with a number of collaborating graduate departments, we will be able to identify support structures that will decrease the attrition rate of all graduate students, regardless of their backgrounds.

Although we both have long records of activity involving women and minority students, our first experiences with the EDGE program challenged many of our long-held assumptions. We were truly surprised when, in the first days of the program, we inadvertently created some of the trauma usually experienced in graduate school. The participants, women who had recently received undergraduate degrees and were about to attend graduate programs in the mathematical sciences, quickly identified areas in which they needed review or intensive effort; in many cases, this process was rather threatening. Of course, this is what typically happens in the first year of graduate school, where students might not yet have a source of support or encouragement. However, since ours was a more controlled environment, we were able to provide a safety net, and to address feelings of isolation or inadequacy. We tried to provide individual help at an appropriate level, and to assist the participants in developing strategies for countering the challenges and discouragement they would inevitably feel at some point in their studies. We attempted to create a participant group and staff of diverse cultures and backgrounds, and encouraged students to learn to draw on the strengths of one another, both in study groups and as a means of personal support. As faculty from small colleges, we complemented our backgrounds by inviting several leading mathematicians from research universities who could impart firsthand the expectations of graduate school.

The EDGE program consists of two basic components: an intensive summer program, held in alternate years at Bryn Mawr and Spelman Colleges, and a follow-up mentoring program. The main goal of the summer program is to equip the participants with the tools needed to successfully complete the graduate work they will encounter in the first year and to go on to pass the first set of examinations in their program. The academic component focuses on two core courses, in real analysis and linear algebra/algebra. The choice of topics for the core courses is based on the conviction that strong preparation in these subjects will serve to prepare students for a variety of programs in pure and applied mathematics. Graduate student mentors who are successfully engaged in graduate work in mathematics conduct problem sessions and give the participants a close look at graduate work through their own experiences. Panel discussions introduce the participants to many young mathematicians at various stages of graduate and postdoctoral work, and minicourses and guest lectures by eminent mathematicians working in timely areas of research, in both academia and industry, round out the academic program.

The mentoring aspect of the program is in our view crucial to achieving the goals of the EDGE program. We believe that organized mentoring is a key component of effective graduate education. Indeed, successful minority and women scientists, many of whom cite serious difficulties at some point in their graduate work, frequently attribute their ultimate success to the timely intervention of a caring teacher or mentor. Our own experiences have convinced us that judgments about students are often flawed, and a student who struggles in one program may thrive in another. Unfortunately, the intervention necessary to see a student through difficult times is often left to chance, and basic advice in handling difficulties often seems to be missing. We work directly with the directors of graduate programs to identify a mentor for each woman so that she will have a support system in place from the start of her graduate study. The mentor agrees to act as an advocate for the student in her first two years of study, to help identify early difficulties in first-year courses, and to assist with the adjustment to graduate work and the culture of graduate study. An interactive Web site will provide an ongoing mechanism for the participants to remain in touch with one another and to chart one another's progress.

Clearly, not every minority or woman student entering a graduate mathematics program needs an experience like that offered by the EDGE program. But for many students the preliminary exposure to graduate-level courses, the networking with other mathematicians, the focus on issues of culture and gender, and the exposure to a broad array of mathematical fields and people—all in a nurturing environment—might make the difference between continuing or leaving after the first year of graduate school. Plans are currently under way for the second summer program, to be held from June 14 to July 9, 1999, at Spelman College in Atlanta, GA, where we expect to admit eight to ten new participants. We encourage interested colleagues to visit our Web site at `http://www.brynmawr.edu/Acads/Math/`.

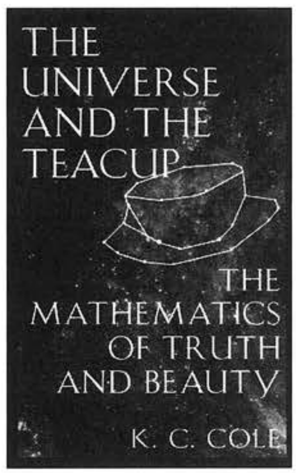
The Universe and the Teacup

Reviewed by Daniel Rockmore

The Universe and the Teacup: The Mathematics of Truth and Beauty
K. C. Cole
Harcourt Brace, 1998
ISBN 0-151-00323-8
Hard cover $22.00

One of my favorite parts of the Passover Seder is the retelling of a story in which a father discusses how to respond to his four sons as they each ask him in their own way about the meaning of the Seder. The sons are of four types: one wise, one wicked, one simple, and one who does not even know how to ask a question. The parable is as much about how to pose a question as it is about how to frame an answer; and as a teacher and researcher, someone whose life seems to be spent asking and answering questions, I always feel a special resonance with this story. It is not too hard to see four kinds of students in the sons: one self-motivated, one recalcitrant, one earnest but confused, and the last, the student who feels so disconnected from the subject that he or she wouldn't even know how to begin thinking about it. Each of these students benefits from a different approach, and the last of them, the one who does not even know how to ask a question, presents a special challenge, particularly for mathematics.

How do we bring such a person to the point where he or she might begin to think about asking a question? How do we tell a story of mathematics that feels relevant and universal? If our listener feels no connection, declarations of the beauty of the subject ring hollow; appeals to technology, while impressive, still often miss the mark, being more about the product than the mathematics that underlies it. So, in short, how do we mediate the experience of mathematics in such a way that it speaks to everyone and not just to the scientist? Analogous questions have been asked and answered in other sciences, most notably biology and physics. Mathematicians need to do this too, for this is the first step on the road to public appreciation. We have a good story to tell, and furthermore, like any good story, it will teach as much to those who tell it as to those who listen to it.



K. C. Cole's recent book *The Universe and the Teacup: The Mathematics of Truth and Beauty* is a book for those who do not even know how to ask a question about mathematics. Ms. Cole is a science writer for the *Los Angeles Times* who often writes on mathematics. By her own admission, her point of view is that of a writer who started out interested in social issues, and these initial conditions have led her to write a book which is "an attempt to demonstrate how mathematics informs the kinds of questions people really think and worry about." She goes on to say that "If I could accomplish one thing in this book, it would be to

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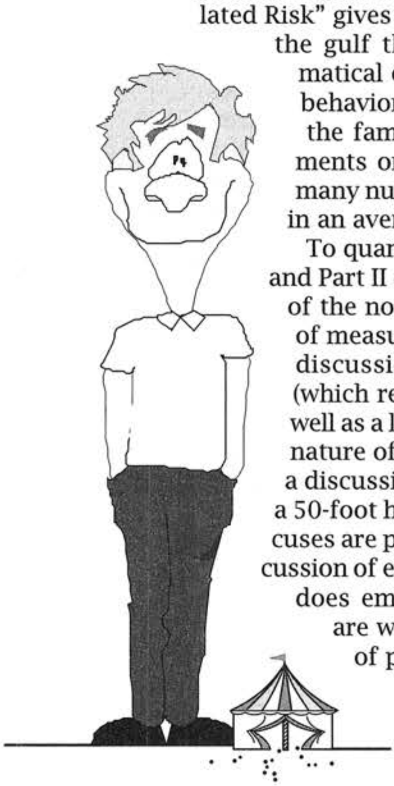
show that an interest in the quality of life is in no way diminished by quantitative arguments...scientists and mathematicians, as well as saints and philosophers, search for the fundamental hows and whys of existence. And although they have different standards and proof, quantitative insights do help us understand qualitative problems."

Ms. Cole understands that "mathematics is not about numbers so much as it is a way of thinking, a way of framing questions that allows us to turn things inside out and upside down to get a better sense of their true nature...a way of thinking that helps make muddy relationships clear." In particular, she wants to explore what happens when this approach is trained on the problem of defining things that we all care about. Sometimes these things are the fodder of everyday concerns like health and safety, other times they are larger issues like justice, truth, and beauty. In any case, mathematics both reveals and is revealed by aspects of these universal concerns and so gives a toehold to everyman, allowing the uninitiated to see what was previously hidden and giving the professional a new perspective. It is an ambitious goal, and along the way she meets with varying degrees of success and failure, but the trip is well worth taking.

The book is divided into four parts. Part I touches on "innumeracy", the problems that so many of us have in understanding the daily barrage of numbers and statistics in such a way that we can incorporate them into our personal decision-making processes. A chapter called "Calculated Risk" gives a very interesting discussion of the gulf that can occur between mathematical estimates of risk and intelligent behavior. Included here is a summary of the famous Kahneman-Tversky experiments on risk aversion, just one of the many nuggets of science not often found in an average mathematical education.



To quantify something is to measure it, and Part II devotes itself to various aspects of the notion of measurement. Problems of measurement lead naturally to both a discussion of the misuse of statistics (which reappears at regular intervals) as well as a little quantum mechanics and the nature of uncertainty. The latter leads to a discussion of scale (where we learn why a 50-foot human is impossible and flea circuses are possible), and from scale to a discussion of emergent behavior. At what point does emergent behavior emerge? Thus are we brought to the dual problems of prediction and detection.

Throughout, technical concepts are brought to life by analogy with real experience. For example, predicting the outcome of a single coin toss or a thousand coin tosses is juxtaposed with predicting a single individual's actions and the behavior of a crowd. Phase transitions are compared with "tipping points", the point in time at which an accumulation of small quantitative changes in behavior cause huge qualitative differences. Filtering describes both the search for a new particle and our ability to concentrate in an office abuzz with the hum of a computer. Cole is at her best in presenting and reflecting on connections like these. At times the example-driven nature of the writing makes these sections feel more like a discussion of physics rather than mathematics, but as mathematicians know, and as Cole points out, "the tools of mathematics allow one to see otherwise invisible patterns and connections." Without the examples we can't see the connections.

Part III, "Interpreting the Social World", is, in my eyes, the most successful part of the book. The three chapters which constitute it consider problems of fairness and justice, as reflected in the mathematics of voting theory (Arrow's Impossibility Theorem), The Prisoner's Dilemma, the problem of fair division, and variations on Axelrod's famous "Tit for Tat" experiments. They all make for fascinating reading, and I would venture to say that none of these topics makes it into the usual mathematics curriculum.

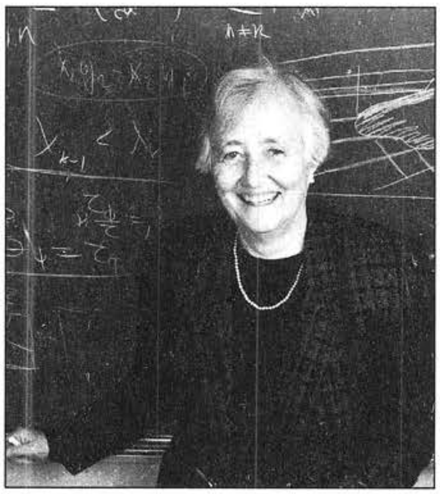
Finally, in Part IV, Cole tackles the subjects of truth and beauty as understood in terms of probability and statistics, invariance and symmetry. She writes that "...maybe it is a bit pretentious to talk about the mathematics of truth. But mathematics offers some powerful ways to get at least closer to the truth—and these methods are in use almost everywhere we look, although most people are not aware of them." These methods mainly include the role of probability and statistics in helping to understand cause and effect, coincidence, and the difference between correlation and causation. These are delicate problems, and while these techniques can bring you "closer to the truth," often they do not furnish the whole truth. History is rife with stories of the misuse and misunderstanding of statistics, and Cole includes several cautionary examples in this regard. In a separate and very interesting chapter, mathematical truth is compared and contrasted with legal and scientific truth, as referees are compared to juries, and juries are compared to repeated experiment.

The discussion of symmetry and invariance is left to the last chapter of the book, "Emmy and Albert: The Unvarying Nature of Truth", which revolves around Emmy Noether's work on general relativity. This is also Ms. Cole's favorite chapter of the book. The connections between symmetry and beauty are a well-trodden area, with Hermann Weyl's *Symmetry* the classic reference. Ms. Cole sees invariance and symmetry as a way to get from truth to beauty, adding that "...deep truths can be defined as invariants—things that do not change no matter what; how invariants are defined by symmetries, which in turn define which properties of nature are conserved, no matter what. These are the selfsame symmetries that appeal to the senses in art and music and natural forms like snowflakes and galaxies. The fundamental truths are based on symmetry, and there's a deep kind of beauty in that."

This chapter is also the most technical, and, unfortunately, the technical writing is not one of the book's strong points. Here and in a few other places there are inaccuracies. For example, a section on geometric symmetries gives a square four symmetries instead of eight and ignores the possibility of translational symmetries for tiling patterns; some discussions include nonrotational symmetries, others don't. Nevertheless, even here, as throughout the book, there are gems of observation: the idea of truth as that which remains invariant in an issue after consideration from every possible angle; the process of searching for invariance as a life goal; a discussion of broken symmetry and artistic appeal, which struck me as I was driving on the highway staring at an endless (and monotonous) blue sky.

As might be imagined from the above synopsis, the breadth of material presented here is both a strength and a weakness of the book. The sheer number of topics makes it difficult to investigate any single mathematical subject in much detail. At its worst this can dissolve into a sort of technical name-dropping, with the effect being much like a dinner party consisting solely of appetizers and dessert: the guests leave feeling full but still wishing for the main course. Nevertheless, the breathless manner in which these subjects appear also seems to reflect Ms. Cole's excitement upon discovering that for the questions that "people really think and worry about," mathematics has developed a useful set of tools. This is an excitement which I believe will lead those who did not even know how to ask a question to a place where they may begin, while those who already knew how to ask the questions will be shown ways to answer, and ask them, differently.

Cathleen Morawetz Receives National Medal of Science



Cathleen S. Morawetz

Cathleen S. Morawetz, professor emerita at the Courant Institute of Mathematical Sciences of New York University, has received a 1998 National Medal of Science "for pioneering advances in partial differential equations and wave propagation resulting in applications to aerodynamics, acoustics and optics."

A press release from the National Science Foundation provided the following description of her work: "In a series of three significant papers in the 1950s, Morawetz used ingenious new estimates for the solution of mixed nonlinear partial differential equations that ultimately led to advanced studies of wing design in aviation. In the early 1960s, she obtained important results in geometrical optics in connection with sonar and radar. It was known then that geometrical optics could be used to determine approximately the acoustic and electromagnetic fields scattered by objects. It was believed that this approximation became more accurate as the wavelength approached zero. Morawetz showed that this is the case and obtained an estimate of the error. Her result placed geometrical optics on a firmer foundation and led to further practical use of this approach."

Cathleen Synge Morawetz was born on May 5, 1923, in Toronto, Canada. After receiving a bachelor's degree from the University of Toronto and a master's degree from the Massachusetts Institute of Technology, she received her doctorate from New York University in 1951. She was a Guggenheim Fellow during 1966–67 and 1978–79. In 1993 she was named Outstanding Woman Scientist by the Association of Women in Science. She delivered the AMS Gibbs Lecture (1981), an Invited Address of the Society for Industrial and Applied Mathematics (1982), and the Emmy Noether Lecture of the Association for Women in Mathematics (1983). She is a member of the National Academy of Sciences. During 1995–96, Morawetz served as president of the AMS (the September 1993 issue of the *Notices*, pages 816–817, carried an account of her scientific work for her presidential candidacy).

The National Medal of Science, established by Congress in 1959, is the nation's highest scientific honor. The first National Medal of Science was awarded to Theodore van Karman in 1962. Since then, 362 individuals, including the 1998 medalists, have received the honor. In the past five years the National Medal of Science has been awarded to four who work in the mathematical sciences: S.-T. Yau (1997), Richard Karp (1996), Stephen Smale (1996), and Martin Kruskal (1994). A distinguished, independent twelve-member committee is appointed by the president to review nominations for the medal. The 1998 committee consisted of Kenneth Arrow, Alfred Y. Cho, Elsa Garmire, Susan L. Graham, George S. Hammond, Arthur L. Jaffe, Eric S. Lander, Marcia K. McNutt, Mario J. Molina, Vera C. Rubin (chair), Robert Schrieffer, and Joan A. Steitz. Bruce Alberts, president of the National Academy of Sciences, served ex-officio on the committee, and Karl Erb of the National Science Foundation was the committee's executive secretary.

—*Allyn Jackson*

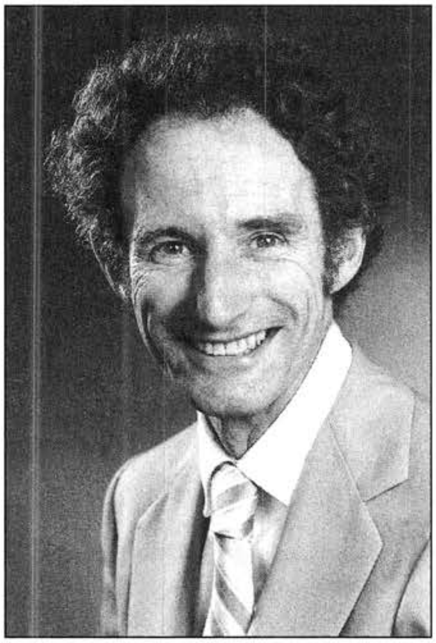
Robert May Receives Balzan Prize

Robert May has received the 1998 Balzan Prize for Biodiversity. He was awarded the prize "for his seminal contributions to the mathematical analysis of biodiversity, in particular his pioneering work on chaos theory and ecological systems, and the development of a variety of methods for estimating the total number of species alive on earth today and their rates of extinction." Presented by the International Prize Foundation E. Balzan, the prize carries a monetary award of 500,000 Swiss francs (about $370,000). Together with two other prize winners, historian Andrzej Walicki and geochemist Harmon Craig, Robert May received the prize in a ceremony held on November 23, 1998, in Rome.

Laudation

May's work has been hugely influential in illuminating fundamental biological problems relevant to the causes and consequences of biological diversity. His earliest contributions are drawn together in the influential book *Stability and Complexity in Model Ecosystems*, which changed the way ecologists think about complex versus simple ecosystems. No longer is the ability to cope with disturbance (or "stability") seen as an automatic consequence of diversity (or "complexity"), as it was in the texts of the 1970s and earlier. Rather, it is now understood that communities with high biological diversity, such as a tropical rainforest, are often likely to be dynamically fragile and typically more vulnerable to disturbance than are simpler temperate systems. This has led to a still-expanding program of research on how the persistence and ultimate conservation of communities depends on food web structures of particular kinds. May's work has emphasized the differences between different environments and helps explain why we may be likely to lose a larger fraction of species in disturbed tropical environments than have been lost in the past in correspondingly disturbed temperate or boreal environments. More generally, this work has set the agenda for a new generation of research on the difference between "demographic stochasticity" and "environmental stochasticity" (terms introduced by May), on food chains, on the relative abundance and rarity of species, on the relation between numbers of species or of individuals and their physical size, and on the dynamical response of complex ecosystems to specific kinds of disturbance.

Motivated by such problems arising from the study of natural populations, May showed that simple nonlinear difference equations can exhibit an astonishing array of dynamical behavior ranging from stable points, to period-doubling bifurcations that produce a cascade of stable cycles, to apparently random or "chaotic" fluctuations (his 1976 *Nature* review paper is still the most cited paper in this general subject). This seminal work raises important and as yet largely unresolved questions about how we gather and analyze data about populations. Especially when spatial patchiness is important, populations can easily show erratic fluctuations, even in environmentally predictable settings. Such phenomena have major implications for the coexistence of species or for protection against invasion of communities and therefore can help to explain patterns of biodiversity.



Sir Robert May

In collaboration with Roy Anderson, May has combined theoretical and empirical studies to explore the circumstances under which infectious diseases (defined broadly to include viruses, bacteria, protozoans and fungi, along with helminth and arthropod parasites) may influence the numerical abundance, geographical distribution, or other ecological features of their plant or animal hosts. This work has advanced our understanding both of how infectious diseases can influence biological diversity and of their importance in conservation biology.

In recent years May has been a leader in developing a variety of rigorous methods for estimating the total number of species alive on earth today. Since 1994 he has also developed several new ways of assessing rates of species extinction in the recent past and likely future. This work is mainly based on comparisons between recent data sets and fossil record data; by comparing rates one can gain a degree of precision absent from attempted estimates of total numbers of extinctions. His other recent work has developed quantitative measures of the taxonomic or evolutionary uniqueness of individual species or groups. Taken together, this general body of work pioneers a new "calculus of biodiversity" (May's phrase), which is an increasingly important tool for conservation planners.

Biographical Sketch

Robert McCredie May was born in Sydney, Australia, on January 8, 1936. He received his bachelor's degree in 1956 and his doctoral degree in theoretical physics in 1959, both from the University of Sydney. He held the position of Gordon Mackay Lecturer in Applied Mathematics at Harvard University before taking a position at the University of Sydney, where he remained during 1962–73. From 1973 to 1988, he was Class of 1877 Professor of Zoology at Princeton University. Currently he holds a Royal Society Research Professorship in the Department of Zoology at the University of Oxford and at Imperial College, London. For the period 1995–2000, he is on leave from those positions while serving as chief scientific adviser to the U.K. government and head of the U.K. Office of Science and Technology. He was awarded a knighthood in 1995 and the Companion of the Order of Australia in 1998. He was elected a fellow of the Royal Society, London (1979), a foreign member of the U.S. National Academy of Sciences (1992), an Overseas Fellow of the Australian Academy of Sciences (1991), and a fellow of Academia Europaea (1994). In 1996 he received the Crafoord Prize of the Royal Swedish Academy of Sciences. May delivered the AMS Josiah Willard Gibbs Lecture at the AMS Annual Meeting in January 1994.

About the Balzan Prize

The Balzan Prize is among the most important humanistic and scientific awards in the world. The winners are selected by a General Prize Committee made up of eighteen prominent scientists and academics. The committee evaluates candidate proposals from universities and academies all over the world. The Italian-Swiss Balzan Foundation, which has headquarters in Milan and Zurich, was started in 1956 with funds from the daughter of Eugenio Balzan, who inherited a large estate from her father and decided to use it to honor his memory. Balzan was born in 1874 and was a proofreader, reporter, and manager for *Corriere della Sera*, the most important Italian daily newspaper. He also became a shareholder in the paper, lived parsimoniously, and invested his earnings shrewdly. In 1933 he settled in Switzerland, mostly because of his opposition to Fascism. He died in 1953 in Lugano. Among previous recipients of the Balzan Prize are the following mathematicians: Andrej Kolmogorov (1962), Enrico Bombieri (1980), Jean-Pierre Serre (1985), Otto Neugebauer (1986), and Armand Borel (1992).

—from Balzan Foundation news release

AMS Meeting in August 2000

In celebration of the new millenium, the AMS is organizing a special meeting, "Mathematical Challenges of the 21st Century", to be held August 7-12, 2000. The site chosen for the meeting is the campus of the University of California, Los Angeles. This meeting is in addition to the Joint Mathematics Meetings to be held January 19-22, 2000, in Washington, DC.

"Mathematical Challenges of the 21st Century" has a larger and more ambitious purpose than the usual AMS meeting. The idea is to focus the attention of the mathematical community, as well as of the general public, on the vital areas of growth in mathematics and its impact across the broad landscape of human endeavor. A concerted effort is being made to invite speakers who are leaders in the field and who will provide broad perspectives not only on developments within mathematics itself but also on the impact that mathematics has in science and in practical applications.

The main part of the program will consist of thirty Plenary Lectures, five on each of the six days of the meeting. At the time of this writing, formal invitations had not yet been sent to prospective speakers, but their names will appear in a future issue of the *Notices*. There will be no Special Sessions, but Contributed Paper Sessions will be held.

Royce Hall

On August 6, the day before the meeting begins, there will be a tour of the Getty Museum and Opening Ceremonies and a reception will be held on the UCLA campus. During the meeting there will be a number of social events, culminating in a banquet to be held on the last day of the meeting, August 12.

The plenary talks and some of the other activities will take place in Royce Hall, a newly reconstructed building that has an auditorium holding about 1,200 people at the center of the UCLA campus. The plan is to house as many participants as possible in the UCLA residence facilities, which, as many know, are hotel-like in character and extremely comfortable and convenient.

The meeting is part of a host of events that come under the auspices of "World Mathematical Year 2000", organized by the International Mathematical Union and sponsored by UNESCO. Countries all over the world are planning a wide variety of meetings and special events. Information on WMY 2000 may be found at the Web site `http://www.math.jussieu.fr/`.

Comprising a sweeping vista of the field, "Mathematical Challenges of the 21st Century" will provide an opportunity to celebrate the achievements of mathematics and to contemplate what the future might bring. It also provides an excellent opportunity to increase public appreciation of the beauty and utility of mathematics. The program committee, whose members are listed below, welcomes suggestions and comments. Anyone interested in the future of mathematics is cordially invited to participate in this important event.

UCLA residence facility

—Allyn Jackson

Program Committee:
Richard Askey, University of Wisconsin
Spencer Bloch, University of Chicago
Felix Browder (chair), Rutgers University
Charles Fefferman, Princeton University
Peter Lax, Courant Institute
Robert MacPherson, Institute for Advanced Study
David Mumford, Brown University
Gian-Carlo Rota, Massachusetts Institute of Technology
Peter Sarnak, Princeton University
Audrey Terras, University of California, San Diego
Srinivasa Varadhan, Courant Institute

Chair of Local Arrangements Committee:
Tony Chan, Chair, Department of Mathematics, UCLA

Implementation Committee:
Felix Browder, Rutgers University
Hope Daly, AMS
Robert Daverman, University of Tennessee
John Ewing, AMS
Robert Fossum, University of Illinois, Urbana-Champaign

Web page: `http://www.ams.org/amsmtgs/mathchall.html`

Photographs for this article are courtesy of the UCLA Conference Services. Photo of Royce Hall © Jim Arzouman, 1995.

Mathematics Opportunities

Mathematics Awareness Month

This year Mathematics Awareness Week expands to become Mathematics Awareness Month (MAM). Throughout April, MAM activities will take place across the United States to promote this year's theme, Mathematics and Biology.

MAM, a Joint Policy Board for Mathematics project, has received first-time corporate sponsorship support from Texas Instruments, Inc. (TI). TI is producing and distributing posters this year, entitled "Vital Rhythms, Mathematics in the Heart". The development of the poster was supervised by Professor De Witt Sumners and John Guckenheimer, president of SIAM. The visual content (gif files) for the poster represents work done by Professor Jim Keener of the University of Utah and A. V. Panfilov of the University of Utrecht. Professor Keener kindly contributed an essay on "Mathematics in the Heart". Complete information on Mathematics Awareness Month 1999 is available at `http://forum.swarthmore.edu/mam/`.

—Timothy Goggins

National Institute for Science Education (NISE) Fellowships

The National Institute for Science Education (NISE), funded by the National Science Foundation and based at the University of Wisconsin-Madison, has openings for two to three one-year fellows for the 1999–2000 College Level One (CL-1) Institute.

The 1999–2000 CL-1 Institute will address the use of technology in introductory undergraduate science, mathematics, engineering, and technology (SMET) courses. The goal of the CL-1 Technology Institute is to provide faculty with "principles of best practice" for the use of technology in introductory SMET courses for both majors and nonmajors.

Fellows are expected to have a record of research and/or extensive classroom practice related to use of technology in introductory SMET courses. Responsibilities will include research and writing to produce a synthesis of present knowledge and a set of principles of best practice, creation of dissemination tools for postsecondary faculty and administrators, organization of seminars and symposia, and extensive interaction with other fellows and NISE members.

Requirements are a doctorate in science, mathematics, engineering, social science, or education. Possible candidates include faculty who teach SMET courses and have experience using technology in their classrooms, education researchers with an expertise in instructional technology, and members of faculty development programs. It is anticipated that one of the fellows will have expertise in the area of high-performance computing and will be supported by the Education, Outreach, and Training component of the NSF-funded Partnership for Advanced Computational Infrastructure. Residence at UW-Madison is preferred.

Applications are reviewed continuously until all positions are filled. Further information and application instructions are available on the World Wide Web at `www.wcer.wisc.edu/nise/nise_fellows/cl1_team_fellows.html` or from the College Level One Team, National Institute for Science Education, 1025 West Johnson Street, Suite 735, Madison, WI 53706; telephone 608-263-5681; fax 608-262-7428.

—From an NISE Announcement

Travel/Host Grants for Research

The Office for Central Europe and Eurasia of the National Research Council offers grants to individual American specialists who plan to establish new research partnerships with their colleagues from Central and Eastern Europe and the Newly Independent States. This program is designed primarily to prepare these new partnerships for competition in programs of the National Science Foundation (NSF).

U.S. citizens and permanent residents are eligible to apply. Because the program is designed to support new collaborations, no more than two grants will be awarded per application in a four-year period. Applicants who have received their doctoral degrees within the past six years will receive special consideration, as will applicants wishing to work with colleagues in less frequently represented countries or regions. Those who hold current NSF grants and are eligible for an NSF international supplement should not apply to this program.

Short-Term Project Development Grants ($2,500–$2,750) support American specialists who wish to host or visit their colleagues in Central and Eastern Europe and the Newly Independent States in order to prepare collaborative research proposals for submission to the NSF. Long-Term Grants ($3,300–$15,300) support American specialists who wish to host or visit their colleagues in these regions for research collaboration for a period of one to six months. Significant publications jointly authored by program participants as a result of their long-term visits are expected.

The deadlines for submission of proposals are: **April 5, 1999** (Project Development only; notification in June 1999), and **July 30, 1999** (Long-Term only; notification in January 2000). For further information and application materials, contact: Office of International Affairs, National Research Council, 2101 Constitution Avenue, NW (FO 2060), Washington, DC 20418; telephone 202-334-3680; fax 202-334-2614; e-mail: `ocee@nas.edu`; World Wide Web `http://www2.nas.edu/oia/22da.html`.

—From an NRC announcement

Project NExT: New Experiences in Teaching

Project NExT (New Experiences in Teaching) is a program for new or recent Ph.D.s in the mathematical sciences that addresses a broad range of professional issues, focusing on the teaching and learning of undergraduate mathematics. Faculty who are just beginning or just completing their first year of full-time teaching at the college/university level are invited to apply to become Project NExT fellows.

The first event for the 1999–2000 fellows will be a workshop, July 28–July 30, 1999, just prior to the summer MAA meeting (the MathFest) in Providence, RI (July 31–August 2, 1999). At this workshop and at Project NExT sessions during the MathFest, fellows will explore and discuss a broad range of issues that are of special relevance to beginning faculty, including: new approaches to teaching calculus and precalculus, alternative methods of teaching and assessing student learning, using technology in the classroom, perspectives from pedagogical research, writing grant proposals, and balancing teaching and research.

Following the workshop, Project NExT fellows will attend the summer MAA MathFest, participate in all the opportunities of that meeting, and choose among special short courses designed for the fellows. During the following year, the fellows will participate in a network that links them with one another and with distinguished teachers of mathematics; in special events at the Joint Mathematics Meetings in Washington, DC, January 19–22, 2000; and in a second workshop in the summer of 2000.

Approximately sixty Project NExT Fellows will be selected for the 1999–2000 year. Funding for room and board at the workshop in Providence and for the short courses at the summer 1999 MathFest will be provided for participants. Institutions at which the fellows are employed are expected to provide financial assistance for travel and attendance at the national meetings. Limited funds are available to assist those institutions that are unable to afford full or partial support.

The application deadline is **April 16, 1999.** For more information, consult the Project NExT home page (`http://archives.math.utk.edu/projnext/`), or contact one of the following: T. Christine Stevens, Director, Project NExT, Department of Mathematics and Computer Science, Saint Louis University, 221 North Grand Blvd., St. Louis, MO 63103; telephone 314-977-2444; e-mail: `stevensc@slu.edu`; Joseph Gallian, Codirector, Department of Mathematics and Statistics, University of Minnesota-Duluth, Duluth, MN 55812; telephone 218-726-7576; e-mail: `jgallian@d.umn.edu`; or Aparna Higgins, Codirector, Department of Mathematics, University of Dayton, Dayton, OH 45469; telephone 937-229-2103; e-mail: `higgins@saber.udayton.edu`. Project NExT is sponsored by the Mathematical Association of America with partial support from the Exxon Education Foundation

—Project NExT announcement

Request for Proposals for 2000 NSF-CBMS Regional Conferences

The National Science Foundation (NSF), with the sponsorship of the Conference Board of the Mathematical Sciences (CBMS), intends to support up to five NSF-CBMS Regional Research Conferences in 2000.

Each five-day conference features a distinguished lecturer who delivers ten lectures on a topic of important current research in one sharply focused area of the mathematical sciences. The lecturer subsequently prepares an expository monograph based on these lectures, which, depending on the topic, is published either by the AMS, by the Society for Industrial and Applied Mathematics (SIAM), or jointly by the American Statistical Association and the Institute of Mathematical Statistics. Support is provided for about thirty participants at each conference, including postdoctoral researchers and graduate students.

Colleges and universities with at least some research competence in the field of the proposal are eligible to apply. Because a major goal of these conferences is to attract new researchers into the field of the conference and to stimulate new research activity, institutions that are interested in upgrading or improving their research efforts are especially encouraged to apply.

Proposals should reach the NSF by **April 12, 1999.** For further information on the NSF-CBMS Regional Conferences and guidelines for preparing proposals, contact: Conference Board of the Mathematical Sciences, 1529-18th Street, NW, Washington, DC 20036; telephone 202-293-1170; fax 202-265-2384; World Wide Web `http://www.maa.org/cbms/nsf/2000nsf.html`; e-mail: `kolbe@math.georgetown.edu` or `rosier@math.georgetown.edu`. See also the announcement of the upcoming NSF-CBMS Regional Conferences, to be held in the summer of 1999, which appeared in the February 1999 *Notices*.

—From a CBMS announcement

Maria Mitchell Women in Science Award

The Maria Mitchell Association offers an annual award to recognize an individual, program, or organization that encourages the advancement of girls and women in studies and careers in science and technology. Maria Mitchell (1818–89) was the first woman astronomer and first woman astronomy professor in the United States.

The award may be given in the natural and physical sciences, mathematics, engineering, computer science, or technology. The winner will be chosen by a national jury of distinguished educators and scientists and will receive a cash award of $5,000. Funding for the award is provided through the year 2000 by the William R. Kenan Jr. Fund for Engineering, Technology, and Science.

Nomination forms are available from the Maria Mitchell Women in Science Award Committee at the Maria Mitchell Association. Nominations must be postmarked by **March 30, 1999.** The award winner will be announced by June 15, 1999. For further information, contact the Maria Mitchell Association, 2 Vestal Street, Nantucket, MA 02554; telephone 508-228-9198; World Wide Web `http://www.mmo.org/wis_desc99.shtml`.

—From a Maria Mitchell Association announcement

Reference and Book List

*The **Reference** section of the* Notices *is intended to provide the reader with frequently sought information in an easily accessible manner. New information is printed as it becomes available and is referenced after the first printing. As soon as information is updated or otherwise changed, it will be noted in this section.*

Upcoming Deadlines

March 1, 1999: Deadline for applications for Enhancing Diversity in Graduate Education (EDGE), the Bryn Mawr College summer program for women. For details, consult the Web site `http://www.brynmawr.edu/Acads/Math/edge.html`, or contact EDGE Program, Box 270, Spelman College, Atlanta, GA 30314.

March 30, 1999: Deadline for postmarked nominations for the Maria Mitchell Women in Science Award. For details, see "Mathematics Opportunities" in this issue.

March 31, 1999: Deadline for applications for the Mittag-Leffler Institute postdoctoral fellowships. For details, consult the World Wide Web at `http://www.ml.kva.se/`.

April 5, 1999: Deadline for submission of proposals for Short-Term Project Development grants from the Office of International Affairs of the National Research Council. For more information, see "Mathematics Opportunities" in this issue.

April 12, 1999: Deadline for proposals for the 2000 NSF-CBMS Regional Conferences. For more information, see "Mathematics Opportunities" in this issue.

April 16, 1999: Deadline for applications for Project NExT fellowships. For more information, see "Mathematics Opportunities" in this issue.

July 19, 1999: Deadline for proposals for the second VIGRE Grant competition. For more information, consult the NSF Web site at `http://www.nsf.gov/cgi-bin/getpub?nsf9916/`.

July 30, 1999: Deadline for submission of proposals for Long-Term Project Development grants from the Office of International Affairs of the National Research Council. For more information, see "Mathematics Opportunities" in this issue.

National Science Board

The National Science Board (NSB) serves as a national science policy advisor to the president and the

Where to Find It

A brief index to information that appears in this and previous issues of the *Notices*.

Congress and as the governing body for the National Science Foundation. The term of service on the NSB is six years.

Following are the names, titles, and affiliations of the current NSB members.

John A. Armstrong, IBM Vice President for Science and Technology (retired).

Marta Cehelsky, Executive Officer, National Science Board, National Science Foundation (ex officio).

Mary K. Gaillard, Professor of Physics, University of California, Berkeley.

Sanford D. Greenberg, Chairman and CEO, TEI Industries, Inc.

M. R. C. Greenwood, Chancellor, University of California, Santa Cruz.

Charles E. Hess, Professor Emeritus and Special Assistant to the Provost, Department of Environmental Horticulture, University of California, Davis.

John E. Hopcroft, Joseph Silbert Dean of Engineering, Cornell University.

Stanley V. Jaskolski, Vice President, Eaton Corporation.

Eamon M. Kelly, Tulane University.

Neal F. Lane, Director, National Science Foundation (ex officio).

Jane Lubchenco, Wayne and Gladys Valley Professor of Marine Biology and Distinguished Professor of Zoology, Oregon State University.

Shirley M. Malcom, Head, Directorate for Education and Human Resources Programs, American Association for the Advancement of Science.

Eve L. Menger, Corning Inc. (retired).

Claudia I. Mitchell-Kernan, Vice Chancellor, Academic Affairs, and Dean, Graduate Division, University of California, Los Angeles.

Diana S. Natalicio, President, University of Texas at El Paso.

Vera C. Rubin, Research Staff, Astronomy, Department of Terrestrial Magnetism, Carnegie Institution of Washington, DC.

Robert M. Solow, Institute Professor Emeritus of Economics, Massachusetts Institute of Technology.

Bob H. Suzuki, President, California State Polytechnic University, Pomona.

Richard Tapia, Noah Harding Professor of Computational and Applied Mathematics, Rice University.

Warren M. Washington, Senior Scientist and Section Head, National Center for Atmospheric Research.

John A. White Jr., Chancellor, University of Arkansas, Fayetteville.

MPS Advisory Committee

Following are the names and affiliations of the members of the Advisory Committee for Mathematical and Physical Sciences of the National Science Foundation. The date of the expiration of each member's term is given after his or her name.

George Castro (ex officio), San Jose State University.

Praveen Chaudhari (10/99), IBM T. J. Watson Research Center.

Alexandre J. Chorin (10/01), University of California, Berkeley.

Lila M. Gierasch (10/01), University of Massachusetts, Amherst.

Judy Giordan (10/99), International Flavors and Fragrances.

David L. Goodstein (10/99), California Institute of Technology.

Norman Hackerman (10/00), Robert A. Welch Foundation.

Jiri Jonas (10/00), Beckman Institute.

Bernard V. Khoury (10/01), American Association of Physics Teachers.

Thomas B. W. Kirk (10/01), Brookhaven National Laboratory.

Michael Knotek (10/00), U. S. Department of Energy.

James S. Langer (10/99), University of California, Santa Barbara.

Richard McCray (10/00), University of Colorado.

Harry Morrison (10/99), Purdue University.

Gerard Mourou (10/00), University of Michigan.

J. Anthony Tyson (10/01), Lucent Technologies.

Isiah M. Warner (10/99), Louisiana State University.

Carol S. Wood (10/00), Wesleyan University.

The address is: Directorate for Mathematical and Physical Sciences, National Science Foundation, 4201 Wilson Boulevard, Suite 1005, Arlington, VA 22230. The Web address is `http://www.nsf.gov/home/mps/`.

Book List

The **Book List** *highlights books that have mathematical themes and hold appeal for a wide audience, including mathematicians, students, and a significant portion of the general public. When a book has been reviewed in the* Notices, *a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. Suggestions for books to include on the list may be sent to the Managing Editor,* e-mail: `notices@ams.org`.

Abraham Robinson: The Creation of Nonstandard Analysis, a Personal and Mathematical Odyssey, by Joseph Warren Dauben. Princeton University Press, 1998. ISBN 0-691-05911X.

Against the Gods: The Remarkable Story of Risk, by Peter L. Bernstein. John Wiley & Sons, 1996. ISBN 0-471-12104-5. (Reviewed January 1999)

The Algorithmic Beauty of Sea Shells (Virtual Laboratory), by Hans Meinhardt, Przemyslaw Prusinkiewicz, and Deborah R. Fowler. Springer-Verlag, 1998. ISBN 3-540-63919-5.

The Apprenticeship of a Mathematician, by André Weil, translation by Jennifer Gage. Birkhäuser Boston, 1992. ISBN 0-817-62650-6.

A Beautiful Mind: A Biography of John Forbes Nash, Jr., by Sylvia Nasar. Simon & Schuster, 1998. ISBN 0-684-81906-6. (Reviewed November 1998)

Challenges, by Serge Lang. Springer-Verlag, 1998. ISBN 0-387-94861-9.

e: The Story of a Number, by Eli Maor. Paperback edition, Princeton University Press, 1998. ISBN 0-691-05854-7.

Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science, by Alan Sokal and Jean Bricmont. English version of *Impostures Intellectuelles* (reviewed August 1998), St. Martin's Press, 1998. ISBN 0-312-19545-1.

Fermat's Enigma: The Epic Quest to Solve the World's Greatest Mathematical Problem, by Simon Singh. Paperback edition, Bantam Books, 1998. ISBN 0-385-49362-2. (Reviewed November 1997)

Fermat's Last Theorem: Unlocking the Secret of an Ancient Mathematical Problem, by Amir D. Aczel. Paperback edition, Delacorte Trade Paper, 1997. ISBN 0-385-31946-0.

The Feynman Processor, by Gerard J. Milburn and Paul Davies. Helix Books, Perseus, 1998. ISBN 0-738-20016-6.

Geometry Civilized: History, Culture, and Technique, by John Heilbron. Oxford University Press, 1998. ISBN 0-19-850078-5.

Goodbye, Descartes: The End of Logic and the Search for a New Cosmology of the Mind, by Keith Devlin. John Wiley & Sons, 1998. ISBN 0-471-14216-6.

An Imaginary Tale: The Story of $\sqrt{-1}$, by Paul J. Nahin. Princeton University Press, 1998. ISBN 0-691-02795-1.

The Jungles of Randomness: A Mathematical Safari, by Ivars Peterson. Paperback edition, John Wiley & Sons, 1998. ISBN 0-471-29587-6.

The Language of Mathematics: Making the Invisible Visible, by Keith Devlin. W.H. Freeman and Company, 1998. ISBN 0-716-73379-X.

Life by the Numbers, by Keith Devlin. John Wiley & Sons, 1998. ISBN 0-471-24044-3.

Logical Dilemmas: The Life and Work of Kurt Gödel, by John W. Dawson Jr. AK Peters, 1997. ISBN 1-56881-025-3.

The Man Who Loved Only Numbers: The Story of Paul Erdős and the Search for Mathematical Truth, by Paul Hoffman. Hyperion, 1998. ISBN 0-786-86362-5. (Reviewed October 1998)

Mathematics for the Curious, by Peter M. Higgins. Oxford University Press, 1998. ISBN 0-192-88072-1.

Mathematics: From the Birth of Numbers, by Jan Gullberg, Peter Hilton. W. W. Norton and Company, 1997. ISBN 0-393-04002-X.

Modern Mathematics in the Light of the Fields Medals, by Michael Monastyrsky. AK Peters, 1997. ISBN 1-568-81065-2.

Moral Calculations: Game Theory, Logic, and Human Frailty, by László Mérő. Copernicus-Springer-Verlag, 1998. ISBN 0-387-98419-4.

My Brain Is Open: The Mathematical Journeys of Paul Erdős, by Bruce Schecter. Simon & Schuster, 1998. ISBN 0-684-84635-7.

The Number Devil, by Hans Magnus Enzensberger. Metropolitan Books, 1998. ISBN 0-805-05770-6.

Paul Dirac: The Man and His Work, by Abraham Pais, Maurice Jacob, David Olive, and Michael Atiyah. Cambridge University Press, 1998. ISBN 0-521-58382-9. (Reviewed October 1998)

Philosophy of Mathematics: An Introduction to a World of Proofs and Pictures, by James Robert Brown. Routledge, 1998. ISBN 0-415-12274-0.

The Pleasures of Counting, by T. W. Körner. Cambridge University Press, 1997. ISBN 0-521-56087-X; 0-521-56823-4. (Reviewed March 1998)

Polyhedra, by Peter Cromwell. Cambridge University Press, 1997. ISBN 0-521-55432-2. (Reviewed September 1998)

Privacy on the Line: The Politics of Wiretapping and Encryption, by Whitfield Diffie and Susan Landau. MIT Press, 1997. ISBN 0-262-04167-7. (Reviewed June/July 1998)

Randomness, by Deborah Bennett. Harvard University Press, 1998. ISBN 0-674-10745-4.

Reasoning with the Infinite: From the Closed World to the Mathematical Universe, by Michel Blay (translated by M. B. DeBevoise). University of Chicago Press, 1998. ISBN 0-226-05834-4.

Strength in Numbers, by Sherman Stein. John Wiley & Sons, 1996. ISBN 0-471-152528-8.

The Universe and the Teacup: The Mathematics of Truth and Beauty, by K. C. Cole. Harcourt Brace, 1998. ISBN 0-151-00323-8. (Reviewed in this issue)

Tracking the Automatic Ant, and Other Mathematical Explorations, by David Gale. Springer-Verlag, 1998. ISBN 0-387-98272-8.

Visual Explanations—Images and Quantities, Evidence and Narrative, by Edward R. Tufte. Graphics Press, 1997. ISBN 0-961-39212-6. (Reviewed January 1999)

What Is Mathematics, Really?, by Reuben Hersh. Oxford University Press, 1997. ISBN 0-19-511368-3.

Women in Mathematics: The Addition of Difference, by Claudia Henrion. Indiana University Press, 1997. ISBN 0-253-33279-6. (Reviewed May 1998)

REFERENCE & BOOK LIST

1999 Frank and Brennie Morgan AMS-MAA-SIAM Prize for Outstanding Research in Mathematics by an Undergraduate Student

The prize is awarded each year to an undergraduate student (or students having submitted joint work) for outstanding research in mathematics. Any student who is an undergraduate in a college or university in the United States or its possessions, or Canada or Mexico, is eligible to be considered for this prize.

The prize recipient's research need not be confined to a single paper; it may be contained in several papers. However, the paper (or papers) to be considered for the prize must be submitted while the student is an undergraduate; they cannot be submitted after the student's graduation. The research paper (or papers) may be submitted for consideration by the student or a nominator. All submissions for the prize must include at least one letter of support from a person, usually a faculty member, familiar with the student's research. Publication of research is not required.

The recipients of the prize are to be selected by a standing joint committee of the AMS, MAA, and SIAM. The decisions of this committee are final. The 1999 prize will be awarded for papers submitted for consideration no later than **June 30, 1999,** by (or on behalf of) students who were undergraduates in December 1998.

Nominations and submissions should be sent to:

Morgan Prize Committee
c/o Robert J. Daverman, Secretary
American Mathematical Society
Department of Mathematics
University of Tennessee
Knoxville, TN 37996

Questions may be directed to the chairperson of the Morgan Prize Committee:

George Andrews
Department of Mathematics
Pennsylvania State University
University Park, PA 16802
telephone: 814-865-6642
e-mail: andrews@math.psu.edu

AMERICAN
MATHEMATICAL
SOCIETY

Call for Nominations

Leroy P. Steele Prizes and Distinguished Public Service Award

The selection committee for these prizes requests nominations for consideration for the 2000 award. Further information about these prizes can be found in the November 1997 *Notices*, pp. 1349–1353 (also available at http://www.ams.org/ams/prizes.html).

Three Leroy P. Steele Prizes are awarded each year in the following categories: (1) the Steele Prize for Lifetime Achievement: for the cumulative influence of the total mathematical work of the recipient, high level of research over a period of time, particular influence on the development of a field, and influence on mathematics through Ph.D. students; (2) the Steele Prize for Mathematical Exposition: for a book or substantial survey or expository-research paper; and (3) the Steele Prize for Seminal Contributions to Research: for a paper, whether recent or not, that has proved to be of fundamental or lasting importance in its field or a model of important research.

The Award for Distinguished Public Service is presented every two years to a research mathematician who has made a distinguished contribution to the mathematics profession during the preceding five years.

Nominations with supporting information should be submitted to the secretary, Robert J. Daverman, Department of Mathematics, University of Tennessee, Knoxville, TN 37996. For the Steele Prizes include a short description of the work that is the basis of the nomination, including complete bibliographic citations. For the Public Service Award, include a short description of the pertinent activities of the nominee. A curriculum vitae should be included for all nominees. The nominations will be forwarded by the secretary to the prize selection committee, which will, as in the past, make final decisions on the awarding of prizes.

Deadline for nominations is March 31, 1999.

AMS
American Mathematical Society

Add this Cover Sheet to all of your Academic Job Applications

How to use this form

1. Using the facing page or a photocopy, (or a TEX version which can be downloaded from the e-math "Employment Information" menu, `http://www.ams.org/employment/`), fill in the answers which apply to *all* of your academic applications. Make photocopies.

2. As you mail each application, fill in the remaining questions neatly on one cover sheet and include it *on top of* your application materials.

The Joint Committee on Employment Opportunities has adopted the cover sheet on the facing page as an aid to job applicants and prospective employers. The form is now available on e-math in a TEX format which can be downloaded and edited. The purpose of the cover form is to aid department staff in tracking and responding to each application.

Mathematics Departments in Bachelor's, Master's and Doctorate granting institutions have been contacted and are expecting to receive the form from each applicant, along with any other application materials they require. Obviously, not all departments will utilize the cover form information in the same manner. Please direct all general questions and comments about the form to: `emp-info@ams.org` or call the Professional Programs and Services Department, AMS, at 800-321-4267 extension 4105.

JCEO Recommendations for Professional Standards in Hiring Practices

The JCEO believes that every applicant is entitled to the courtesy of a prompt and accurate response that provides timely information about his/her status. Specifically, the JCEO urges all institutions to do the following after receiving an application:

(1) Acknowledge receipt of the application—immediately; and
(2) Provide information as to the current status of the application, as soon as possible.

The JCEO recommends a triage-based response, informing the applicant that he/she
(a) is not being considered further;
(b) is not among the top candidates; or
(c) is a strong match for the position.

Academic Employment in Mathematics

AMS STANDARD COVER SHEET

Last Name ____________________

First Name ____________________

Middle Names ____________________

Address *through June 1999* ____________________ **Home Phone** ____________________

____________________ **e-mail Address** ____________________

Current Institutional Affiliation ____________________ **Work Phone** ____________________

Highest Degree and Source ____________________

Year of Ph.D. (optional) ____________________

Ph.D. Advisor ____________________

If the Ph.D. is not presently held, date on which you expect to receive ____________________

Indicate *the mathematical subject area(s) in which you have done research using, if applicable, the 1991 Mathematics Subject Classification printed on the back of this form. If listing more than one number, list first the one number which best describes your current primary interest.*

Primary Interest ____________________

Secondary Interests *optional* ____________________

Give a brief synopsis *of your current research interests (e.g. finite group actions on four-manifolds). Avoid special mathematical symbols and please do not write outside of the boxed area.*

____

____

Most recent, if any, position held *post Ph.D.*

University or Company ____________________

Position Title ____________________

Indicate the position for which you are applying and position posting code, if applicable

____

If unsuccessful for this position, would you like to be considered for a temporary position?

☐ Yes ☐ No If yes, please check the appropriate boxes.

☐ Postdoctoral Position ☐ 2+ Year Position ☐ 1 Year Position

List the names, affiliations, and e-mail addresses *of up to four individuals who will provide letters of recommendation if asked. Mark the box provided for each individual whom you have already asked to send a letter.*

☐ ____________________

☐ ____________________

☐ ____________________

☐ ____________________

This form is provided courtesy of the American Mathematical Society.

This cover sheet is provided as an aid to departments in processing job applications. It should be included with your application material.

Please print or type. Do not send this form to the AMS.

1991 Mathematics Subject Classification

00 General
01 History and biography
03 Logic and foundations
04 Set theory
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General mathematical systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra, matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory, homological algebra
19 K-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
39 Finite differences and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations, optimal control
51 Geometry
52 Convex and discrete geometry
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
68 Computer science
70 Mechanics of particles and systems
73 Mechanics of solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
86 Geophysics
90 Economics, operations research, programming, games
92 Biology and other natural sciences, behavioral sciences
93 Systems theory, control
94 Information and communication, circuits

Mathematics Calendar

The most comprehensive and up-to-date Mathematics Calendar information is available on e-MATH at `http://www.ams.org/mathcal/`.

March 1999

*1–4 **Interfaces in Continuous Media**, Centro de Matemática e Aplicações Fundamentais da Universidade de Lisboa, Lisbon, Portugal.

Focus: In the last decades there have been remarkable advancements in the study of nonlinear partial differential equations, motivated not only by the twentieth century developments in pure and applied mathematics, but also by the industrial modelling and scientific progress. New theories and techniques have been developed to address the search for classical and generalized solutions for equations or systems of partial differential equations, and their qualitative properties such as regularity or asymptotic behavior. Most of these questions are still poorly understood and new emerging issues in physical sciences, mathematical finance, and other applied disciplines proved a test for known theories and an inspirational source for the introduction of new ones.

Scientific Organizers: M. Chipot (Univ. Zürich) and J. F. Rodrigues (Univ. Lisboa).

Support: A certain number of grants for young mathematicians, as well as for other scientists, will be available for participation at the meetings and for short or medium stays in Lisbon to stimulate joint collaboration and research.

Information: M. Morales, NPDEA-99 secretariat, CMAF/Univ. de Lisboa, Av. Prof. Gama Pinto 2, 1699 Lisboa Codex, Portugal; e-mail: `npde99@lmc.fc.ul.pt`; `http://npde99.lmc.fc.ul.pt`; tel: 351-1-790-48-62; fax: 351-1-795-42-88.

1–4 **M/SET 99, International Conference on Mathematics/Science Education & Technology**, San Antonio, Texas. (Sept. 1998, p. 1050)

3–5 **Theory and Applications of Realtime Computation**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. (Sept. 1998, p. 1050)

*3, 10, 17 and 24 **Seminari Les bases matemàtiques de la civilització tecnològica**, Auditori de la Caixa de Sabadell, Carrer d'en Font, 1, Sabadell, Spain.

Organizer: J. Aguadé (Universitat Autònoma de Barcelona) and Centre de Recerca Matemàtica.

Speakers: J. L. Fernández (Universidad Autónoma de Madrid), P. Morillo (Universitat Politècnica de Catalunya), A. M. Colell (Universitat Pompeu Fabra), H. Neunzert (Institut für Techno- und Wirtschaftsmathematik), J. Mosterín (Instituto de Filosofía, CSIC), J. Girbau (Universitat Autònoma de Barcelona), I. Colomina (Institut Cartogràfic de Catalunya).

Information: e-mail: `crm@crm.es` or `aguade@mat.uab.es`.

5 **Audition**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

*5–6 **VI Trobada de Topologia**, Universitat de les Illes Balears, Palma de Mallorca.

Organizers: M. Castellet (Centre de Recerca Matemàtica), A. Murillo (Universidad de Málaga) and J. A. Crespo (Universitat de les Illes Balears) and Centre de Recerca Matemàtica.

Speakers: J. A. Crespo (Universitat de les Illes Balears), W. Dicks (Universitat Autònoma de Barcelona), A. G. Tato (Universidad de Santiago de Compostela), M. Izquierdo (Mälardalen Univ.), V. Muñoz (Universidad de Málaga), J. J. Nuño (Universitat de València).

Information: For further information: `http://crm.es/info/vi-et/`.

7–13 **Dirac Operators, Index Theorems and Numerical Invariants of Manifolds**, Greifswald University, Germany, Island of Usedom. (Jun/Jul. 1998, p. 759)

7–14 **Eighth International Conference on Geometry**, Nahsholim, Israel. (Sept. 1998, p. 1050)

8–12 **Audition**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p.

This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found on the last page of each issue.

An announcement will be published in the *Notices* if it contains a call for papers and specifies the place, date, subject (when applicable), and the speakers; a second announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in every third issue until it has been held and a reference will be given in parentheses to the month, year, and page of the issue in which the complete information appeared. Asterisks (*) mark those announcements containing new or revised information.

In general, announcements of meetings and conferences held in North America carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. Meetings held outside the North American area may carry more detailed information. In any case, if there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the *Notices* in care of the American Mathematical Society in Providence or electronically to `notices@ams.org` or `mathcal@ams.org`.

In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **six months** prior to the scheduled date of the meeting.

The complete listing of the Mathematics Calendar will be published only in the September issue of the *Notices*. The March, June, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through e-MATH on the World Wide Web. To access e-MATH, use the URL: `http://e-math.ams.org/` (or `http://www.ams.org/`). (For those with VT100-type terminals or for those without WWW browsing software, connect to e-MATH via Telnet (`telnet e-math.ams.org`; login and password `e-math`) and use the Lynx option from the main menu.)

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*8-12 **Fields Institute Workshop on Interactive Measure-Valued Processes**, The Fields Institute for Research in Mathematical Sciences, Toronto, Ontario, Canada.
Organizers: D. Dawson (Fields Institute), E. Perkins (UBC).
Confirmed Speakers: T. Cox (Syracuse Univ.), R. Durrett (Cornell Univ.), S. Evans (Univ. of California, Berkeley), K. Fleischmann (Weierstrass Institute for Applied Analysis and Stochastics), A. Greven (Univ. of Erlangen), T. Kurtz (Univ. of Wisconsin, Madison), S. Kuznetsov (Univ. of Colorado, Boulder), J.-F. Le Gall (École Normale Supérieure, Paris), Y. Le Jan (Université Paris Sud), V. Limic (Univ. of California, San Diego), P. March (Ohio State Univ.), C. Mueller (Univ. of Rochester), L. Mytnik (Technion Univ.), R. Tribe (Univ. of Warwick), J. Vaillancourt (Université de Sherbrooke).
Information: For further information about the workshop and the program, please see the program Web site `http://www.fields.utoronto.ca/probability.html`, or write to: The Fields Institute for Research in Mathematical Sciences, 222 College Street, Second Floor, Toronto, Ontario, M5T 3J1, Canada; Tel: 416-348-9710; Fax: 416-348-9385; e-mail: `measure@fields.utoronto.ca`.

12-13 **AMS Southeastern Section Meeting**, University of Florida, Gainesville, Florida. (Jun/Jul. 1998, p. 759)

13-15 **International Conference on Scientific Computations**, Beirut Arab University, Beirut, Lebanon. (Oct. 1998, p. 1228)

13-17 **1999 Arizona Winter School: Local-to-Global Principles in Arithmetical Algebraic Geometry**, University of Arizona, Tucson, Arizona. (Oct. 1998, p. 1229)

16-18 **German-American Academic Council Lectures on Prophet Theory**, Lehigh University, Bethlehem, Pennsylvania. (Feb. 1999, p. 276)

16-20 **1999 UAB-GIT International Conference on Differential Equations and Mathematical Physics**, University of Alabama at Birmingham, Birmingham, Alabama. (Jun/Jul. 1998, p. 759)

*16-21 **Japan-U.S. Mathematics Institute (JAMI) Conference and Workshop on Minimal Surfaces, Geometric Analysis, and Symplectic Geometry**, Johns Hopkins University, Baltimore, Maryland.
Organizing Committee: K. Fukaya, W. Minicozzi, J. Morava, S. Nishikawa, and J. Spruck.
Confirmed Speakers: T. Colding, K. Fukaya, M. Furuta, H. Hofer, N. Kapouleas, P. Kronheimer, W. Meeks, K. Ono, H. Rosenberg, R. Schoen, G. Tian, and K. Yamada.
Program: The program will focus on recent developments in minimal surface theory and symplectic geometry, and more broadly in geometric analysis, emphasizing common themes and techniques. Activities include a conference March 19-21 with invited lectures and a workshop March 16-18 where there will be informal sessions and short talks.
Information: Please contact Johns Hopkins University, Department of Mathematics, Baltimore, MD 21218; tel: 410-516-4178; fax: 410-516-5549; e-mail: `jami@math.jhu.edu`; `http://mathnt.mat.jhu.edu/JAMI98-99/`.

17-19 **International Conference on Differential Equations and Nonlinear Mechanics**, University of Central Florida, Orlando, Florida. (Nov. 1998, p. 1377)

*18-20 **Seminar on Stochastic Process 1999**, Fields Institute, Toronto, Ontario, Canada.
Program Committee: E. Cinlar (Princeton Univ.), S. Evans (UC Berkeley), G. Lawler (Duke Univ.), T. Salisbury (York Univ.), M. Sharpe (UCSD), R. Williams (UCSD).
Plenary Speakers: D. Aldous (UC Berkeley), B. Driver (UCSD), H. Föllmer (Humboldt Univ.), L. Mytnik (Technion), W. Werner (Univ. Paris Sud).
Information: Additional information is available from the Web site `http://www.math.yorku.ca/Probability/ssp.html`; or contact T. Salisbury, e-mail: `salt@nexus.yorku.ca`; address: The Fields Institute for Research in Mathematical Sciences, 222 College Street, Second Floor, Toronto, Ontario, M5T 3J1, Canada; tel: 416-348-9710; fax: 416-348-9385.

18-21 **AMS Central Sectional Meeting**, University of Illinois-Urbana, Urbana, Illinois. (Aug. 1997, p. 846)

20-23 **ASL Annual Meeting**, San Diego, California. (Jan. 1999, p. 65)

20-23 **Measurable and Topological Dynamics**, University of Maryland, College Park, Maryland. (Dec. 1998, p. 1500)

*21-23 **DIMACS Workshop on Large Scale Discrete Optimization in Robotics and Vision**, DIMACS Center, Rutgers University, Piscataway, New Jersey.
Organizers: J. Malik (`malik@cs.berkeley.edu`), J. Ponce (`ponce@cs.uiuc.edu`).
Local Arrangements: P. Pravato (`pravato@dimacs.rutgers.edu`), 732-445-5928.
Aim: This workshop will address the fundamental mathematical and computational problems underlying computer vision and robotics. A set of talks from major researchers in the field will help give a perspective on the leading issues today and the likely directions for future progress. Points of contact with computer science theory and algorithms, probabilistic inference, and other areas of applied mathematics in general will be stressed.
Information: Contact: J. Malik (`malik@cs.berkeley.edu`); WWW: `http://dimacs.rutgers.edu/Workshops/Robotics/`.

22-24 **Ninth SIAM Conference on Parallel Processing for Scientific Computing**, Adam's Mark San Antonio-Riverwalk Hotel, San Antonio, Texas. (Jun/Jul. 1998, p. 759)

25-27 (Revised dates) **DIMACS Workshop on Mobile Networks and Computing**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Sept. 1998, p. 1050)

24-27 **Fifth SIAM Conference on Mathematical and Computational Issues in the Geosciences**, Adam's Mark San Antonio-Riverwalk Hotel, San Antonio, Texas. (Jun/Jul. 1998, p. 759)

25-26 **Third International Multidisciplinary Congress in Quality and Reliability**, Paris, France. (Aug. 1998, p. 899)

25-28 **International Conference on Algebra and its Applications**, Ohio University, Athens, Ohio. (Oct. 1998, p. 1229)

*29-31 **Workshop on Smooth Ergodic Theory**, Lisbon, Portugal.
Invited Speakers: D. Dolgopyat (Univ. of California, Berkeley), M. Pollicott (Univ. of Manchester), J. Schmeling (Freie Universität, Berlin), N. Simányi (József Attila University, Szeged), D. Szász (Mathematical Institute, Hungarian Academy of Sciences, Budapest), M. Viana (Instituto de Matematica Pura e Aplicada, Rio de Janeiro).
Organizers: L. Barreira, P. Duarte, and R. Loja Fernandes.
Support: Partially supported by FCT's Pluriannual Funding Program, and Projects ICCTI and Praxis XXI.
Information: Center for Mathematical Analysis, Geometry, and Dynamical Systems, Instituto Superior Técnico, Lisbon, Portugal; e-mail: `cam@math.ist.utl.pt`; Center's homepage: `http://www.math.ist.utl.pt/cam/`.

29-April 1 **British Mathematical Colloquium**, University of Southampton, Southampton, England. (Dec. 1998, p. 1500)

April 1999

6-9 **London Mathematical Society Invited Lecture Series**, University of Bath, Bath, United Kingdom. (Oct. 1998, p. 1229)

7-9 **Fourth International Conference on Typed Lambda Calculi and Applications (TLCA'99)**, l'Aquila, Italy. (Jun/Jul. 1998, p. 759)

10-11 **AMS Western Sectional Meeting**, University of Nevada, Las Vegas, NV. (Apr. 1997, p. 481)
Information: W. Drady, `wsd@ams.org`.

12-15 **Nonlinear Evolution Equations and Wave Phenomena: Computation and Theory**, Athens, Georgia. (Apr. 1998, p. 535)

*12-30 **School on Differential Geometry**, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.
Directors: B. Dubrovin (ISAS/SISSA, Trieste), G. Tian (MIT, USA).
Information: Abdus Salam, International Centre for Theoretical Physics, Strada Costier 11-34014 Trieste, Italy; tel: +39-40-2240111;

fax: +39-40-224163; e-mail: sci_info@ictp.trieste.it; http://www.ictp.trieste.it/.

15-17 **4th April Dialogue**, National Science Foundation and the Hilton Arlington & Towers, Arlington, Virginia. (Feb. 1999, p. 276)

15-20 **Second International Conference on Multivariate Scattered Data Fitting**, Puerto Vallarta, Jalisco, Mexico. (Jan. 1999, p. 65)

15-17 **Complex Dynamics: The University of Arkansas Annual Lectures in the Mathematical Sciences.**, University of Arkansas, Fayetteville, Arkansas. (Dec. 1998, p. 1500)

15-17 **Thirty-second Biennial Kappa Mu Epsilon National Convention**, Florida Southern College, Lakeland, Florida. (Dec. 1998, p. 1500)

16-18 **Workshop on Logic and Cognitive Science**, University of Pennsylvania, Institute for Research in Cognitive Science (IRCS), Philadelphia, Pennsylvania. (Jan. 1999, p. 65)

17-18 **Riviere-Fabes Symposium on Analysis and PDE**, University of Minnesota, Minneapolis, Minnesota. (Sept. 1998, p. 1050, Feb. 1999, p. 276)

18-24 **Spring School on Functional Analysis**, Paseky nad Jizerou, Czech Republic. (Feb. 1999, p. 276)

*19-23 **Fields Institute Workshop on Numerical Methods and Stochastics**, The Fields Institute for Research in Mathematical Sciences, Toronto, Ontario, Canada.
Organizing Committee: T. Lyons (Imperial College), T. Salisbury (York Univ.).
Invited Speakers: D. Crisan (Imperial College, London), A. M. Davie (Univ. of Edinburgh), J. D. Gaines (Univ. of Edinburgh), A. Guionnet (Université de Paris Sud), T. J. Lyons (Imperial College, London), P. Del Moral (Université Paul Sabatier), P. Protter (Purdue Univ.), J. B. Walsh (Univ. of British Columbia).
Information: For further information about the workshop and the program, please see the program Web site http://www.fields.utoronto.ca/probability.html, or write to: The Fields Institute for Research in Mathematical Sciences, 222 College Street, Second Floor, Toronto, Ontario, M5T 3J1, Canada; Tel: 416-348-9710; Fax: 416-348-9385; e-mail: numeric@fields.utoronto.ca.

19-23 **Local Interaction and Global Phenomena in Vegetation and Other Systems**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 759)

*22-24 **Hyperbolic Systems of Conservation Laws**, Centro de Matemática e Aplicações Fundamentais da Universidade de Lisboa, Lisbon, Portugal.
Focus: In the last decades there have been remarkable advancements in the study of nonlinear partial differential equations, motivated not only by the twentieth century developments in pure and applied mathematics, but also by the industrial modelling and scientific progress. New theories and techniques have been developed to address the search for classical and generalized solutions for equations or systems of partial differential equations, and their qualitative properties such as regularity or asymptotic behavior. Most of these questions are still poorly understood and new emerging issues in physical sciences, mathematical finance, and other applied disciplines proved a test for known theories and an inspirational source for the introduction of new ones.
Scientific Organizers: J. P. Dias (Univ. Lisboa) and P. LeFloch (CNRS/Ec. Polytechnique).
Support: A certain number of grants for young mathematicians, as well as for other scientists, will be available for participation at the meetings and for short or medium stays in Lisbon to stimulate joint collaboration and research.
Information: M. Morales, NPDEA-99 secretariat, CMAF/Univ. de Lisboa, Av. Prof. Gama Pinto 2, 1699 Lisboa Codex, Portugal; e-mail: npde99@lmc.fc.ul.pt; http://npde99.lmc.fc.ul.pt; tel: 351-1-790-48-62; fax: 351-1-795-42-88.

22-24 **Inverse Problems in Stratified Media**, University of Aarhus, Aarhus, Denmark. (Jan. 1999, p. 66)

24-25 **AMS Eastern Sectional Meeting**, State University of New York, Buffalo, NY. (Apr. 1997, p. 481)
Information: W. Drady, wsd@ams.org.

*24-27 **IMA "HOT TOPICS" Workshop: Challenges and Opportunities in Genomics: Production, Storage, Mining and Use**, Institute for Mathematics and Its Applications, University of Minnesota, Minneapolis, Minnesota.
Organizers: S. Kim, V. Kumar, D. Misemer, D. Polla, I. Rigoutsos.
Information: Institute for Mathematics and Its Applications, Univ. of Minnesota, 207 Church St. S.E., 400 Lind Hall, Minneapolis, MN 55455; Phone: 612-624-6066, e-mail: staff@ima.umn.edu or Web page: http://www.ima.umn.edu/biology/spring/genomics.html.

May 1999

*10-August 20 **Complexity, Computation and the Physics of Information**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.
Organizers: A. Albrecht (Imperial), P. Knight (Imperial), R. M. Solovay (Berkeley), W. Zurek (LANL).
Objective: The study of information is linked to a wide range of interdisciplinary research which is defining new frontiers in physics and mathematics. Mathematical notions such as "algorithmic entropy" (or "algorithmic complexity") are central to the fundamental problem of constructing rigorous definitions of entropy and information, while the importance of these concepts to key physical processes (including quantum cosmology, the arrow of time, exotic quantum systems and signal transmission) attracts the attention of theoretical and experimental physicists. An exciting application is that of "quantum computation", which defines challenging problems in mathematics, materials physics, and computer science. The program will bring together members of all the relevant scientific communities to focus on the physics, mathematics, and applications of information and entropy.
Information: Contact the Director, Isaac Newton Institute for Mathematical Sciences, 20 Clarkson Road, Cambridge CB3 0EH, UK; tel: 01223-335999; e-mail: info@newton.cam.ac.uk. Information can also be found on the World Wide Web at the URL http://www.newton.cam.ac.uk/.

7-8 **1999 ASL Spring Meeting**, New Orleans, Louisiana (in conjunction with a meeting of the Central Division of the American Philosophical Association, May 5-8, 1999). (Oct. 1998, p. 1229)

10-12 **Sixth SIAM Conference on Optimization**, Radisson Atlanta Hotel, Atlanta, Georgia. (Jun/Jul. 1998, p. 760)

12-15 **1999 SIAM Annual Meeting**, Radisson Atlanta Hotel, Atlanta, Georgia. (Jun/Jul. 1998, p. 760)

13-14 **Introduction to Epidemiology and Immunology**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

*13-16 **Nonlinear Parabolic Problems**, Centro de Matemática e Aplicações Fundamentais da Universidade de Lisboa, Lisbon, Portugal.
Focus: In the last decades there have been remarkable advancements in the study of nonlinear partial differential equations, motivated not only by the twentieth century developments in pure and applied mathematics, but also by the industrial modelling and scientific progress. New theories and techniques have been developed to address the search for classical and generalized solutions for equations or systems of partial differential equations, and their qualitative properties such as regularity or asymptotic behavior. Most of these questions are still poorly understood and new emerging issues in physical sciences, mathematical finance, and other applied disciplines proved a test for known theories and an inspirational source for the introduction of new ones.
Scientific Organizers: H. Amann (Univ. Zürich), c. Rocha (Inst. Sup. Técnico) and J. F. Rodrigues (Univ. Lisboa).
Support: A certain number of grants for young mathematicians, as well as for other scientists, will be available for participation at the meetings and for short or medium stays in Lisbon to stimulate joint collaboration and research.
Information: M. Morales, NPDEA-99 secretariat, CMAF/Univ. de Lisboa, Av. Prof. Gama Pinto 2, 1699 Lisboa Codex, Portu-

gal; e-mail: npde99@lmc.fc.ul.pt; http://npde99.lmc.fc.ul.pt/; tel: 351-1-790-48-62; fax: 351-1-795-42-88.

14-16 **BLMS'99, Joint meeting of the London Mathematical Society and the Belgian Mathematical Society**, Université Libre de Bruxelles, Brussels, Belgium. (Sept. 1998, p. 1050)

* 14-16 **Conference on Geometry and Topology, 1999**, Harvard University, Cambridge, Massachusetts.

Speakers: M. F. Atiyah (Univ. of Cambridge), R. H. Bott (Harvard Univ.), F. Hirzebruch (Max Planck Institute for Mathematics), I. M. Singer (MIT).

Information: For more information, contact stanek@math.havard.edu.

* 16-23 **The 37th International Symposium on Functional Equations**, Marshall University, Huntington, West Virginia.

Participation: Participation is by invitation of the scientific committee. Those seeking an invitation should write to the local organizer, describing the nature of their interest in the subject and preferably including a list of relevant publications.

Honorary Chairman: J. Aczel (Waterloo).

Scientific Committee: W. Benz (Hamburg), R. Ger (Katowice), J. Raetz (Bern), L. Reich (Graz), A. Sklar (Chicago).

Local Organizer: B. Ebanks, 37th ISFE, Department of Mathematics, Marshall Univ., Huntington, WV 25755; e-mail: math@marshall.edu; fax: 304-696-4646.

* 17-19 **Stochastic Evolution Equations**, Centro de Matemática e Aplicações Fundamentais da Universidade de Lisboa, Lisbon, Portugal.

Focus: In the last decades there have been remarkable advancements in the study of nonlinear partial differential equations, motivated not only by the twentieth century developments in pure and applied mathematics, but also by the industrial modelling and scientific progress. New theories and techniques have been developed to address the search for classical and generalized solutions for equations or systems of partial differential equations, and their qualitative properties such as regularity or asymptotic behavior. Most of these questions are still poorly understood and new emerging issues in physical sciences, mathematical finance, and other applied disciplines proved a test for known theories and an inspirational source for the introduction of new ones.

Scientific Organizers: K. D. Elworthy (Univ. Warwick), and I. Simão, (Univ. Lisboa).

Support: A certain number of grants for young mathematicians, as well as for other scientists, will be available for participation at the meetings and for short or medium stays in Lisbon to stimulate joint collaboration and research.

Information: M. Morales, NPDEA-99 secretariat, CMAF/Univ. de Lisboa, Av. Prof. Gama Pinto 2, 1699 Lisboa Codex, Portugal; e-mail: npde99@lmc.fc.ul.pt/; http://npde99.lmc.fc.ul.pt; tel: 351-1-790-48-62; fax: 351-1-795-42-88.

17-21 **Mathematical Approaches for Emerging and Reemerging Infectious Diseases**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

* 17-21 **Méthodes homologiques**, C.I.R.M. (Centre International de Rencontres Mathématiques), Luminy, France.

Information: http://www.math.univ-montp2.fr/vaquerias/homologiques.html.

19-22 **Fourth International Joint Meeting of the AMS and the Sociedad Matematica Mexicana (SMM)**, University of North Texas, Denton, Texas. (Nov. 1998, p. 1377)

19-22 **Mathematics from Physics: Recent Trends and New Developments**, University of Illinois, Urbana, Illinois. (Jan. 1999, p. 66)

* 21-22 **Fourth Mississippi State Conference On Differential Equations & Computational Simulations**, Mississippi State University, Mississippi State, Mississippi.

Organized By: Department of Mathematics and Statistics and NSF Engineering Research Center.

Co-Sponsor: Electronic Journal of Differential Equations.

Principal Speakers: L. C. Evans (Univ. of California, Berkeley), C. Farhat (Univ. of Colorado, Boulder), I. Fonseca (Carnegie Mellon Univ.), A. Noor (Univ. of Virginia), J. Serrin (Univ. of Minnesota), P. Waltman (Emory Univ.), M. Wheeler (Univ. of Texas, Austin).

Aim: This interdisciplinary conference will provide a joint forum where mathematicians, scientists, and engineers from academia and industry can exchange research ideas involving theoretical and applied developments in differential equations and computational simulations. In addition to the seven principal lectures, there will be sessions of contributed talks. This conference is held bi-annually. Reviewed manuscripts will be published as a special issue of the Electronic Journal of Differential Equations.

Abstracts: Abstracts for contributed papers should be submitted no later than March 31, 1999, to the program chairman, J. Zhu, jzhu@math.msstate.edu.

Information: For further information on the conference organization, program, and submission of abstracts, visit the conference Web page at http://www.msstate.edu/Dept/Math/conf.html, or contact one of the following organizers: R. Shivaji, Department of Mathematics & Statistics, Mississippi State, MS 39762; e-mail: shivaji@math.msstate.edu; tel: 601-325-3414/7142; fax: 601-325-0005; B. Soni, NSF Engineering Research Center, Mississippi State, MS 39762; e-mail: bsoni@erc.msstate.edu; tel: 601-325-8278; fax: 601-325-7692.

24-26 **International Symposium on Discontinuous Galerkin Methods: Theory, Computation and Applications**, Salve Regina College, Newport, Rhode Island. (Jan. 1999, p. 66)

24-28 **Fifth SIAM Conference on Applications of Dynamical Systems**, Snowbird Ski and Summer Resort, Snowbird, Utah. (Jun/Jul. 1998, p. 760)

* 25-29 **International Conference on Dynamical System Modelling and Stability Investigation (DSMSI'99)**, Kiev, Ukraine.

Organizers: Kiev State University, Institute of Mechanics, Institute of Mathematics, and the Institute of Space Research.

Organizing Committee: R. Agarwal (Singapore), A. E. Babayev (Kiev), O. G. Cheborin (Kiev), J. Diblik (Brno, Czech Republik), D. Ya. Khusainov (Kiev), Y. A. Komarov (Kiev), A. T. Kozhametov (Uzbekistan), A. G. Mazko (Kiev), E. O. Tsitritsky (Kiev).

Invited Speakers: R. Agarwal (Singapore), S. N. Chow (Atlanta, USA), A. Friedman (Minnesota, USA), K. P. Hadeler (Tubingen, Germany), A. Iserles (Cambridge, England), I. Kiguradze (Tbilisi, Georgia), T. Kusano (Fukuoka, Japan), J. Mawhin (Louvain-La-Neuve, Belgium), F. Neuman (Brno, Czech Republic), I. Prigogine (Brussels, Belgium), G. Sell (Minneapolis, USA), R. Teman (Orsay, France).

Purpose: The purpose of the conference is to bring together leading experts from all over the world to present their recent achievements, and discuss and share new ideas relevant to their fields. The conference will feature invited lectures by well-known speakers from different countries, as well as talks on topics of current interest in the field. Sessions will be organized for contributed papers.

Topics: The conference will cover the following topics: (1) Mathematical methods of stability investigation; (2) Mathematical modeling of processes. Contributed papers will be accepted based on the abstracts.

Registration: Registration fee is $50 ($10 for participants from CIS countries), which includes a free copy of the Book of Abstracts.

Deadline: The deadline is March 15, 1999.

Abstracts: Please check our Web site at http://www.pcg.kiev.ua/conf/ for an abstract template in LaTeX format. Otherwise please send your abstract in the following form to the address below or e-mail in Word format. The abstract should have left and right margins of 3 cm, and should be camera-ready for printing.

Information: Please contact us at: DSMSI'99 Conference, Dept. of Complex System Simulation, Faculty of Cybernetics, Kiev University, Vladimirskaya str., 64, 252033, Kiev, Ukraine; e-mail: conf@stab.cyb.univ.kiev.ua; http://www.pcg.kiev.ua/conf/; tel: (380 44) 266 4086; Fax: (380 44) 266 1059.

26-28 **Crystallographic Groups and their Generalizations II**, K. U. Leuven (Campus Kortrijk), Kortrijk, Belgium. (Aug. 1998, p. 899)

26–29 **Third International Conference on Dynamic Systems and Applications**, Atlanta, Georgia. (Sept. 1998, p. 1051)

26–29 **Twelfth Biennial Conference of the Association of Christians in the Mathematical Sciences**, Gordon College, Wenham, MA. (Oct. 1998, p. 1229)

26–30 **Great Plains Operator Theory Symposium**, Iowa State University, Ames, Iowa. (Feb. 1999, p. 276)

27–29 **Mathematics Towards The Third Millennium**, Accademia Nazionale dei Lincei, Rome, Italy. (Oct. 1998, p. 1230)

29–June 1 **CMS Summer 1999 Meeting**, Memorial University of Newfoundland, St. John's, Newfoundland. (Feb. 1999, p. 276)

*30–June 5 **Spring School on Analysis**, Paseky nad Jizerou, Czech Republic.
Organizers: J. Lukes, L. Pick (Charles University, Prague, Czech Republic).
Topic: Function spaces and their applications.
Aim: The purpose of this meeting is to bring together adepts who share a common interest in the field. Graduate students and others beginning their mathematical careers are encouraged to participate.
Speakers: J. Appell (Universitaet Wuerzburg, Germany), Nonlinear Operators in Function Spaces; E. Pustylnik (Technion-Israel Institute of Technology, Haifa, Israel), The Structure of Intermediate Spaces and Real Interpolation; C. Perez (Universidad Autonoma de Madrid, Spain), Poincare-Sobolev Inequalities and Weighted Estimates for Singular Integral Operators and Fractional Integrals.
Information: Department of Mathematical Analysis, Sokolovska 83, 18675 Praha 8, Czech Republic; e-mail: pasejune@karlin.mff.cuni.cz; tel/fax: +420-2-232-3390; http://www.karlin.mff.cuni.cz/katedry/kma/ss.

*31–June 4 **Partial Differential Equations Meeting**, Saint Jean de Monts, France.
Scientific Committee: A. Bachelot, J.-M. Bony, J.-Y. Chemin, F. Colombini, B. Davies, A. Grigis, G. Grubb, B. Helffer, L. Hörmander, A. Melin, G. Métivier, J. Nourrigat, D. Robert.
List of Speakers: P. G. Ciarlet (Paris 6), H. Hedenmalm (Lund), R. Mazzeo (Stanford), V. Maz'ya (Linkoping), G. Popov (Nantes), M. Pulvirenti (Rome), S. Schochet (Tel Aviv), A. Shnirelman (Tel Aviv), D. Tataru (Northwestern Univ.), A. Uribe (Michigan), G. Velo (Bologna), E. Zuazua (Aut. Madrid).
Information: The Village Vacances Familles of St. Jean de Monts will provide lodging facilities (cost 1 450FF). Registration and information soon available at http://www.maths.univ-rennes1.fr/edp/stjean.html.

31–June 4 **The 19th International Conference on Distributed Computing Systems (ICDCS '99)**, Austin, Texas. (Nov. 1998, p. 1377)

31–June 4 **Turku Symposium on Number Theory in Memory of Kustaa Inkeri**, University of Turku, Finland. (Sept. 1998, p. 1051)

June 1999

1–3 **International Conference on Differential Equations and Related Topics**, Pusan National University, Pusan, Korea. (Jan. 1999, p. 66)

1–4 **Day on Diffraction'99**, St. Petersburg Branch of Steklov Mathematical Institute, St. Petersburg, Russia. (Nov. 1998, p. 1377)

*2–4 **Joint DIMACS-DIMATIA Workshop on Algebraic Methods and Arithmetic Circuits**, DIMACS Center, Rutgers University, Piscataway, New Jersey.
Organizers: E. Allender (allender@cs.rutgers.edu), J. Krajicek (krajicek@math.cas.cz), P. Pudlak (pudlak@matsrv.math.cas.cz), M. Saks (saks@math.rutgers.edu).
Aim: This workshop will bring together people working with algebraic methods and arithmetic circuits as they relate to diverse areas of theoretical computer science, including the complexity of propositional proof systems (propositional, algebraic, and others), algebraic and symbolic computation, complexity of computing over the reals and other fields (along with connections to the model theory of fields), and connections to Boolean circuit complexity and the study of complexity classes.
Local Arrangements: P. Pravato (pravato@dimacs.rutgers.edu), 732-445-5928.
Information: Contact E. Allender (allender@cs.rutgers.edu); WWW: http://dimacs.rutgers.edu/Workshops/DIMATIAII/.

3–5 **Applications of Heavy Tailed Distributions in Economics, Engineering and Statistics**, American University, Washington, DC. (Jan. 1999, p. 66)

4–9 **Geometry, Analysis & Mathematical Physics: Analysis & Geometry**, Obernai (near Strasbourg), France. (Jan. 1999, p. 66)

6–19 **Second Summer School of Mathematical Biology**, Termoli, Italy. (Feb. 1999, p. 276)

7–9 **Theoretical, Experimental & Computational Mechanics**, Cincinnati, Ohio. (Oct. 1998, p. 1230)

7–11 **11th International Conference on Formal Power Series and Algebraic Combinatorics (FPSAC'99)**, Universitat Politecnica de Catalunya, Barcelona, Spain. (Feb. 1999, p. 276)

7–11 **From Individual to Aggregration: Modeling Animal Grouping**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

7–11 **International Society of The Arts, Mathematics, and Architecture (ISAMA99)**, San Sebastian, Spain. (Jan. 1999, p. 67)

7–11 **Random Matrices and Their Applications: Quantum Chaos, GUE Conjecture for Zeros of Zeta Functions, Combinatorics, and All That**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 760)

7–11 **Second IMACS Conference on Monte Carlo Methods**, Varna, Bulgaria. (Sept. 1998, p. 1051)

10–12 **1999 International Conference on Preconditioning Techniques for Large Sparse Matrix Problems in Industrial Applications**, University of Minnesota, Hubert H. Humphrey Institute, Minneapolis, Minnesota. (Nov. 1998, p. 1378)

13–17 **Conference on The Mathematics of Public-Key Cryptography**, The Fields Institute, Toronto, Ontario, Canada. (Sept. 1998, p. 1051)

*13–17 **Computability Theory and Applications (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado.
Information: See http://www.ams.org/meetings/src.html for more information.

*13–17 **From Manifolds to Singular Varieties (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado.
Information: See http://www.ams.org/meetings/src.html for more information.

14–19 **MATHTOOLS'99, 2nd International Conference "Tools for Mathematical Modelling"**, Saint-Petersburg State Technical University, Saint-Petersburg, Russia. (Dec. 1998, p. 1501)

*16–19 **Theoretical Fluid Dynamics and Related Topics**, Centro de Matemática e Aplicações Fundamentais da Universidade de Lisboa, Lisbon, Portugal.
Focus: In the last decades there have been remarkable advancements in the study of nonlinear partial differential equations, motivated not only by the twentieth century developments in pure and applied mathematics, but also by the industrial modelling and scientific progress. New theories and techniques have been developed to address the search for classical and generalized solutions for equations or systems of partial differential equations, and their qualitative properties such as regularity or asymptotic behavior. Most of these questions are still poorly understood and new emerging issues in physical sciences, mathematical finance, and other applied disciplines proved a test for known theories and an inspirational source for the introduction of new ones.
Scientific Organizers: H. Beirão da Veiga (Univ. Pisa), A. Sequeira (Inst. Sup. Técnico) and V. A. Solonnikov (Univ. Lisboa and POMI St. Petersburg).
Support: A certain number of grants for young mathematicians, as well as for other scientists, will be available for participation at the meetings and for short or medium stays in Lisbon to stimulate joint collaboration and research.

Information: M. Morales, NPDEA-99 secretariat, CMAF/Univ. de Lisboa, Av. Prof. Gama Pinto 2, 1699 Lisboa Codex, Portugal; e-mail: npde99@lmc.fc.ul.pt; http://npde99.lmc.fc.ul.pt/; tel: 351-1-790-48-62; fax: 351-1-795-42-88.

17-20 **Six Projects in Mathematics and Physics-A Cooperation Project between Scientists from the CIS and Germany**, Technische Universitaet Berlin, Germany. (Aug. 1998, p. 899)

*20-24 **Homotopy Methods in Algebraic Topology (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado.
Information: See http://www.ams.org/meetings/src.html for more information.

20-24 **The Sixth Conference of The Canadian Number Theory Association (CNTA '99)**, University of Manitoba, Winnipeg, Canada. (Jan. 1999, p. 67)

21-25 **International Workshop on Special Functions: Asymptotics, Harmonic Analysis, and Mathematical Physics**, City University of Hong Kong, Hong Kong, China. (Nov. 1998, p. 1378)

21-July 2 **Computational Algebra With Applications**, University of Wyoming, Laramie, Wyoming. (Jan. 1999, p. 67)

23-25 **Bar-Ilan Symposium on The Foundations of Artificial Intelligence (BISFAI-99)**, Ramat Gan, Israel. (Jan. 1999, p. 67)

*23-26 **Nonlinear Modeling and Control, An International Seminar**, Nayanova University, Samara, Russia.
Languages: English and Russian.
Aim: The seminar's aim is the exchange of information about recent trends in mathematical modeling and control theory and their applications to various problems in physics, chemistry, biology, medicine, economy, and industrial concerns.
Call For Papers: Original papers related to the aim of seminar are solicited. Potential speakers should submit an abstract before April 30. The cover page should contain title, affiliation, and e-mail address of each author. Electronic submissions in LaTeX are encouraged.
Sponsors: Samara Municipal Nayanova University, Samara State University, Russian Academy of Natural Sciences, International Federation of Nonlinear Analysts.
Information: V. Sobolev (organizer, e-mail: sable@ssu.samara.ru or sobolev@gw.mnu.samara.ru) or He. Gorelova (seminar coordinator), e-mail: modeling@ssu.samara.ru; Nayanova University, Molodogvardeiskaya 196, Samara, 443001,Russia.

25-30 **Intermediate Questions of Model Theory and Universal Algebra**, Novosibirsk State Technical University & Math. Institute of Siberian branch of Academy of Russia, Novosibirsk, Russia. (Sept. 1998, p. 1052)

*25-30 **Number Theory and Arithmetical Geometry: Arakelov Geometry and Applications**, Obernai(near Strasbourg), France.
Organizers: J.-B. Bost (chairman, Orsay), U. Jannsen (vice-chairman, Cologne) in association with the European Mathematical Society.
Speakers: A. Abbes (Paris-Nord), J.-M. Bismut (Orsay), J. I. Burgos (Barcelona), P. Cohen (Lille), S. David (Paris), R. Ferretti (Zürich), C. Gasbarri (Cologne), H. Gillet (Chicago), H. Köhler (Bonn), J. Kramer (Berlin), S. S. Kudla (Maryland), K. Künnemann (Cologne), J.-H. Evertse (Leiden), V. Maillot (Paris), M. McQuillan (Oxford), D. Roessler (Bures-sur-Yvette), L. Szpiro (Orsay), H. Tamvakis (Philadelphia), E. Ullmo (Orsay), P. Vojta (Berkeley).
Focus: The conference will focus on: Foundational results in Arakelov geometry: hermitian geometry and analysis on complex manifolds, intersection theory and Riemann-Roch theorems; Applications to diophantine approximation; Arakelov geometry of abelian varieties and their moduli spaces.
Participation: The conference is open to researchers worldwide, whether from industry or academia. Participation will be limited to 100. The emphasis will be on discussion about new developments. A poster session will be organized. The registration fee covers full board and lodging. Grants will be available for younger scientists, in particular those from less favored regions in Europe.
Deadline: Application deadline: March 22, 1999.
Information: For information and application forms, contact the head of the EURESCO Unit: J. Hendekovic, European Science Foundation, 1 quai Lezay-Marnésia, 67080 Strasbourg Cedex, France; tel: +33-3-88-76-71-35; fax: +33-3-88-36-69-87; e-mail: euresco@esf.org; on-line information and application on WWW at http://www.esf.org/euresco/.

*26-July 2 **Algebra and Discrete Mathematics, Infinite Combinatorics and their Impact on Algebra**, Hattingen, Germany.
Organizers: R. Göbel (vice-chairman, Essen), S. Shelah (chairman, Jerusalem) in association with the European Mathematical Society.
Speakers: B. Balcar (Prague), A. Blass (Michigan), J. Brendle (Kobe, Japan), M. Droste (Dresden), M. Dugas (Waco, Texas), M. Dzamonja (Norwich), P. Eklof (Irvine), M. Goldstern (Vienna), R. Grossberg (Pittsburgh), W. Hodges (London), E. Hrushovsky (IHES & Jerusalem), T. Hyttinen (Helsinki), M. Kojman (Negev, Israel), P. Komjath (Budapest), S. Koppelberg (Berlin), M. C. Laskowski (Maryland), C. Metelli (Napoli), D. Monk (Colorado), O. Spinas (Zürich), S. Thomas (New York), B. Velickovic (Paris), M. Ziegler (Freiburg).
Focus: The conference will focus on combinatorial methods and results in set theory and their application to algebra. It will emphasize recent advances in cardinal arithmetic and highlight the interplay between these aspects of set theory and various subfields of algebra. This interplay is particularly significant for commutative algebra and module theory. Some recent exciting results will be developed explicitly by invited speakers who have research backgrounds in either logic or algebra. The central goal of the meeting will be to enhance this type of interaction between algebra and infinite combinatorics.
Participation: The conference is open to researchers world-wide, whether from industry or academia. Participation is limited to 100. The emphasis will be on discussion about new developments. A poster session will be organized. The registration fee covers full board and lodging. A limited number of grants will be available upon request.
Deadline: Application deadline: March 1, 1999.
Information: For information and application forms, contact the head of the EURESCO unit: J. Hendekovic, European Science Foundation, 1 quai Lezay-Marnésia, 67080 Strasbourg Cedex, France; tel: +33-3-88-76-71-35; fax: +33-3-88-36-69-87; e-mail: euresco@esf.org; on-line information and application on WWW at http://www.esf.org/euresco/.

27-July 1 **1999 Summer Conference on Brauer Groups**, University of Montana, Missoula, Montana. (Jan. 1999, p. 67)

27-July 4 **ACACSE'99: Applied Clifford Algebra in Cybernetics, Robotics, Image Processing and Engineering International Workshop as a Special Parallel Session of the 5th International Conference on Clifford Algebras and their Applications in Mathematical Physics**, Ixtapa, Zihuatanejo, Mexico. (Jan. 1999, p. 67)

27-July 25 **Summer Mathematics Program for Undergraduate Women**, Carleton and St. Olaf Colleges, Northfield, Minnesota. (Feb. 1999, p. 277)

*28-30 **International Conference on Geometry**, University of Porto, Portugal.
Speakers: There will be one-hour invited lectures given by the following speakers: L. Cordero (Universidad de Santiago de Compostela), A. Costa (UNED, Madrid), R. Donagi (Univ. of Pennsylvania), T. Monteiro Fernandes (Universidade de Lisboa), I. Penkov (Univ. of California, Riverside), J. Rhodes (Univ. of California, Berkeley). The program of the conference will also include sessions for shorter communications (30 minutes).
Organizers: G. Chaves, P. Gothen, L. Magalhaes.
Support: Supported by the Fundacao para a Ciencia e a Tecnologia.
Information: If you wish to receive the second announcement, to be available in February 1999, please send a message with your name and e-mail address to agc99@fc.up.pt. For more information, please contact

the Organizing Committee at agc99@fc.up.pt, or see the Web page: http://www.fc.up.pt/mp/agc99.htm.

* 28-July 2 **Fourth Hungarian Colloquium on Limit Theorems in Probability and Statistics**, Balatonlelle, Hungary.
Aim: To honour 65th birthday of Pal Revesz.
Organizing Committee: I. Berkes, E. Csaki, A. Foldes, T. Mori, D. Szasz.
Information: e-mail: limit@math-inst.hu; Web: http://www.math-inst.hu/~limit/.

* 28-July 2 **Nonlinear Partial Differential Equations: An International Conference in Memory of S. N. Kruzhkov**, Université de Franche-Comté, Besançon, France.
Aim: S. N. Kruzhkov (1936-1997), professor at the M. V. Lomonosov Moscow State University, greatly influenced the theory of nonlinear partial differential equations by many important and very original contributions. The objective of this international conference is to pay just tribute to his memory, by presenting recent developments in the domains where his ideas are particularly fruitful.
Steering Committee: N. S. Bakhvalov, M. G. Crandall, C. M. Dafermos, P. -L. Lions, O. A. Oleinik.
Topics: Conservation laws; Hamilton-Jacobi equations and viscosity solutions; Entropic solutions and renormalized solutions; Nonlinear parabolic problems; Korteweg-de Vries equation.
Speakers: Plenary lectures will be delivered by the members of the steering committee and: A. Bressan (Trieste), X. Cabré (Barcelone), Th. Gallouët (Marseille), A. S. Kalashnikov (Moscow), C. E. Kenig (Chicago), S. Luckhaus (Leipzig), F. Otto (Santa Barbara), E. Yu. Panov (Novgorod), D. Serre (Lyon), I. V. Skrypnik (Donetsk), H. M. Soner (Princeton), P. E. Souganidis (Madison), L. G. Tartar (Pittsburgh), J. L. Vazquez (Madrid).
Deadline: For submissions: March 21, 1999.
Scientific Committee: C. Bardos (Paris), G. Barles (Tours), Ph. Bénilan (Besançon), J. Carrillo (Madrid), V. L. Kamynin (Moscow), F. Murat (Paris), B. Perthame (Paris).
Organizing Committee: B. Andreianov, L. Barthélemy, A. Benabdallah, Ph. Bénilan, J. -C. Miellou, M. Mokhtar-Kharroubi, F. Simondon; secretaries: M. Diguglielmo, C. Pagani.
Registration Fees: FF 500 (FF 600 if paid after May 16, 1999).
Registration: Use the Web page for on-line registration or send the pre-registration form (available on the Web site as PostScript) to Mme. Diguglielmo, Équipe de Mathématiques, Université de Franche-Comté, 25030 Besançon Cedex, France - fax (33)3.81.66.65.26.
Information: For further information consult the Web page http://pegase.univ-fcomte.fr/Actu/Index.html or contact the organizing committee by e-mail: SNKConf@math.univ-fcomte.fr, or by telephone (33)3.81.66.63.40.

29-July 3 **Theory and Mathematics in Biology and Medicine (TMBM99)**, Vrije Universiteit, Amsterdam, The Netherlands (Sept. 1998, p. 1052)

* 30-July 1 **International Workshop on Implicit Computational Complexity (ICC'99)**, Trento, Italy.
Aim: The mission of ICC'99 is to further the development of implicit computational complexity and its applications, in particular in database theory, functional programming languages, and formal methods in hardware and software design. In addition to research reports on advances in implicit computational complexity, the workshop will strive to facilitate the discovery of conceptual bridges and unifying principles.
Format: The workshop will meet on Wednesday, June 30, and Thursday, July 1, 1999, preceding LICS'99 and RTA'99. The program will consist of about 6 invited talks and sessions of contributed papers. The last workshop event will be a session of invited talks in finite model theory, joint with two other FLoC workshops: "Complexity-theoretic and Recursion-theoretic methods in Databases, Artificial Intelligence and Finite Model Theory" and "Finite Model Theory And Its Applications".
Topics: The workshop is dedicated to the characterization, analysis, comparison, development, and implementation of computational complexity issues within the following areas and approaches: Descriptive complexity (finite model theory); proof theory (e.g. bounded arithmetic, other weak theories, weak higher order logics, linear logic); applicative formalisms (e.g. function algebras, ramified recurrence, control mechanisms in lambda calculi).
Submissions: Proposed contributions to the workshop program are keenly sought. The results must be unpublished and not submitted for publication elsewhere. However, papers submitted to LICS'99 may also be submitted to ICC'99; acceptance to LICS (announced well before acceptance to ICC) will take precedence. One author of each accepted paper is expected to present the paper at the meeting.
Important Dates: Submission deadline: Tuesday, March 2, 1999; acceptance notifications: by Wednesday, March 31; workshop dates: June 30 and July 1; LICS'99 dates: July 2 through 5; FLoC (conferences, workshops, tutorials): June 30 through July 12.
Program Committee: S. Bellantoni (Toronto), S. Buss (San Diego), R. Constable (Cornell), S. Cook (Toronto), A. Dawar (Cambridge, co-chair), E. Graedel (Aachen), Y. Gurevich (Microsoft), L. Hella (Helsinki), N. Jones (DIKU Copenhagen), C. Lautemann (Mainz), D. Leivant (Indiana, co-chair), H. Schwichtenberg (Munich), J. Tyszkiewicz (Warsaw and New South Wales).
Information: http://icc99.cs.indiana.edu/.

* 30-July 2 **First International Symposium on Imprecise Probabilities and Their Applications**, Ghent, Belgium.
Themes: The first symposium will emphasize two main themes: (i) The connections between the various mathematical theories of imprecise probability and the possibility of achieving some kind of unification or synthesis; (ii) applications to other fields: Important work has already been done in statistics, economics, finance, experimental psychology, artificial intelligence and expert systems, engineering, systems theory, reliability, robotics and other fields, and it is expected that some of this work will be surveyed at the symposium.
Information: Those wishing to present a paper at the symposium should submit a short paper of 4 to 10 pages by 31 January 1999. We expect electronic submissions, in Postscript format. Papers should be sent to the symposium e-mail address: isipta99@ensmain.rug.ac.be. Please see the symposium Web site http://ensmain.rug.ac.be/~isipta99/ for detailed instructions about how to submit papers and for further information about the symposium.

July 1999

2-5 **Fourteenth Annual IEEE Symposium on Logic in Computer Science**, Trento, Italy. (Dec. 1998, p. 1501)

2-10 **The 1999 Federated Logic Conference (FLoC '99)**, Trento, Italy. (Sept. 1998, p. 1052)

* 4-9 **Geometry and Quantization of Symplectic Manifolds and Quantum Integrable Systems**, Centro Stefano Franscini, Ascona, Switzerland.
Topics: Geometry and quantization of symplectic and Poisson manifolds, (quantum) group actions, quantum integrable systems.
Organizers: A. Alekseev (Uppsala), G. Felder (Zurich).
Speakers: B. Enriquez (Ecole Polytechnique), P. Etingof (Harvard), E. Frenkel (Berkeley), I. Frenkel* (Yale), K. Gawedzki (IHES), V. Guillemin (MIT), L. Jeffrey (Toronto), M. Jimbo (Kyoto), M. Kontsevich* (IHES), B. Kostant (MIT), E. Meinrenken (Toronto), T. Ratiu (Lausanne), M. Semenov-Tian-Shansky (Dijon), A. Varchenko (Chapel Hill), M. Vergne (Paris), A. Veselov (Loughborough), C. Woodward (Rutgers); *to be confirmed.
Deadline: April 15, 1999. Participation is limited to 60 persons.
Information: http://www.math.ethz.ch/~felder/CSF99/.

4-11 **Paul Erdős and His Mathematics**, Hungarian Academy of Sciences, Budapest, Hungary. (Jan. 1999, p. 68)

5-9 **The Fourth International Congress on Industrial and Applied Mathematics**, Edinburgh, Scotland. (Dec. 1997, p. 1500)

* 5-9 **Quadratic Forms and Their Applications**, University College, Dublin, Ireland.
Support: The conference is supported by the European Union under the auspices of

the TMR network project "K-theory, linear algebraic groups and related structures". Some financial support is available, particularly for young researchers from EU states.
Aim: The aim of the meeting is to bring together mathematicians who are either specialists in quadratic forms and related topics, or use them in their research. There will be 12 1-hour survey lectures and a number of shorter research talks.
Speakers: A. Berge (Bordeaux), J. J. Boutros (Paris), J. H. Conway (Princeton), D. Hoffmann (Besancon), C. Kearton (Durham), M. Kreck (Mainz/Oberwolfach), R. Parimala (Bombay), M. Rost (Regensburg), W. Scharlau (Muenster), J. P. Serre (Paris), M. Taylor (Manchester), C. T. C. Wall (Liverpool).
Organizers: E. Bayer-Fluckiger (Besancon, bayer@math.univ-fcomte.fr), D. Lewis (Dublin, dwlewis@ollamh.ucd.ie), A. Ranicki (Edinburgh, aar@maths.ed.ac.uk).
Information: Electronic registration: http://mathsa.ucd.ie/TMR/quadconf.html.

7-17 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota. (Mar. 1998, p. 427)

8-9 **100 Years After Sophus Lie**, University of Leipzig, Leipzig, Germany. (Feb. 1999, p. 277)

9-17 **Computation in Group Theory and Geometry**, University of Warwick, Coventry, England. (Jan. 1999, p. 68)

11-August 15 **Seventh Annual Canada/USA Mathcamp**, University of Washington, Seattle, Washington. (Dec. 1998, p. 1502)

12-16 **First International Joint Meeting of the American Mathematical Society and the Australian Mathematical Society**, Melbourne, Australia. (Nov. 1998, p. 1378)

12-17 **Journees Arithmetiques 1999**, Rome, Italy. (May 1998, p. 642)

12-18 **Third International Conference on Symmetry in Nonlinear Mathematical Physics**, Kiev, Ukraine. (Jan. 1999, p. 68)

13-16 **International Conference on Applied Partial Differential Equations**, Tongji University, Shanghai, China. (Oct. 1998, p. 1230)

15-17 **Applications of Physics in Financial Analysis**, Trinity College, Dublin, Ireland. (Feb. 1999, p. 277)

16-18 **ESA'99 - Seventh Annual European Symposium on Algorithms**, Prague, Czech Republic. (Jan. 1999. p. 68)

16-18 **Olga Taussky Todd Celebration of Careers in Mathematics for Women**, Mathematical Sciences Research Institute, Berkeley, California. (Jan. 1999, p. 68)

18-23 **Vision Geometry VIII (SD90)**, Colorado Convention Center, Denver, Colorado. (Jan. 1999, p. 69)

*18-28 **Foundations of Computational Mathematics (FoCM)**, University of Oxford, Oxford, England.
Speakers: J. Ball (Oxford), I. Daubechies (Princeton), J.-P. Dedieu (Toulouse), A. Edelman (MIT), J. Heintz (Buenos Aires), N. Higham (Manchester), R. McLachlan (Massey), J. Nocedal (Northwestern), E. Novak (Erlangen), P. Olver (Minneapolis), B. Poonen (UC Berkeley), R. Rannacher (Heidelberg), G. Sapiro (Minneapolis), A. Stuart (Stanford), D. Talay (Sophia Antipolis), W. Thurston (UC Davis), L. Valiant (Harvard), S.-T. Yau (Harvard).
Workshops: Nonplenary lectures will be held in fourteen workshops, spanning a broad range of mathematical topics. The workshops are: Analysis and approximation of infinite-dimensional problems; Approximation theory; Complexity theory, real machines and homotopy; Computational dynamics; Computational geometry and topology; Computational number theory; Geometric integration and computation on manifolds; Information-based complexity; Multiresolution, computer vision and PDEs; Numerical linear algebra; Optimization; Relations to computer science; Stochastic computation; Symbolic algebra and analysis.
Information: See http://www.dampt.cam.ac.uk/user/na/FoCM/ for details.

*19-December 17 **Structure Formation in the Universe**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.
Organizers: V. A. Rubakov (Institute for Nuclear Research, Moscow), P. J. Steinhardt (Pennsylvania), N. G. Turok (Cambridge).
Objective: Understanding how structure emerged in the universe provides one of today's great scientific challenges. Huge quantities of new astronomical data, including maps of the cosmic microwave sky fluctuations and of the distribution of galaxies, are providing stringent constraints on possible theories. At the same time, the results of new particle physics experiments are beginning to imply very strong constraints on the possible nature of the dark matter. The two structure formation theories investigated in most detail so far involve quantum fluctuations generated during inflation, and cosmic defects produced at symmetry breaking phase transitions. Both theories involve physics beyond the standard model, and if either is proven correct, there will be important implications for high energy theory.
Topics: The program will begin with discussions of the latest observational data, including the statistical techniques needed to analyze the new data sets, with the aim of fitting the observations together in a coherent framework. Extensions and variants of current theories, as well as entirely novel approaches will then be considered. During the program, fundamental questions regarding the big bang and inflationary theory will be addressed, as well as connections to string theory and quantum gravity.
Information: Contact the Director, Isaac Newton Institute for Mathematical Sciences, 20 Clarkson Road, Cambridge CB3 0EH, UK; tel: 01223-335999; e-mail: info@newton.cam.ac.uk. Information can also be found on the World Wide Web at the URL http://www.newton.cam.ac.uk/.

*20-24 **IMA "HOT TOPICS" Workshop: Decision Making Under Uncertainty: Energy and Environmental Models**, Institute for Mathematics and Its Applications, University of Minnesota, Minneapolis, Minnesota.
Organizers: F. Auzerais, B. Burridge, C. Greengard, R. Wets.
Information: Institute for Mathematics and Its Applications, Univ. of Minnesota, 207 Church St. S.E., 400 Lind Hall, Minneapolis, MN 55455; Phone: 612-624-6066, e-mail: staff@ima.umn.edu or Web page: http://www.ima.umn.edu/decision-making/decision-making.html.

*25-30 **DO'99, A DIMACS/RUTCOR Workshop on Discrete Optimization**, Rutgers University, Piscataway, New Jersey.
Goal: The main goal of DO'99 is to survey the state of the art in discrete optimization.
Speakers: Expository lectures presenting the major subareas of the field, including its theoretical foundations, methodology and applications will be given by E. Balas, E. Boros, P. Brucker, R. Burkard, V. Chvatal, G. Cornuejols, Y. Crama, F. Glover, P. Hammer, A. Hoffman, K. Hoffman, T. Ibaraki, B. Korte, J. Krarup, T. Magnanti, S. Martello, G. Nemhauser, B. Pulleyblank, A. Recski, P. Toth, D. Williamson, H. Wolkowicz, and L. Wolsey. DO'99 will also feature a series of sessions for contributed papers representing the latest research results in the field.
Organizers: E. Boros (boros@rutcor.rutgers.edu), P. L. Hammer (hammer@rutcor.rutgers.edu).
Information: Additional information can be found on the internet at http://rutcor.rutgers.edu/~do99/. Abstracts of papers intended for possible presentation at DO'99 should be sent to DO'99 (DO'99@rutcor.rutgers.edu) or: DO'99 - RUTCOR, Rutgers Univ., 640 Bartholomew Road, Piscataway, NJ 08854. For registration and information, please contact the organizers.

25-August 7 **The 14th International Conference on Banach Algebras**, Pomona College, Claremont, California. (Sept. 1998, p. 1052)

*26-30 **Conference on Functional Differential and Difference Equations**, Instituto Superior Técnico, Lisbon, Portugal.
Organizers: T. Faria (Universidade de Lisboa), J. M. Ferreira e Pedro Freitas (Center for Mathematical Analysis, Geometry and Dynamical Systems, IST).
Invited Speakers: O. Arino (Pau), W. Fitzgibbon (Houston), I. Gyori (Veszprém), J. K. Hale (Georgia Tech.), W. Huang (Alabama), T. Krisztin (Szeged), G. Ladas (Rhode Island), S. Lunel (Amsterdam), M. Mackey (McGill), J. Mallet-Paret (Brown), R. Nussbaum (Rutgers), W. Oliva (Lisbon), G. Sell (Minnesota),

G. Wirsching (Eichstätt), J. Wu (Toronto).
Registration and Deadlines: Participants should send an application to the organizers not later than March 15, 1999. Please use the registration form on the WWW address below. Titles and abstracts for 25-minute contributed talks are due by April 5, 1999. The registration fee is 5,000 Portuguese Escudos (free for students).
Information: For additional information please contact the organizers at: Dep. Matemática, Instituto Superior Técnico, Av. Rovisco Pais 1, P-1096 Lisboa, Portugal; fax: 351-1-3523014; e-mail: fdde99@math.ist.utl.pt; WWW: http://www.math.ist.utl.pt/fdde99/.

26-30 **ENUMATH 99 - Third European Conference on Numerical Mathematics and Advanced Applications**, University of Jyvaskyla, Jyvaskyla, Finland. (Sept. 1998, p. 1052)

* 26-30 **International Conference on Theory of Fixed Points and its Applications**, São Paulo, Brazil.
Scientific Committee: R. F. Brown (chair), A. Dold, E. Fadell, D. L. Gonçalves, B. Jiang.
Organizing Committee: L. Borsari, D. L. Gonçalves (co-chair), P. Wong (co-chair).
Aim: The purpose of this conference is to bring together mathematicians working in the field of topological fixed point theory and related subjects, to exchange ideas and to present results of their current research. The focus will be on applications of Lefschetz/Nielsen theory as well as on new techniques that contribute to the advancement of topological fixed point theory.
Information: Details of the conference as well as the registration form are available on the Web page: http://www.ime.usp.br/~fixpoint/. To contact the organizing committee use the e-mail address: fixpoint@ime.usp.br; or the regular address: D. L. Gonçalves, Departamento de Matemática - IME-USP, Caixa Postal 66281 - Agencia Cidade de São Paulo, 05315-970 - São Paulo - SP - Brasil; e-mail: dlgoncal@ime.usp.br.

26-August 6 **SMS-NATO ASI: Integrable Systems: From Classical to Quantum**, Université de Montréal, Montréal, Canada. (Jan. 1999, p. 69)

* 26-August 13 **School on Algebraic Geometry**, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.
Directors: L. Göttsche (ICTP), J. Le Potier (Université de Paris VII, France), E. J. N. Looijenga (University of Utrecht, The Netherlands), M. S. Narasimhan (ICTP).
Deadline: Deadline for requesting participation: February 15, 1999.
Information: Abdus Salam International Centre for Theoretical Physics, Strada Costiera, 11-34014 Trieste, Italy; tel: +39-40-2240111; fax: +39-40-224163; e-mail: sci_info@ictp.trieste.it; http://www.ictp.trieste.it/.

* 27-August 1 **Loops'99**, Czech University of Agriculture, Prague, Czech Republic.
Focus: The number of new results in loop theory is steadily increasing and many of them deserve wider dissemination.
Program Committee: O. Chein, A. Drapal, M. Kinyon, H. Pflugfelder.
Organizing Committee: T. Kepka, P. Nemec, J. D. Phillips.
Speakers: J. O. Ademiran, M. Akivis, M. Arkowitz, T. Bouetou, L. G. X. de Barros, A. Drapal, T. Foguel, V. V. Goldberg, E. Goodaire, O. Chein, M. Herzog, B. Im, R. Iordanescu, E. Jespers, K. W. Johnson, F. Kalhoff, T. Kepka, M. Kinyon, A. Kreuzer, K. Kunen, M. de Lourdes, G. E. Moorhouse, P. Nemec, A. Nesterov, E. Paal, H. Pflugfelder, J. D. Phillips, C. Polcino-Millies, G. Rosenberger, L. Sabinin, T. Q. Sibley, A. R. T. Solarin, J. Stasheff, K. Strambach, B. Tasic, A. A. Ungar, H. Urbantke.
Fees: The conference fee is $50 (paid on arrival). The price of accommodation (in well-equipped student dormitories) will be approximately $15 per person per night in a double room and in a single room (these prices may change).
Information: If you are interested in this conference and wish to obtain further information, please contact (preferably by e-mail) any member of the local organizing committee: T. Kepka, Department of Algebra MFF UK, Sokolovska 83, 186 00 Praha 8, The Czech Republic, e-mail: kepka@karlin.mff.cuni.cz; P. Nemec, Department of Mathematics, TF CZU Kamycka 129, 165 21 Praha 6 - Suchdol, The Czech Republic, e-mail: nemec@karlin.mff.cuni.cz or nemec@tf.czu.cz; Web page: http://www.karlin.mff.cuni.cz/~loops99/.

30-August 1 **The Second Annual Conference of Bridges: Mathematical Connections in Art, Music, and Science**, Southwestern College, Winfield, Kansas. (Jan. 1999, p. 69)

August 1999

August-December **MSRI Program in Galois Groups and Fundamental Groups**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1053)

August-May 2000 **MSRI Program in Noncommutative Algebra**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1053)

1-6 **1999 ASL European Summer Meeting (Logic Colloquium '99)**, Utrecht, The Netherlands. (Jan. 1999, p. 69)

1-7 **EQUADIFF 99**, Free University, Berlin, Germany. (Nov. 1998, p. 1378)

2-13 **IMA Summer Program: IMA Workshop on Codes, Systems and Graphical Models**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

8-14 **Second International Conference on Boundary Value Problems, Integral Equations and Related Problems**, Chengde, Hebei, and Beijing, China. (Feb. 1999, p. 277)

9-14 **Gyorgy Alexits Memorial Conference**, Budapest, Hungary. (Jun/Jul. 1998, p. 760)

9-20 **Summer School on Empirical Processes**, University of Aarhus, Denmark. (Dec. 1998, p. 1502)

10-15 **International Conference on Mathematical Logic**, Novosibirsk, Russia. (Jan. 1999, p. 69)

16-18 **Conference in Honor of Daniel J. Kleitman's 65th Birthday**, M.I.T., Cambridge, Massachusetts. (Dec. 1998, p. 1502)

16-21 **International Conference on Differential and Functional Differential Equations**, Moscow, Russia. (Feb. 1999, p. 278)

* 16-27 **Symposium on Arithmetic Fundamental Groups and Noncommutative Algebra**, Mathematical Sciences Research Institute, Berkeley, California.
Funding: The symposium is supported with a fund established by Dr. and Mrs C. V. Newsom in honor of the memory of J. von Neumann, along with funding from the National Security Agency.
Overview: Geometric considerations have dominated recent activity in both of these areas, which are linked by the themes of group actions and deformations. This symposium will focus on these two areas, and these links, bringing together aspects of algebraic geometry, field theory, number theory, representation theory, topology, ring theory, and group theory. Besides standing on its own, the symposium will also be useful to attendees intending to participate in the fall 1999 activities at MSRI, by providing mathematical background and context regarding these areas and their connections. The symposium will provide a presentation of key results in the areas covered, including an overview of current developments and research directions. The intended audience will include researchers from these and related fields, as well as recent Ph.D.s and advanced graduate students desiring a broader perspective on the areas. Special talks appropriate for nonexperts (including students and postdoctorals) will consist of interrelated minicourses, each of three or four lectures. These will systematically present one mathematical aspect providing coordinating background for individual lectures on current research topics.
Topics: Galois Theory Topics: Extensions of function fields, and the relationship to fundamental groups of varieties, give Galois theory its fundamentally geometric flavor. This holds even when the main consideration is to obtain information about the absolute Galois group of the rational numbers. The inverse Galois problem in recent years has advanced through the study of branched covers of the Riemann sphere, and of the corresponding arithmetic and geometric Galois groups. This approach draws on representation theory both of finite groups and of fundamental groups of moduli spaces, such as braid groups. Topology and deformation theory come

into play, along with a study of Galois actions, in understanding the arithmetic of covers, analyzing the absolute Galois group of the rationals, and in realizing finite groups as Galois groups. Other applications of this approach concern graph theory, cryptography, polynomial maps over finite fields, explicit forms of Hilbert's irreducibility theorem, and other constructive aspects of algebra. Fundamental groups of varieties defined over more general fields have been studied in part by specialization to varieties over the complex numbers, where classical topological methods can be used. Another recent approach has been to use patching and deformation methods in formal and rigid geometry, which extend complex methods to other settings. This latter approach has led to results about fundamental groups over fields of positive characteristic and about absolute Galois groups of function fields. Achievements here include Grothendieck's anabelian conjecture, arithmetic Galois groups appearing as extensions of known groups, Abhyankar's conjecture, and the geometric case of Shafarevich's conjecture. **Noncommutative Algebra Topics**: One of the striking changes in noncommutative algebra over the last decade has been in the emphasis on the study of concrete examples, frequently those that have arisen in neighboring areas, rather than on the abstract theory. This has led to some significant and unexpected interactions not only with other areas but also between some of the major areas of algebra. The most obvious example, of course, has been the rise of the whole area of quantum groups, with its applications to many areas of mathematics and physics, but there are numerous other examples. To give some examples: the application of the theory of simple rings and rings of differential operators have led to significant applications to Harish-Chandra's theory of eigendistributions, and the representation theory of reductive Lie algebras through the work of Wallach, Levasseur, and Stafford; methods of algebraic geometry have been successfully used by Tate and Van den Bergh to provide a detailed description of the properties of the Sklyanin algebras (These first appeared in Sklyanin's work on the Quantum Inverse Scattering Method, and are also fundamental to work on Noncommutative Geometry. Until the work of Tate and Van den Bergh, even a basis for these algebras was unknown.); several of the famous Kaplansky conjectures on Hopf algebras have been solved; Zelmanov made striking use of Jordan and Lie theory to solve the restricted Burnside problem. More recently, Kac, Martinez, and Zelmanov have used more ring-theoretic techniques to classify Jordan algebras with linear growth and to make substantial progress in the classification of super-conformal algebras.

Organizing Committee: M. D. Fried (Univ. of California, Irvine), D. Harbater (Univ. of Pennsylvania), and L. W. Small (Univ. of California, San Diego).

Participation: The organizers actively seek participants from a wide variety of backgrounds, including recent Ph.D.s, students, and individuals not currently in the area who would benefit from the symposium topics. Women and underrepresented minorities are especially encouraged to consider attending. Everyone interested in receiving an invitation to attend should submit the following information before **April 1, 1999**, to AMS Symposium Coordinator, P. O. Box 6887, Providence, RI 02940; or by e-mail to `wsd@ams.org`. Please type or print the following: (1) Full name and mailing address; (2) phone numbers for office, home, and fax; (3) e-mail address; (4) your anticipated arrival/departure dates; (5) scientific background relevant to the symposium topics (please indicate if you are a student or when you received your Ph.D.); (6) the amount of financial assistance requested (or indicate if no support is required). Letters of invitation with specific offers of support (if any) will be mailed about mid May, along with information about the program, local housing, and travel. Participants will be responsible for making their own travel and housing arrangements. Conference funding from the endowment and grant is limited; individuals who can obtain support from other sources are encouraged to do so.

Information: Further details about the content of the symposium will appear on the MSRI Web site (`http://www.msri.org`), on `http://www.math.uci.edu/~mfried/#conf/`, and on e-Math. Questions about the scientific program should be addressed to the organizers at `mfried@math.uci.edu`, `harbater@math.upenn.edu`, or `lwsmall@ucsd.edu`; questions of a nonscientific nature should be directed to the symposium coordinator at the address provided above.

Note: Both the Galois and Noncommutative Algebra programs plan workshops during the fall 1999 MSRI semester. The Galois program plans two during October: a) Constructive Galois Theory (week of October 4); b) Arithmetic fundamental groups and moduli spaces (week of October 11). The Noncommutative Algebra program plans a workshop on Hopf algebras in late October to be followed by workshops, in the winter, on combinatorial algebra and interactions between algebraic geometry and noncommutative ring theory. Details for these will also appear on the MSRI Web site.

19–21 **20th Anniversary of Boundary Elements Conference (BEM 20)**, University of Central Florida, Orlando, Florida. (Mar. 1998, p. 427)

20–26 **Eleventh International Congress of Logic, Methodology and Philosophy of Science**, Krakow, Poland. (Jan. 1999, p. 70)

23–27 **International Conference on Topology and its Applications**, Kanagawa University, Yokohama, Japan. (Aug. 1998, p. 899)

*23–29 **International Conference on Nonlinear Partial Differential Equations**, Lviv, Ukraine.

Organizers: Institute of Applied Mathematics and Mechanics of National Academy of Sciences of Ukraine together with Lviv State University. The idea of this conference was supported by National Academy of Sciences of Ukraine, Ukrainian Mathematical Society, International Federation of Nonlinear Analysts together with Polish Academy of Sciences.

Aim: The conference is dedicated to the outstanding mathematician J. P. Schauder.

Topics: Functional analysis in the theory of PDE, qualitative theory of nonlinear PDE, topological methods in the theory of PDE, free boundary problems, methods of PDE in applied and industrial mathematics.

Scientific Committee: H. Amann, E. Di Benedetto, B. Bojarski, S. D. Eidelman, A. Friedman, W. Jager, V. Lakhsmikantham, O. A. Ladyzhenskaya, V. A. Marchenko, O. A. Oleinik, S. I. Pohozaev, I. V. Skrypnik, N. N. Uraltseva, M. I. Vishik.

Organizing Committee: B. V. Bazaliy, A. Granas, A. Kartsatos, V. M. Kyrylich, G. S. Kit, E. Ya. Khruslov, A. A. Kovalevsky, S. P. Lavrenyuk, V. A. Marchenko, Ya. G. Pritula, A. M. Samoilenko, M. M. Sheremeta, A. E. Shishkov, I. V. Skrypnik (head of the Committee), C. P. Tsokos, A. F. Tedeev (scientific secretary), I. O. Vakarchuk, M. M. Zarichnyi.

Information: A. F. Tedeev, Institute of Applied Mathematics and Mechanics NAS Ukraine, R. Luxemburg Str. 74, 340114 Donetsk, Ukraine; e-mail: `tedeev@iamm.ac.donetsk.ua`.

23–September 4 **Generalized Dirac Operators and their Geometric Scattering Theory**, Banach Center, Warsaw, Poland. (Jan. 1999, p. 70)

25–28 **XI International Workshop on Numerical Methods in Viscoelastic Flows**, Vaals, The Netherlands. (Feb. 1999, p. 278)

30–September 1 **Sixth International Symposium on Generalized Convexity and Monotonicity**, University of the Aegean, Karlovassi, Samos Island, Greece. (Jan. 1999, p. 70)

September 1999

1–3 **First International Conference on the Integration of Dynamics, Monitoring and Control (DYMAC 99)**, Manchester, United Kingdom. (Sept. 1998, p. 1053)

5–11 **XX International Seminar on Stability Problems for Stochastic Models**, Maria Curie-Sklodowska University, Lublin-Naleczow, Poland. (Jan. 1999, p. 70)

*6–24 **School on Modern Statistical Methods in Medical Research (in conjunction with ICMS, Edinburgh, Scotland, UK)**, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.

Directors: E. J. T. Goetghebeur (University of Ghent, Belgium), J. L. Hutton (University of Newcastle-upon-Tyne, United Kingdom),

P. J. Solomon (University of Adelaide, Australia).

Deadline: Deadline for requesting participation: February 28, 1999.

Information: Abdus Salam International Centre for Theoretical Physics, Strada Costiera, 11-34014 Trieste, Italy; tel: +39-40-2240111; fax: +39-40-224163; e-mail: sci_info@ictp.trieste.it; http://www.ictp.trieste.it/.

*6–December 17 **Mathematical Developments in Solid Mechanics and Materials Science**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.

Organizers: K. Bhattacharya (Caltech), P. Suquet (Marseille), J. R. Willis (Cambridge).

Objective: There is great current interest in how the microscopic structure of a solid material influences its macroscopic response to stress. Conversely, the application of stress can influence microstructure. Microscopic damage may occur, leading ultimately to the formation of large cracks and structural failure. Phase transformations occur in some materials, creating structures at various length scales which evolve with stress. The challenge, both for mathematics and physical modelling, is to comprehend relationships between models at different length scales. This has led already to a well-developed theory of "homogenization" when the scales are widely separated, and has both exploited and stimulated advances in the calculus of variations. When the scales are separated but still comparable, there is a need for a micromechanical rationale for including scale effects in macroscopic models. The phenomena may be unstable, at least at the microscopic level, making demands both for modelling and for the analysis of partial differential equations. In particular, the (possibly hierarchical) developments of large-scale patterns is an open problem.

Focus: The main focus of the program will be on microstructure formation and evolution, as related to phase transformations, damage development and fracture. Each subject has its own group of specialists (in various mixes, mathematicians, physicists, engineers, materials scientists). There are already overlaps, both between subjects and disciplines, and it is intended that the program will exploit and extend these, to common advantage.

Information: Contact the Director, Isaac Newton Institute for Mathematical Sciences, 20 Clarkson Road, Cambridge CB3 0EH, UK; tel: 01223-335999; e-mail: info@newton.cam.ac.uk. Information can also be found on the World Wide Web at the URL http://www.newton.cam.ac.uk/.

*9–11 **IX Congress for the learning and teaching of Mathematics (JAEM)**, Lugo (Galicia), Spain.

Activities: The activities of Jaem include: Plenary conferences; communications about ten different topics; workshops; competitions of photography and educational software, mathematics exhibitions, and trips and excursions to different places in Galicia.

Topics: Technologies in the teaching of mathematics (graphic calculators and computers); the teaching of statistics: a challenge pending; workshops and other options in mathematics; mathematics in real life and their connection with other subjects in school; from arithmetics thinking to algebraic thinking; basis of the learning of mathematics in primary teaching; the teaching of mathematics at the university; teacher training in mathematics; having fun with maths; mathematics in the secundary school.

Information: More information about the conference can be found on the Web page: http://www.cesga.es/cefocop_lugo/jaem/or by sending an e-mail message to: cflugo@teleline.es.

14–16 **ElectrIMACS—Conference on Electrical Machines, Converters and Systems**, Lisbon, Portugal. (Apr. 1998, p. 535)

14–18 **International Conference on Analytic Methods of Analysis and Differential Equations (AMADE)**, Minsk, Belarus. (Jan. 1999, p. 70)

15–19 **GD'99 - Seventh International Symposium on Graph Drawing**, Stirin Castle, Prague, Czech Republic. (Jan. 1999, p. 71)

16–22 **The Fourth International Workshop On Differential Geometry and Its Applications**, Brasov, Romania. (Jan. 1999, p. 71)

20–24 **The 10th Biennial Computational Techniques and Applications Conference and Workshops (CTAC99)**, Australian National University, Canberra, Australia. (Feb. 1999, p. 278)

20–26 **International Symposium on Classical Analysis**, Kazimierz Dolny, Poland. (Jan. 1999, p. 71)

October 1999

October **National Conference on Issues Related to Doctoral Programs in Mathematics Education**, University of Missouri, Columbia, Missouri. (Jan. 1999, p. 71)

2–3 **AMS Eastern Sectional Meeting**, Providence College, Rhode Island. (Sept. 1997, p. 1031)

Information: W. Drady, e-mail: wsd@ams.org.

4–8 **Workshop on the Complexity of Multivariate Problems**, Hong Kong Baptist University, Hong Kong, China. (Jan. 1999, p. 71)

*6–9 **New Trends in the Calculus of Variations**, Centro de Matemática e Aplicações Fundamentais da Universidade de Lisboa, Lisbon, Portugal.

Focus: In the last decades there have been remarkable advancements in the study of nonlinear partial differential equations, motivated not only by the twentieth century developments in pure and applied mathematics, but also by the industrial modelling and scientific progress. New theories and techniques have been developed to address the search for classical and generalized solutions for equations or systems of partial differential equations, and their qualitative properties such as regularity or asymptotic behavior. Most of these questions are still poorly understood and new emerging issues in physical sciences, mathematical finance, and other applied disciplines proved a test for known theories and an inspirational source for the introduction of new ones.

Scientific Organizers: M. L. Mascarenhas (Univ. Lisboa) and J. Palhoto de Matos (Inst. Sup. Técnico).

Support: A certain number of grants for young mathematicians, as well as for other scientists, will be available for participation at the meetings and for short or medium stays in Lisbon to stimulate joint collaboration and research.

Information: M. Morales, NPDEA-99 secretariat, CMAF/Univ. de Lisboa, Av. Prof. Gama Pinto 2, 1699 Lisboa Codex, Portugal; e-mail: npde99@lmc.fc.ul.pt; http://npde99.lmc.fc.ul.pt; tel: 351-1-790-48-62; fax: 351-1-795-42-88.

8–10 **AMS Central Sectional Meeting**, University of Texas, Austin. (Sept. 1997, p. 1031)

Information: W. Drady, e-mail: wsd@ams.org.

15–17 **AMS Southeastern Section Meeting**, University of North Carolina, Charlotte, North Carolina. (Nov. 1998, p. 1378)

*23–24 **Midwest Partial Differential Equations Seminar, Fall 1999**, University of Illinois, Urbana-Champaign, Illinois.

Theme: A semi-annual conference on recent developments in partial differential equations.

Confirmed Speakers: P. Constantin (Univ. of Chicago), C. Doering (Univ. of Michigan, Ann Arbor), L. C. Evans (Univ. of California, Berkeley), N. Goldenfeld (Univ. of Illinois, Urbana).

Support: Some financial support is available to graduate students, who are encouraged to attend.

Registration: Registration is not required, and there is no registration fee.

Organizers: J. Bronski, R. Jerrard, R. Laugesen.

Information: For complete, up-to-date conference information, please see http://www.math.uiuc.edu/~laugesen/mwpde.html or contact R. Laugesen (laugesen@math.uiuc.edu, Dept. of Mathematics, Univ. of Illinois, IL 61801).

January 2000

17–21 **International Conference on Mathematical Analysis and its Applications, 2000 (ICMAA2000)**, National Sun Yat-sen

University, Kaohsiung 804, Taiwan, R.O.C. (Jan. 1999, p. 71)

19-22 **Joint Mathematics Meeting**, Sheraton Washington Hotel & Omni Shoreham Hotel, Washington, District of Columbia. (Sept. 1997, p. 1031)

21-22 **1999-2000 ASL Winter Meeting**, Washington, DC. (Jan. 1999, p. 72)

February 2000

20-22 **International Conference on Stochastic Optimization: Algorithms and Applications**, University of Florida, Center for Applied Optimization, Gainesville, Florida. (Jan. 1999, p. 72)

The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.

April 2000

*14-16 **AMS Southeastern Section Meeting**, University of Southwestern Louisiana, Lafayette, Louisiana.
Information: See the AMS Meetings & Conferences pages on e-MATH, or contact Donna Salter, `dls@ams.org`.

June 2000

*12-15 **First AMS-Scandanavian International Mathematics Meeting**, University of Odense, Odense, Denmark.
Sponsors: Sponsored by the AMS, Dansk Matematisk Forening, Suomen matemaattinen yhdistys, Icelandic Mathematical Society, and Svenska matematikersamfundet.
Information: Watch the AMS Meetings & Conferences pages on e-MATH, or contact `dls@ams.org` for details.

August 2000

*7-12 **Mathematical Challenges of the 21st Century**, UCLA, Los Angeles, California.
Information: Watch the AMS Meetings and Conferences pages on e-MATH for details, or contact `dls@ams.org`.

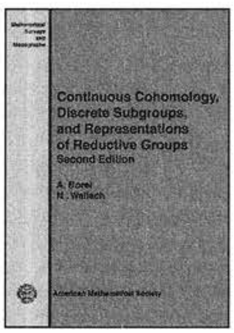
September 2000

*18-22 **International Data Analysis Conference**, Innsbruck, Austria.
Goal: The congress will take place at Innsbruck in the middle of the Alps. In the first year of the second millenium it is an opportunity to summarize the most up-to-date methods in data analysis and to look forward into the next century. All aspects of data analysis will be considered, ranging from applied aspects to fundamental questions on the description and analysis of real data. Further details are given in the second information. There will be a social program with possibilities for excursions.
Invited Speakers: R. E. Barlow (Berkeley), S. Bodjanova (Austin), R. Dutter (Wien), L. Fahrmeir (München), K. Felsenstein (Wein), M. S. Nikulin (Bordeaux), H.-J. Zimmermann (Aachen).
Topics: All aspects of data sciences are considered, ranging from the description of real data to different methods of data analysis. These include: analysis of fuzzy data; applied data analysis; Bayesian data analysis; computerized data analysis; data and networks; data description; data encryption; data mining; data security; descriptive data analysis; exploratory data analysis; fuzzy data analysis; graphical data analysis; statistical data analysis.
Call for Papers: Authors are invited to submit a paper in the field of data analysis. Practical applications of data analysis techniques to real data are welcome. Proposals for papers by a one-page abstract.
Fee: Participants: ATS 3,700; accompanying persons: ATS 1,700; students: ATS 1,100.
Information: R. Viertl, Institut f. Statistik, Technische Universität Wien, Wiedner Hauptstr. 8/107, A-1040 Wien, Austria; e-mail: `viertl@tuwien.ac.at`.

New Publications Offered by the AMS

New Series from the AMS! The AMS is pleased to announce a new subseries of the *Translations in Mathematical Monographs* publications entitled, *Iwanami Series in Modern Mathematics*. The books will present English translations of original Japanese works from Iwanami Shoten publishers (Tokyo). We will offer affordably-priced volumes from two Iwanami Shoten series: *Foundations of Modern Mathematics* and *Developments of Modern Mathematics*. Information about the inaugural publication is included in this month's *New Publications Offered by the AMS* section of the *Notices*, see page 383.

Algebra and Algebraic Geometry



Continuous Cohomology, Discrete Subgroups, and Representations of Reductive Groups

Second Edition

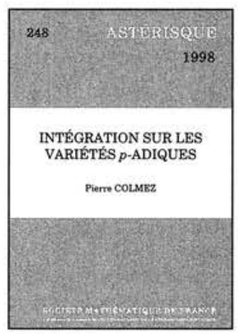
A. Borel, *Institute for Advanced Study, Princeton, NJ*, and **N. Wallach**, *University of California, San Diego, La Jolla*

It has been nearly twenty years since the first edition of this work. In the intervening years, there has been immense progress in the use of homological algebra to construct admissible representations and in the study of arithmetic groups. This second edition is a corrected and expanded version of the original, which was an important catalyst in the expansion of the field. Besides the fundamental material on cohomology and discrete subgroups present in the first edition, this edition also contains expositions of some of the most important developments of the last two decades.

Contents: Notation and preliminaries; Relative Lie algebra cohomology; Scalar product, Laplacian and Casimir element; Cohomology with respect to an induced representation; The Langlands classification and uniformly bounded representations; Cohomology with coefficients in $\Pi_\infty(G)$; The computation of certain cohomology groups; Cohomology of discrete subgroups and Lie algebra cohomology; The construction of certain unitary representations and the computation of the corresponding cohomology groups; Continuous cohomology and differentiable cohomology; Continuous and differentiable cohomology for locally compact totally disconnected groups; Cohomology with coefficients in $\Pi_\infty(G)$: The p-adic case; Differentiable cohomology for products of real Lie groups and t.d. groups; Cohomology of discrete cocompact subgroups; Noncompact S-arithmetic subgroups; References; Index; Leitfaden to some results.

Mathematical Surveys and Monographs

June 1999, approximately 265 pages, Hardcover, ISBN 0-8218-0851-6, LC 98-44527, 1991 *Mathematics Subject Classification*: 22E41; 22E40, 22E45, 57T15, **All AMS members $47**, List $59, Order code SURV-BORELN



Intégration sur les Variétés p-Adiques

Pierre Colmez, *École Normale Supérieure, Paris, France*

A publication of Société Mathématique de France.

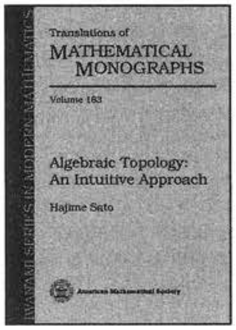
In this book, the author shows that there is a unique "reasonable" way of integrating closed 1-forms on smooth algebraic varieties defined over a p-adic field. In contrast with the previously known constructions, this p-adic integration does not require that the varieties under consideration have good reduction. Having a theory which works for all primes can be used to adelize certain constructions. For example, if X is a smooth and proper algebraic curve defined over a number field, one can define in a purely analytic way a pairing between divisors of degree 0 using adelic Green functions. From this pairing one can recover the Néron-Tate height pairing and p-adic analogues considered by Gross and Coleman in the case of good reduction.

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Intégrales abéliennes complexes; Intégrales abéliennes p-adiques; Ensembles bornés; Revêtements universels p-adiques; Résultats de théorie des groupes; Bibliographie.

Astérisque, Number 248

September 1998, 155 pages, Softcover, 1991 *Mathematics Subject Classification*: 11S, 14H, 14K, 14L, 30F, 30G, 32J, **Individual member $30**, List $33, Order code AST/248N



Recommended Text

Supplementary Reading

Algebraic Topology: An Intuitive Approach

Hajime Sato, *Nagoya University, Japan*

The single most difficult thing one faces when one begins to learn a new branch of mathematics is to get a feel for the mathematical sense of the subject. The purpose of this book is to help the aspiring reader acquire this essential common sense about algebraic topology in a short period of time. To this end, Sato leads the reader through simple but meaningful examples in concrete terms. Moreover, results are not discussed in their greatest possible generality, but in terms of the simplest and most essential cases.

In response to suggestions from readers of the original edition of this book, Sato has added an appendix of useful definitions and results on sets, general topology, groups and such. He has also provided references.

Topics covered include fundamental notions such as homeomorphisms, homotopy equivalence, fundamental groups and higher homotopy groups, homology and cohomology, fiber bundles, spectral sequences and characteristic classes. Objects and examples considered in the text include the torus, the Möbius strip, the Klein bottle, closed surfaces, cell complexes and vector bundles.

Contents: Objectives; Homeomorphisms and homotopy equivalences; Topological spaces and cell complexes; Fundamental groups and higher homotopy groups; Homology; Homology groups of cell complexes; Cohomology; Homology of product spaces and the universal coefficient theorem; Fiber bundles and vector bundles; Spectral sequences; A view from current mathematics; Appendix; Answers to exercises; Recommended reading; Index.

Translations of Mathematical Monographs (*Iwanami Series in Modern Mathematics*), Volume 183

February 1999, 122 pages, Softcover, ISBN 0-8218-1046-4, LC 98-53247, 1991 *Mathematics Subject Classification*: 55-01; 57-01, **All AMS members $16**, List $20, Order code MMONO/183N

Analysis

Tensor Products and Independent Sums of $\mathcal{L}_p$-Spaces, $1 < p < \infty$

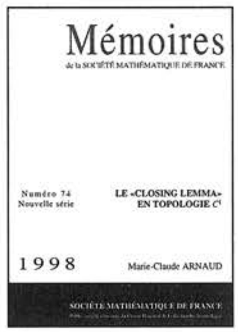
Dale E. Alspach, *Oklahoma State University, Stillwater*

Two methods of constructing infinitely many isomorphically distinct $\mathcal{L}_p$-spaces have been published. In this volume, the author shows that these constructions yield very different spaces and in the process develop methods for dealing with these spaces from the isomorphic viewpoint.

Contents: Introduction; The constructions of $\mathcal{L}_p$-spaces; Isomorphic properties of $(p, 2)$—sums and the spaces R_p^α; The isomorphic classification of R_p^α, $\alpha < \omega_1$; Isomorphisms from $X_p \otimes X_p$ into $(p, 2)$—sums; Selection of bases in $X_p \otimes X_p$; $X_p \otimes X_p$-preserving operators on $X_p \otimes X_p$; Isomorphisms of $X_p \otimes X_p$ onto complemented subspaces of $(p, 2)$—sums; $X_p \otimes X_p$ is not in the scale R_p^α, $\alpha < \omega_1$; Final remarks and open problems; Bibliography.

Memoirs of the American Mathematical Society, Volume 138, Number 660

March 1999, 77 pages, Softcover, ISBN 0-8218-0961-X, LC 98-53108, 1991 *Mathematics Subject Classification*: 46B20; 46E30, **Individual member $23**, List $39, Institutional member $31, Order code MEMO/138/660N



Le «Closing Lemma» en Topologie C^1

Marie-Claude Arnaud, *Université Paris Sud, Orsay, France*

A publication of Société Mathématique de France.

Using an algebraic result due to Mai, Arnaud gives a simpler proof of the C^1 closing lemma of Pugh and Robinson and gives a more precise result. A new case is solved: the case of symplectic vector fields.

The theorem of density of periodic points in the nonwandering set is deduced, as Pugh and Robinson did, adding a result on symplectic vector fields. Then, a new result is proven: the C^1 orbit closing lemma, which allows for transforming a recurrent point to a periodic one by approximating its orbit.

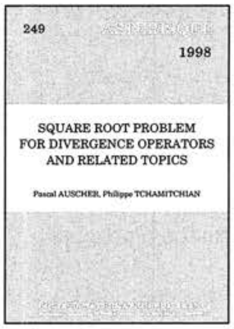
Arnaud gives a generalization of the ergodic version of the closing lemma of R. Mañé to the case of non-compact manifolds and positive Borel measures which are finite on compacta.

This item will also be of interest to those working in geometry and topology.

Contents: Introduction; Énoncés du ≪closing lemma≫; Les théorèmes de densité comprenant un lemme de fermeture d'orbite; Une version ergodique du ≪closing lemma≫; Plan de la démonstration du ≪closing lemma≫; Démonstration des résultats intermédiaires; Bibliographie.

Memoires de la Société Mathématique de France, Number 74

March 1999, approximately 126 pages, Softcover, ISBN 2-85629-071-X, 1991 *Mathematics Subject Classification*: 58F30, 58F22, 58F05, 58F11, 58F25, **Individual member $30**, List $33, Order code SMFMEM/74N*



Square Root Problem for Divergence Operators and Related Topics

Pascal Auscher, *Université de Picardie Jules-Verne, Amiens, France*, and **Philippe Tchamitchian**, *Université d'Aix-Marseille III, Marseille, France*

A publication of Société Mathématique de France.

This work presents recent progress on the square root problem of Kato for differential operators in divergence form on $\mathbb{R}^n$. Topics discussed include functional calculus, heat and resolvent kernel estimates, square function estimates and Carleson measure estimates for square roots.

In the first chapter, it is shown in a quantitative way how the theorems of Aronson-Nash and De Giorgi are equivalent. The central chapters use recent developments in functional calculus and harmonic analysis to propose a new point of view on Kato's problem, unifying previous results and extending them. The last chapter examines the associated Riesz transforms, their relation to Calderón-Zygmund operators and their behavior on L^p-spaces.

Contents: Introduction; Preliminaries; Gaussian estimates; Quadratic functionals, Carleson measures and square roots of differential operators; Positive answers to the square root problem; Square roots of differential operators, singular integrals and L^p theory; The space ABMO; Coefficients depending on one variable; Improved constants; Reduction of dimension principle; Bibliography.

Astérisque, Number 249

October 1998, 172 pages, 1991 *Mathematics Subject Classification*: 35J15, 47A60, 42B25; 42B20, 35K10, 47F05, 46G20, **Individual member $50**, List $55, Order code AST/249N*

Difféomorphismes de Smale des Surfaces

Christian Bonatti and **Rémi Langevin**, *Université de Bourgogne, Dijon, France*

A publication of Société Mathématique de France.

This work is devoted to the C^1-structurally stable diffeomorphisms (called here *Smale diffeomorphisms*) of compact surfaces.

The main result consists in a finite combinatorial presentation of the global topological dynamics (*i.e.* the class of topological conjugacy) of Smale diffeomorphisms. For that the authors consider *saturated hyperbolic sets* (*i.e.* hyperbolic sets which are equal to the intersection of their invariants manifolds) and build some canonical (up to conjugacy) invariant neighborhood (the *domain*) of these saturated sets. Then they prove that the dynamics restricted to the domain is characterized by the *geometrical type* of some Markov partition of the hyperbolic set: it is a simple combinatorics describing in which order, position and direction the image of some rectangle of the Markov partition crosses the rectangles. Then the global dynamic is obtained by gluing the domains along their boundary.

One important step of the proof consists in a precise analysis of the topological position (the *pattern*) of the invariant curves of the Smale diffeomorphisms. As a corollary of the main result the authors determine that the pattern of the invariant curves essentially characterizes the dynamics on the domains.

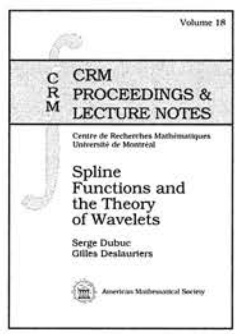
Some of the abstract geometrical types do not correspond to any Smale diffeomorphisms on compact surfaces. The authors define the genus of a type, as a minorant of the genus of any compact surface on which the type can be realized as the geometrical type of a Markov partition of some saturated hyperbolic set; then they characterize the geometrical types of finite genus.

This item will also be of interest to those working in geometry and topology.

Contents: Introduction; Pièces basiques et ensembles saturés; Géométrie des courbes invariantes; Domaine d'un ensemble hyperbolique saturé; Construction de partitions de Markov; Partitions de Markov géométrisées et conjugaison topologique de difféomorphismes de Smale; Les dessins et la dynamique; Genre d'une partition de Markov géométrique et réalisabilité (par C. Bonatti et E. Jeandenans); Pièces basiques et homéomorphismes pseudo-Anosov (par C. Bonatti et E. Jeandenans); Bibliographie.

Astérisque, Number 250

October 1998, 235 pages, Softcover, 1991 *Mathematics Subject Classification*: 58F15, 58F09, 58F12, **Individual member $50**, List $55, Order code AST/250N*



Spline Functions and the Theory of Wavelets

Serge Dubuc, *Université de Montréal, PQ, Canada*, and **Gilles Deslauriers**, *Ecole Polytechnic de Montréal, PQ, Canada*, Editors

This work is based on a series of thematic workshops on the theory of wavelets and the theory of splines. Important applications are included. The volume is divided into four parts: Spline Functions, Theory of Wavelets, Wavelets in Physics, and Splines and Wavelets in Statistics.

Part one presents the broad spectrum of current research in the theory and applications of spline functions. Theory ranges from classical univariate spline approximation to an abstract framework for multivariate spline interpolation. Applications include scattered-data interpolation, differential equations and various techniques in CAGD.

Part two considers two developments in subdivision schemes; one for uniform regularity and the other for irregular situations. The latter includes construction of multidimensional wavelet bases and determination of bases with a given time frequency localization.

In part three, the multifractal formalism is extended to fractal functions involving oscillating singularites. There is a review of a method of quantization of classical systems based on the theory of coherent states. Wavelets are applied in the domains of atomic, molecular and condensed-matter physics.

In part four, ways in which wavelets can be used to solve important function estimation problems in statistics are shown. Different wavelet estimators are proposed in the following distinct cases: functions with discontinuities, errors that are no longer Gaussian, wavelet estimation with robustness, and error distribution that is no longer stationary.

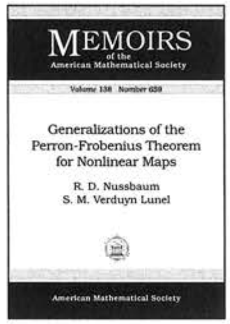
Some of the contributions in this volume are current research results not previously available in monograph form. The volume features many applications and interesting new theoretical developments. Readers will find powerful methods for studying irregularities in mathematics, physics, and statistics.

This item will also be of interest to those working in applications.

Contents: *Spline functions:* **L. P. Bos** and **D. Holland**, Radial extensions of vertex data; **H. Brunner**, The use of splines in the numerical solutions of differential and Volterra integral equations; **F. Dubeau** and **J. Savoie**, On best error bounds for deficient splines; **F. Dubeau** and **J. Savoie**, Optimal error bounds for spline interpolation on a uniform partition; **J.-P. Dussault** and **N. Pfister**, Modelization of flexible objects using constrained optimization and B-spline surfaces; **J. C. Fiorot** and **P. Jeannin**, New control polygons for polynomial curves; **A. Le Méhauté** and **A. Bouhamidi**, Splines in approximation and differential operators: (m, ℓ, s) interpolating-spline; **P. Sablonnière**, New families of B-splines on uniform meshes of the plane; *Theory of wavelets:* **N. Dyn** and **D. Levin**, Analysis of Hermite-interpolatory subdivision schemes; **M. Holschneider**, Some directional microlocal classes defined using wavelet transforms; **A. Karoui** and **R. Vaillancourt**, Nonseparable biorthogonal wavelet bases of $L^2(\mathbb{R}^n)$; **J. Kovačević** and **R. Bernardini**, Local bases: Theory and applications; **K.-S. Lau** and **M.-F. Ma**, On the L^p-Lipschitz exponents of the scaling functions; **S. Maes**, Robust speech and speaker recognition using instantaneous frequencies and amplitudes obtained with wavelet-derived synchrosqueezing measures; **E. Schulz** and **K. F. Taylor**, Extensions of the Heisenberg group and wavelet analysis in the plane; *Wavelets in physics:* **S. Twareque Ali**, Coherent states and quantization; **J.-P. Antoine**, Wavelets in molecular and condensed-matter physics; **J.-P. Antoine, Ph. Antoine**, and **B. Piraux**, Wavelets in atomic physics; **G. Battle**, The wavelet ϵ-expansion and Hausdorff dimension; **J. Elezgaray, G. Berkooz**, and **P. Holmes**, Modelling the coupling between small and large scales in the Kuramoto-Sivashinsky equation; **C. R. Handy** and **R. Murenzi**, Continuous wavelet transform analysis of one-dimensional quantum ground states; **A. Arneodo, E. Bacry, S. Jaffard**, and **J. F. Muzy**, Oscillating singularities and fractal functions; *Splines and wavelets in statistics:* **A. Antoniadis**, Wavelet estimators for change-point regression models; **R. Averkamp** and **C. Houdré**, Wavelet thresholding for non (necessarily) Guassian noise: A preliminary report; **D. L. Donoho** and **T. P. Y. Yu**, Deslauries-Dubuc: Ten years after; **J. O. Ramsay** and **N. Heckman**, Some theory for L-spline smoothing; **R. von Sachs, G. P. Nason**, and **G. Kroisandt**, Spectral representation and estimation for locally stationary wavelet processes.

CRM Proceedings & Lecture Notes, Volume 18

April 1999, 397 pages, Softcover, ISBN 0-8218-0875-3, 1991 *Mathematics Subject Classification*: 65D07, 41A30; 41A15, 42C15, 94A12, 65D15, 81V45, 62G07, **Individual member $66**, List $110, Institutional member $88, Order code CRMP/18N



Generalizations of the Perron-Frobenius Theorem for Nonlinear Maps

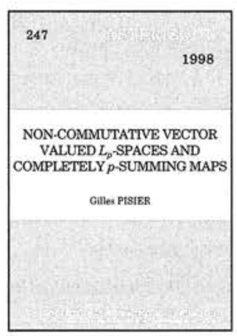
R. D. Nussbaum, *Rutgers University, Piscataway, NJ*, and **S. M. Verduyn Lunel**, *Vrije University, Amsterdam, Netherlands*

The classical Frobenius-Perron Theorem establishes the existence of periodic points of certain linear maps in $\mathbb{R}^n$. The authors present generalizations of this theorem to nonlinear maps.

Contents: Introduction; Basic properties of admissible arrays; Further properties of admissible arrays; Computation of the sets $P(n)$; Necessary conditions for array admissible sets; Proof of Theorem C; $P(n) \neq Q(n)$ for general n; $P_2(n)$ satisfies rule A and rule B; The case of linear maps; Bibliography; Appendix A Description of the program; Appendix B Numerical data.

Memoirs of the American Mathematical Society, Volume 138, Number 659

March 1999, 98 pages, Softcover, ISBN 0-8218-0969-5, LC 98-53118, 1991 *Mathematics Subject Classification*: 47Nxx, **Individual member $24**, List $40, Institutional member $32, Order code MEMO/138/659N



Non-Commutative Vector Valued L_p-Spaces and Completely p-Summing Maps

Gilles Pisier, *Texas A&M University, College Station*

A publication of Société Mathématique de France.

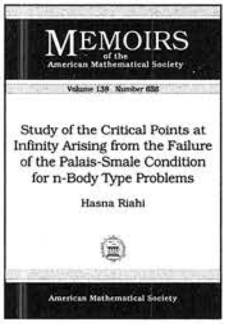
The author introduces a non-commutative analog of Banach space valued L_p-spaces in the category of operator spaces. The approach developed in the first part of the book naturally leads to a theory of "completely p-summing maps" between operator spaces, analogous to the Grothendieck-Pietsch-Kwapień theory (*i.e.* "absolutely p-summing maps") for Banach spaces. As an application, a characterization of maps factoring through the operator space version of Hilbert space is obtained. More generally, the mappings between operator spaces which factor through a non-commutative L_p-space (or through an ultraproduct of them) using completely p-summing maps are studied. Also discussed in this setting is the factorization through subspaces, or through quotients of subspaces of L_p-spaces.

Contents: Introduction; Background and Notation; Non-commutative vector valued L_p-spaces (discrete case); The operator space structure of the commutative L_p-spaces; Non-commutative vector valued L_p-spaces (continuous case); Duality, non-commutative RNP and uniform convexity; Completely p-summing maps; Operators factoring through

OH; Completely bounded factorization through L_p, S_p and utraproducts; Illustrations in concrete situations; Bibliography.; Index

Astérisque, Number 247

July 1998, 129 pages, Softcover, 1991 *Mathematics Subject Classification*: 46L50, 46E40, 46B70, 47B10, 47D15, **Individual member $30**, List $33, Order code AST/247N*



Study of the Critical Points at Infinity Arising from the Failure of the Palais-Smale Condition for n-Body Type Problems

Hasna Riahi, *Ecole Nationale d'Ingénieurs de Tunis, Tunisia*

In this work, the author examines the following: When the Hamiltonian system $m_i\ddot{q}_i + (\partial V/\partial q_i)(t,q) = 0$ with periodicity condition $q(t+T) = q(t)$, $\forall t \in \mathfrak{R}$ (where $q_i \in \mathfrak{R}^{\ell}$, $\ell \geq 3$, $1 \leq i \leq n$, $q = (q_1, ..., q_n)$ and $V = \sum V_{ij}(t, q_i - q_j)$ with $V_{ij}(t,\xi)$ T-periodic in t and singular in ξ at $\xi = 0$) is posed as a variational problem, the corresponding functional does not satisfy the Palais-Smale condition and this leads to the notion of critical points at infinity.

This volume is a study of these critical points at infinity and of the topology of their stable and unstable manifolds. The potential considered here satisfies the strong force hypothesis which eliminates collision orbits. The details are given for 4-body type problems then generalized to n-body type problems.

Contents: Introduction; Breakdown of the Palais-Smale condition; Morse Lemma near infinity; A modified functional for the 4-body problem; Retraction theorem and related results for the 4-body problem; Generalization of the n-body problem.

Memoirs of the American Mathematical Society, Volume 138, Number 658

March 1999, 112 pages, Softcover, ISBN 0-8218-0873-7, LC 98-53119, 1991 *Mathematics Subject Classification*: 58E05; 34C25, 70F10, 70H05, **Individual member $25**, List $41, Institutional member $33, Order code MEMO/138/658N

Limits of Certain Subhomogeneous C^*-Algebras

Klaus Thomsen, *Institut for Matematiske fag, Aarhus C, Danmark*

A publication of Société Mathématique de France.

In this work, it is shown that the Elliott invariant is a complete invariant for the simple unital C^*-algebras which can be realized as an inductive limit of a sequence of finite direct sums of algebras of the form $\{f \in C(\mathbb{T}) \oplus M_n : f(x_i) \in M_d, i = 1, 2, \ldots, N\}$, where $x_1, x_2, \ldots, x_N$ is an arbitrary (finite) set on the circle $\mathbb{T}$ and d is a natural number dividing n. The corresponding range of invariants is identified and the classification result is extended to the non-unital case. A series of results about the structure of these C^*-algebras and the maps between them are also obtained.

Contents: Introduction; The building blocks; The KK-theory of building blocks of type 2; An appropriate uniqueness result; Injective connecting maps; Approximate divisibility; The final preparations; The main results; On the automorphism group; The range of the Elliott invariant; The non-unital case; Qualitative conclusions; Bibliography.

Memoires de la Société Mathématique de France, Number 71

September 1998, 125 pages, Softcover, ISBN 2-85629-064-7, 1991 *Mathematics Subject Classification*: 46L35, 46L80, 46M40, **Individual member $23**, List $26, Order code SMFMEM/71N*

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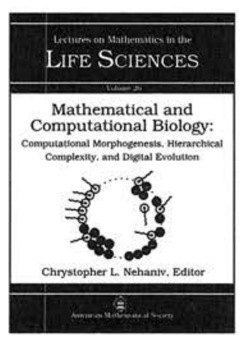
Applications



Mathematical and Computational Biology: Computational Morphogenesis, Hierarchical Complexity, and Digital Evolution

Chrystopher L. Nehaniv, *University of Hertfordshire, Hatfield, UK*, Editor

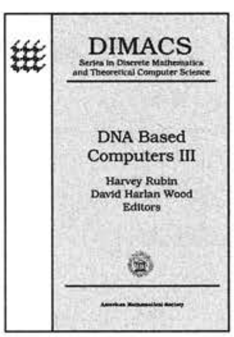
This volume contains 13 selected lectures from the International Workshop on Mathematical and Computational Biology subtitled "Computational Morphogenesis, Hierarchical Complexity and Digital Evolution" held at the University of Aizu (Japan). This interdisciplinary workshop brought together researchers working on aspects of evolutionary, mathematical, and computational biology that are of particular interest for computer scientists, biologists, and mathematicians. Discussion topics include mathematical approaches for addressing evolutionary problems (such as replication, multicellularity, individuality, and morphogenesis), the theoretical tools for rigorously developing these questions, software systems and applications.

Of special concern were self-replication, the evolution of individuality, symbiogenesis, evolutionary developmental biology, computational morphogenesis, interaction dynamics, the evolution and maintenance of sex, and properties of the digital genetic code. Lectures are organized roughly according to increase of biological scale in the order of themes presented at the workshop.

Contents: E. Szathmáry, Chemes, genes, memes: A revised classification of replicators; **J. D. Lohn**, Cellular space models of self-replicating systems; **L. Bull**, On the evolution of eukaryotes: Computational models of symbiogenesis and multicellularity; **R. E. Michod** and **D. Roze**, Cooperation and conflict in the evolution of individuality. III: Transitions in the unit of fitness; **C. L. Nehaniv** and **J. L. Rhodes**, On the manner in which biological complexity may grow; **T. Unemi**, A simple evolvable development system in Euclidean space; **V. V. Savchenko**, **A. G. Basnakian**, and **A. A. Pasko**, Computer simulation and analysis of a growing mammalian cell colony; **J. R. Peck**, **J. M. Yearsley**, and **D. Waxman**, Why do asexual and self-fertilising populations tend to occur in marginal environments?; **K. Sigmund**, The social life of automata; **L. M. Schmitt** and **C. L. Nehaniv**, The linear geometry of genetic operators with applications to the analysis of genetic drift and genetic algorithms using tournament selection; **S. Okuyama**, Evolution of diseases; **G. Pirillo**, Maximal circular codes and applications to theoretical biology; **Q.-P. Gu**, **S. Peng**, and **Q.-M. Chen**, Sorting permutations and its application in genome analysis.

Lectures on Mathematics in the Life Sciences, Volume 26

April 1999, 201 pages, Softcover, ISBN 0-8218-0941-5, 1991 *Mathematics Subject Classification*: 92-06, 92-02, 92B05, 92D15, **Individual member $35**, List $59, Institutional member $47, Order code LLSCI/26N



DNA Based Computers III

Harvey Rubin, *University of Pennsylvania, Philadelphia,* and **David Harlan Wood**, *University of Delaware, Newark,* Editors

This volume presents the proceedings from the third DIMACS workshop on "DNA Based Computers" held at the University of Pennsylvania (Philadelphia). The workshop was part of the Special Year on Molecular Biology and the Special Year on DNA Computing. The focus of this proceedings volume is on the multidisciplinary nature of the workshop with emphasis on the interaction between biology and biochemistry on one hand and computer science and mathematics on the other.

Contents: J. G. Wetmur, Physical chemistry of nucleic acid hybridization; **A. J. Hartemink** and **D. K. Gifford**, Thermodynamic simulation of deoxyoligonucleotide hybridization for DNA computation; **J. Khodor** and **D. K. Gifford**, The efficiency of sequence-specific separation of DNA mixtures for biological computing; **J. Chen** and **D. H. Wood**, A new DNA separation technique with a low error rate; **M. Hagiya**, **M. Arita**, **D. Kiga**, **K. Sakamoto**, and **S. Yokoyama**, Towards parallel evaluation and learning of Boolean μ-formulas with molecules; **E. Laun** and **K. J. Reddy**, Wet splicing systems; **F. Guarnieri**, **M. Orlian**, and **C. Bancroft**, Parallel operations in DNA-based computation; **A. S. Fraenkel**, Protein folding, spin glass and computational complexity; **N. Jonoska**, **S. A. Karl**, and **M. Saito**, Creating 3-dimensional graph structures with DNA; **Y. Gao**, **M. Garzon**, **R. C. Murphy**, **J. A. Rose**, **R. Deaton**, **D. R. Franceschetti**, and **S. E. Stevens, Jr.**, DNA implementation of nondeterminism; **V. Gupta**, **S. Parthasarathy**, and **M. J. Zaki**, Arithmetic and logic operations with DNA; **L. F. Landweber**, **R. J. Lipton**, and **M. O. Rabin**, DNA^{2}DNA computations: A potential "killer app?"; **A. D. Ellington**, **M. P. Robertson**, **K. D. James**, and **J. C. Cox**, Strategies for DNA computing; **T. L. Eng** and **B. M. Serridge**, A surface-based DNA algorithm for minimal set cover; **N. Morimoto**, **M. Arita**, and **A. Suyama**, Solid phase DNA solution to the Hamiltonian path problem; **B. Fu** and **R. Beigel**, On molecular approximation algorithms for NP optimization problem; **J. H. Reif**, Local parallel biomolecular computation; **M. Ogihara** and **A. Ray**, DNA-based parallel computation by "counting"; **A. J. Blumberg**, Parallel computation on a DNA substrate; **M. Conrad** and **K.-P. Zauner**, Design for a DNA conformational processor; **T. L. Eng**, Linear DNA self-assembly with hairpins generates linear context-free grammars; **R. Freund**, **Gh. Păun**, **G. Rozenberg**, and **A. Salomaa**, Watson-Crick finite automata; **L. Kari**, **G. Păun**, **G. Thierrin**, and **S. Yu**, At the crossroads of DNA computing and formal languages: Characterizing recursively enumerable languages using insertion-deletion systems; **T. Yokomori** and **S. Kobayashi**, DNA-EC: A model of DNA-computing based on equality checking; **Y. Sakakibara** and **C. Ferretti**, Splicing on tree-like structures.

DIMACS: Series in Discrete Mathematics and Theoretical Computer Science

April 1999, approximately 351 pages, Hardcover, ISBN 0-8218-0842-7, LC 98-55491, 1991 *Mathematics Subject Classification*: 68Q40, 68U99, 68Q15, **Individual member $47**, List $79, Institutional member $63, Order code DIMACS-RUBINN

Differential Equations

Systèmes de Lois de Conservation et Stabilité BV

Christophe Cheverry, *CNRS, Rennes, France*

A publication of Société Mathématique de France.

In this volume, the Cauchy problem for strictly hyperbolic systems of conservation laws is considered. Classical results give the existence for all times if the total variation and the sup-norm of the initial data are small enough. The author discusses various situations where the restrictions on the variation can be relaxed.

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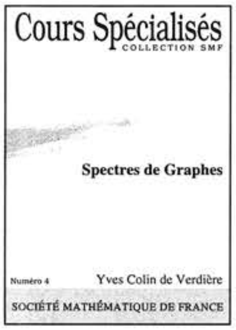
Contents: Introduction; Mise en place; Décroissance au sens large; Temps d'existence; Stabilité BV; Applications; Bibliographie.

Memoires de la Société Mathématique de France, Number 75

April 1999, approximately 112 pages, Softcover, ISBN 2-85629-072-8, 1991 *Mathematics Subject Classification*: 35L65, **Individual member $30**, List $33, Order code SMFMEM/75N

Discrete Mathematics and Combinatorics



Spectres de Graphes

Yves Colin de Verdière, *Institut Fourier, St. Martin d'Hères, France*

A publication of Société Mathématique de France.

The aim of this book is to develop for finite graphs some analogues of the spectral theory of Schrödinger operators on compact manifolds.

For graphs, the basic objects are sets of Schrödinger type operators (with or without magnetic fields). These sets include the canonical Laplacians on graphs, which are usually considered, as well as singular limits of continuous Schrödinger operators, singular limits of reversible Markov processes or finite elements methods.

After two introductory chapters of definitions and basic examples—functional analysis, Perron-Frobenius and Courant nodal theorems, eigenvalues perturbation theory—the following subjects are discussed: spectral gaps and Cheeger's inequalities, multiplicities of eigenvalues and Cheng's type theorem, discrete and continuous Schrödinger operators and electrical networks.

This item will also be of interest to those working in analysis.

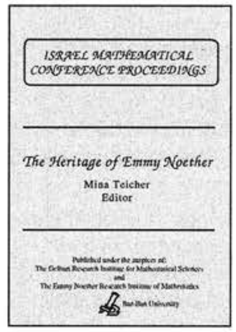
Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Définitions et exemples; Spectres; Le trou spectral des graphes et leurs propriétés d'expansion; Limites singulières et Γ-convergence; Multiplicités des valeurs propres et invariants associés; Discret et continu; Réseaux électriques; Bibliographie; Index.

Cours Spécialisés—Collection SMF, Number 4

October 1998, 114 pages, Softcover, ISBN 2-85629-068-X, 1991 *Mathematics Subject Classification*: 05C10, 05C15, 05C50, 35J10, 58G25, **Individual member $23**, List $26, Order code COSP/4N

General and Interdisciplinary



The Heritage of Emmy Noether

Mina Teicher, *Bar-Ilan University, Ramat-Gan, Israel*, Editor

A publication of Bar-Ilan University.

Named for the noted mathematician, the Emmy Noether Research Institute for Mathematics held a two-day conference dedicated to her heritage and her influence on mathematics and physics in the 20th and 21st centuries. This volume presents the proceedings of that conference. It includes a comprehensive description of her contributions to commutative and noncommutative algebra, algebraic geometry, topology, and physics given by world experts in these fields. Also included is a profile of her life. The volume is a comprehensive collection of Noether's valuable contributions to mathematics and physics.

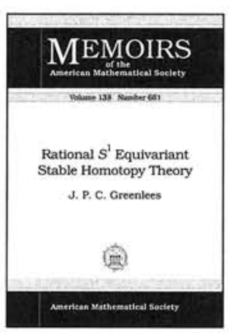
Distributed worldwide by the AMS.

Contents: M. Teicher, On Emmy Noether; **C. Procesi**, 150 years of invariant theory; **H. Flenner**, Emmy Noether and the development of commutative algebra; **W. Scharlau**, Emmy Noether's contributions to the theory of algebras; **F. Hirzebruch**, Emmy Noether and topology; **N. Byers**, E. Noether's discovery of the deep connection between symmetries and conservation laws; **Y. Ne'eman**, The impact of Emmy Noether's theorems on XXIst century physics.

Israel Mathematical Conference Proceedings, Volume 12

December 1998, 101 pages, Softcover, 1991 *Mathematics Subject Classification*: 13, 14, 16, 17; 54, **Individual member $23**, List $39, Institutional member $31, Order code IMCP/12N

Geometry and Topology



Rational S^1-Equivariant Stable Homotopy Theory

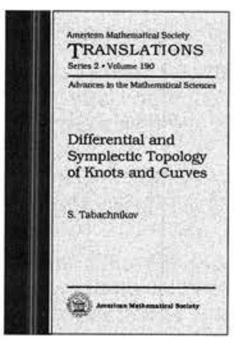
J. P. C. Greenlees, *University of Sheffield, England*

The memoir presents a systematic study of rational S^1-equivariant cohomology theories, and a complete algebraic model for them. It provides a classification of such cohomology theories in simple algebraic terms and a practical means of calculation. The power of the model is illustrated by analysis of the Segal conjecture, the behaviour of the Atiyah-Hirzebruch spectral sequence, the structure of S^1-equivariant K-theory, and the rational behaviour of cyclotomic spectra and the topological cyclic homology construction.

Contents: General introduction; *Part I. The algebraic model of rational* $\mathbb{T}$*-spectra:* Introduction to Part I; Topological building blocks; Maps between $\mathcal{F}$-free $\mathbb{T}$-spectra; Categorical reprocessing; Assembly and the standard model; The torsion model; *Part II. Change of groups functors in algebra and topology:* Introduction to Part II; Induction, coinduction and geometric fixed points; Algebraic inflation and deflation; Inflation, Lewis-May fixed points and quotients; *Part III. Applications:* Introduction to Part III; Homotopy Mackey functors and related constructions; Classical miscellany; Cyclic and Tate cohomology; Cyclotomic spectra and topological cyclic cohomology; *Part IV. Tensor and Hom in algebra and topology:* Introduction; Torsion functors; Torsion functors for the semifree standard model; Wide spheres and representing the semifree torsion functor; Torsion functors for the full standard model; Product functors; The tensor-Hom adjunction; The derived tensor-Hom adjunction; Smash products, function spectra and Lewis-May fixed points; Appendix A. Mackey functors; Appendix B. Closed model categories; Appendix C. Conventions; Appendix D. Indices; Appendix E. Summary of models; Bibliography.

Memoirs of the American Mathematical Society, Volume 138, Number 661

March 1999, 289 pages, Softcover, ISBN 0-8218-1001-4, LC 98-53107, 1991 *Mathematics Subject Classification*: 55N91, 55P41, 55P42, 55P62; 18E30, 19D55, 19L47, 20C99, 55T15, 55T25, **Individual member $36**, List $60, Institutional member $48, Order code MEMO/138/661N



Differential and Symplectic Topology of Knots and Curves

S. Tabachnikov, *University of Arkansas, Fayetteville*, Editor

This book presents a collection of papers on two related topics: topology of knots and knot-like objects (such as curves on surfaces) and topology of Legendrian knots and links in 3-dimensional contact manifolds.

Featured is the work of international experts in knot theory ("quantum" knot invariants, knot invariants of finite type), in symplectic and contact topology, and in singularity theory. The interplay of diverse methods from these fields makes this volume unique in the study of Legendrian knots and knot-like objects such as wave fronts. A particularly enticing feature of the volume is its international significance. The volume successfully embodies a fine collaborative effort by worldwide experts from Belgium, France, Germany, Israel, Japan, Poland, Russia, Sweden, the U.K., and the U.S.

Contents: J. C. Álvarez Paiva, Contact topology, taut immersions, and Hilbert's fourth problem; **E. Ferrand**, On Legendre cobordisms; **V. Goryunov**, Vassiliev invariants of knots in $\mathbb{R}^3$ and in a solid torus; **T. Januszkiewicz** and **J. Świątkowski**, Finite type invariants of generic immersions of M^n into $\mathbb{R}^{2n}$ are trivial; **S. K. Lando**, On enumeration of unicursal curves; **A. B. Merkov**, Vassiliev invariants classify flat braids; **M. Polyak**, New Whitney-type formulas for plane curves; **B. Shapiro**, Tree-like curves and their number of inflection points; **S. Tabachnikov**, Geometry of exact transverse line fields and projective billiards; **V. Tchernov**, Shadows of wave fronts and Arnold-Bennequin type invariants of fronts on surfaces and orbifolds; **M. Umehara**, A unified approach to the four vertex theorems. I; **G. Thorbergsson** and **M. Umehara**, A unified approach to the four vertex theorems. II; **V. A. Vassiliev**, Topology of two-connected graphs and homology of spaces of knots.

American Mathematical Society Translations—Series 2 (*Advances in the Mathematical Sciences*), Volume 190

March 1999, approximately 289 pages, Hardcover, ISBN 0-8218-1354-4, 1991 *Mathematics Subject Classification*: 57Gxx; 53Cxx, **Individual member $59**, List $99, Institutional member $79, Order code TRANS2/190N

Complex Analytic Geometry of Complex Parallelizable Manifolds

Jörg Winkelmann, *Ruhr-Universität Bochum, Germany*

A publication of Société Mathématique de France.

In this work, the author examines complex parallellizable manifolds, i.e., complex manifolds arising as quotients of complex Lie groups by discrete subgroups. Special emphasis is put on quotients by discrete subgroups which are co-compact or at least of finite co-volume.

These quotient manifolds are studied from a complex-analytic point of view. Topics considered include submanifolds, vector bundles, cohomology, deformations, maps and functions. Furthermore, arithmeticity results for compact complex nilmanifolds are deduced.

To improve accessibility, an exposition of basic results on lattices in complex Lie groups is also included.

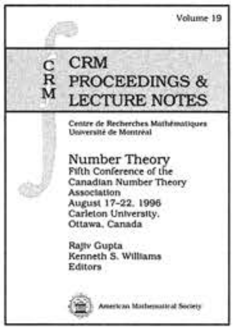
Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Arithmetic groups; Closed orbits and density results; Subvarieties; Holomorphic mappings; Vector bundles; Flat bundles; Deformations and cohomology; On the structure of complex nilmanifolds; Holomorphic functions on an algebraic group invariant under a Zariski dense subgroup; Density properties: Overview; Bibliography; Index.

Memoires de la Société Mathématique de France, Number 72, Number 73

October 1998, 219 pages, Softcover, ISBN 2-85629-070-1, 1991 *Mathematics Subject Classification*: 22E40, 32M10; 14E09, 14L30, 14K22, 20G20, 32C10, 32G05, 32H02, 32J99, 57S30, **Individual member $50**, List $55, Order code SMFMEM/72/73N

Number Theory



Number Theory

Fifth Conference of the Canadian Number Theory Association

Rajiv Gupta, *University of British Columbia, Vancouver, Canada*, and **Kenneth S. Williams**, *Carleton University, Ottawa, ON, Canada*, Editors

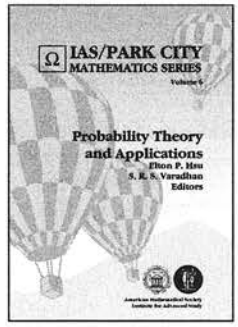
This book contains papers presented at the fifth Canadian Number Theory Association (CNTA) conference held at Carleton University (Ottawa, ON). The invited speakers focused on arithmetic algebraic geometry and elliptic curves, diophantine problems, analytic number theory, and algebraic and computational number theory. The contributed talks represented a wide variety of areas in number theory. David Boyd gave an hour-long talk on "Mahler's Measure and Elliptic Curves". This lecture was open to the public and attracted a large audience from outside the conference.

Contents: **A. Baragar**, Rational curves with zero self intersection on certain $K3$ surfaces; **B. C. Berndt** and **H. H. Chan**, Notes on Ramanujan's singular moduli; **M.-J. Bertin**, The operator $x+(1/x)-2$ and the reciprocal integers; **F. Beukers**, Integral points on cubic surfaces; **D. A. Buell**, The last exhaustive computation of class groups of complex quadratic number fields; **K.-K. Choi** and **J. D. Vaaler**, Diophantine approximation in projective space; **R. J. Cook**, Bounds for odd perfect numbers; **W. Duke**, Automorphic L-functions in level aspect; **R.-M. Elkenbracht-Huizing**, **P. L. Montgomery**, **R. D. Silverman**, **R. K. Wackerbarth**, and **S. S. Wagstaff, Jr.**, The number field sieve on many computers; **P. Erdős** and **M. R. Murty**, On the order of $a \pmod p$; **C. Friesen**, A special case of Cohen-Lenstra heuristics in function fields; **W. F. Galway**, An asymptotic expansion of Ramanujan; **C. Greither**, Improving Ramachandra's and Levesque's unit index; **S. Gurak**, On the middle factor of the period polynomial for finite fields; **A. Ivić** and **C. Pomerance**, On the distribution of champs; **J. W. Jones** and **D. P. Roberts**, Sextic number fields with discriminant $(-1)^j 2^a 3^b$; **M. Kaneko**, Traces of singular moduli and the Fourier coefficients of the elliptic modular function $j(\tau)$; **P. Kaplan**, Problème d'Eisenstein pour le conducteur 3; **M. Langevin**, Liens entre le théorème de Mason et la conjecture (abc); **X.-J. Li**, On the trace of Hecke operators for Maass forms; **S. Lindhurst**, An analysis of Shanks's algorithm for computing square roots in finite fields; **M.-C. Liu** and **T. Wang**, On the equation $a_1p_1+a_2p_2+a_3p_3=b$ with prime variables in arithmetic progressions; **S. Louboutin** and **R. A. Mollin**, Solutions to $x^2-Dy^2=Q$; **K. Ono** and **K. Soundararajan**, Integers represented by ternary quadratic forms; **P. L. Pacelli**, Some uniformity results following from the Lang conjectures; **Y. N. Petridis**, Fourier coefficients of cusp forms; **A. J. van der Poorten**, Beer and continued fractions with periodic periods; **C. J. Smyth**, An inequality for polynomials; **S. H. Son**, Some integrals of theta functions in Ramanujan's lost notebook; **H. A. Verrill**, Arithmetic of a certain Calabi-Yau threefold; **L. Ya. Vulakh**, Diophantine approximation in Euclidean spaces; **M. Waldschmidt**, Transcendance et indépendance algébrique de valeurs de fonctions modulaires; **S. Wong**, On the rank of ideal class groups; **R. K. Guy**, Conference problems session conducted by J. L. Selfridge; **P. Ribenboim**, Homework!.

CRM Proceedings & Lecture Notes, Volume 19

April 1999, 392 pages, Softcover, ISBN 0-8218-0964-4, 1991 *Mathematics Subject Classification*: 11-06, **Individual member $66,** List $110, Institutional member $88, Order code CRMP/19N

Probability



Probability Theory and Applications

Elton P. Hsu, *Northwestern University, Evanston, IL*, and **S. R. S. Varadhan**, *Courant Institute, New York University, NY*, Editors

This volume, with contributions by leading experts in the field, is a collection of lecture notes of the six minicourses given at the IAS/Park City Summer Mathematics Institute. It introduces advanced graduates and researchers in probability theory to several of the currently active research areas in the field. Each course is self-contained with references and contains basic materials and recent results. Topics include interacting particle systems, percolation theory, analysis on path and loop spaces, and mathematical finance.

The volume gives a balanced overview of the current status of probability theory. An extensive bibliography for further study and research is included. This unique collection presents several important areas of current research and a valuable survey reflecting the diversity of the field.

Members of the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) receive a 20% discount from list price.

Contents: *R. Durrett, Stochastic Spatial Models:* Introduction; The voter model; Coalescing random walks; Voter model with mutation; The block construction; Long range limits; Rapid stirring limits; Bibliography; *J. T. Chayes, A. L. Puha, and T. Sweet, Independent and Dependent Percolation:* Preface; The basics of percolation; Rescaling and finite-size scaling in percolation; Critical exponent inequalities; Two fundamental questions; Finite-size scaling and the incipient infinite cluster; The BK(R) inequality; The Potts model and the random cluster model; Bibliography; *L. Jensen and H.-T. Yau, Hydrodynamical Scaling Limits of Simple Exclusion Models:* Introduction; The simple exclusion model; Proof of Theorem 1.4; Local ergodicity; Two-block estimate; Relative entropy; The Green-Kubo formula and asymmetric simple exclusion processes; Some open problems; Bibliography; *D. W. Stroock, An Introduction to Analysis on Path Space:* Introduction; Gaussian measures on a Hilbert space; Rolling on; About $\mathcal{W}_M$; A few facts, and something else; Bibliography; *E. P. Hsu, Analysis on Path and Loop Spaces:* Introduction; Euclidean Brownian motion; Gradient operator; Ornstein-Uhlenbeck operator; Brownian motion on manifolds; Gradient formulas; Integration by parts; Logarithmic Sobolev inequalities; Bibliographical comments; Bibliography; *M. Avellaneda, An Introduction to Option Pricing and the Mathematical Theory of Risk:* Bibliography.

IAS/Park City Mathematics Series, Volume 6

March 1999, 374 pages, Hardcover, ISBN 0-8218-0590-8, LC 98-51767, 1991 *Mathematics Subject Classification*: 60-01, 60-02, **All AMS members $45,** List $56, Order code PCMS/6N

Previously Announced Publications

Monge Ampère Equation: Applications to Geometry and Optimization

Luis A. Caffarelli, *New York University, Courant Institute*, and **Mario Milman**, *Florida Atlantic University, Boca Raton*, Editors

In recent years, the Monge Ampère Equation has received attention for its role in several new areas of applied mathematics:

- As a new method of discretization for evolution equations of classical mechanics, such as the Euler equation, flow in porous media, Hele-Shaw flow, etc.,
- As a simple model for optimal transportation and a div-curl decomposition with affine invariance and
- As a model for front formation in meteorology and optimal antenna design.

These applications were addressed and important theoretical advances presented at a NSF-CBMS conference held at Florida Atlantic University (Boca Raton). L. Cafarelli and other distinguished specialists contributed high-quality research results and up-to-date developments in the field. This is a comprehensive volume outlining current directions in nonlinear analysis and its applications.

Contents: J.-D. Benamou and **Y. Brenier**, A numerical method for the optimal time-continuous mass transport problem and related problems; **L. A. Caffarelli, S. A. Kochengin**, and **V. I. Oliker**, On the numerical solution of the problem of reflector design with given far-field scattering data; **M. J. P. Cullen** and **R. J. Douglas**, Applications of the Monge-Ampére equation and Monge transport problem to meterology and oceanography; **M. Feldman**, Growth of a sandpile around an obstacle; **W. Gangbo**, The Monge mass transfer problem and its applications; **B. Guan**, Gradient estimates for solutions of nonparametric curvature evolution with prescribed contact angle condition; **L. G. Hanin**, An extension of the Kantorovich norm; **M. McAsey** and **L. Mou**, Optimal locations and the mass transport problem; **E. Newman** and **L. P. Cook**, A generalized Monge-Ampére equation arising in compressible flow; **J. Urbas**, Self-similar solutions of Gauss curvature flows.

Contemporary Mathematics, Volume 226

October 1998, 172 pages, Softcover, ISBN 0-8218-0917-2, LC 98-38822, 1991 *Mathematics Subject Classification*: 35J60, 35B65, 35A30, 46N10, 49Q20, 58E12, **Individual member $23**, List $39, Institutional member $31, Order code CONM/226RT93

Recommended Text

Mirror Symmetry and Algebraic Geometry

David A. Cox, *Amherst College, MA*, and **Sheldon Katz**, *Oklahoma State University, Stillwater*

Mirror symmetry began when theoretical physicists made some astonishing predictions about rational curves on quintic hypersurfaces in four-dimensional projective space. Understanding the mathematics behind these predictions has been a substantial challenge. This book is the first completely comprehensive monograph on mirror symmetry, covering the original observations by the physicists through the most recent progress made to date. Subjects discussed include toric varieties, Hodge theory, Kähler geometry, moduli of stable maps, Calabi-Yau manifolds, quantum cohomology, Gromov-Witten invariants, and the mirror theorem.

Features:

- Numerous examples worked out in detail
- An appendix on mathematical physics
- An exposition of the algebraic theory of Gromov-Witten invariants and quantum cohomology
- A proof of the mirror theorem for the quintic threefold

This item will also be of interest to those working in mathematical physics.

Mathematical Surveys and Monographs, Volume 68

March 1999, 467 pages, Hardcover, ISBN 0-8218-1059-6, 1991 *Mathematics Subject Classification*: 14-02; 81-02, **All AMS members $55**, List $69, Order code SURV/68RT93

Mirror Symmetry III

Duong H. Phong, *Columbia University, New York*, **Luc Vinet**, *University of Montreal, PQ, Canada*, and **Shing-Tung Yau**, *Harvard University, Cambridge, MA*, Editors

This book presents surveys from a workshop held during the theme year in geometry and topology at the Centre de recherches mathématiques (CRM, University of Montréal). The volume is in some sense a sequel to *Mirror Symmetry I* (1998) and *Mirror Symmetry II* (1996), co-published by the AMS and International Press.

Included are recent developments in the theory of mirror manifolds and the related areas of complex and symplectic geometry. The long introductory articles explain the key physical ideas and motivation, namely conformal field theory, supersymmetry, and string theory. Open problems are emphasized. Thus the book provides an efficient way for a very broad audience of mathematicians and physicists to reach the frontier of research in this fast expanding area.

Features:

- Crucial research pertaining to future developments in algebraic and symplectic geometry and to the physics of unified string theories
- Well-known authors who are leaders in the field
- Introductory article by Greene and Yau
- A solid and even blend of ideas and techniques from both mathematics and physics

This item will also be of interest to those working in mathematical physics.

This book is co-published by the AMS, International Press, and Centre de Recherches Mathématiques.

Contents: B. R. Greene, Aspects of quantum geometry; **S.-T. Yau**, Introduction to enumerative invariants; **T. H. Parker**, Compactified moduli spaces of pseudo-holomorphic curves; **M. Verbitsky**, Mirror symmetry for hyper-Kähler manifolds; **M. Gross**, Connecting the web: A prognosis; **A. Klemm** and **P. Mayr**, Strong coupling singularities and non-abelian gauge symmetries in $N = 2$ string theory; **S. Kachru**, Remarks on (0,2) Calabi-Yau models; **K. Liu**, Relations among fixed point; **J. Jorgenson** and **A. Todorov**, An analytic discriminant for polarized algebraic $K3$ surfaces; **D. R. Morrison**, Through the looking glass; **B. Siebert**, An update on (small) quantum cohomology.

AMS/IP Studies in Advanced Mathematics, Volume 10

January 1999, 312 pages, Hardcover, ISBN 0-8218-1193-2, LC 98-37643, 1991 *Mathematics Subject Classification*: 14-06; 32-06, 81-06, **All AMS members $34**, List $42, Order code AMSIP/10RT93

AMS Video

Introduction to Geometric Probability

Gian-Carlo Rota, *Massachusetts Institute of Technology, Cambridge*

This lecture examines the notion of invariant measure from a fresh viewpoint. The most familiar examples of invariant measures are area and volume, which are invariant under the group of rigid motions. Master expositor Gian-Carlo Rota shows how, starting with a few simple axioms, one can concoct new invariant measures and explore their properties. One set of such measures, known as the intrinsic volumes, are quite new and still somewhat mysterious. However, they have intriguing probabilistic interpretations and in fact can be shown to form a basis for the space of all continuous invariant measures. Rota also discusses the remarkable connection between the intrinsic volumes and the Euler characteristic. Reaching deep ideas while remaining at an elementary level, this lecture would be accessible to undergraduate mathematics majors.

This item will also be of interest to those working in geometry and topology.

November 1998, NTSC format on one-half inch VHS videotape, approximately 60 minutes, ISBN 0-8218-1351-X, 1991 *Mathematics Subject Classification*: 52, 60, **Individual member $34.95**, List $54.95, Institutional member $44.95, Order code VIDEO/102RT93

Multichannel Optical Networks: Theory and Practice

Peng-Jun Wan, *Illinois Institute of Technology, Chicago*, **Ding-Zhu Du**, *University of Minnesota, Minneapolis*, and **Panos M. Pardalos**, *University of Florida, Gainesville*, Editors

Time division multiplexing (TDM) has been the fundamental basis for adding capacity to digital telecommunications networks for decades. However, within the past two years, wavelength division multiplexing (WDM) has been emerging as an important and widely deployed complement to TDM. Sales of systems based on the new technology have risen at breathtaking speed. The driving force behind this sales explosion was the unexpected rapid exhaustion of long distance fiber network capacity. This fiber exhaust, combined with favorable economics for WDM, led to the use of this technology over other alternatives.

The WDM deployment raises fundamental and challenging problems that require novel and innovative solutions. This volume presents papers from an interdisciplinary workshop held at DIMACS on multichannel optical networks. Leading computer science theorists and practitioners discussed admissions control, routing and channel assignment, multicasting and protection, and fault-tolerance. The book features application of theoretical and/or algorithmical results to practical problems and addresses the influence of practical problems to theoretical/algorithmic studies. The volume can serve as a text for an advanced course in computer science, networking, and operations research.

Contents: V. Auletta, I. Caragiannis, C. Kaklamanis, and **P. Persiano**, Efficient wavelength routing in trees with low-degree converters; **P.-J. Wan** and **L. Liu**, Maximal throughput in wavelength-routed optical networks; **O. Gerstel**, Minimizing the cost of an optical network; **V. Kumar**, Bandwidth allocation algorithms for tree and ring networks; **K. Sivalingam, J. Wang, X. Wu**, and **M. Mishra**, Improved on-line scheduling algorithms for optical WDM networks; **B. Beauquier**, Broadcasting in WDM optical rings and tori; **E. J. Harder** and **H.-A. Choi**, Gossiping in WDM all-optical square mesh networks; **C. Zhou** and **Y. Yang**, On the number of wavelengths required to embed multicast assignments in WDM networks; **D. S. Kim, D.-Z. Du**, and **P. M. Pardalos**, On conflict-free channel set assignments for optical cluster-based hypercube networks; **S. Ramamurthy** and **B. Mukherjee**, Fault-tolerant design of wavelength-routed optical networks; **O. Crochat, J.-Y. Le Boudec**, and **O. Gerstel**, Protection interoperability for WDM optical networks; **J. Skorin-Kapov** and **J.-F. Labourdette**, On minimum congestion routing in broadcast optical networks with regular and arbitrary topologies; **C. Qiao, Y. Mei, M. Yoo**, and **X. Zhang**, Polymorphic control for cost-effective design of optical networks; **C.-C. Yu, S. Bhattacharya**, and **P. Shen**, Adaptive cycle time for real-time TWDM: Tool and performance analysis; **F. Siu** and **R. K. C. Chang**, Optimal node assignment in reconfigurable WDM lightwave networks with regular virtual topologies; **I. Chlamtac, A. Fumagalli**, and **V. Elek**, Performance of photonic slot routing networks; **R. Bartoš, P. De La Torre**, and **R. Kannan**, Space-time-wavelength network with group communication locality.

DIMACS: Series in Discrete Mathematics and Theoretical Computer Science, Volume 46

January 1999, 249 pages, Hardcover, ISBN 0-8218-1004-9, LC 98-44528, 1991 *Mathematics Subject Classification*: 03B05, 90A05, 68T15, 68Q25, 68Q42, 68R10, 90C27, 90C30, 90B40, 68T01, 68Q15; 68Q22, 68Q25, 68P10, **Individual member $33**, List $55, Institutional member $44, Order code DIMACS/46RT93

Selections from MSRI's Video Archive, Volume 2

The Chern Symposium, March 5–7, 1998

A publication of MSRI.

This CD-ROM features video presentations from the Chern symposium in geometry sponsored jointly by the University of CA (Berkeley) and MSRI. The symposium presented developments in differential geometry over the past few decades. Recent progress and new directions in the field were also covered.

The CD requires Real™Video Player, which can be downloaded for free from the RealNetworks Internet home page. RealVideo Player is available for Windows95/Windows NT, Windows 3.1, MacOS, IRIX 6.2/6.3, Solaris 2.5 and Linux 2.0.

Distributed worldwide by the American Mathematical Society.

®RealVideo is a registered trademark and RealNetworks is a trademark of RealNetworks, Inc.

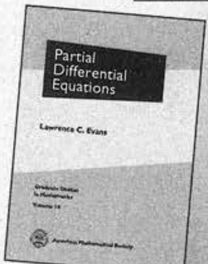
Contents: J. Simons, Introductory remarks; **R. Bott**, Configuration space invariants of knots and 3-manifolds; **R. Bryant**, Finsler manifolds of constant flag curvature; **Xiu-Xiong Chern**, Extremal metrics in Riemann surfaces and the uniformization theorem; **S. S. Chern**, Projective geometry; **F. Hirzebruch**, Why do I like Chern classes?; **B. Lawson**, Algebraic cycles and the classical groups; **K. Liu**, Mirror principle; **E. Meinrenken**, Duistermaat-Heckman formulas for group valued moment maps; **C.-L. Terng**, Backlund transformations and loop ground actions; **A. Weinstein**, From Riemann geometry to Poisson geometry and back again.

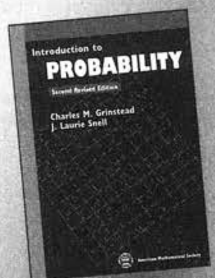
Selections From MSRI's Video Archive

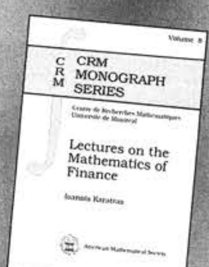
July 1998, CD-ROM, 1991 *Mathematics Subject Classification*: 53, List $15, Order code MSRICD/2RT93

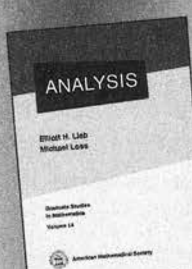
American Mathematical Society

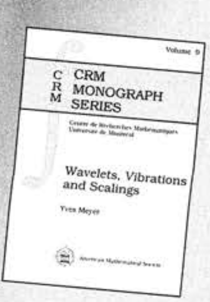
PUBLICATIONS *of* CONTINUING INTEREST











Graduate Textbooks from the AMS

We are pleased to offer this selection of graduate textbooks from the AMS. These titles can serve many useful purposes in an academic program of study. Some volumes are used as primary course texts, some for supplemental reading and others for independent study. Visit the AMS Bookstore for more texts in your subject area; go to www.ams.org/bookstore/. Of particular interest will be current and backlist selections from the highly popular *Graduate Studies in Mathematics* series.

Recommended Text

Partial Differential Equations

Lawrence C. Evans, *University of California, Berkeley*

Graduate Studies in Mathematics, Volume 19; 1998; ISBN 0-8218-0772-2; 662 pages; Hardcover; **All AMS members $60**, List $75, Order Code GSM/19CI93

Recommended Text

Introduction to Probability
Second Revised Edition

Charles M. Grinstead, *Swarthmore College, PA*, and
J. Laurie Snell, *Dartmouth College, Hanover, NH*

1997; ISBN 0-8218-0749-8; 510 pages; Hardcover; **All AMS members $39**, List $49, Order Code IPROBCI93

Independent Study

Lectures on the Mathematics of Finance

Ioannis Karatzas, *Columbia University, NY*

Provides an excellent introduction to a wide range of topics in mathematical finance.

—*Mathematical Reviews*

The young researcher/postgraduate student will be able to glance at the forefront of current research in mathematical finance. The author's clear and careful writing makes reading a pleasure. A lot of material, hitherto available only in research papers, will now reach a wider audience. This is a most useful addition to the fast growing literature on mathematical finance.

—*Short Book Reviews, a publication of the International Statistical Institute*

CRM Monograph Series, Volume 8; 1997; ISBN 0-8218-0909-1; 148 pages; Softcover; **All AMS members $31**, List $39, Order Code CRMM/8.SCI93

Recommended Text

Analysis

Elliott H. Lieb, *Princeton University, NJ*, and **Michael Loss**, *Georgia Institute of Technology, Atlanta*

Lieb and Loss offer a practical presentation of real and functional analysis at the beginning graduate level ... could be used as a two-semester introduction to graduate analysis ... not all of the topics covered are typical. The authors introduce the subject with a thorough presentation ... [an] informative exposition.

—*CHOICE*

I find the selection of the material covered in the book very attractive and I recommend the book to anybody who wants to learn about classical as well as modern mathematical analysis.

—*European Mathematical Society Newsletter*

[The text was used as] a supplemental resource ... appropriate because Lieb and Loss's approach to this subject is quite unusual ... When looking at a particularly complicated set of ideas, I suggest [that students], "Have a look at Lieb/Loss. They have a nice way of cutting through all the difficulties and giving you a real picture of what is going on" ... I would certainly recommend this book [as a supplemental text] to colleagues who are teaching graduate real analysis.

—*Steven G. Krantz, Washington University, St. Louis*

Analysis is a unique book. It is written very much from the perspective of a user of analysis ... I do not know of any other book that shows so well what it takes to do research in applied and variational analysis or to solve real analysis problems as they naturally arise in mathematical physics and quantum mechanics ... The book is also very attractively produced ... The AMS is setting a new standard ... proving that quality editions do not have to be expensive ... [Students] found the concrete and constructive nature of the approach in the book very attractive.

—*Bruno Nachtergaele, University of California, Davis*

The book was ideal for my purposes, which included some introduction to some problems in mathematical physics, some "reinforcement" of what they already learned in real variable, and a good overview of the inequalities that working analysts need to use ... I personally find the book an extremely useful and convenient reference for research purposes.

—*Lawrence E. Thomas, University of Virginia, Charlottesville*

The text can be used as a first year graduate course on real analysis or as an introduction to harmonic analysis and PDE. Advanced undergraduates can also have an independent reading after they complete an advanced calculus class ... It is a very interesting text. It is perhaps the best text for students wanting to specialize in harmonic analysis or PDE.

—*Jose Barrionuevo, University of South Alabama, Mobile*

Text is clear and rigorous and a joy to look at; both authors are to be congratulated.

—*Dr. David B. Cook, University of Sheffield, UK*

The essentials of modern analysis ... are presented in a rigorous and pedagogical way ... readers ... are guided to a level where they can read the current literature with understanding ... treatment of the subject is as direct as possible.

—*Zentralblatt für Mathematik*

Graduate Studies in Mathematics, Volume 14; 1997; ISBN 0-8218-0632-7; 278 pages; Hardcover; **All AMS members $28**, List $35, Order Code GSM/14CI93

Supplementary Reading

Wavelets, Vibrations and Scalings

Yves Meyer, *University of Paris-Dauphine, France*

CRM Monograph Series, Volume 9; 1997; ISBN 0-8218-0685-8; 133 pages; Hardcover; **All AMS members $23**, List $29, Order Code CRMM/9CI93

Recommended Text

Algebra
Third Edition

Saunders Mac Lane and **Garrett Birkhoff**

Nearly any ten years there seems to arrive a new edition of this now classical book the review of which (1st edition 1967, Zbl. 153,324; 2nd edition 1979, Zbl. 428.00002) the reviewer hardly can improve. The main advantage of the authors had been the introduction of thoroughly categorical concepts into algebra.

—*Zentralblatt für Mathematik*

The book is clearly written, beautifully organized, and has an excellent and wide-ranging supply of exercises ... contains ample material for a full-year course on modern algebra at the undergraduate level.

—*Mathematical Reviews*

AMS Chelsea Publishing; 1988; ISBN 0-8218-1646-2; 626 pages; Hardcover; **All AMS members $35**, List $39, Order Code CHEL/330.HCI93

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U. S., please include $6.50 per item. *Prepayment required.* Order from: **American Mathematical Society**, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax 1-401-455-4046 or call toll free 1-800-321-4AMS (4267) in the U. S. and Canada,1-401-455-4000 worldwide. Or place your order through the AMS bookstore at www.ams.org/bookstore/. Residents of Canada, please include 7% GST.

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Classified Advertisements

Positions available, items for sale, services available, and more

ALABAMA

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
Mathematical Sciences Department

The Mathematical Sciences Department at the University of Alabama in Huntsville invites applications for two tenure-track faculty positions with the rank of lecturer beginning August 1999. The positions are renewable upon the result of annual performance evaluations. Applicants must possess at least a master's degree or, preferably, a doctoral degree in mathematics or mathematics education, demonstrate evidence of excellent teaching ability, and have expertise or strong interest in computer-assisted mathematics curriculum. Send a letter of application, vita, transcripts, and three letters of reference to Chairman, Department of Mathematical Sciences, University of Alabama in Huntsville, Huntsville, AL 35899. Review of applicants will begin April 20, 1999, and will continue until the positions are filled. Women and minorities are encouraged to apply. The University of Alabama in Huntsville is an Affirmative Action/ Equal Opportunity Institution.

CALIFORNIA

CLAREMONT MCKENNA COLLEGE
Department of Mathematics

Claremont McKenna College invites applications for a tenure-track position in mathematics at the assistant professor level, starting in the fall of 1999. Candidates must have a Ph.D. in mathematics; demonstrated excellence in teaching across a broad range of undergraduate courses; and a productive, ongoing research program. This position is subject to final budgetary approval.

Claremont McKenna College is a highly selective undergraduate institution enrolling approximately 1,000 students. CMC is a member of the Claremont Colleges, which also include Pomona, Scripps, Pitzer, Harvey Mudd, and the Claremont Graduate University. Collectively the Claremont Colleges constitute an academic community of 6,000 students; their combined faculties include over 40 mathematicians. Claremont is located thirty-five miles east of Los Angeles.

Applicants should provide a curriculum vitae, three letters of reference, and a professional statement describing their experience and philosophy in both teaching and research. Evaluation of applications will begin by February 28, 1999, and will continue until a candidate is selected. AA/EOE. Send all materials to:

Search Committee
Department of Mathematics
Claremont McKenna College
850 Columbia Avenue
Claremont, CA 91711

INDIANA

INDIANA UNIVERSITY-PURDUE UNIVERSITY, INDIANAPOLIS
Indianapolis, IN

The Department of Mathematical Sciences has a tenure-track assistant professor position in statistics to begin August 1999. The Department has a growing graduate program in statistics and offers a competitive salary and excellent benefits. A Ph.D. in statistics or in a related area, strong research potential, and a commitment to excellence in teaching are required. A letter of application, résumé, and three letters of recommendation should be sent to Robert Kleyle, Department of Mathematical Sciences, Indiana University-Purdue University, Indianapolis, 402 N. Blackford St., Indianapolis, IN 46202. Review of applications will begin 1/15/99 and will continue

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Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 1998 rate is \$100 per inch or fraction thereof on a single column (one-inch minimum), calculated from top of headline. Any fractional text of 1/2 inch or more will be charged at the next inch rate. No discounts for multiple ads or the same ad in consecutive issues. For an additional \$10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified advertising.

Upcoming deadlines for classified advertising are as follows: April issue–January 16, 1999; May issue–February 23, 1999; June/July issue–April 26, 1999; August issue–May 21, 1999; September issue–June 21, 1999; October issue–July 23, 1999.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 1373 (vol. 44).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada, or 401-455-4084 worldwide, for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940, or via fax, 401-331-3842, or send e-mail to `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.

until the position is filled. Women and minorities are encouraged to apply. AA/EOE.

UNIVERSITY OF NOTRE DAME
Department of Mathematics
Howard J. Kenna Chair in Mathematics

The Department of Mathematics of the University of Notre Dame, Notre Dame, IN, seeks applications and nominations for its Howard J. Kenna Chair in Mathematics.

The successful candidate for this chair at the full professor level will be a nationally and internationally recognized mathematician in a central discipline of mathematics. Of special interest to the Department are candidates whose research activities inform and interconnect with one or more of the Department's mathematical enterprises. For an essential overview of the Department, see `http://www.math.nd.edu/math/`.

Applications should include a letter of interest; curriculum vitae; and the names, addresses, and telephone numbers of three references. Applications and nominations should be sent to: Professor Alexander J. Hahn, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556.

The review of candidates will begin immediately and will continue until the position is filled. The desired starting date is September 1, 1999.

MARYLAND

JOHNS HOPKINS UNIVERSITY
Department of Mathematics
3400 N. Charles St.
Baltimore, MD 21218

The Department of Mathematics invites applications for one or more positions at the associate or full professor level in the general areas of analysis, algebra, and topology beginning fall 1999 or later. Preference will be given to candidates whose work is related to mathematical physics in a broad sense. The Johns Hopkins University actively encourages interest from minorities and women. Applicants should send a curriculum vitae to Chair, Hiring Committee. First round preference will be given to applications received by April 1, 1999. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer.

MISSOURI

SOUTHWEST MISSOURI STATE UNIVERSITY

The Department of Mathematics at Southwest Missouri State University anticipates a tenure-track assistant or associate professor position in applied mathematics or statistics beginning August 1999. This is a tenure-track position. Applicants must have a Ph.D. in mathematics or statistics, evidence of excellence in teaching, potential for research, commitment to professional activities, and effective communication skills. A minimum of five years of experience equivalent to academic service to SMSU is required for the associate professor position. Interest in actuarial science and research interest compatible with the faculty will be considered in favor of the candidates. Salary is commensurate with experience. Further information is available over the Web at `http://math.smsu.edu/`.

To ensure consideration, application materials should be received by March 15, 1999. Send application (résumé, letter of interest, transcripts, description of current research, e-mail address and phone numbers of all references, and preferably the AMS Standard Cover Sheet) and three letters of reference to: ASA Position, Department of Mathematics, Southwest Missouri State University, Springfield, MO 65804-0094; fax: 417-836-6696. AA/EOE.

NORTH CAROLINA

NORTH CAROLINA STATE UNIVERSITY
Center for Research in Scientific Computation

The Center for Research in Scientific Computation at North Carolina State University, in collaboration with MedAcoustics, Inc., Raleigh, NC, expects to make a University-Industry Cooperative Postdoctoral Research appointment starting August 16, 1999 (availability of the position is contingent upon funding). The appointment will be in the area of applied mathematics and scientific computation. The successful candidate for this position is expected to participate in a collaborative multidisciplinary team carrying out fundamental research investigations to provide a better understanding and predictive capability of the dynamics of wave propagation from coronary stenoses through human body tissues. The research efforts will involve the modeling of wave propagation in a viscoelastic, heterogeneous, and anisotropic medium; development of computational algorithms for both forward and inverse problem analytic studies; and the design of corresponding experiments for model validation and verification. Since the project requires physical modeling, theoretical analysis, and computational skills, candidates who are outstanding in at least one of these areas and willing and able to learn quickly in the others will be given highest priority. This position offers a unique opportunity for multidisciplinary mentored postdoctoral research on a mathematical project arising in an industrial/university collaborative effort.

Applicants should send a vita and brief description of research interests and three letters of recommendation to: Search Committee, Attn: Hien T. Tran, Center for Research in Scientific Computation/Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695-8205; e-mail: `tran@control.math.ncsu.edu`. Applications will be considered at any time after January 15, 1999, as funding becomes available. NCSU is an AA/EOE. However, if this position is funded by the NSF, the successful applicant must be a U.S. citizen or lawfully admitted permanent resident alien of the U.S. by Jan. 1, 1999. In its commitment to diversity and equity, NCSU and the CRSC seek applications from women, minorities, and persons with disabilities. Individuals with disabilities desiring accommodations in the application process should contact Rory Schnell, CRSC; tel: 919-515-5289; fax: 919-515-1636; e-mail: `rlschnel@eos.ncsu.edu`.

TENNESSEE

UNIVERSITY OF TENNESSEE AT KNOXVILLE

The mathematics department at the University of Tennessee at Knoxville seeks to fill a postdoctoral position in some part of algebra. The position is guaranteed for two years and may be extended for a third year if performance is satisfactory. Continuation at the University of Tennessee beyond the third year is not possible. The teaching load for this position will be three semester-long courses during each academic year.

Candidates should provide evidence of their ability to teach in English and should have had their Ph.D. for no more than two years by September 1999.

Candidates should submit a curriculum vitae, a description of their research accomplishments and plans, and a statement about teaching. These documents as well as three letters of recommendation should be submitted to Professor John B. Conway, Dept. of Mathematics, University of Tennessee, Knoxville, TN 37996-1300. Use of the recent AMS application form is encouraged.

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VERMONT

UNIVERSITY OF VERMONT
Dean
College of Engineering and Mathematics

The University of Vermont invites applications and nominations for the position of the dean of the College of Engineering and Mathematics. The College is composed of the Departments of Computer Science, Civil and Environmental Engineering, Electrical and Computer Engineering, Mechanical Engineering, and Mathematics and Statistics.

The dean is chief executive officer of the College and is expected to provide innovative leadership to build on the excellent research and educational activities of the College. Primary responsibilities of the position include academic leadership, administrative oversight of fiscal and personnel matters, strategic planning, maintaining and enhancing relations with alumni and industrial partners, and development efforts for the College. Candidates should have a distinguished record of scholarly achievement; a strong commitment to excellence in teaching, research, and service; demonstrated administrative ability; and effective interpersonal and communication skills. The dean reports directly to the provost, who is the chief academic and administrative officer of the University.

The University of Vermont (UVM) was founded in 1791 and is the state's land-grant institution. Located in Burlington, Vermont, on the shores of Lake Champlain between the Adirondacks and the Green Mountains, UVM is home to eight colleges in addition to the College of Engineering and Mathematics and the Graduate College. The UVM undergraduate enrollment is 7,500; there are 1,100 graduate students, 385 medical students, and 1,300 non-degree students.

The College of Engineering and Mathematics enrolls 500 undergraduate majors and 150 graduate students pursuing M.S. or Ph.D. degrees and teaches approximately 24,000 credit hours per year. The College has 65 regular full-time faculty members, an annual general-fund budget of $7.3 million, and receives approximately $3.3 million from grants, contracts, and income-generating activities. The College also interfaces with many other programs in the University, e.g., Materials Science, Biomedical Engineering, Vermont Space Grant Consortium, and Ground Water Research. More information about the College is available at: http://www.emba.uvm.edu/.

The University of Vermont is an Equal Opportunity/Affirmative Action Employer. Women and those from diverse racial, ethnic and cultural backgrounds are encouraged to apply. Review of applications will begin immediately. Applications will be accepted until the position is filled; however, we strongly encourage the submission of materials by March 15. A curriculum vitae and letter of interest should be sent to:

John W. Frymoyer, M.D.
Chair, Engineering and
Mathematics Search Committee
Dean, College of Medicine
E-109 Given Building
Burlington, VT 05405

CANADA

QUEEN'S UNIVERSITY AT KINGSTON
Department of Mathematics and Statistics

The Department of Mathematics and Statistics at Queen's University anticipates hiring one to three postdoctoral fellows, each for a period of two years (nonrenewable) beginning September 1, 1999. Fellows will teach one course per term (two terms per year).

Applicants, who must have received their doctoral degree after April 1997, will be considered only in the following areas: algebraic K-theory, commutative algebra and algebraic geometry, discrete mathematics (with emphasis on algebraic graph theory), invariant theory and homotopy theory, number theory. Each applicant must specify in which area he or she wishes to be considered.

Interested candidates should arrange to have a curriculum vitae, a description of research interests, copies of up to five publications, at least three reference letters focusing on the candidate's research, and at least one reference letter on the candidate's teaching arrive at the address below. Candidates should have demonstrated interest and ability in teaching. Applications should be received by March 31, 1999.

Professor James A. Mingo
Associate Head
Department of Mathematics & Statistics
Queen's University
Kingston, Ontario K7L 3N6
Canada

Queen's University has an employment equity program and encourages applications from all qualified candidates, including women, aboriginal peoples, people with disabilities, and visible minorities.

Fax: 613-533-2964; e-mail: POSITION@MAST.QUEENSU.CA; Web: http://mast.queensu.ca.

CYPRUS

UNIVERSITY OF CYPRUS
Department of Mathematics and Statistics
P.O. Box 537
1678 Nicosia, Cyprus

We announce, subject to final approval, a tenure-track position in pure or applied mathematics. Outstanding candidates from any area will be considered, but preference will be given to applicants who complement existing strengths in algebra, analysis, differential equations, numerical analysis, and mathematical physics. At this stage send a résumé to the Search Committee at the above address. Knowledge of Greek is required.

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The Instituto de Matemáticas, UNAM-Morclia (Mexico), is a young research center in pure and applied math. Due to severe budget cuts in Mexico, we are seeking donations of books for our library in advanced mathematics in any field. Please send donations to Nicolas Romero, No. 150 Col. Centro, Morelia, Michoacan, Mexico, C.P. 58000. We may cover the postage. Information: lidia@matem.unam.mx; fax: 43-12-04-48.

AMERICAN MATHEMATICAL SOCIETY

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(January–December)

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City ***State*** ***Country***

Date of Birth . . . .
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Degrees, with institutions and dates . . . .

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Present position . . . .

Firm or institution . . . .

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City ***State*** ***Zip/Country***

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***Introductory ordinary member rate** applies to the first five **consecutive** years of ordinary membership. Eligibility begins with the first year of membership in any category other than student and nominee. Dues are $50.*

*For **ordinary members** whose annual professional income is below $55,000, the dues are $99; for those whose annual professional income is $55,000 or more, the dues are $132.*

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*For a **joint family membership,** one member pays ordinary dues, based on his or her income; the other pays ordinary dues based on his or her income, less $20. (Only the member paying full dues will receive the* Notices *and the* Bulletin *as a privilege of membership, but both members will be accorded all other privileges of membership.)*

*Minimum dues for **contributing members** are $198. The amount paid which exceeds the higher ordinary dues level and is purely voluntary may be treated as a charitable contribution.*

*For either **students** or **unemployed individuals,** dues are $33, and annual verification is required.*

*The annual dues for **reciprocity members** who reside outside the U.S. and Canada are $66. To be eligible for this classification, members must belong to one of those foreign societies with which the AMS has established a reciprocity agreement, and annual verification is required. Reciprocity members who reside in the U.S. or Canada must pay ordinary member dues ($99 or $132).*

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*Members can purchase a **multi-year membership** by prepaying their current dues rate for either two, three, four or five years. This option is not available to category-S, unemployed, or student members.*

1999 Dues Schedule (January through December)

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[1] **Student Verification** (sign below)

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. . . . *currently working toward a degree.*

[2] **Unemployed Verification** (sign below) *I am currently unemployed and actively seeking employment.*

[3] **Reciprocity Membership Verification** (sign below) *I am currently a member of the society indicated on the right and am therefore eligible for reciprocity membership.*

. . . .
Signature

[4] ☐ *send* **NOTICES** ☐ *send* **BULLETIN**

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- ☐ Gesellschaft für Angewandte Mathematik und Mechanik
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1999 Von Neumann Conference

Symposium on Arithmetic Fundamental Groups and Noncommutative Algebra

Mathematical Sciences Research Institute
Berkeley, California
August 16–27, 1999

With the support of a fund established by Dr. and Mrs. Carrol V. Newsom in honor of the memory of John von Neumann, along with funding from the National Security Agency, a symposium on *Arithmetic Fundamental Groups and Noncommutative Algebra* will take place Monday, August 16, to Friday, August 27, 1999, at the Mathematical Sciences Research Institute in Berkeley.

The topic was selected by the AMS Committee on Summer Institutes and Special Symposia, whose members at the time of selection were Robert Osserman, Jeffrey B. Rauch, Leon Takhatajan (chair), Clarence Eugene Wayne, and Ruth J. Williams. (The other committee member, Michael D. Fried, did not participate in the selection process.) Proceedings wil be published by the AMS.

Organizing Committee

Michael D. Fried, University of California, Irvine
David Harbater, University of Pennsylvania
Lance W. Small, University of California, San Diego

Symposium Overview

Geometric considerations have dominated recent activity in both of these areas, which are linked by the themes of group actions and deformations. This symposium will focus on these two areas and these links, bringing together aspects of algebraic geometry, field theory, number theory, representation theory, topology, ring theory, and group theory. Besides standing on its own, the symposium will also be useful to attendees intending to participate in the fall 1999 activities at MSRI by providing mathematical background and context regarding these areas and their connections.

The symposium will provide a presentation of key results in the areas covered, including an overview of current developments and research directions. The intended audience will include researchers from these and related fields, as well as recent Ph.D.s and advanced graduate students desiring a broader perspective on the areas. Special talks appropriate for nonexperts (including students and postdoctorals) will consist of interrelated minicourses, each of three or four lectures. These will systematically present one mathematical aspect, providing coordinating background for individual lectures on current research topics.

Many participants in this symposium would specifically come to MSRI for either or both weeks of the event (with the first week being more introductory in nature). Others may choose to stay longer at MSRI (using other funding) for the corresponding special programs during fall 1999.

Galois Theory Topics

Extensions of function fields, and the relationship to fundamental groups of varieties, give Galois theory its fundamentally geometric flavor. This holds even when the main consideration is to obtain information about the absolute Galois group of the rational numbers. The Inverse Galois Problem in recent years has advanced through the study of branched covers of the Riemann sphere and of the corresponding arithmetic and geometric Galois groups. This approach draws on representation theory both of finite groups and of fundamental groups of moduli spaces, such as braid groups. Topology and deformation theory come into play, along with a study of Galois actions, in understanding the arithmetic of covers, analyzing the absolute Galois group of the rationals, and in realizing finite groups as Galois groups. Other applications of this approach concern graph theory, cryptography, polynomial maps over finite fields, explicit forms of Hilbert's irreducibility theorem, and other constructive aspects of algebra.

Fundamental groups of varieties defined over more general fields have been studied in part by specialization to varieties over the complex numbers, where classical topological methods can be used. Another recent approach has been to use patching and deformation methods in formal and rigid geometry, which extend complex methods to other settings. This latter approach has led to results about fundamental groups over fields of positive characteristic and about absolute Galois groups of function fields. Achievements here include Grothendieck's anabelian conjecture, arithmetic Galois groups appearing as extensions of known groups, Abhyankar's conjecture, and the geometric case of Shafarevich's conjecture.

Noncommutative Algebra Topics

One of the striking changes in noncommutative algebra over the last decade has been in the emphasis on the study of concrete examples, frequently those that have arisen in neighboring areas, rather than on the abstract theory. This has led to some significant and unexpected interactions not only with other areas but also between some of the major areas of algebra. The most obvious example, of course, has been the rise of the whole area of quantum groups, with its applications to many areas of mathematics and physics, but there are numerous other examples. To give some specific examples:

- The application of the theory of simple rings and rings of differential operators have led to significant applications to Harish-Chandra's theory of eigendistributions and the representation theory of reductive Lie algebras through the work of Wallach, Levasseur, and Stafford.

- Methods of algebraic geometry have been successfully used by Tate and Van den Bergh to provide a detailed description of the properties of the Sklyanin algebras (these first appeared in Sklyanin's work on the Quantum Inverse Scattering Method and are also fundamental to work on noncommutative geometry. Until the work of Tate and Van den Bergh, even a basis for these algebras was unknown.)
- Several of the famous Kaplansky conjectures on Hopf algebras have been solved.
- Zelmanov made striking use of Jordan and Lie theory to solve the restricted Burnside problem. More recently, Kac, Martinez, and Zelmanov have used more ring-theoretic techniques to classify Jordan algebras with linear growth and to make substantial progress in the classification of superconformal algebras.

Further details about the content of the symposium will appear on the MSRI Web site (http://www.msri.org/), on http://www.math.uci.edu/~mfried/#conf/, and on e-MATH.

The organizers actively seek participants from a wide variety of backgrounds, including recent Ph.D.s, students, and individuals not currently in the area who would benefit from the symposium topics. Women and underrepresented minorities are especially encouraged to consider attending.

Everyone interested in receiving an invitation to attend should submit the following information before **April 1, 1999**, to AMS Symposium Coordinator, P.O. Box 6887, Providence, RI 02940; or by e-mail to wsd@ams.org. Please type or print the following:

1. Full name and mailing address.
2. Phone numbers for office, home, and fax.
3. E-mail address.
4. Your anticipated arrival/departure dates.
5. Scientific background relevant to the symposium topics; please indicate if you are a student or when you received your Ph.D.
6. The amount of financial assistance requested (or indicate if no support is required).

Letters of invitation with specific offers of support (if any) will be mailed about mid May, along with information about the program, local housing, and travel. Participants will be responsible for making their own travel and housing arrangements. Conference funding from the endowment and grant is limited; individuals who can obtain support from other sources are encouraged to do so.

Questions about the scientific program should be addressed to the organizers at mfried@math.uci.edu, harbater@math.upenn.edu, or lwsmall@ucsd.edu; questions of a nonscientific nature should be directed to the Symposium Coordinator at the address provided above.

Note: Both the Galois and noncommutative algebra programs plan workshops during the fall 1999 MSRI semester. The Galois program plans two during October: 1) Constructive Galois Theory (week of October 4), and 2) Arithmetic fundamental groups and moduli spaces (week of October 11).

The noncommutative algebra program plans a workshop on Hopf algebras in late October, to be followed by workshops in the winter on combinatorial algebra and interactions between algebraic geometry and noncommutative ring theory.

Details for these will also appear on the MSRI Web site.

Meetings & Conferences of the AMS

PROGRAM ALERT: In order that AMS meeting programs include the most timely information for each speaker, abstract deadlines have been moved to dates much closer to the meeting. What this means is that most meeting programs will appear in the *Notices* *after* the meeting takes place. However, complete meeting programs will be available on e-MATH about two to three weeks after the abstract deadline. ***Remember***, e-MATH is your most comprehensive source for up-to-date meeting information. See `http://www.ams.org/meetings/`.

Gainesville, Florida

University of Florida

March 12–13, 1999

Meeting #940

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: May 1999
Issue of *Abstracts*: Volume 20, Issue 2

Registration and Meeting Information

The meeting will take place on the University of Florida campus near the entrance at SW 2nd Avenue and SW 13th Street, about two blocks south of the intersection of University Avenue (State Route 26) and 13th Street (U.S. 441). Registration will take place on the third floor of Little Hall in Room 353 from 7:30 a.m. to 4:00 p.m. on Friday and from 7:30 a.m. to noon on Saturday. Registration fees (payable on-site only) are $30/AMS or CMS members; $45 nonmembers; $10 emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Invited Addresses will take place in Carleton Auditorium to the west of Little Hall, and Special Sessions and Contributed Paper Sessions will take place in Little Hall and the Fine Arts Building to the south.

Program Information

The complete program of this meeting is available at `http://www.ams.org/amsmtgs/2046_program.html`.

Urbana, Illinois

University of Illinois, Urbana-Champaign

March 18–21, 1999

Meeting #941

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: May 1999
Issue of *Abstracts*: Volume 20, Issue 2

Registration and Meeting Information

The registration desk will be located on the third floor of Altgeld Hall and will be open from 7:30 a.m. to 5:00 p.m. on Friday and from 8:00 a.m. to 5:00 p.m. on Saturday. Talks will take place in Altgeld Hall and nearby buildings. The first Invited Address for this meeting will be at 6:45 p.m., Thursday, March 18, in Beckman Institute Auditorium. The speaker will be **Alexandra Bellow**, Northwestern University.

Registration fees: (payable on-site only) $30/AMS or CMS members; $45/nonmembers; $10/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Program Information

The complete program of this meeting is available at `http://www.ams.org/amsmtgs/2045_program.html`.

Las Vegas, Nevada

University of Nevada, Las Vegas

April 10-11, 1999

Meeting #942

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: February 1999
Program issue of *Notices*: June 1999
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: February 17, 1999

Invited Addresses

Igor Frenkel, Yale University, *Representation theory and four dimensional conformal field theory.*

Gregory J. Kuperberg, University of California, Davis, *Title to be announced.*

Lorenzo A. Sadun, University of Texas, Austin, *Title to be announced.*

John Steel, University of California, Berkeley, *Title to be announced.*

Special Sessions

Analysis and Geometry (Code: AMS SS I1), **Peter Li** and **Song-Ying Li**, University of California, Irvine.

Combinatorial Theory (Code: AMS SS G1), **Kequan Ding**, University of Illinois, Urbana, **Peter Shiue**, University of Nevada, Las Vegas, and **Yeong-Nan Yeh**, Academia Sinica.

Control and Dynamics of Partial Differential Equations (Code: AMS SS A1), **Zhonghai Ding**, University of Nevada, Las Vegas.

Diophantine Problems (Code: AMS SS J1), **Arthur Baragar**, University of Nevada, Las Vegas, and **Michael Bennett**, University of Illinois.

Geometric Group Theory (Code: AMS SS H1), **Eric M. Freden**, Southern Utah University, and **Eric Lewis Swenson**, Brigham Young University.

Graph Theory (Code: AMS SS B1), **Hung-Lin Fu**, National Chiao-Tung University-Taiwan, **Chris A. Rodger**, Auburn University, and **Michelle Schultz**, University of Nevada, Las Vegas.

Invariants, Distributions, Differential Operators and Harmonic Analysis (Code: AMS SS K1), **Ronald L. Lipsman**, University of Maryland, College Park.

Nonlinear PDEs - Methods and Applications (Code: AMS SS C1), **David Costa**, University of Nevada, Las Vegas.

Number Theory (Code: AMS SS F1), **Gennady Bachman**, University of Nevada, Las Vegas, **Richard A. Mollin**, University of Calgary, and **Peter J. Shiue**, University of Nevada, Las Vegas.

Numerical Analysis and Computational Mathematics (Code: AMS SS E1), **Jun Zhang**, University of Minnesota and University of Kentucky, and **Jennifer Zhao**, University of Michigan, Dearborn.

Set Theory (Code: AMS SS D1), **Douglas Burke** and **Derrick DuBose**, University Nevada-Las Vegas.

Symmetries of Knots and Three-manifolds (Code: AMS SS M1), **Swatee Naik**, University of Nevada, Reno, and **Jozef H. Przytycki**, George Washington University.

Buffalo, New York

State University of New York at Buffalo

April 24-25, 1999

Meeting #943

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: February 1999
Program issue of *Notices*: June 1999
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: March 3, 1999

Invited Addresses

Michele M. Audin, University of Louis Pasteur, *Integrable systems and spaces of curves.*

Russel Caflisch, University of California, Los Angeles, *Title to be announced.*

Jeffrey H. Smith, Purdue University, *Symmetric spectra.*

Alexander Voronov, Michigan State University, *Operad theory and some applications.*

Gregg J. Zuckerman, Yale University, *Harmonic algebra.*

Special Sessions

Combinatorics and Graph Theory (Code: AMS SS C1), **Harris Kwong**, SUNY College at Fredonia.

Complex Geometry (Code: AMS SS G1), **Terrence Napier**, Lehigh University, and **Mohan Ramachandran**, SUNY at Buffalo.

Integrable Systems (Code: AMS SS J1), **Michéle Audin**, Université Louis Pasteur et NCRS, and **Lisa Claire Jeffrey**, McGill University.

Knot and 3-Manifolds (Code: AMS SS E1), **Thang T.Q. Le**, SUNY at Buffalo, **William W. Menasco**, SUNY at Buffalo, and **Morwen B. Thistlethwaite**, University of Tennessee.

Mathematical Physics (Code: AMS SS D1), **Jonathan Dimock**, SUNY at Buffalo.

Operads, Algebras, and Their Applications (Code: AMS SS H1), **Alexander A. Voronov**, Michigan State University.

Representations of Lie Algebras (Code: AMS SS F1), **Duncan J. Melville**, Saint Lawrence University.

Smooth Categories in Geometry and Mechanics (Code: AMS SS A1), **F. William Lawvere**, SUNY at Buffalo.

Thin Films: Solid and Liquid (Code: AMS SS B1), **E. Bruce Pitman**, SUNY at Buffalo, and **Brian Spencer**, SUNY at Buffalo.

Denton, Texas

University of North Texas

May 19–22, 1999

Meeting #944

Fourth International Joint Meeting of the AMS and the Sociedad Matemática Mexicana (SMM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: February 1999
Program issue of *Notices*: June/July 1999
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: Expired
For abstracts: March 24, 1999

Invited Addresses

Raymundo Bautista, UNAM, *Title to be announced.*

William Fulton, University of Michigan, Ann Arbor, *Title to be announced.*

Francisco Gonzalez Acuna, UNAM, *Title to be announced.*

Ronald L. Graham, AT&T Labs, *Title to be announced* (Erdős Memorial Lecture).

Jack K. Hale, Georgia Institute of Technology, *Title to be announced.*

Onesimo Hernandez-Lerma, CINVESTAV del IPN, *Title to be announced.*

Special Sessions

Algebraic Geometry and Commutative Algebra (Code: AMS SS F1), **Javier Elizondo**, UNAM, **Xavier Gomez-Mont**, CIMAT, **Alberto Corso**, Michigan State University, and **David A. Jorgensen**, University of Texas at Arlington.

Algebraic Topology (Code: AMS SS Q1), **Frederick R. Cohen** and **Samuel Gitler**, University of Rochester, and **Carlos Prieto**, UNAM.

Combinatorics and Combinatorial Geometry (Code: AMS SS N1), **Jorge Urrutia**, IMATE-UNAM and University of Ottawa, and **Wlodzimierz Kuperberg**, Auburn University.

Complex Analysis (Code: AMS SS R1), **E. Ramirez de Arellano**, CINVESTAV, and **John E. Fornaess**, University of Michigan, Ann Arbor.

Continuum Theory (Code: AMS SS D1), **Wayne Lewis**, Texas Tech University, and **Sergio Macias** and **Alejandro Illanes**, UNAM.

Differential Equations, Nonlinear Analysis, and Numerical Solutions to PDEs. (Code: AMS SS E1), **John W. Neuberger**, University of North Texas, and **Alfredo C. Nicolas**, UAM.

Differential Geometry and Geodesics (Code: AMS SS S1), **Phillip E. Parker**, Wichita State University, and **Lilia Del Riego**, University of San Luis Potosi.

Functional Analysis and Its Applications (Code: AMS SS C1), **S. Perez-Esteva**, UNAM, and **Josefina Alvarez**, University of New Mexico.

Geometric and Symbolic Dynamical Systems (Code: AMS SS G1), **Luca Q. Zamboni**, University of North Texas, and **Edgardo Ugalde**, University of San Luis Potosi.

Low Dimensional Topology (Code: AMS SS H1), **Mark W. Brittenham**, University of North Texas, **Francisco Gonzalez Acuna**, IM-UNAM, and **Luis Valdez-Sanchez**, University of Texas at El Paso.

Noncommutative Geometry, Quantum Groups, and Applications (Code: AMS SS L1), **Micho Durdevich**, UNAM, and **Hanna Ewa Makaruk** and **Robert M. Owczarek**, Los Alamos National Laboratory.

Nonlinear Models in Biology and Celestial Mechanics (Code: AMS SS M1), **Ernesto Perez-Chavela** and **Jorge X. Velasco-Hernandez**, UAM, **Mary E. Parrott**, University of South Florida, and **Ernesto A. Lacomba**, UAM.

Representation Theory of Algebras (Code: AMS SS A1), **Jose A. de la Pena** and **Christof Geiss**, UNAM, and **Birge Zimmerman**, University of California, Berkeley.

Ring Theory (Code: AMS SS K1), **Carlos Signoret-Poillon**, UNAM-UAM, **Sergio Lopez-Permouth**, Ohio University, and **Ricardo Alfaro**, University of Michigan, Flint.

Smooth Dynamical Systems (Code: AMS SS P1), **David A. Delatte** and **Dan Mauldin**, University of North Texas, **Jose Seade**, UNAM, **Mariusz Urbanski**, University of North Texas, and **Alberto Verjovsky**, UNAM.

Stochastic Processes (Code: AMS SS J1), **Frederi G. Viens**, University of North Texas, **Jorge A. Leon**, CINVESTAV, and **Juan Ruiz de Chavez**, UAM.

Stochastic Systems and Control (Code: AMS SS B1), **Daniel Hernandez-Hernandez** and **Onesimo Hernandez-Lerma**, CINVESTAV, and **Guillermo Ferrayra**, Louisiana State University.

Melbourne, Australia

Melbourne, Australia

July 12–16, 1999

Meeting #945

First International Joint Meeting of the American Mathematical Society and the Australian Mathematical Society
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: April 1999

Program issue of *Notices*: Not Applicable
Issue of *Abstracts*: Not Applicable

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: April 2, 1999

Invited Addresses

Jennifer Chayes, Microsoft, *Title to be announced.*

Michael Eastwood, University of Adelaide, *Title to be announced.*

Roger Grimshaw, Monash University, *Title to be announced.*

Gerhard Huisken, University of Tuebingen, *Title to be announced.*

Vaughan Jones, University of California, Berkeley, *Title to be announced.*

Hyam Rubinstein, Melbourne University, *Title to be announced.*

Richard M. Schoen, Stanford University, *Title to be announced.*

Neil Trudinger, Australian National University, *Title to be announced.*

Special Sessions

Algebraic Groups and Related Topics, **Eric Friedlander**, Northwestern University, and **Gustav Lehrer**, University of Sydney.

Computability and Complexity, **Rod Downey**, Victoria University.

Differential Geometry and Partial Differential Equations, **Benjamin H. Andrews**, Australian National University, **Michael G. Eastwood**, University of Adelaide, **Klaus Ecker**, Monash University, and **Gerhard Huisken**, Princeton University and University of Tuebingen.

Fluid Dynamics, **Susan Friedlander**, Northwestern University, and **Roger H. J. Grimshaw**, Monash University.

General Relativity, **Robert Bartnik**, University of Canberra, **Gregory Galloway**, University of Miami, and **Anthony Lun**, Monash University.

Geometric Group Theory, **Swarup Gadde** and **Walter Neumann**, University of Melbourne.

Geometric Themes in Group Theory, **Gustav I. Lehrer**, University of Sydney, **Cheryl E. Praeger**, University of Western Australia, and **Stephen D. Smith**, University of Illinois, Chicago.

Group Actions, **Marston Conder**, **Gaven Martin**, and **Eamonn O'Brien**, University of Auckland.

Low Dimensional Topology, **William H. Jaco**, Oklahoma State University, and **Hyam Rubinstein**, Melbourne University.

Mathematical Physics: Many Body Systems, **Alan L. Carey**, University of Adelaide, **Paul A. Pearce**, University of Melbourne, and **Mary Beth Ruskai**, University of Massachusetts, Lowell.

Mathematics Learning Centers, **Judith Baxter**, University of Illinois, Chicago, **Marian Kemp**, Murdoch University, **Jackie Nicholas**, University of Sidney, and **Jeanne Wald**, Michigan State University.

Moduli Spaces of Riemann Surfaces, Mapping Class Groups and Invariants of 3-manifolds, **Ezra Getzler**, Northwestern University, and **Richard Hain**, Duke University.

Nonlinear Dynamics and Optimization, **A. F. Ivanov**, Penn State University and University of Ballarat, **A. Mees**, University of Western Australia, and **A. Rubinov**, University of Ballarat.

Operations Research Methods and Applications, **Adi Ben-Israel**, Rutgers University, and **Moshe Sniedovich**, University of Melbourne.

Probability Theory and Its Applications, **Timothy Brown**, University of Melbourne, **Phil Pollett**, University of Queensland, and **Ruth J. Williams**, University of California, San Diego.

Recent Trends in Operator Theory and Harmonic Analysis, **Michael T. Lacey**, Georgia Institute of Technology, and **Alan G. R. McIntosh**, Macquarie University.

Solitons, Integrable Systems and Singular Limits, **Jared Bronski**, University of Illinois, Urbana, **Nalini Joshi**, University of Adelaide, **Peter Miller**, Monash University, and **Colin Rogers**, University of New South Wales.

Abstracts

Please note that abstract submission is only available via the Web site maintained by the local organizers: `http://www.maths.monash.edu.au/~ams99/abstract.shtml`.

Housing and Registration

For up-to-date information regarding accommodations, local information, registration, and travel, please refer to the Web site maintained by the local organizers: `http://www.maths.monash.edu.au/~ams99/`.

Salt Lake City, Utah

University of Utah

September 25–26, 1999

Meeting #946

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: June 1999
Program issue of *Notices*: November 1999
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: June 8, 1999
For abstracts: August 3, 1999

Providence, Rhode Island

Providence College

October 2-3, 1999

Meeting #947

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 1999
Program issue of *Notices*: November 1999
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 16, 1999
For abstracts: August 11, 1999

Invited Addresses

Dan M. Barbasch, Cornell University, *Title to be announced.*

Henri Berestycki, Université Paris VI and Ecole Normale Supérieure, *Title to be announced.*

David Mumford, Brown University, *Title to be announced.*

Guoliang Yu, University of Colorado, *Title to be announced.*

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS A1), **Vesselin N. Gasharov**, Cornell University, and **Ira M. Gessel**, Brandeis University.

Geometry and Representation Theory of Algebraic Groups (Code: AMS SS C1), **James E. Humphreys** and **Ivan Mirkovic**, University of Massachusetts.

Operator K-Theory and its Applications to Geometry and Topology (Code: AMS SS D1), **Guoliang Yu**, **Carla E. Farsi**, and **Jeffrey S. Fox**, University of Colorado, Boulder.

Representation Theory of Reductive Groups (Code: AMS SS B1), **Dan M. Barbasch** and **Birgit Speh**, Cornell University.

Austin, Texas

University of Texas, Austin

October 8-10, 1999

Meeting #948

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: August 1999
Program issue of *Notices*: December 1999
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 16, 1999
For abstracts: August 11, 1999

Invited Addresses

Mikhail Kapranov, Northwestern University, *Title to be announced.*

John Roe, Oxford and Pennsylvania State University, *Title to be announced.*

Catherine Sulem, University of Toronto, *Title to be announced.*

Tatiana Toro, University of Washington, *Title to be announced.*

Special Sessions

Aperiodic Tiling (Code: AMS SS D1), **Charles Radin** and **Lorenzo Sadun**, University of Texas, Austin.

Banach and Operator Spaces: Isomorphic and Geometric Structure (Code: AMS SS E1), **Edward Odell** and **Haskell P. Rosenthal**, University of Texas, Austin.

DNA Topology (Code: AMS SS J1), **Isabel K. Darcy**, University of Texas, Austin, and **Makkuni Jayaram**, University of Texas, Austin.

Dehn Surgery and Kleinian Groups (Code: AMS SS L1), **John Luecke** and **Alan Reid**, University of Texas, Austin.

Free Surface Interfaces and PDEs (Code: AMS SS K1), **Kirk Lancaster**, Wichita State University, and **Thomas Vogel**, Texas A&M University.

Harmonic Analysis and PDEs (Code: AMS SS C1), **William Beckner** and **Luis A. Caffarelli**, University of Texas, Austin, **Toti Daskalopoulos**, University of California, Irvine, and **Tatiana Toro**, University of Washington.

Mathematical Problems in Transport Phenomena (Code: AMS SS M1), **Jose Antonio Carrillo** and **Irene M. Gamba**, University of Texas, Austin.

Mathematical and Computational Finance (Code: AMS SS H1), **Stathis Tompaidis**, University of Texas, Austin.

Nonlinear Waves (Code: AMS SS G1), **Catherine Sulem**, University of Toronto.

Recent Developments in Index Theory (Code: AMS SS F1), **Daniel S. Freed**, University of Texas, Austin, and **John Roe**, Pennsylvania State University.

The Development of Topology in the Americas (Code: AMS SS A1), **Cameron Gordon**, University of Texas, Austin, and **Ioan Mackenzie James**, University of Oxford.

The Diverse Mathematical Legacy of Jean Leray (Code: AMS SS N1), **Eric M. Friedlander**, Northwestern University, and **Susan J. Friedlander**, University of Illinois, Chicago.

Wavelets and Approximation Theory (Code: AMS SS B1), **Don Hong**, Eastern Tennessee State University, and **Michael Prophet**, Murray State University.

Charlotte, North Carolina

University of North Carolina at Charlotte

October 15–17, 1999

Meeting #949

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: August 1999
Program issue of *Notices*: December 1999
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 23, 1999
For abstracts: August 18, 1999

Invited Addresses

Valery Alexeev, University of Georgia, *Title to be announced.*

Béla Bollobás, University of Memphis and Cambridge University, *Title to be announced.*

Konstantin M. Mischaikow, Georgia Institute of Technology, *Title to be announced.*

Yakov Sinai, Princeton University, *Title to be announced.*

Special Sessions

Commutative Algebra (Code: AMS SS B1), **Sarah Glaz**, University of Connecticut, and **Evan G. Houston** and **Thomas G. Lucas**, University of North Carolina at Charlotte.

Knot Theory and Its Applications (Code: AMS SS A1), **Yuanan Diao**, University of North Carolina at Charlotte.

Operator Theory, including Applications in Operator Algebras and Wavelets (Code: AMS SS F1), **Alan L. Lambert** and **Xingde Dai**, University of North Carolina at Charlotte.

Optimal Control and Computational Optimization (Code: AMS SS D1), **Mohammed A. Kazemi**, University of North Carolina at Charlotte, and **Gamal N. Elnagar**, University of South Carolina at Spartanburg.

Spectral Theory of Differential Operators and Applications (Code: AMS SS C1), **Boris R. Vainberg** and **Stanislav Molchanov**, University of North Carolina at Charlotte.

Stochastic PDEs and Turbulence (Code: AMS SS E1), **Weinan E**, Courant Institute, New York University.

Washington, District of Columbia

Marriott Wardman Park Hotel and Omni Shoreham Hotel

January 19–22, 2000

Note: This is a World Math Year 2000 (WMY2000) event.

Meeting #950

Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), and the annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Bernard Russo
Announcement issue of *Notices*: October 1999
Program issue of *Notices*: January 2000
Issue of *Abstracts*: Volume 21, Issue 1

Deadlines

For organizers: April 20, 1999
For consideration of contributed papers in Special Sessions: August 10, 1999
For abstracts: October 5, 1999
For summaries of papers to MAA organizers: To be announced

AMS Invited Addresses

Arthur M. Jaffe, Harvard University, *Title to be announced* (AMS Retiring Presidential Address).

Roger Penrose, Oxford University, *Title to be announced* (AMS Josiah Willard Gibbs Lecture).

Lowell, Massachusetts

University of Massachusetts, Lowell

April 1–2, 2000

Eastern Section
Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 1, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Walter Craig, Brown University, *Title to be announced.*

Erwin Lutwak, Polytechnic University, *Title to be announced.*

Alexander Nabutovsky, Courant Institute of Mathematical Sciences, NYU, *Title to be announced.*

Mary Beth Ruskai, University of Massachusetts, Lowell, *Title to be announced.*

Special Sessions

Invariance in Convex Geometry (Code: AMS SS A1), **Daniel A. Klain**, Georgia Institute of Technology, and **Elisabeth Werner**, Case Western Reserve University.

Notre Dame, Indiana

University of Notre Dame

April 7–9, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 7, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Lafayette, Louisiana

University of Southwestern Louisiana

April 14–16, 2000

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 14, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Odense, Denmark

Odense University

June 12–15, 2000

First AMS-Scandinaivan International Mathematics Meeting. Sponsored by the AMS, Dansk Matematisk Forening, Suomen matemaattinen yhdistys, Icelandic Mathematical Society, Norsk Matematisk Forening, and Svenska matematikersamfundet.

Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Los Angeles, California

University of California-Los Angeles

August 7–12, 2000

Note: This is a World Math Year 2000 (WMY2000) event.

Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Toronto, Ontario Canada

University of Toronto

September 22–24, 2000

Central Section
Associate secretary: Susan J. Friedlander

Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New York, New York

Columbia University

November 3–5, 2000

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 3, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Paula Cohen, Université des Sciences et Technologies de Lille, France, *Title to be announced.*

New Orleans, Louisiana

New Orleans Marriott and ITT Sheraton New Orleans Hotel

January 10–13, 2001

Joint Mathematics Meetings, including the 107th Annual Meeting of the AMS, 84th Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 11, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Columbia, South Carolina

University of South Carolina

March 16–18, 2001

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 15, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Lawrence, Kansas

University of Kansas

March 30–31, 2001

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Hoboken, New Jersey

Stevens Institute of Technology

April 28–29, 2001

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Williamstown, Massachusetts

Williams College

October 13-14, 2001

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 11, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California

San Diego Convention Center

January 6-9, 2002

Joint Mathematics Meetings, including the 108th Annual Meeting of the AMS and 85th Meeting of the Mathematical Association of America (MAA).
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 4, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: Bernard Russo, Department of Mathematics, University of California, Irvine, CA 92697; e-mail: brusso@math.uci.edu; telephone: 949-824-5505.

Central Section: Susan J. Friedlander, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

Eastern Section: Lesley M. Sibner, Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: lsibner@magnus.poly.edu; telephone: 718-260-3505.

Southeastern Section: John L. Bryant, Department of Mathematics, Florida State University, Tallahassee, FL 32306-4510; e-mail: bryant@math.fsu.edu; telephone: 850-644-5805.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.**

Meetings:

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 106 in the January 1999 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX or AMS-LaTeX may submit abstracts with such coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

1999:

June 13-July 1: Joint Summer Research Conferences in the Mathematical Sciences, Boulder, CO. See pp. 1435-1441 (1998) for details.

July 26-August 13: Summer Research Institute on Smooth Ergodic Theory and Applications, Seattle, WA. See pp. 1442-1443 (1998) for details.

August 16-27: 1999 Von Neumann Conference, Symposium on Arithmetic Fundamental Groups and Noncommutative Algebra, Berkeley, CA. See pp. 405-406 (this issue) for details.

Cosponsored Conference:

July 18-28, 1999: Foundations of Computational Mathematics (FoCM), University of Oxford, England. See http://www-sccm.stanford.edu/FoCM/ for details.

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