ISSN 0002-9920

Notices

of the American Mathematical Society

October 2010

Volume 57, Number 9

About the Cover:
New Orleans Vieux Carré
(see page 1151)

fondation SCIENCES MATHÉMATIQUES DE PARIS

CALL FOR APPLICATIONS

ACADEMIC YEAR 2011-2012

The Foundation Sciences Mathématiques de Paris is pleased to offer the following opportunities to outstanding scientists and excellent students:

- **The Foundation Prize 2011**
- **The Research Chair 2011**
- **Fifteen postdoctoral positions**
- **PGSM: Ten master course scholarships (new!)**

How to apply

Procedures of applications available at
www.sciencesmaths-paris.fr
and, for PGSM, at
www.sciencesmaths-paris.fr/pgsm

FOUNDATION SCIENCES MATHÉMATIQUES DE PARIS - WWW.SCIENCESMATHS-PARIS.FR
IHP, 11 RUE PIERRE ET MARIE CURIE F75231 PARIS CEDEX 05
TEL. : +33 1 44 27 68 03 - FAX : +33 1 44 27 68 04

FOUNDERS — SCIENTIFIC PARTNERS — PARTNERS

CNRS, UPMC, Université Paris Diderot, ENS — Collège de France, Dauphine Université Paris, Université Paris Descartes, INRIA — Mairie de Paris

American Mathematical Society

SALE The AMS Annual Publisher's Discount Sale

Save 50% to 75% on hundreds of titles!

Algebra and Algebraic Geometry

College Algebra

Henry Burchard Fine

AMS Chelsea Publishing, Volume 354; 1961; 631 pp.; hardcover; ISBN: 978-0-8218-3863-1; List US$72; Sale Price US$25.20; Order code: CHEL/354.H

Selected Works of Phillip A. Griffiths with Commentary

Enrico Arbarello, Robert L. Bryant, C. Herbert Clemens, Maurizio Cornalba, Mark L. Green, Joe Harris, David R. Morrison, and Wilfried Schmid, Editors

This book is jointly published by the AMS and International Press.

Collected Works, Volume 18; **Set**: 2003; 2598 pp.; hardcover; ISBN: 978-0-8218-1066-8; List US$319; Sale Price US$79.75; Order code: CWORKS/18

Invariant Theory

Mara D. Neusel, *Texas Tech University, Lubbock, TX*

Student Mathematical Library, Volume 36; 2007; 314 pp.; softcover; ISBN: 978-0-8218-4132-7; List US$49; Sale Price US$24.50; Order code: STML/36

Analysis

Interpolation and Sampling in Spaces of Analytic Functions

Kristian Seip, *Norwegian University of Science and Technology, Trondheim, Norway*

University Lecture Series, Volume 33; 2004; 139 pp.; softcover; ISBN: 978-0-8218-3554-8; List US$30; Sale Price US$15.00; Order code: ULECT/33

Differential Equations

Partial Differential Equations

Harold Levine, *Stanford University, CA*

Titles in this series are co-published with International Press, Cambridge, MA.

AMS/IP Studies in Advanced Mathematics, Volume 6; 1997; 706 pp.; hardcover; ISBN: 978-0-8218-0775-0; List US$80; Sale Price US$20.00; Order code: AMSIP/6

Notes on Dynamical Systems

Jürgen Moser, and Eduard J. Zehnder, *ETH-Zurich, Switzerland*

Titles in this series are co-published with the Courant Institute of Mathematical Sciences at New York University.

Courant Lecture Notes, Volume 12; 2005; 256 pp.; softcover; ISBN: 978-0-8218-3577-7; List US$36; Sale Price US$18.00; Order code: CLN/12

Spectral Problems Associated with Corner Singularities of Solutions to Elliptic Equations

V. A. Kozlov and V. G. Maz'ya, *University of Linköping, Sweden*, and J. Rossmann, *University of Rostock, Germany*

Mathematical Surveys and Monographs, Volume 85; 2001; 436 pp.; hardcover; ISBN: 978-0-8218-2727-7; List US$105; Sale Price US$26.25; Order code: SURV/85

General Interest

The Coxeter Legacy

Reflections and Projections

Chandler Davis and Erich W. Ellers, *University of Toronto, ON, Canada*, Editors

A co-publication of the AMS and The Fields Institute for Research in Mathematical Sciences (Toronto, Ontario, Canada).

2006; 320 pp.; hardcover; ISBN: 978-0-8218-3722-1; List US$69; Sale Price US$24.15; Order code: COXETER

The Fermat Diary

C. J. Mozzochi, *Princeton, NJ*

2000; 196 pp.; hardcover; ISBN: 978-0-8218-2670-6; List US$32; Sale Price US$16.00; Order code: FERMATD

Ramanujan: Letters and Commentary

Bruce C. Berndt, *University of Illinois, Urbana, IL*, and Robert A. Rankin, *University of Glasgow, Scotland*

History of Mathematics, Volume 9; 1995; 347 pp.; softcover; ISBN: 978-0-8218-0470-4; List US$59; Sale Price US$20.65; Order code: HMATH/9.S

A Mathematical Gift, III

The interplay between topology, functions, geometry, and algebra

Koji Shiga, *Yokohama, Japan*, and Toshikazu Sunada, *Tohoku University, Sendai, Japan*

Mathematical World, Volume 23; 2005; 129 pp.; softcover; ISBN: 978-0-8218-3284-4; List US$30; Sale Price US$15.00; Order code: MAWRLD/23

Geometry and Topology

Global Calculus

S. Ramanan, *Chennai Mathematics Institute, India*

Graduate Studies in Mathematics, Volume 65; 2005; 316 pp.; hardcover; ISBN: 978-0-8218-3702-3; List US$58; Sale Price US$20.30; Order code: GSM/65

Variational Problems in Geometry

Seiki Nishikawa, *Mathematical Institute, Tohoku University, Sendai, Japan*

Translations of Mathematical Monographs (*Iwanami Series in Modern Mathematics*), Volume 205; 2002; 209 pp.; softcover; ISBN: 978-0-8218-1356-0; List US$49; Sale Price US$24.50; Order code: MMONO/205

Logic and Foundations

Computable Functions

A. Shen, *Independent University of Moscow, Russia*, and N. K. Vereshchagin, *Moscow State Lomonosov University, Russia*

Student Mathematical Library, Volume 19; 2003; 166 pp.; softcover; ISBN: 978-0-8218-2732-1; List US$32; Sale Price US$16.00; Order code: STML/19

Mathematical Physics

Strings and Geometry

Michael Douglas, *Rutgers University, Piscataway, NJ*, Jerome Gauntlett, *University of London, England*, and Mark Gross, *University of California San Diego, La Jolla, CA*, Editors

Titles in this series are co-published with the Clay Mathematics Institute (Cambridge, MA).

Clay Mathematics Proceedings, Volume 3; 2004; 376 pp.; softcover; ISBN: 978-0-8218-3715-3; List US$72; Sale Price US$25.20; Order code: CMIP/3

Spectral Theory and Mathematical Physics: A Festschrift in Honor of Barry Simon's 60th Birthday

Fritz Gesztesy, Managing Editor, *University of Missouri, Columbia, MO*, Percy Deift, *New York University, Courant Institute, NY*, Cherie Galvez, *California Institute of Technology, Pasadena, CA*, Peter Perry, *University of Kentucky, Lexington, KY*, and Wilhelm Schlag, *University of Chicago, IL*, Editors

Proceedings of Symposia in Pure Mathematics, Volume 76; **Set**: 2007; 960 pp.; hardcover; ISBN: 978-0-8218-3783-2; List US$169; Sale Price US$42.25; Order code: PSPUM/76

Number Theory

Brauer Type Embedding Problems

Arne Ledet, *Texas Tech University, Lubbock, TX*

Titles in this series are co-published with The Fields Institute for Research in Mathematical Sciences (Toronto, Ontario, Canada).

Fields Institute Monographs, Volume 21; 2005; 171 pp.; hardcover; ISBN: 978-0-8218-3726-9; List US$55; Sale Price US$19.25; Order code: FIM/21

Automorphic Forms and Applications

Peter Sarnak, *Princeton University, NJ*, and Freydoon Shahidi, *Purdue University, West Lafayette, IN*, Editors

Titles in this series are co-published with the Institute for Advanced Study/Park City Mathematics Institute.

IAS/Park City Mathematics Series, Volume 12; 2007; 427 pp.; hardcover; ISBN: 978-0-8218-2873-1; List US$75; Sale Price US$18.75; Order code: PCMS/12

Probability

Information Theory and Stochastics for Multiscale Nonlinear Systems

Andrew J. Majda and Rafail V. Abramov, *Courant Institute of Mathematical Sciences, New York University, NY*, and Marcus J. Grote, *University of Basel, Switzerland*

Titles in this series are co-published with the Centre de Recherches Mathématiques.

CRM Monograph Series, Volume 25; 2005; 133 pp.; hardcover; ISBN: 978-0-8218-3843-3; List US$41; Sale Price US$20.50; Order code: CRMM/25

Please note: Order online to receive your discount. Discount applies to limited quantities. Direct sales only. Not available to bookstores or agents.

AMS BOOKSTORE

AMS American Mathematical Society

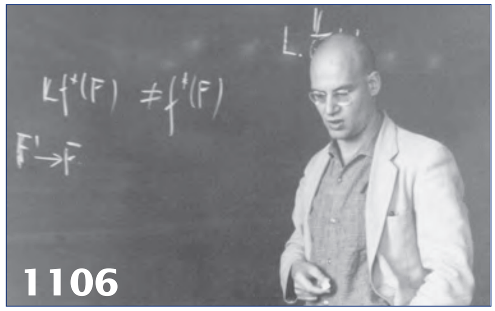
Go to **www.ams.org/bookstore** to view the entire list of titles on sale.

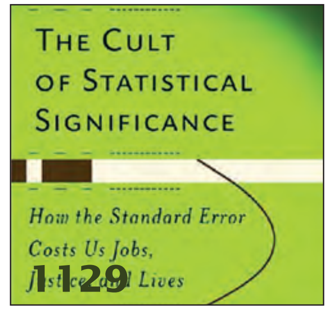
Notices
of the American Mathematical Society

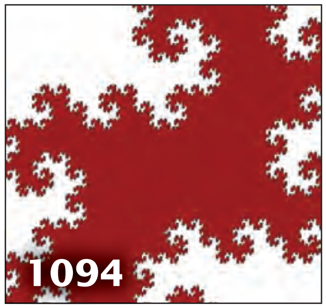
October 2010

Communications

Commentary







Features

The feature articles this month exhibit the dynamic and diversity of modern mathematics. The article by Chris Byrnes considers applications of modern topology to questions of physics. The article by Dick Gundy shows how wavelets can be used to understand probability theory. And the article by Jerry Folland considers questions of communication that will resonate with us all. The interview with Luc Illusie about Alexander Grothendieck will give us all pause for thought.

—*Steven G. Krantz*
Editor

Notices
of the American Mathematical Society

SUBSCRIPTION INFORMATION: Subscription prices for Volume 57 (2010) are US$488 list; US$390 institutional member; US$293 individual member. (The subscription price for members is included in the annual dues.) A late charge of 10% of the subscription price will be imposed upon orders received from nonmembers after January 1 of the subscription year. Add for postage: Surface delivery outside the United States and India—US$27; in India—US$40; expedited delivery to destinations in North America—US$35; elsewhere—US$120. Subscriptions and orders for AMS publications should be addressed to the American Mathematical Society, P.O. Box 845904, Boston, MA 02284-5904 USA. All orders must be prepaid.

ADVERTISING: *Notices* publishes situations wanted and classified advertising, and display advertising for publishers and academic or scientific organizations. Advertising material or questions may be sent to classads@ams.org (classified ads) or notices-ads@ams.org (display ads).

SUBMISSIONS: Articles and letters may be sent to the editor by email at notices@math.wustl.edu, by fax at 314-935-6839, or by postal mail at Department of Mathematics, Washington University in St. Louis, Campus Box 1146, One Brookings Drive, St. Louis, MO 63130. Email is preferred. Correspondence with the managing editor may be sent to notices@ams.org. For more information, see the section "Reference and Book List".

NOTICES ON THE AMS WEBSITE: Supported by the AMS membership, most of this publication is freely available electronically through the AMS website, the Society's resource for delivering electronic products and services. Use the URL http://www.ams.org/notices/ to access the *Notices* on the website.

[*Notices of the American Mathematical Society* (ISSN 0002-9920) is published monthly except bimonthly in June/July by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2294 USA, GST No. 12189 2046 RT****. Periodicals postage paid at Providence, RI, and additional mailing offices. POSTMASTER: Send address change notices to *Notices of the American Mathematical Society*, P.O. Box 6248, Providence, RI 02940-6248 USA.] Publication here of the Society's street address and the other information in brackets above is a technical requirement of the U.S. Postal Service. Tel: 401-455-4000, email: notices@ams.org.

Departments

From the AMS Secretary

I thank Randi D. Ruden for her splendid editorial work, and for helping to assemble this issue. She is essential to everything that I do.

—Steven G. Krantz
Editor

The American Mathematical Society presents

The AMS Einstein Public Lecture in Mathematics

Terence Tao

Professor of Mathematics,
University of California, Los Angeles

The Cosmic Distance Ladder

Galaxy-1: NASA/JPL-Caltech/STScI

Mars: NASA/JPL-Caltech/University of Arizona
Saturn: NASA/ESA/Erich Karkoschka (University of Arizona)
Jupiter: NASA/JPL

Saturday, October 9, 2010
6:15 p.m. with a reception to follow
Schoenberg Hall on the UCLA campus

How do we know the distances from the earth to the sun and moon, from the sun to the other planets, and from the sun to other stars and distant galaxies? Clearly we cannot measure these directly. Nevertheless there are many indirect methods of measurement, combined with basic mathematics, which can give quite convincing and accurate results without the need for advanced technology (for instance, even the ancient Greeks could compute the distances from the earth to the sun and moon to moderate accuracy). These methods rely on climbing a "cosmic distance ladder," using measurements of nearby distances to deduce estimates on distances slightly farther away. In this lecture, Tao will discuss several of the rungs in this ladder.

Sponsored by the American Mathematical Society • Hosted by the UCLA Department of Mathematics
This event is part of the AMS 2010 Fall Western Sectional Meeting, October 9-10

www.ams.org/meetings/einstein-lect.html

Galaxy-2 (background): MPIA/NASA/Calar Alto Observatory

Opinion

Agenda for a Mathematical Renaissance

Most of us have wondered at some point in our careers how to motivate the interest of students in mathematics and encourage young talents to learn mathematics. In 1975 Paul Halmos [3] said: "The best way to learn is to do; the worst way to teach is to talk. The best way to teach is to make students ask, and do. Don't preach facts—stimulate acts." Halmos was a wise and respected scholar and there is general agreement that what he said is correct and important, but change is so difficult that perhaps we need more than words; we need a new agenda.

One may begin with a recent analysis developed for *The Wall Street Journal* [4] that evaluates 200 professions. According to the study *mathematician* is the top job in the U.S., placing first in terms of good environment, income, employment outlook, physical demands, and low stress. *Actuary* and *statistician*, two related professions, rank second and third, respectively. The sociological analysis provides answers to the young student's question "Why do mathematics?" Mathematicians are in demand in terms of job prospects. Also, should anyone wonder if interest in mathematics has slowed down, the study shows that the role of mathematicians, both pure and applied, in the development of our society is as important as ever.

Science and technology developed in an impressive way before, during, and immediately after World War II, which attracted post-war students to careers in research. This trend received a powerful stimulus in the 1960s and 1970s with the advent of the space age: launch of the Soviet satellite Sputnik (1957), Gagarin's first human travel into space (1961), and the first manned mission to land on the Moon (Neil A. Armstrong and Edwin E. Aldrin, Apollo 11, 1969). The impact of these advances was huge. Science was recognized for the political and economic power it could generate. In those golden years, research became as important to society as it was fascinating to practitioners.

Decades later, society's interest in many areas of research has diminished in most countries around the world. With exceptions in biomedical areas, genetics, or software engineering, the importance of mathematics and science in society is less often recognized. Mathematics and the sciences are no longer perceived as offering desirable career opportunities. Both in developed and developing countries, brilliant mathematics students who could have chosen careers in mathematics are not doing so.

It is strange that students' interest is low at a time when career opportunities for professional mathematicians are greater than ever [2]. This is true both for the applied fields where demand for mathematicians will continue to grow rapidly in the next decades and for traditional areas that are rich with new developments—see the seven Millennium Problems, cf. [1]. Yet today we notice a fundamental lack of appreciation for the richness and relevance of mathematics itself.

It is possible for mathematics and mathematicians to regain social stature. The scientific enterprise can function at full potential if there is a fast flow of knowledge between the creators and users of mathematics. This is something mathematics education can and should facilitate, especially since mathematics is currently so active and vital both in research and applications.

The culture of this millennium shows itself to be highly interactive and collaborative. It is an opportunity for mathematicians to work with scientists in other fields and also to reach out to the community at large. Mathematicians are uniquely qualified to articulate the value of mathematics in catalyzing major advances in science, health, business, economics, biomedical engineering, genetics, software engineering, and, more generally, in proving the patterns and the truths of the universe in which we live.

The trend toward interactivity is an important feature of the sciences in our time. Unfortunately, some institutions have been slow to adapt to this reality. Mathematics loses a lot when it is isolated or fragmented according to various paradigms. Universities around the world, as well as many industries and government agencies, will benefit from removing barriers to collaboration. In particular, powerful and diverse interactions between academic and industrial mathematicians should be enhanced. While the primary missions of academia and industries are different, the two cultures have much to learn from one another.

In short, while *mathematician* is a top job in the U.S. today, it is no longer possible for a mathematician to remain aloof from the passing needs of the world or to continue working in an ivory tower. As funds get scarce, the future of our profession is at stake. It is time for mathematicians to bring the vitality and usefulness of modern mathematics to the classrooms, to demonstrate its social impact, and to support this century's mathematical renaissance.

References

[1] http://www.claymath.org/millennium.

[2] P. A. Griffiths, Mathematics at the turn of the millennium, *Current Science Online* **77** (1999), 750–758.

[3] P. Halmos, The problem of learning to teach, *Amer. Math. Monthly* **82** (1975), 466–476.

[4] S. E. Needleman, Doing the math to find the good jobs. Mathematicians land top spot in new ranking of best and worst occupations in the U.S., *The Wall Street Journal*, Jan. 26, 2009, p. D2 (http://online.wsj.com/article_email/SB123119236117055127-lMyQjAxMDI5MzAxNjEwOTYyWj.html).

[5] A. N. Whitehead, *The Aims of Education and Other Essays*, MacMillan Co, 1929 (reprinted in *Education in the Age of Science*, edited by Brand Blanshard, New York, Basic Books, 1959).

—*Teodora-Liliana Rădulescu*
Department of Mathematics,
"Fraţii Buzeşti" National College
teodoraradulescu@yahoo.com

—*Vicenţiu Rădulescu*
Institute of Mathematics "Simion Stoilow"
of the Romanian Academy
vicentiu.radulescu@imar.ro
vicentiu.radulescu@math.cnrs.fr

Topological Methods for Nonlinear Oscillations

Christopher I. Byrnes

Introduction

Periodic phenomena play a pervasive role in natural and in man-made systems. They are exhibited, for example, in simple mathematical models of the solar system and in the observed circadian rhythms by which basic biological functions are regulated. Electronic devices producing stable periodic signals underlie both the electrification of the world and wireless communications. My interest in periodic orbits was heightened by research into the existence of oscillations in nonlinear feedback systems. While these kinds of applications are illustrated in Examples 2.2 and 4.2, a more detailed expedition into this important application area is omitted here for the sake of space and focus.

Periodic orbits have played a prominent role in the mathematics of dynamical systems and its applications to science and engineering for centuries, due to both the importance of periodic phenomena and the formidable intellectual challenges involved in detecting or predicting periodicity. As a first step toward addressing this challenge, Poincaré developed his method of sections, beginning with the observation that, if a periodic orbit γ for a smooth vector field X exists, if $x_0 \in \gamma$ and if $\mathcal{H}$ is a hyperplane complementary to the tangent line $T_{x_0}(\gamma)$ to x_0 at γ, then on a sufficiently small neighborhood $S \subset \mathcal{H}$ of x_0 one can define, by the implicit function theorem, a (least) positive time $t_x > 0$ so that for each $x \in M$ the solution to the differential equation defined by X with initial condition x returns to $\mathcal{H}$. In particular, one can define a smooth Poincaré, or "first-return", map $\mathcal{P}$ on S, which sends the initial condition x to the solution of the differential equation at time t_x. Moreover, the dynamics of the iterates of $\mathcal{P}$ on S are then intimately related to the dynamics of X, near γ, in positive time. Conversely, if a "local section" S transverse to X exists for which there exists a Poincaré map $\mathcal{P}$, the existence of periodic points for $\mathcal{P}$ implies the existence of periodic orbits for X, allowing for the use of powerful topological fixed point and periodic point theorems in the study of nonlinear oscillations. The importance of Poincaré's method of sections led G. D. Birkhoff to develop two sets of necessary and sufficient conditions [1] for the existence of a section for a differential equation evolving in $\mathbb{R}^n$. One of these was formulated in terms of what Birkhoff called an "angular variable", and the other involved what, in modern terminology, would be called an "angular one-form". Both concepts are reviewed in this article.

The existence of a section is, of course, both one of the standard paradigms for the existence of nonlinear oscillations and one of the grand tautologies of nonlinear dynamics, since to know whether S is section for X is to know a lot about the long-time behavior of the trajectories of the corresponding differential equation—in which case one might already know whether there are periodic orbits. Nonetheless, this paradigm has actually been used with great success in applications, most notably beginning with Birkhoff's proof of Poincaré's Last Theorem, which arose in the restricted three-body problem in celestial mechanics. An easier paradigm is provided by the

Christopher Byrnes, former dean of the School of Engineering and Applied Science at Washington University in St. Louis, was a distinguished visiting professor in optimization and systems theory at the Royal Institute of Technology in Stockholm when he died unexpectedly in February 2010.

principle of the torus, which has been widely used in applications to biology, chemistry, dynamics, engineering, and physics [13]. In this literature, if $\mathbb{D}^N$ denotes the closed unit disc in $\mathbb{R}^N$, a submanifold $M \subset \mathbb{R}^n$ that is diffeomorphic to $\mathbb{D}^{n-1} \times S^1$ is called a *toroidal region*, and the principle of the torus asserts that, if a smooth vector field X leaves a toroidal region positively invariant and has a section S that is diffeomorphic to $\mathbb{D}^{n-1}$, then X has a periodic orbit in M by Brouwer's fixed point theorem. Of course, among the limiting features of the principle of the torus is the need not only to find a section but also to have the ability to characterize familiar topological spaces such as toroidal regions, disks, and spheres. Fortunately, remarkable advances in dynamics and topology since Poincaré's time now allow us to effectively address both of these technical issues.

Among the tools from dynamics that play a role in the results described in this paper are the properties of nonlinear dynamical systems that dissipate energy. This has been developed in two separate schools, one pioneered by Liapunov and the other beginning with Levinson and significantly developed by Hale, Ladyzhenskaya, Sell, and others. One of the main results of the latter school concerns the existence of Liapunov stable global attractors for dissipative systems. The topological methods described here are also global, allowing one to bring techniques such as the classical combination of cobordism and homotopy theory, as described in [14], to bear on the study of nonlinear oscillations. The early use of topological methods in the study of nonlinear dynamics dates back to the work of Poincaré, Birkhoff, Lefschetz, Morse, Krasnosel'skiĭ, Smale, and many others. The results described here also rely on global topological methods developed by F. W. Wilson Jr. in his study of the topology of Liapunov functions for global attractors. For the case of periodic orbits, Wilson's results form the starting point for the derivation of necessary conditions, derived in [5], for the existence of an asymptotically stable periodic orbit for a smooth vector field defined on an orientable manifold. The proof uses a very general cobordism theorem of Barden, Mazur, and Stallings [10] in dimensions bigger than 5. In lower dimensions, crucial use is also made of the solution of the Poincaré Conjecture in dimensions 3 and 4 by Perelman and Freedman and a result of Kirby and Siebenmann on smoothings of 5-manifolds. The remarkable fact that the necessary conditions are sufficient for the existence of a periodic orbit follows from an explicit cobordism argument [5] involving the period maps of one-forms, introduced by Abel.

In this paper, I give a brief overview of the proofs of these results and then describe how to combine them to derive a new sufficient condition, which replaces a topological assumption with an assumption that the dynamical system dissipates energy. These sufficient conditions are easier to use in practice and are illustrated in several ways, including examples taken from population dynamics and feedback control systems. This exposition concludes with an existence theorem that is valid for a much more general class of smooth manifolds but that requires a more restrictive hypothesis. Among several applications, this result is illustrated in the case of the existence of periodic orbits for smooth vector fields on compact 3-manifolds, with or without boundary.

In closing, it is a pleasure to acknowledge valuable advice from Roger Brockett, Tom Farrell, Dave Gilliam, Moe Hirsch, John Morgan, Ron Stern, and Shmuel Weinberger.

Stability of Equilibria, Periodic Orbits, and Compact Attractors

In this section, some basic results about asymptotic stability of compact sets that are invariant with respect to a smooth vector field X are reviewed and illustrated for a feedback design problem presented in Example 2.2. Except for the last two sections of this survey, I will only need these results for vector fields defined on $\mathbb{R}^n$, on the "toroidal cylinder", $\mathbb{R}^n \times S^1$, or on the solid torus, $\mathbb{D}^n \times S^1$. In this section, I will confine the discussion to the case of vector fields on the toroidal cylinder, which in this section is denoted by M. In Sections 3 and 4, vector fields on solid tori are studied in more detail. It should be noted, however, that these results, suitably formulated, do hold for smooth paracompact manifolds, with or without boundary, and with careful modification they also hold in infinite dimensions [9].

Any point in M has coordinates (x, θ), where $x \in \mathbb{R}^n$ and $\theta \in S^1$, and therefore any smooth vector field X on M has the form

$$X = \begin{pmatrix} f_1(x,\theta) \\ f_2(x,\theta) \end{pmatrix}$$

where f_1 takes values in $\mathbb{R}^n$ and f_2 takes values in $\mathbb{R}$. The vector space of smooth vector fields on M is denoted by $\mathrm{Vect}(M)$. In particular, a smooth vector field defines, and is defined by, an ordinary differential equation (ODE)

$$\dot{x} = f_1(x,\theta) \quad (2.1)$$

$$\dot{\theta} = f_2(x,\theta) \quad (2.2)$$

to which the local existence, uniqueness, and smoothness theorem for solutions to ODEs applies, since small variations in an initial condition $z_0 = (x_0, \theta_0)$ take place in an open subset of $\mathbb{R}^n \times \mathbb{R}$. $\Phi(t, z_0)$, defined for sufficiently small t, will denote the solution initialized at z_0 at time $t_0 = 0$. In this paper, only vector fields for which $\Phi(t, z_0)$

is defined, for each $z_0 \in M$ and for all $t \geq 0$, are considered. Any such X defines a *semiflow*

$$\Phi : [0, \infty) \times M \to M. \tag{2.3}$$

When t is fixed, it is often convenient to use the notation $\Phi_t(z) := \Phi(t, z)$. In particular, Φ defines a semigroup of smooth embeddings Φ_t of M.

An equilibrium for X is a point $z_0 \in M$ satisfying $X(z_0) = 0$ or, equivalently, $\Phi(t, z_0) = z_0$ for all $t \geq 0$. A solution curve of (2.3) initialized at a nonequilibrium point $z \in M$ is periodic provided $\Phi_t(z) = z$ for some $t > 0$. The minimum time $T > 0$ such that $\Phi_T(z) = z$ is its *period* and the set of points in M transcribed by a periodic solution is called a *periodic orbit*. A subset I of M is *positively invariant* for a vector field X if $\Phi(t, z) \in I$ for each $z \in I$ and every $t \geq 0$. I is *invariant* if $\Phi(t, z) \in I$ for each $z \in I$ and every $t \in \mathbb{R}$. Equilibria and periodic orbits are invariant sets. A compact invariant set K is a *maximal compact invariant set* for the semigroup (2.3) provided every compact invariant set of (2.3) is contained in K.

For any $B \subset M$, the ω-limit set of B is defined [9] as

$$\omega(B) = \{z \in B |\ \text{for}\ \ z_j \in B \ \text{and}\ \ t_j \to +\infty, \quad \text{with}\ j \to +\infty, \Phi(t_j, z_j) \to z\}. \tag{2.4}$$

For $B = \{z\}$, this coincides with the ω-limit set $\omega(z)$ introduced by Birkhoff in [1]. The α-limit sets, $\alpha(B)$ and $\alpha(z)$, are defined as in (2.4) with the sequence of times t_j tending to $-\infty$. Following [9], a closed set $A \subset M$ is said to *attract* a closed set $B \subset M$ provided the distance

$$\delta(\Phi_t(B), A) := \sup_{z \in B} \inf_{y \in A} d(\Phi_t(z), y) \tag{2.5}$$

between the sets $\Phi_t(B)$ and A tends to 0 as $t \to +\infty$, where d is any complete metric on M.

Definition 2.1 ([9])**.** A compact invariant subset K is said to

1. be *stable* provided that for every neighborhood V of K, there exists a neighborhood V' of K, satisfying $\Phi_t(V') \subset V$, for all $t \geq 0$;
2. *attract points locally* if there exists a neighborhood W of K such that K attracts each point in W;
3. be *asymptotically stable* if K is stable and attracts points locally.

Remark 2.1. If K is a compact invariant set, the notion of attracting a point or attracting a compact set is independent of the choice of metric, as it should be. Moreover, since K is compact, condition (3) is equivalent to the existence of a positively invariant neighborhood $K \subset L$ for which K attracts L [9, Lemma 3.3.1]. The largest open set, $\mathcal{D}$, attracted by K is called the *domain of attraction* of the attractor K.

Definition 2.2. If a compact subset $K \subset M$ satisfies conditions (1) and attracts every point of M, then K is called a *global attractor*.

Compact attractors exist in many situations in which the dynamical system dissipates energy, a notion that can be mathematized in several ways. There are two formulations of dissipativity that are very useful. In reverse chronological order, one has its roots in the work by Levinson on the forced van der Pol oscillator and is developed in [9] for the case of Banach spaces. In this exposition, it takes the following form.

Definition 2.3. $X \in \mathrm{Vect}(M)$ is *point-dissipative* provided there exists a compact set $K \subset M$ that attracts all points in M.

Remark 2.2. For any $\epsilon > 0$, the ϵ-neighborhood, $B = B_\epsilon(K)$, of a global attractor K is a relatively compact *absorbing set*; i.e., every trajectory eventually enters and remains in B. A system is point-dissipative if, and only if, there exists a relatively compact absorbing set.

Point-dissipative systems on $\mathbb{R}^n$ are also sometimes referred to as being "ultimately bounded" systems, and their origin lies in classical nonlinear analysis.

Example 2.1. Consider a C^∞ periodically time-varying ordinary differential equation

$$\dot{x} = f(x, t), \quad f(x, t + T) = f(x, t) \tag{2.6}$$

evolving on $\mathbb{R}^n$. Historically, a central question concerning periodic systems is whether there exists an initial condition $(x_0, 0)$ generating a periodic solution having period T. Such solutions are called *harmonic* solutions. Following the pioneering work of Levinson on dissipative forced systems in the plane, V. A. Pliss formulated the following general definition for periodically time-varying systems:

Definition 2.4 ([16])**.** The periodic differential equation (2.6) is *dissipative* provided there exists an $R > 0$ such that

$$\overline{\lim_{t \to \infty}} \|x(t; x_0, t_0)\| < R. \tag{2.7}$$

In particular, the ball $B(0, R)$ of radius R about $0 \in \mathbb{R}^n$ is an absorbing set for the time-varying system (2.7). As noted in [16], the system (2.6) defines a time-invariant vector field X on the toroidal cylinder M via

$$\dot{x} = f(x, \tau) \tag{2.8}$$

$$\dot{\tau} = 1. \tag{2.9}$$

To say that (2.6) is dissipative on $\mathbb{R}^n$ is to say that (2.8) is point-dissipative on M. For a dissipative periodic system, one can define a smooth Poincaré map $\mathcal{P} : \mathbb{R}^n \to \mathbb{R}^n$ defined via

$$\mathcal{P}(x_0) = \Phi(T; x_0, 0). \tag{2.10}$$

An important consequence [16] of (2.7) is that there exists a closed ball $0 \in B \subset \mathbb{R}^n$ and an $r \in \mathbb{N}$

such that if $x_0 \in B$, then $x(t; x_0, 0) \in B$ for $t \geq rT$; i.e.,

$$\mathcal{P}^r : B \to B. \tag{2.11}$$

Applying Brouwer's fixed point theorem to $\mathcal{P}^r$, Pliss [16] showed the existence of a forced oscillation. In fact, Browder's fixed point theorem asserts that any map satisfying (2.11) must have a fixed point in B so that there always exists a harmonic solution.

The theory of dissipative systems has been studied by many mathematicians. Indeed, dissipative systems play a central role in the work of Krasnosel'skiĭ, Hale, Ladyzhenskaya, Sell, and others for both finite- and infinite-dimensional systems. In the present context, the principal result is the following.

Theorem 2.1. *If $X \in \mathrm{Vect}(M)$ is point-dissipative, then there exists a compact attractor $\mathcal{A}$ for X on M. $\mathcal{A}$ is the maximal compact attractor and satisfies*

$$\mathcal{A} = \{z \in M : \{\Phi(t, z) : -\infty < t < \infty\} \text{ is relatively compact}\}. \tag{2.12}$$

In particular, if $B \subset M$ is relatively compact, then $\omega(B) \subset \mathcal{A}$. Moreover, $\mathcal{A}$ is connected.

Remark 2.3. For an ODE evolving on $\mathbb{R}^n$, any trajectory with initial condition z such that $\{\Phi(t, z) : -\infty < t < \infty\}$ is bounded is called *Lagrange stable*.

Example 2.2. The problem considered in this example is referred to as a "set-point control" problem in the systems and control literature and is widely used in engineering applications in which certain physical variables need to be maintained asymptotically close to a desired constant. Important examples include controlling the temperature and air quality in buildings, for which heating, ventilation, and air conditioning consume the largest portion of energy costs, and controlling the altitude or airspeed of aircraft, a problem of great importance for air traffic control. In more detail, consider the system

$$\begin{aligned} \dot{x}_1 &= -gx_1 + u_1, \quad \dot{x}_2 = -gx_2 + u_2, \\ \dot{x}_3 &= x_1 u_2 - x_2 u_1 - \alpha x_3, \end{aligned} \tag{2.13}$$

which models [2] the control of a rotor by an AC motor, with (x_1, x_2) being the components of the magnetic field, u_1, u_2 being the current through the armature coils, g the resistance in the coils, x_3 modeling the angular velocity of the rotor, and α the coefficient of friction. The control objective studied in [2] was to design a C^∞"control law"

$$u_1 = u_1(x_1, x_2, x_3, d), \quad u_2 = u_2(x_1, x_2, x_3, d) \tag{2.14}$$

so that the system (2.13)–(2.14) has the property that, in "steady-state," $\lim_{t\to\infty} x_3(t) = d$, for a desired constant rate of rotation $d > 0$. In the engineering literature, a system of this form, in which explicit control laws are "fed back" into a control system, such as (2.13), is called a *closed-loop system*, and the control laws are referred to as *feedback laws.*

A natural starting point is to determine necessary conditions on the control laws in order to have the closed-loop system (2.13)–(2.14) be point-dissipative on some positively invariant open set $\mathcal{D} \subset \mathbb{R}^3$ *and* solve the set-point control problem for all initial conditions $x \in \mathcal{D}$. Point-dissipativity would imply the existence of a global compact attractor $\mathcal{A} \subset \mathcal{D}$, while solving the set-point control problem would consist of ensuring that $x_3|_{\mathcal{A}} = d$. Since $\mathcal{A}$ is invariant, $\dot{x}_3|_{\mathcal{A}} = 0$, which implies $x_1\dot{x}_2 - x_2\dot{x}_1 = \alpha d$ or

$$\dot{\theta} = \frac{\alpha d}{x_1^2 + x_2^2} > 0, \quad \text{for } x \in \mathcal{A}, \tag{2.15}$$

where (r, θ) denotes polar coordinates in the (x_1, x_2)-plane. In particular, the magnetic field must rotate in steady-state, as it should in order to generate torque. In fact, for conventional AC motors, the rotational rate of the magnetic field of the AC motor should be constant, and imposing the condition $\dot{\theta} = f > 0$ yields several additional conclusions. For example, since any trajectory on $\mathcal{A}$ will be a closed curve in the affine plane, $x_3 = d$, having constant amplitude $A = \sqrt{\alpha d/f}$, the global compact attractor $\mathcal{A}$ must consist of this single periodic orbit. If one assumes that the control laws (2.14) are defined on all of $\mathbb{R}^3$ and that the rotational rate for the magnetic field of the AC motor is constant for all initial conditions in $\mathcal{D}$, one is led to the further constraint

$$x_1 u_2 - x_2 u_1 = f(x_1^2 + x_2^2) \tag{2.16}$$

on (2.14), which yields

$$u_1 = \kappa x_1 - f x_2 + x_1 h(x_1, x_2) + H_1(x_1, x_2, x_3)(x_3 - d),$$

$$u_2 = \kappa x_2 + f x_2 + x_2 h(x_1, x_2) + H_2(x_1, x_2, x_3)(x_3 - d),$$

for some $\kappa \in \mathbb{R}$. Setting $h = 0$, each of these control laws produces a closed-loop system having a periodic orbit γ with period $T = 2\pi/\kappa$ on $x_3 = d$, evolving as a classical harmonic motion, $\dot{x}_1 = -f x_2, \dot{x}_2 = f x_1$, on the circle $(x_1^2 + x_2^2) = \alpha d/f$. In [2], Brockett shows that the feedback law

$$u_1 = g x_1 - f x_2 + \beta(d - x_3)x_1 \tag{2.17}$$

$$u_2 = g x_2 + f x_1 + \beta(d - x_3)x_2 \tag{2.18}$$

where $f, \beta > 0$ solves the set-point control problem, inducing an asymptotically stable periodic orbit γ on $\mathcal{D} = \mathbb{R}^3 - X_3$, where X_3 is the x_3-axis. In fact, this system is point-dissipative on $\mathcal{D} \simeq \mathbb{R}^2 \times S^1$, with γ as its compact global attractor. This is easiest to see using Liapunov methods, which are described below.

A very powerful way to formulate dissipation of energy near an equilibrium was developed by Liapunov in his 1892 thesis and has since been extended to uniformly attractive closed invariant sets. The main results for compact invariant sets suffice for point-dissipative systems.

Definition 2.5. Suppose X leaves an open subset $D \subset M$ positively invariant and that $K \subset D$ is a compact invariant subset. A Liapunov function V for X on the pair (D, K) is a C^∞ function $V : D \to \mathbb{R}$ that satisfies

(1) $V|_K = 0$ and $V(z) > 0$ for $z \notin K$,
(2) $\dot{V} < 0$ on $D - K$, and
(3) V tends to a constant value (possibly ∞) on the boundary, ∂D, of D.

Theorem 2.2. *Suppose X leaves an open subset $D \subset M$ positively invariant and that $K \subset D$ is a compact invariant subset. If a function V exists satisfying conditions* (1) *and* (3) *of Definition* 2.5 *and if $\dot{V} \le 0$ on D, then K is stable. If V also satisfies condition* (2)*, then K is a global compact attractor on D.*

Example 2.3 (Example 2.2 (bis))**.** Consider the "closed-loop" vector field $X \in \mathrm{Vect}(\mathbb{R}^3)$ obtained by implementing the feedback law (2.17) in the system (2.13)

$$\begin{aligned} \dot{x}_1 &= -f x_2 + \beta(d - x_3)x_1, \\ \dot{x}_2 &= f x_1 + \beta(d - x_3)x_2, \\ \dot{x}_3 &= f(x_1^2 + x_2^2) - \alpha x_3. \end{aligned} \tag{2.19}$$

As noted above, (2.19) has a periodic solution γ with initial condition $x(0) = (\sqrt{\alpha d/f}, 0, d)^T$. Following [2], consider the function $V : \mathcal{D} \to [0, \infty)$ defined by

$$\begin{aligned} V(x_1, x_2, x_3) &= \beta(d - x_3)^2 + f(x_1^2 + x_2^2) \\ &\quad - \alpha d \ln(x_1^2 + x_2^2) + \alpha d(\ln(\alpha d/f) - 1). \end{aligned} \tag{2.20}$$

The function V satisfies conditions (1) and (3) of Definition 2.5 for $K = \gamma$. Moreover,

$$\dot{V}(x_1, x_2, x_3) = -2\alpha\beta(d - x_3)^2 \le 0, \tag{2.21}$$

along trajectories of X, so that γ is stable. Since V is nonincreasing along trajectories, it follows that for any $x \in \mathcal{D}$, $\omega(x_0)$ is an invariant subset of $\dot{V}^{-1}(0)$—a very useful result known as *LaSalle's invariance principle*. To say $\dot{V} = 0$ is to say that $x_3 = d$ and, as shown in Example 2.2, the only invariant set on which $x_3 = d$ is γ. This proves that γ is a global attractor on $\mathcal{D}$. A typical sublevel set of V together with a trajectory converging to γ is depicted in Figure 1.

In fact, F. W. Wilson Jr. has shown that Liapunov functions for compact attractors always exist. In this setting, his result takes the following form.

Theorem 2.3. *Suppose that $X \in \mathrm{Vect}(M)$. A necessary condition for a compact subset $K \subset M$ to be a global compact attractor on an open positively invariant domain $D \subset M$ is that there exist a Liapunov function V for X on the pair (D, K).*

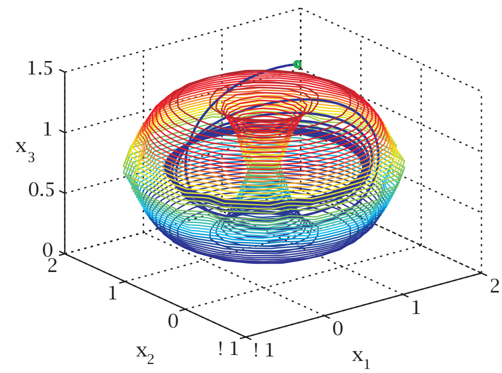


Figure 1. The sublevel set $V^{-1}[0, 1]$ and the trajectory of X for initial condition $(1, .75, 1.5)$.

Remark 2.4. Wilson [19] also studied the topology of Liapunov functions in the case that K is a smooth submanifold. For example, if $K \simeq S^1$, as in the case of an asymptotically stable periodic orbit, then the domain of attraction $\mathcal{D}$ of K always satisfies $\mathcal{D} \simeq \mathbb{R}^{n-1} \times S^1$, in harmony with Examples 2.2–2.3 and Figure 1, for which $\mathcal{D} = \mathbb{R}^3 - X_3 \simeq \mathbb{R}^2 \times S^1$.

Angular Variables and Angular One-Forms

The purpose of this section is to recast Birkhoff's seminal ideas on the existence of sections for smooth dynamical systems in modern terms and to delineate the extent to which these ideas are applicable. For the closed-loop system (2.19), an important role in the analysis of the nonlinear oscillator was played by the variable θ, measuring the rotation of the magnetic field. More formally, for the Liapunov function V defined in (2.20) and for a fixed choice of $c > 0$, denote the sublevel set $V^{-1}[0, c]$ by M and consider the function

$$J : M \to S^1, \quad J(r, \theta, x_3) = \theta, \tag{3.1}$$

which satisfies $\dot{J}(x) = \langle dJ(x), X(x) \rangle = f > 0$. The sign of $\dot{J}$ is irrelevant; only the fact that $\dot{J}$ is sign definite is important. The existence of such an "angular variable" also arises in the two-body problem with a central force field, since conservation of angular momentum implies that $\dot{\theta} = c$, for c a constant and for (r, θ) in an invariant plane of motion.

The importance of angular variables in the theory of nonlinear oscillations was elucidated by G. D. Birkhoff in his 1927 book on nonlinear dynamics. In [1, pp.143–145] Birkhoff derived two sets of necessary and sufficient conditions for the existence of what he called a "surface of section" for an arbitrary differential equation evolving in $\mathbb{R}^n$. For Birkhoff, a smooth section for $X \in \mathrm{Vect}(\mathbb{R}^n)$ is a hypersurface $S \subset M$ in some region $M \subset \mathbb{R}^n$ so that, for each $x \in M$, the "flow line" (trajectory) through x intersects S transversely at a (least) forward time $t_x > 0$ and, replacing t by $-t$, at a least time $s_x > 0$ in reverse time. In this case, he defines the map $\phi(x) = 2\pi s_x/(s_x + t_x)$ and notes that ϕ "increases along every streamline (trajectory of X) by 2π between successive intersections with S". Abstracting from this construction, he called any map ϕ satisfying $\frac{d}{dt}(\phi(x(t))) > 0$ for all trajectories $x(t) \in M$ an *angular variable* for X. Moreover, if ϕ is an angular variable, he observes that $S = \phi^{-1}(0)$ is a surface of section for X on M.

Of course, an angular variable is actually a multivalued function, but it can be made single-valued as a map with values in S^1. For example, Birkhoff's construction leads to the map

$$J(x) = \exp(2\pi i s_x/(s_x + t_x)). \tag{3.2}$$

Birkhoff's second set of conditions is the existence of smooth functions a_i such that

$$\sum_{i=1}^{n} a_i X_i > 0 \text{ and } \frac{\partial a_i}{\partial x_j} = \frac{\partial a_j}{\partial x_i}, \text{ for } i, j = 1, \dots, n,$$

where the X_i are the coordinates of X, abstracting the observation that $\dot{J} = \sum_{i=1}^{n} \frac{\partial J}{\partial x_i} X_i$ is actually a well-defined, real-valued function on M.

More precisely, suppose $M \subset \mathbb{R}^n$ consists of an open subset together with a smooth boundary. In the language of one-forms, one may define $\omega = \sum_{i=1}^{n} a_i dx_i$ and note that Birkhoff's conditions assert that ω is closed, i.e., $d\omega = 0$, and that the natural pairing of the one-form ω and the vector field X satisfies

$$\langle \omega, X \rangle = \sum_{i=1}^{n} a_i X_i > 0. \tag{3.3}$$

It is important to note that (3.3) can be checked pointwise (in particular, without explicit knowledge of trajectories) just as in the applications of Liapunov functions. In this spirit, one may also formulate the existence of an angular variable without reference to the trajectories $x(t)$. If $\mathrm{Vect}_+(M)$ denotes the set of vector fields that point inward on the boundary of M, then M is positively invariant under any $X \in \mathrm{Vect}_+(M)$.

Definition 3.1 ([5]). Suppose $X \in \mathrm{Vect}_+(M)$. We say that a map $J : M \to S^1$ is an *angular variable* for X if it satisfies

$$\dot{J} = \langle dJ, X \rangle > 0 \tag{3.4}$$

everywhere on M. If ω is a closed one-form on M, then ω is an *angular one-form* for X provided that (3.3) holds everywhere on M.

For example, if M is the solid torus, $\mathbb{D}^{n-1} \times S^1 \subset \mathbb{R}^n$, the smooth boundary of M is $S^{n-2} \times S^1$, where S^r denotes the r-sphere. In this case, every closed one-form can be written as $\omega = \sum_{i=1}^{n-1} a_i dx_i + a_n d\theta$. In fact, there exists $c \in \mathbb{R}$ such that

$$\omega = c\,d\theta + df \tag{3.5}$$

for a smooth function $f : M \to \mathbb{R}$.

This is most easily seen using the basic theory of fundamental groups, e.g., the fundamental group $\pi_1(M)$ of M satisfies $\pi_1(M) \simeq \mathbb{Z}$ with a generator given by a simple closed path γ transversing $\{0\} \times S^1$ in either direction. Choose a fixed "base point" $x_0 \in M$ and an arbitrary upper limit $x \in M$ for the integral

$$\int_{x_0}^{x} \omega. \tag{3.6}$$

Of course, this integral may depend on a choice of path joining x_0 to x. Suppose that γ_1, γ_2 are two such paths and consider the closed path $\tilde{\gamma}$ constructed by traversing γ_1 and then γ_2 in the opposite direction. To say that $\int_{x_0}^{x} \omega$ is path independent is to say that $\int_{\tilde{\gamma}} \omega = 0$ for every closed path $\tilde{\gamma}$. If $c = \int_{\gamma} \omega$, then $\int_{\gamma}(\omega - c\,d\theta) = 0$ and, since every closed path $\tilde{\gamma}$ is homotopic to a multiple of γ, $\int_{\tilde{\gamma}}(\omega - c\,d\theta) = 0$ for all closed paths $\tilde{\gamma}$. Therefore $\int_{x_0}^{x}(\omega - c\,d\theta) = f(x)$ is independent of path and $\omega = c\,d\theta + df$.

If c in (3.5) is an integer, then ω is called an integral closed one-form, and every such one-form defines a smooth *period map* $J : M \to S^1$ in the following manner. As noted above, (3.6) is only defined up to "periods" of ω, i.e., up to the elements of the subgroup

$$\Pi(\omega) = \left\{ \int_{\gamma} \omega : [\gamma] \in \pi_1(M) \right\} = (c) \subset \mathbb{Z} \subset \mathbb{R}.$$

If $c \neq 0$, then $\Pi(\omega)$ is an infinite cyclic subgroup, and therefore the *period map* J of ω defines a smooth surjection from M to a circle

$$J : M \to S^1, \tag{3.7}$$

defined via

$$J(x) = \left[\int_{x_0}^{x} \omega \right] \in \mathbb{R} \bmod (c). \tag{3.8}$$

Moreover, J satisfies

$$\dot{J} = \langle dJ, X \rangle > 0 \tag{3.9}$$

if and only if ω is an angular one-form for X.

Remark 3.1. If ω is an angular one-form, then it can be shown that $c \neq 0$. Moreover, the normalization $\omega/|c|$ is an integral angular one-form, where the constant in (3.5) is ± 1. Therefore, an angular variable exists. Conversely, since $S^1 \simeq \mathbb{R}/\mathbb{Z}$, a smooth map $J : M \to S^1$ can be regarded as a multivalued map $J : M \to \mathbb{R}$ where the value $J(x)$ is determined only up to an integer constant. Nonetheless, $\omega = dJ$ is well-defined as a one-form on M, since the derivative of a constant is zero. Moreover, if J is an angular variable for X, then $\langle \omega, X \rangle = \langle dJ, X \rangle > 0$, so that ω is an angular one-form. It is convenient to employ a synthesis of these two approaches.

Remark 3.2. The calculations made above, such as (3.5), for the solid torus also hold, without change of notation, for the toroidal cylinder $\mathbb{R}^n \times S^1$.

Periodic Orbits on Solid Tori and Toroidal Cylinders

While Birkhoff was not specific about the ambient submanifold $M \subset \mathbb{R}^n$ in which a surface of section might exist for X or what that might imply for the topology of M, his statements clearly exclude the choice $M = \mathbb{R}^n$ and specifically include surfaces of section having a boundary. Moreover, it is necessary for his construction that M be an invariant set. The development of angular variables in [5] includes the case of a smooth manifold with boundary that is only required to be positively invariant and allows for a characterization of M topologically when there exists a locally asymptotically stable orbit.

Theorem 4.1 ([5]). *Suppose that $n > 1$. If γ is an asymptotically stable periodic orbit of $X \in \mathrm{Vect}(\mathbb{R}^n)$, then there exists a smooth, positively invariant n-dimensional submanifold $\gamma \subset M \subset \mathbb{R}^n$, homeomorphic to a solid n-torus, on which X has an angular variable $J : M \to S^1$. In fact, M is diffeomorphic to $\mathbb{D}^{n-1} \times S^1$, except perhaps when $n = 4$.*

Remark 4.1. The idea underlying the proof is to build a positively invariant solid torus using a Liapunov function V on the domain of stability $\mathcal{D}$ of γ, generalizing what was observed about the system (2.19). Indeed, for c sufficiently small,

$$M_c = V^{-1}[0, c] \tag{4.1}$$

is a positively invariant compact subset, consisting of an open subset and with a smooth boundary. More succinctly, M_c is a compact orientable smooth manifold with boundary. Moreover, for c sufficiently small, M_c clearly admits an angular variable, since γ does. The rest of the proof uses several key ingredients, starting with the fact that, according to Remark 2.4, the domain of attraction, $\mathcal{D}$, for γ is diffeomorphic to $\mathbb{R}^{n-1} \times S^1$. It can also be shown that the inclusion $M_c \subset \mathcal{D}$ induces an isomorphism of homotopy groups. In other words, the inclusion is a homotopy equivalence. On the other hand the projection $p_2 : \mathbb{R}^{n-1} \times S^1 \to S^1$ onto the second factor, $p_2(x, \theta) = \theta$, is also a homotopy equivalence, since $\mathbb{R}^n$ is contractible. Consequently, M_c is homotopy equivalent to S^1.

For $n = 2$, by the classification of surfaces it then follows that $M_c \simeq \mathbb{A}$, the standard two-dimensional annulus. For $n = 3$, the solution by Perelman of the classical Poincaré conjecture [15] implies that, up to diffeomorphism, $\mathbb{D}^2 \times S^1$ is the only 3-dimensional compact, orientable manifold that is homotopy equivalent to S^1. Similarly, for $n = 4$, the solution by Freedman of the 4-dimensional Poincaré conjecture [7] implies that, up to homeomorphism, $\mathbb{D}^3 \times S^1$ is the only 4-dimensional compact, orientable manifold that is homotopy equivalent to S^1. In higher dimensions, there are infinitely many smooth compact orientable manifolds homotopy equivalent to S^1, but M_c is special. Adapting some constructions of Wilson [19], one can show that ∂M_c is homotopy equivalent to $S^{n-1} \times S^1$. This fact, along with some homotopy theory, allows one to use Freedman's proof of the 4-dimensional Poincaré conjecture [7] to show that, for $n = 5$, M_c is homeomorphic to $\mathbb{D}^4 \times S^1$, while a fundamental result due to Kirby and Siebenmann [11] implies that M_c is diffeomorphic to $\mathbb{D}^4 \times S^1$. An application of the theorem of Barden, Mazur, and Stallings [10] completes the proof [5] of Theorem 4.1 for $n \geq 6$.

Remark 4.2. It is unknown how many differentiable structures on $\mathbb{D}^3 \times S^1$ may exist.

In fact, the necessary conditions for the existence of an asymptotically stable periodic orbit are also sufficient for the existence of a periodic orbit.

Theorem 4.2 ([5]). *If $M \subset \mathbb{R}^n$ is a smooth submanifold which is diffeomorphic to $\mathbb{D}^{n-1} \times S^1$, then any $X \in \mathrm{Vect}(\mathbb{R}^n)$ leaving M positively invariant and having an angular variable $J : M \to S^1$ has a periodic orbit in M. Moreover, the homotopy class of this periodic solution generates $\pi_1(M)$.*

The idea behind the proof is to first use a level set $S_\theta = J^{-1}(\theta)$, for any regular value θ of an angular variable J, as a section for X and to next prove that, after modifying J if necessary, $S_\theta \simeq \mathbb{D}^{n-1}$. In particular, one can apply Brouwer's fixed point theorem to the Poincaré map $\mathcal{P} : S_\theta \to S_\theta$.

Briefly, since J is an angular variable, then $dJ = \omega = c\,d\theta + df$ according to (3.5) and, according to Remark 3.1, $c \neq 0$. Without loss of generality, one can assume $c = 1$ and can embed ω in the family of one-forms $\omega_\lambda = d\theta + \lambda df$, $0 \leq \lambda \leq 1$, which defines a homotopy

$$\tilde{J} : M \times [0, 1] \to S^1, \quad \tilde{J}(x, \lambda) = \int_{x_0}^{x} \omega_\lambda \tag{4.2}$$

between the period mappings $J_0 = J(\cdot, 0)$ and $J_1 = J(\cdot, 0) = J$ and therefore a deformation of $J_0^{-1}(\theta) \simeq \mathbb{D}^{n-1}$ into $J_1^{-1}(\theta) \simeq S$. The remainder of the proof in [5] uses the fruitful relationship between homotopy and cobordism, as described in [14], to show that this deformation is a diffeomorphism.

Remark 4.3. In [5], Theorems 4.1 and 4.2 are proven for the more general case in which $\mathbb{R}^n$ is replaced by an arbitrary orientable paracompact manifold N of dimension $n > 1$.

One corollary of Theorem 4.1 and the proof of Theorem 4.2 is that, except perhaps when $n = 4$, the seemingly stringent hypotheses of the principle of the torus are actually necessary for the existence of a locally asymptotically stable periodic orbit. More importantly, a combination of the proofs of Theorems 4.1 and 4.2 yields an amplification of Theorem 4.2 that combines topology and dynamics in a form that is easier to apply in practice.

Theorem 4.3. *Suppose that $N \simeq \mathbb{R}^n \times S^1$. If $X \in \mathrm{Vect}(N)$ is point-dissipative and has an angular variable J, then X has a periodic orbit γ. Moreover, the homotopy class determined by γ generates $\pi_1(N)$.*

This result was originally proved [3, Theorem 2.1] for the class of dissipative periodic systems discussed in Example 2.1, but the proof extends to the general case. The key idea is to use a Liapunov function V for the global attractor $\mathcal{A}$ for X to build a positively invariant torus for X as in Remark 4.1 and then apply Theorem 4.2. Since $\mathcal{A}$ is not in general smooth, this argument does require a bit more work than the proof of Theorem 4.1.

Theorem 4.3 generalizes Example 2.1 and gives a new proof of Browder's theorem on the existence of harmonic oscillations for dissipative periodic systems (2.6) as well. Indeed, any dissipative system (2.6) was noted to be equivalent to the point-dissipative system (2.8) evolving on the toroidal cylinder $N = \mathbb{R}^n \times S^1$. Since (2.8) has τ as an angular variable, a periodic solution $\{\Phi(t, x_0, 0)\} \subset N$ exists. That $\{\Phi(t, x_0, 0)\}$ is *harmonic* follows from the fact that the homotopy class of $\Phi(\cdot, x_0, 0)$ generates $\pi_1(N) \simeq \mathbb{Z}$.

As the next example shows, Theorem 4.3 also applies directly to the May-Leonard equations, modeling the population dynamics of three competing species with immigration [6].

Example 4.1. The May-Leonard model for three competing species with immigration ($\epsilon > 0$),

$$\dot{N}_1 = N_1(1 - N_1 - \alpha N_2 - \beta N_3) + \epsilon \tag{4.3}$$

$$\dot{N}_2 = N_2(1 - \beta N_1 - N_2 - \alpha N_3) + \epsilon \tag{4.4}$$

$$\dot{N}_3 = N_3(1 - \alpha N_1 - \beta N_2 - N_3) + \epsilon, \tag{4.5}$$

where $0 < \beta < 1 < \alpha, \quad \alpha + \beta > 2$, leaves the positive orthant

$$\mathcal{P}^+ = \{(N_1, N_2, N_3) : N_i > 0, \ \ i = 1, 2, 3\}$$

positively invariant. Let $X \in \mathrm{Vect}(\mathcal{P}^+)$ denote the vector field defined by this differential equation.

The function $V(N_1, N_2, N_3) = N_1 + N_2 + N_3$ is positive on $\mathcal{P}^+$ and has derivative $\dot{V} = L_X V(N_1, N_2, N_3) = N_1 + N_2 + N_3 - (N_1^2 + N_2^2 + N_3^2) - (\alpha + \beta)(N_1 N_2 + N_2 + N_3 + N_1 N_3)$, which is negative for (N_1, N_2, N_3) sufficiently large in norm, so that $B(0, R) \cap \mathcal{P}^+$ is an absorbing set, for the ball of some radius R. Since $\epsilon > 0$, the vector field $X|_{\partial \mathcal{P}^+}$ points inward, and therefore there is a smaller, relatively compact absorbing set in $\mathcal{P}^+$. Hence, by Remark 2.2, X is point-dissipative.

Following [6], there is a unique equilibrium $(\nu(\epsilon), \nu(\epsilon), \nu(\epsilon)) = (1 + (1 + 4\epsilon\rho)^{1/2})/2\rho \in \mathcal{P}^+$, where $\rho = 1 + \alpha + \beta$. Immigration stabilizes the population around this equilibrium if $\epsilon > 2(\rho - 3)/(\rho + 3)^2$, but for

$$\epsilon < 2(\rho - 3)/(\rho + 3)^2 \tag{4.6}$$

the equilibrium is unstable with a one-dimensional stable manifold $W^s(0) = \{(N, N, N)\}$, where $N_i = N > 0$ for $i = 1, 2, 3$.

In this case, $M = \mathcal{P}^+ - W^s \simeq \mathbb{R}^2 \times S^1$ is positively invariant. Moreover, the one-form

$$\omega = \frac{(N_1 dN_2 - N_2 dN_1) + (N_2 dN_3 - N_3 dN_2) + (N_3 dN_1 - N_1 dN_3)}{N_1^2 + N_2^2 + N_3^2 - (N_1 N_2 + N_2 N_3 + N_1 N_3)} \tag{4.7}$$

is an angular one-form for X on M. Therefore, by Theorem 4.3, there exists a periodic orbit $\gamma \in \mathcal{P}^+$ whenever (4.6) is satisfied, as is illustrated in Figure 2.

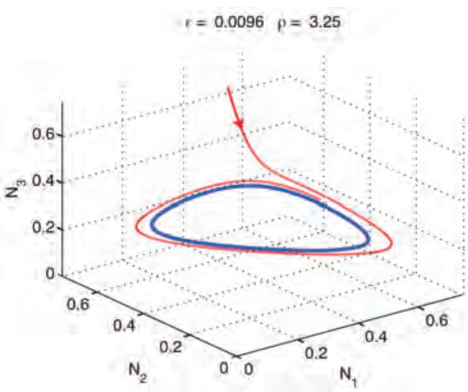


Figure 2. A periodic trajectory for $\alpha = 1.5$, $\beta = .75$.

Remark 4.4. The existence of periodic orbits for the May-Leonard equations when (4.6) is satisfied is well known, and some of our calculations were inspired by the analysis of these equations in [6], although our use of angular one-forms and dissipativity is new and more streamlined. Indeed, the treatment in [6] proves the existence of a periodic solution by checking some comparatively very restrictive hypotheses in an existence theorem due to Grasman [6]. In fact, Grasman's theorem is a corollary of Theorem 4.3.

Example 4.2. (Voltage Controlled Oscillators with Nonlinear Loop Filters.) A phase-locked loop (PLL) is a basic electronic component used in wireless communication networks for the transmission of stable periodic signals. A PLL consists of three components: a *phase detector* (PD), a *voltage-controlled oscillator* (VCO), and a ("low-pass") *loop* *filter* (LF), each of which can be described in terms of a mathematical model. For example, in a very simple, commercially available form, the LF has the form $\dot{y} = -y + u$, where $u, y \in \mathbb{R}$ are the input and output of a one-dimensional system, the VCO is an integrator, $\dot{\theta} = y$ and the closed-loop system produced by a PD that compares the phase results in the feedback control $u = \alpha - a\sin(\theta)$, where $\alpha > a > 0$. In this case the region $y > \alpha - a$ is positively invariant, and using Poincaré-Bendixson theory for the pseudo-polar coordinates (y, θ) in this region shows that the interconnected feedback system results in a sustained, or self-excited, oscillation in the steady-state response of $y(t)$. In this example, I consider the 3-dimensional, nonlinear LF defined by

$$\dot{x}_1 = -2x_1 - x_1 e^{x_2} + x_2 \quad (4.8)$$
$$\dot{x}_2 = -x_1 - 3x_2 - x_2^3 + \beta y \quad (4.9)$$
$$\dot{y} = u \quad (4.10)$$

with the same VCO and feedback law as above, resulting in the interconnected feedback system on $M = \mathbb{R}^3 \times S^1$ defined by

$$\dot{x}_1 = -2x_1 - x_1 e^{x_2} + x_2 \quad (4.11)$$
$$\dot{x}_2 = -x_1 - 3x_2 - x_2^3 + \beta y \quad (4.12)$$
$$\dot{y} = -y + \alpha + a\sin(\theta) \quad (4.13)$$
$$\dot{\theta} = y \quad (4.14)$$

where $\alpha > a > 0$. When $\beta = 0$, this system is uncoupled, consisting of a two-dimensional globally asymptotically stable system on $\mathbb{R}^2$ and the classic voltage-controlled oscillator. In fact, using Theorem 4.3, one can show that there exists a sustained oscillation for any $\beta \geq 0$. First, note that since $\alpha > a$ $N = \{(x_1, x_2, y, \theta) : y > 0\}$ is a positively invariant submanifold which is diffeomorphic to $\mathbb{R}^3 \times S^1$. Moreover, θ is an angular variable for X on N since $y > 0$. Finally, using the energy function

$$V(x_1, x_2, y) = x_1^2 + x_2^2 + (y - \alpha)^2, \quad (4.15)$$

it is straightforward to see that the system is point-dissipative on N, provided $\beta \geq 0$. Therefore, by Theorem 4.3 there exists a periodic orbit, as is illustrated in Figure 3.

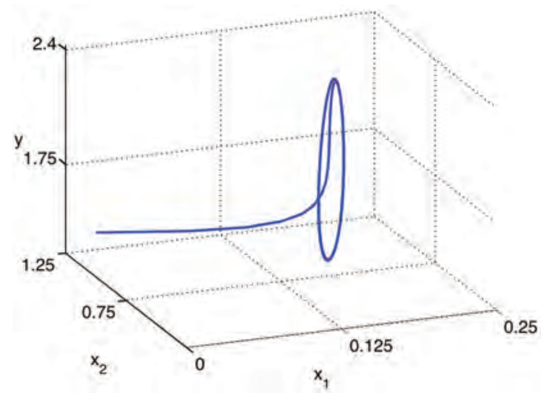


Figure 3. A periodic orbit in the case for $a = 1, \alpha = 2$, and $\beta = 1$.

The Existence of Periodic Orbits for Vector Fields on Closed Three Manifolds

In this and the next section, I will presume familiarity with the concept of a smooth manifold. An excellent introduction, and invitation, to the subject is the book [14]. As a prelude to investigating how generally the sufficient conditions in Theorem 4.2 might hold, consider the case of $X \in \mathrm{Vect}(M)$, where M is a compact orientable 3-manifold. For example, an irrational constant vector field on the 3-torus, $\mathbb{T}^3$, is nowhere vanishing and *aperiodic* by Kronecker's theorem on Diophantine approximations. Moreover, it is easy to construct a constant coefficient angular one-form for such a vector field. Another class of counterexamples can be constructed from the Heisenberg group $N = H_3(\mathbb{R})$ of nonsingular upper-triangular 3×3 real matrices and its discrete subgroups $\Gamma_k = H_3(k\mathbb{Z})$, where $H_3(k\mathbb{Z})$ consists of the upper triangular Heisenberg matrices with integer entries all divisible by $k \in \mathbb{Z}$ with $k \geq 1$. Explicitly, L. Auslander, Hahn, and L. Markus have shown that there exist (left invariant) vector fields on N that descend to vector fields on the compact 3-manifolds $N_k = N/\Gamma_k$ having N_k as their smallest closed invariant set. In particular, any such vector field is aperiodic, and I have constructed examples which also possess angular one-forms [4]. Actually, these are the only counterexamples in dimension 3.

Theorem 5.1 ([4]). *Suppose that M is a compact orientable 3-manifold without boundary. Every $X \in \mathrm{Vect}(M)$ having an angular variable has a periodic orbit except when M is a nilmanifold, i.e., except when either*

(1) $M \simeq \mathbb{T}^3$, *or*
(2) $M \simeq N/\Gamma_k$.

If J is an angular variable for a complete vector field on a compact 3-manifold without boundary, then $S = J^{-1}(0)$ is a compact surface that is a global section for X on M. Since M is orientable and X is transverse to S, S is orientable and can be shown to be connected [4]. Therefore S is a compact orientable connected surface S_g with g holes, and there is a Poincaré map $\mathcal{P} : S_g \to S_g$. In particular, periodic orbits will exist provided $\mathcal{P}$ has a periodic point, i.e., a fixed point of $\mathcal{P}^k$ for $k \in \mathbb{Z}$ with $k \geq 1$.

For what follows, I will also need to assume some familiarity with algebraic topology, particularly homology or cohomology and the notion of the Euler characteristic of a space. For example, the surfaces S_g have Euler characteristic $\chi(S_g) = 2 - 2g$. At about the same time that Birkhoff published [1], S. Lefschetz published a remarkable fixed point theorem that vastly generalized Brouwer's fixed point theorem. As a special case of the general theorem, if $f : M \to M$ is a continuous map on a smooth compact manifold, with or without boundary, Lefschetz introduced an integer $\Lambda(f)$, which can be computed in terms of f and the homology or cohomology vector spaces of M, and for which $\Lambda(f) \neq 0$ implies that f has a fixed point. In 1953, one of Lefschetz's students, F. B. Fuller, extended this result to a neat theorem that implies that if $P : N \to N$ is a homeomorphism on a compact manifold N, with or without boundary, then

(5.1)
$$\chi(N) \neq 0 \implies \Lambda(P^k) \neq 0, \text{ for some } k = 1, 2, \ldots$$

and hence P has a periodic orbit. In particular, if $S \simeq S_g$ for $g \neq 1$, then the Poincaré map always has a periodic point ,and therefore X has a periodic orbit. In case $g = 1$, the section S is a 2-torus and the remainder of the proof of Theorem 5.1 consists of checking when $\Lambda(f) \neq 0$ by hand and what $\Lambda(f) = 0$ means geometrically, following [18]. The remarkable fact is the role played by nilmanifolds, which can also be expressed algebraically in terms of fundamental groups.

The Existence of Nonlinear Oscillations on *n*-Manifolds With or Without Boundary

In the decade following Fuller's publication of his theorem on periodic points, there were substantial applications of algebraic topology to the study of the existence of periodic orbits for dynamical systems having an angular variable. If a vector field X generates a solution backward and forward for all time, then the solutions of the corresponding differential equation define a mapping

$$\Phi : \mathbb{R} \times M \to M, \tag{6.1}$$

which is said to be a *flow*. The case of flows is more tractable than semiflows and was developed quite generally by S. Schwartzman [17]. An important special case of his results is the following.

Theorem 6.1 ([17])**.** *Let M be a compact manifold, with or without boundary, and suppose $X \in \mathrm{Vect}(M)$ defines a flow on M. The following conditions on a closed submanifold $S \subset M$ are equivalent:*

1. *S is a cross section.*
2. *The smooth map $\Phi : \mathbb{R} \times S \to M$ defines a covering space with an infinite cyclic group of covering transformations.*
3. *The map $\Phi : \mathbb{R} \times S \to M$ is a surjective local diffeomorphism.*
4. *There exists a smooth angular variable $J : M \to S^1$.*

In particular, if the covering space has a nonvanishing Euler characteristic, then X has a periodic orbit. On the other hand, for systems that dissipate energy, the objects of interest are often asymptotically stable invariant sets, positively invariant submanifolds, and semiflows. In this direction, Fuller [8] also used the method of angular variables in the more difficult case of a semiflow in a general setting that includes the case of a compact manifold. In this case, following [8], a smooth connected hypersurface S is said to be a *positive cross section* for $X \in \mathrm{Vect}_+(M)$ provided S is a local section for X everywhere in S and, for each $x \in M$, there is a time $t_x > 0$ such that $\Phi_{t_x}(x) \in S$. Among the additional topological challenges in the fundamental work of Fuller on the existence of nonlinear oscillations for such dissipative systems is that, while the Poincaré map is an embedding, it is typically not a (surjective) diffeomorphism, and his theorem on periodic points does not apply. Nonetheless, Fuller was able to prove the existence of periodic orbits in several interesting situations.

Fortunately, a refinement of the notion of angular one-forms provides a general approach to surmounting this technical difficulty.

Definition 6.1. When $\partial M \neq \emptyset$, ω is said to be a *nonsingular angular one-form* provided it is an angular one-form for X and $\omega|_{\partial M}$ is nonsingular.

By Sard's theorem for manifolds with boundary [14] and the compactness of M, it follows that the period map (3.7) of a nonsingular angular form ω is a fiber bundle, since both J and $J|_{\partial M}$ are submersions. Moreover, using the existence of a nonsingular angular one-form, one can show that $\mathcal{P}_*$ is homotopic to a diffeomorphism of S, and therefore $\mathcal{P}_*$ is an automorphism of the integral homology ring $H_*(S)$ of S. This key fact enables us to use a corollary of a result of Halpern, generalizing Fuller's periodic point theorem.

Theorem 6.2. *Suppose that M is a compact manifold with boundary for which $\chi(M) \neq 0$. Any continuous map $f : M \to M$ inducing an automorphism f_* on $H_*(M)$ satisfies $\Lambda(f^k) \neq 0$, for some $k \geq 1$. In particular, f has a periodic point.*

We summarize these results concerning the existence of periodic orbits as follows.

Theorem 6.3 ([4])**.** *Suppose that M is a smooth, compact connected orientable manifold, with or without boundary, and suppose $X \in \mathrm{Vect}_+(M)$ has a nonsingular angular one-form. There exists a smooth compact, connected and oriented submanifold $S \subset M$ having codimension one and boundary $\partial S = S \cap \partial M$ such that*

1. *S is a global positive section for X, and*
2. *$\mathcal{P}_* : H_*(S) \to H_*(S)$ is an automorphism.*

Consequently, if $\chi(S) \neq 0$, then X has a periodic orbit.

Remark 6.1. All compact submanifolds S satisfying conditions (1)–(2) have canonically isomorphic integral homology rings, so that $\chi(S)$ is intrinsically defined. There are counterexamples due to Fuller for $n \geq 4$ that show the inequality in (3.3) must be strict.

Denoting as before the annulus in two dimensions by $\mathbb{A}$, the *hollow torus*, $M = \mathbb{A} \times S^1$, is also the product of the torus $\mathbb{T}^2$ and an interval and therefore admits nowhere vanishing aperiodic vector fields, some of which have a nonsingular angular one-form. This is the only source of counterexamples to the existence of periodic orbits for vector fields on a 3-manifold with boundary having a nonsingular angular one-form.

Theorem 6.4 ([4]). *Suppose M is a three-dimensional manifold with boundary. Every $X \in \mathrm{Vect}_+(M)$ that has an angular one-form ω has a periodic solution whose homotopy class has infinite order in $\pi_1(M)$, except when M is diffeomorphic to a hollow torus $\mathbb{A} \times S^1$.*

There are several other corollaries of Theorem 6.3. For example, [4] contains a general result for closed 5-manifolds that implies that periodic orbits exist for vector fields with an angular one-form on any closed 5-manifold with $\pi_1(M) \simeq \mathbb{Z}$. A similar result is proven in [4] for vector fields defined on a compact manifold M with boundary that is homotopy equivalent to S^1.

Conclusions

Nonlinear oscillations are fascinating and important but hard to rigorously detect or predict. Since Poincaré's time, the best known and most accessible methods in applied mathematics and related fields rely on small parameter analysis and provide local existence criteria for periodic motions having sufficiently small amplitudes. On the other hand, since the period of nonlinear oscillations is generally not known a fortiori, the existence of nonlinear oscillations is a global phenomenon, and therefore any comprehensive theory would necessarily be global in nature. This article continues in the tradition of Poincaré, Birkhoff, and others in studying cross sections for vector fields, creating a global approach to developing criteria for the existence of periodic orbits using methods drawn from the global theory of nonlinear dynamical systems that dissipate some mathematical form of energy and methods drawn from algebraic and differential topology, particularly the fruitful combination of cobordism and homotopy theory.

One of the major points of departure for this approach is the ability to include motions of a dynamical system that leave a manifold with boundary positively invariant, rather than invariant both forward and backward in time. This enables one to discuss and characterize what must occur topologically when a locally asymptotically stable periodic orbit exists, a necessary condition that itself proves to be sufficient for the existence of periodic orbits. Using the language and methods of dissipative systems formulated by Hale, Ladyzhenskaya, and others, this sufficient condition is reformulated into a global sufficient condition that is fairly easy to apply in several specific examples. The article concludes with a formulation of stricter sufficient conditions for the existence of periodic orbits for vector fields defined, however, on general compact manifolds, with or without boundary, that fiber over a circle.

My own interest in this subject is the existence of asymptotically stable periodic motions in nonlinear feedback systems, both manmade and natural, and possible future directions of research should include the incorporation of stability criteria, including classical tools such as Hopf bifurcations and describing function methods and the intriguing possibility of extending this work to the case of invariant tori.

References

[1] G. D. Birkhoff, *Dynamical systems*, Amer. Math. Soc. Coll. Pub. **9** (revised ed.), Providence, 1966.

[2] R. W. Brockett, Pattern generation and the control of nonlinear systems, *IEEE Trans. on Automatic Control* **48** (2003), 1699–1712.

[3] C. I. Byrnes, On the topology of Liapunov functions for dissipative periodic processes, *Emergent Problems in Nonlinear Systems and Control*, Springer-Verlag, to appear.

[4] ______, On the existence of periodic orbits for vector fields on compact manifolds, submitted to *Trans. of the Amer. Math. Soc.*

[5] C. I. Byrnes and R. W. Brockett, Nonlinear oscillations and vector fields paired with a closed one-form, submitted to *J. of Differential Equations.*

[6] M. Farkas, *Periodic motions*, Springer-Verlag, Berlin, 1994.

[7] M. H. Freedman and F. Quinn, *Topology of 4-manifolds*, Princeton University Press, Princeton, 1990.

[8] F. B. Fuller, On the surface of section and periodic trajectories. *Amer. J. of Math.* **87** (1965), 473–480.

[9] J. K. Hale, *Asymptotic behavior of dissipative systems*, AMS Series: Surv Series **25**, 1988.

[10] M. Kervaire, Le théorèm de Barden-Mazur-Stallings, *Comment. Math. Helv.* **40** (1965), 31–42.

[11] R. C. Kirby and L. C. Siebenmann, *Foundational Essays on Topological Manifolds, Smoothings, and Triangulations*, Annals of Math. Studies, AM-88. (revised ed.), Princeton University Press, Princeton, 1977.

[12] O. Ladyzhenskaya, *Attractors for semigroups and evolution equations*, Lezioni Lincee, Cambridge University Press, 1991.

[13] B. Li, Periodic orbits of autonomous ordinary differential equations: Theory and applications, *Nonlinear Analysis* **TMA 5** (1981), 931–958.

[14] J. W. Milnor, *Topology from a differentiable viewpoint,* University Press of Virginia, Charlottesville, Virginia, 1965.
[15] J. W. Morgan and G. Tian, *Ricci flow and the Poincaré conjecture*, Amer. Math. Soc, Clay Mathematics Monographs, Vol. 3, 2007.
[16] V. A. Pliss, *Nonlocal problems in the theory of nonlinear oscillations*, Academic Press, New York and London, 1966.
[17] S. Schwartzman, Global cross sections of compact dynamical systems, *Proc. N.A.S.* **48** (1962), 786–791.
[18] W. P. Thurston, *Three-dimensional geometry and topology, Vol. 1*, Princeton U. Press, 1997.
[19] F. W. Wilson Jr., The structure of the level sets of a Lyapunov function, *J. of Diff. Eqns.* **3** (1967), 323–329.

Tilings, Scaling Functions, and a Markov Process

Richard F. Gundy

Introduction

We discuss a class of Markov processes that occur, somewhat unexpectedly, in the construction of wavelet bases obtained from *multiresolution analyses* (MRA). The processes in question have been around for a long time. One of the first references that should be cited is a paper by Doeblin and Fortêt [10] (1937), entitled "Sur les chaînes à liaisons complètes". In English, they are sometimes called "historical Markov processes" and have been used extensively to study the Ising model. However, their wavelet connection does not seem to have filtered into the standard texts on time-scale analysis.

The material for this article is drawn from the publications [9], [12], [13], as well as the prior contributions by various people who are cited in the appropriate places. To keep the exposition self-contained and as elementary as possible, we discuss the special case of the "quincunx matrix" in which the proofs are somewhat simpler and, in some cases, radically different from those found in the above references.

In the first section, we describe a remarkable coincidence: two discoveries, the first concerning a gambling strategy and the second concerning a wavelet basis, both leading to the same mathematics. *It is remarkable that these discoveries, each of fundamental importance, were separated by 330 years!* The wavelet discovery was a particular class of trigonometric polynomials within a class of functions called *quadrature mirror filters* (QMF functions, for short). These functions turn out to be probabilities; hence their connection to gambling.

Richard F. Gundy is professor of statistics and mathematics at Rutgers University. His email address is `gundy@rci.rutgers.edu`.

The names associated with the gambling strategy are Pascal and Fermat; the wavelet discovery to which we refer is due to Ingrid Daubechies.

In the subsequent sections, we are concerned with the class of 1-periodic functions $p(\xi)$, quadrature mirror filters, that generate an MRA on $\mathbb{R}$ or $\mathbb{R}^2$. Some do so, but most do not; our problem is to find out which is which. The probability methods presented here provide new information on this topic. We show that there is a one-to-one correspondence between two disparate classes of scaling functions, one defined on $\mathbb{R}$, the other defined on $\mathbb{R}^2$. Second, the probability perspective allows us to exhibit a large class of continuous $p(\xi)$ that generate MRAs. When the function $p(\xi)$ is smooth and generates an MRA, it must satisfy known necessary conditions. However, these necessary conditions may be violated in the extreme for MRAs in which the generator $p(\xi)$ is smooth *except* at a few points. "Few" here means as few as four.

In one dimension, all of the MRAs we consider involve the dilation $\mathbb{Z} \to 2\mathbb{Z}$; in two dimensions, an interesting special case is the "quincunx" dilation, described below. In the first case, where $\xi \in \mathbb{R}^1$, the QMF function $p(\xi)$ is periodic (with period one); in the second case, when $\xi \in \mathbb{R}^1$, $p(\xi)$ is doubly periodic on the unit square. From this, one might assume that the natural fundamental domains for these functions would be $\{(0,1), \mathbb{Z}\}$ or $\{(0,1) \times (0,1), \mathbb{Z}^2\}$. But the natural assumption is too naïve. In one dimension, the appropriate domain is sometimes a disconnected set called a C-tile, described below. In two dimensions, the "fundamental" fundamental domain is a fractal set called the "twin dragon". But in the final analysis, these tiles and dragons will both be superseded by the space $2^{\mathbb{Z}}$ of infinite binary sequences. To explain how this comes about, we will make a detour in which we examine some aspects of radix representation for $\mathbb{Z}$ and $\mathbb{Z}^2$.

Some Definitions

In the discussion that follows, we distinguish two copies of Euclidean space: $t \in \mathbb{R}^n$ is considered to be the "time" variable and $\xi \in \mathbb{R}^n$ the (Fourier transform) "frequency" variable. A QMF function $p(\xi), \xi \in \mathbb{R}^n, 0 \le p(\xi) \le 1$ is, first of all, a non-negative function that is periodic with period one in each variable. There is a dilation associated with $p(\xi)$, an $n \times n$ matrix $B(i,j)$ with integer entries, with the property that all the eigenvalues λ satisfy $|\lambda| > 1$. Matrices with these properties are called expanding. Since B maps $\mathbb{Z}^n \to \mathbb{Z}^n$, we may choose a full set of coset representatives $d^k, k = 0, 1, \ldots, q-1, (q = |\det B|)$ from $\mathbb{Z}^n/B(\mathbb{Z}^n)$. The vectors d^k are called digits. A proof that $q = |\det(B)|$ may be found in Wojtaszczyk ([23], Proposition 5.5, page 109). For any such selection we assume that $p(\xi)$ satisfies the QMF condition

$$(1) \qquad p(0) = \sum_{k=1}^{m} p\left(B^{-1}(\xi + d^k)\right) = 1.$$

We always assume that $p(\xi)$ is continuous in the topology of the moment. At this moment it is the usual topology. Later, it will be a totally disconnected topology. In one dimension, for the dilation 2 with $d^0 = 0, d^1 = 1$, condition (1) is simply $p(\xi/2) + p((\xi+1)/2) = 1$, and $p(0) = 1$.

Two questions are addressed in this article: (1) How do we construct QMF functions? (2) What are necessary and sufficient conditions for a given function to generate a scaling function for an MRA in $\mathbb{R}^1$ and $\mathbb{R}^n$? We concentrate on two special cases: (a) one dimension, with dilation 2; (b) two dimensions, with a particular matrix $B, \det B = 2$. The discussion of the general case of two-by-two matrices B with $\det B = \pm 2$ may be found in [13].

What Is a Scaling Function?

First of all, it is a real-valued function $\varphi(t), t \in \mathbb{R}$, that satisfies a *self-similarity* property with respect to a group of *affine* transformations generated by $(A, \mathbb{Z}^n)$, where A is an expanding matrix with integer entries. In all cases, it will turn out that the transpose of $A := B$, where B is the matrix specified in the previous section, as we shall see presently. Second, $\varphi(t)$ is a function whose translates of $\varphi(t-j), j \in \mathbb{Z}^n$, form an orthonormal family, spanning a subspace V_0 of $L^2(\mathbb{R}^n)$. We let $V_j \subset V_{j+1}, j \in \mathbb{Z}$ be the sequence of subspaces of $L^2(R^n)$ with the property $f(t) \in V_0$ if and only if $f(A^j t) \in V_j$. Furthermore, assume that there is a sequence $\{c_k; k \in \mathbb{Z}^n\} \in l^2$ such that

$$(a) \quad \varphi(t) = |\det(A)|^{1/2} \sum_{k \in \mathbb{Z}^n} c_k \varphi(At - k) \quad \text{with } \sum_{k \in \mathbb{Z}^n} |c_k|^2 = 1$$

$$(2) \qquad (b) \quad \int \varphi(t)\varphi(t-k)dt = \delta(0,k), \quad k \in \mathbb{Z}^n;$$

$$(c) \quad \lim_{j \to \infty} \|P_j f - f\| = 0, \quad \text{for all } f(t) \in L^2(\mathbb{R}^n),$$

where P_j is the orthogonal projection onto V_j.

The triple $(\varphi, A, \{V_j, j \in \mathbb{Z}\})$ defines the MRA. The coefficients $c_k, k \in \mathbb{Z}^n$ specified in property (a) will be called *refinement coefficients*. These coefficients appear in the function $p(\xi)$ from the Introduction. See $(\hat{2})$ below.

Some scaling functions are of the form $\varphi(t) = \chi_T(t)$ where $\chi_T(t)$ is the indicator function of a subset of $\mathbb{R}^n$ of the form

$$(3) \qquad T = T(A, \mathcal{D}) := \{t \in \mathbb{R}^n : t = \sum_{j=1}^{\infty} A^{-j} d_j, \quad d_j \in \mathcal{D}, j \ge 1\}$$

where for each $j \ge 1$, d_j is chosen from the set $\mathcal{D} = \{d^k, k = 0, 1, \ldots, q-1\}$ of coset representatives of the group $\mathbb{Z}^n/A(\mathbb{Z}^n)$. These sets are *self-affine* in the sense that $\chi_T(t) = \sum_{d_j \in D} \chi_T(At - d_j)$. This is property (a) for indicator scaling functions.

Definition. A set T is a *tile* if $\sum_{j \in \mathbb{Z}^n} \chi_T(t - j) = 1$ almost everywhere. For indicators, this is property (b). The primary tile example is the Haar scaling function: here T is the unit interval $t = \sum_{j=1}^{\infty} 2^{-j} d_j, \mathcal{D} = \{0, 1\}$. In this case, T is self-affine; however, not every tile we will encounter is self-affine. (See the section "An Infinite Sequence of Games".)

The probability theory begins when we take the squared modulus of the Fourier transform $|\hat{\varphi}(\xi)|^2$ of the scaling function $\varphi(t)$ defined in (2). (For functions on $\mathbb{R}^n$ we write the Fourier transform $\hat{\varphi}(\xi) = \int \varphi(t) \exp(-2\pi i \langle t, \xi \rangle) dt$; for sequences $c_k, k \in \mathbb{Z}^n$, $\hat{c}(\xi) = \sum_{k \in Z^n} c_k \exp(-2\pi i \langle k, \xi \rangle)$.

The three properties in (2) may be expressed in terms of B, the transpose of A:

$$(\hat{a}) |\hat{\varphi}(\xi)|^2 = p(B^{-1}\xi)|\hat{\varphi}(B^{-1}\xi)|^2.$$

$(\hat{2})$ Here $p(\xi) = (|\det B|)^{-1}|\hat{c}(\xi)|^2 = \left| |\det B|^{-1/2} \sum_{k \in \mathbb{Z}^n} c_k \exp(-2\pi i \langle \xi, k \rangle) \right|^2$

where $c_k, k \in \mathbb{Z}^n$ are the refinement coefficients from display (2). The periodic function $\tilde{p}(\xi) := |\det(B)|^{-1/2}\hat{c}(\xi)$ is called a *low-pass filter*.

$$(\hat{b}) \sum_{k \in \mathbb{Z}^n} |\hat{\varphi}(\xi + k)|^2 = 1 \text{ a.e.};$$

$$(\hat{c}) \lim_{k \to \infty} |\hat{\varphi}(B^{-k}\xi)|^2 = 1 \text{ a.e.}$$

The conditions $(\hat{a})$, $(\hat{c})$ imply condition (a) and $(a), (c)$ imply $(\hat{c})$. See Madych ([18], Proposition 1, and Corollaries 2 and 3, page 266), and Hernández and Weiss ([14], Theorem 1.6, page 45, and Theorem 5.2, page 382).

Now we record two probability comments that are fundamental to what follows. First, a low-pass filter is the Fourier transform of a discrete probability distribution $\{|\det(B)|^{-1/2} c_k; k \in \mathbb{Z}^n\}$ if and only if $\varphi(t)$ is the indicator function of a tile. This follows from two observations: (a) the Lebesgue measure of a tile is necessarily one (see the section "Coding $\mathbb{R}^1$ and $\mathbb{R}^2$ into $2^{\mathbb{Z}}$: Case 1; $\mathbb{Z}^1$ vs. $\mathbb{Z}^2$"); (b) a nonnegative function is orthogonal to its translates only if the supports of the translates are disjoint. If $\varphi(t)$ is a tile, it turns out that $p(\xi)$ is the characteristic function of the difference of two independent identically distributed random variables $X - X'$, where X is uniformly distributed over the digits $d^k, k = 0, 1, \ldots, q-1$. This observation will be used to good effect in the above-mentioned section. (For example, if $\varphi(t) = \chi_{(0,1)}(t)$, we may take $X - X'$ to be two independent "fair coin" Bernoulli variables; the characteristic function of the difference $X - X'$ is given by $p(\xi) = \left(\frac{1}{2}\right)|(1+\exp(-2\pi i\xi))/\sqrt{2}|^2 = |(1+\exp(-2\pi i\xi)/2)|^2$. The digits are $d^0 = 0, d^1 = 1$, $A = B = 2$, and $c_0 = c_1 = 1/\sqrt{2}$. The fact that $|\chi_{(0,1)}(\xi)|^2 = \prod_{k=1}^{\infty} p(\xi/2^k)$ is classical. In general, the squared modulus of a low-pass filter is not the characteristic function of a random variable.

On the other hand, the QMF condition does suggest a different kind of probability construction. If $\varphi(t)$ is a scaling function, then $p(\xi)$, as defined above, satisfies the QMF condition: to verify this, we write $m \in \mathbb{Z}^n$ as $m = Bm' + d^k$. From conditions $(\hat{a}), (\hat{b})$ we get

$$\sum_{m\in\mathbb{Z}^n} \left|\hat{\varphi}(B^{-1}(\xi+m))\right|^2 = \sum_{m'\in\mathbb{Z}^n} \left|\hat{\varphi}(B^{-1}(\xi+d^k)+m')\right|^2 = 1 \quad \text{for each fixed digit } d^k.$$

We take note of this and the fact that $|\hat{\varphi}(0)|^2 = \int |\varphi(t)|^2 dt = 1$, together with $(\hat{a})$, to obtain

$$1 = \sum_{k\in\mathbb{Z}^n} |\hat{\varphi}(\xi+k)|^2 = \sum_{d_j\in D} p\left(B^{-1}(\xi+d^k)\right) = p(0),$$

as shown in (1). From $(\hat{a})$ and the fact that $p(\xi)$ is a QMF function, we see that this implies that the function $|\hat{\varphi}(\xi)|^2$ is a (formal) infinite product:

$$|\hat{\varphi}(\xi)|^2 = \prod_{j=1}^{\infty} p(B^{-j}\xi). \tag{4}$$

This infinite product version of $(\hat{a})$ also suggests *two* interpretations for the Fourier transform $|\hat{\varphi}(\xi)|^2$. As we have seen, when $\varphi(t) = \chi_T(t)$, $p(\xi)$ is a characteristic function of $X - X'$, so that $|\hat{\varphi}(\xi)|^2$ is the Fourier transform of the infinite convolution of probabilities corresponding to a sum of independent random variables with values in the time domain. When $\varphi(t)$ is not necessarily a tile, there is another perspective: we regard $|\hat{\varphi}(\xi)|^2$ as a probability in the frequency domain. In fact, $\prod_{j=1}^{m} p(B^{-j}\xi), m \geq 1$, are probabilities on $R^n \times (m \text{ factors}) \times R^n$, since $p(\xi)$ satisfies the QMF condition. The foregoing sequence of partial products defines probabilities associated with a sequence of zero-sum games. The sequence of payoffs for these games forms a Markov process of the type mentioned in the Introduction. Let us see how this works in a special case.

The Pascal-Fermat Correspondence

Many historians use the date 1654 to mark the beginning of computational probability theory. It was during that year that Pascal and Fermat exchanged their thoughts on the "problem of points" in response to a question posed by the essayist and gambler Antoine Gombaud, aka Chevalier de Méré. For the purpose of this discussion, let me pose a particular form of his problem as follows: Two players, Alice and Bob, of different skills, are playing a sequence of games. Each game represents an independent trial, resulting in a score of 1 for the winner, 0 for the loser. Let us assume that the probability that Alice wins an individual game is $\alpha, 0 \leq \alpha \leq 1$. In that case, the probability that Bob wins a single game is $1 - \alpha$. They play a sequence of games until one of the players has won a fixed number of games. That number N is fixed at the outset. Can we write a formula for the probability $P(\alpha, N)$ that Alice is the overall winner? Without any hard computation, a number of things are clear:

- The number of individual trials to determine a winner cannot exceed $2N - 1$.
- Since the trials are independent, the desired probability may be computed using the binomial expansion: simply sum over all sequences of length $2N - 1$ containing at least N wins for Alice. These sequences have a total probability $P(\alpha, N)$, a polynomial in α that is strictly positive if $0 < \alpha \leq 1$.
- The degree of this polynomial is exactly $2N - 1$, since there is a positive chance that the winner will not be determined until trial $2N - 1$. The only root of this polynomial $P(\alpha, N)$ is at $\alpha = 0$, and this root has multiplicity N. This is true because we can compute $P(\alpha, N)$ in another way: restrict the sum to sequences that terminate with the Nth win for Alice on the kth game, where $N \leq k \leq 2N - 1$.

For example, if $N = 2$, the first computation gives $P(\alpha, 2) = \alpha^3 + 3(1-\alpha)\alpha^2 = \alpha^2(\alpha + (1-\alpha)) + 2(1-\alpha)\alpha^2$. The second computation leads to the expression $\alpha^2 + 2(1-\alpha)\alpha^2 = \alpha^2(3 - 2\alpha)$.

- Finally, observe that $P(\alpha, N) + P(1-\alpha, N) = 1$; that is, we have a zero-sum game.

Daubechies' QMF Function

Now let us move ahead by about three hundred and fifty years. The notion of a QMF function has emerged. As we will explain in the next paragraph, certain (but not all) QMF functions generate wavelet bases or, more precisely, scaling functions. The problem that Ingrid Daubechies [6] confronted in the 1980s was the search for a class of scaling functions $\varphi(t)$ that were (i) smooth to a specified degree and (ii) compactly supported. Since these functions are to be used for data analysis, she starts with the search for a suitable finite set of real-valued refinement coefficients $c_k, k \in \mathbb{Z}$, with the hope that these coefficients will lead to a solution to the equation $(2a)$. (Notice that in order for $\varphi(t)$ to be compactly supported, it is necessary that $c_k \neq 0$ for only finitely many $k \in \mathbb{Z}$.) Finding a suitable sequence of coefficients is the same as finding the polynomial low-pass filter $\tilde{p}(\xi) = (\sqrt{2})^{-1}\hat{c}(\xi)$. Her strategy is to proceed in two steps. First, solve what turns out to be a simpler problem: find a QMF polynomial $p(\xi)$ and form the infinite product given in (3). It is not too difficult to see that the inverse Fourier transform of $|\hat{\varphi}(\xi)|^2$ will inherit some degree of regularity from the factors to satisfy requirement (i). For example, if $p(\xi)$ has the factor $\cos^{2N}(\pi\xi)$, which is a factor of the Fourier transform of an N-order basic spline, then this spline will appear in the infinite convolution $\varphi(t)$. In addition, $p(\xi)$ should vanish only at $\xi = 1/2$, since additional zeros, depending on their nature, can be big trouble: that is, the sum in $(\hat{b})$ may be less than one for certain ξ due to the presence of unwanted zeros in the sequence $p(2^{-j}\xi), j \geq 1$. So, to be on the safe side, she looks for polynomials whose only zeros (at $\xi = 1/2$) are those required by the QMF condition.

Daubechies [6] produces a class of QMF trigonometric polynomials $p_N(\xi)$ by some clever combinatorics. It turns out that the class of polynomials she finds coincides, under a change of variables, with the algebraic polynomials found by Pascal and Fermat. To see why this is the case, let us suppose that we have a solution $p(\xi)$ that satisfies the above requirements. We note that any QMF polynomial is a nonnegative cosine polynomial. It is an elementary fact that such trigonometric polynomials may be written as algebraic polynomials in the variable $\alpha(\xi) = \cos^2(\pi\xi)$. For the moment, call this algebraic polynomial $P(\alpha) : P(\cos^2(\pi\xi)) = p(\xi)$. The QMF condition $(P(\alpha) + P(1-\alpha) = 1)$ allows us to interpret $P(\alpha)$ as the probability of winning a two-player zero-sum game. The polynomial $P(\alpha)$ is required to have a single root of multiplicity N at $\alpha = 0$ in order to satisfy the smoothness requirement and to avoid the possible "big trouble" mentioned above. With the benefit of hindsight, we see that the requirements imposed on $p(\xi)$ for Daubechies' problem are met by the class of polynomials $P(\alpha, N)$ discovered by Pascal and Fermat in 1654. The case $N = 1$, where $p(\xi) = \cos^2(\pi\xi)$, gives the QMF polynomial for the Haar scaling function, the indicator function of the unit interval. Notice that $|\hat{\varphi}(\xi)|^2$ is the Fourier transform of the linear B-spline (the tent on the interval $|t| \leq 1$), which is the convolution of two indicator functions of the interval $|t| \leq 1/2$. So, just to obtain a continuous $\varphi(t)$, one must use a Pascal-Fermat polynomial with $N > 1$. Smoothness increases with N, at the expense of increasing the length of the support of φ.

In her monograph ([7], page 211) Daubechies reports that it was Yves Meyer who suggested the change of variables from ξ to α; Meyer's endgame to derive the polynomials $P(\alpha, N)$ uses Bézout's lemma. Here, it is the Bézout lemma that is taught to first-year university students in France and to fourth-year undergraduate students in the United States.

The Pascal-Fermat connection was first described in [12].

Producing the Scaling Function

The second part of the problem is to prove that these QMF polynomials lead to the existence of compactly supported scaling functions. We may also ask whether the solution scaling functions are unique. A famous factorization fact, known as the Fejér-Riesz spectral factorization lemma, asserts that any nonnegative cosine polynomial may be expressed as the squared modulus of a cosine polynomial with *real* coefficients, restricted to the unit circle. (See Daubechies [7], page 172.) In particular, the Fejér-Riesz lemma implies that any QMF polynomial may be expressed as $p(\xi) = |(\sqrt{2})^{-1}\sum_{k=0}^{N} c_k \exp(-2\pi i k\xi)|^2$ for some sequence $c_k, k = 0, 1, \ldots, N$. That is, we can find a (nonunique) polynomial square root $\tilde{p}(\xi)$ for the function $p(\xi)$.

All of this means that we can define the convergent infinite product $\hat{\varphi}(\xi) := \prod_{j=1}^{\infty} \tilde{p}(2^{-j}\xi)$. By Fourier inversion, we obtain a compactly supported function $\varphi(t)$. For this $\varphi(t)$, the coefficients $c_j, j = 0, 1, \ldots, N$, are the ones that are specified by property (a). Next question: do the functions $\{\varphi(t-k), k \in \mathbb{Z}\}$ constitute an orthonormal family, as specified by property (b) or $(\hat{b})$? This is the most elusive of the three properties, and we postpone the full discussion it deserves. A hint: the crucial fact was emphasized above by the remark that $p(\xi) = 0$ if and only if $\xi = 1/2$. If this is the case, then the factors $p(\xi/2^j)$, $j \geq 1$, are strictly positive, surely a necessary condition for $(\hat{b})$. Property $(\hat{c})$ is easy to verify: it follows from the fact that the infinite product $|\hat{\varphi}(\xi)|^2$ is continuous and $p(0) = |\hat{\varphi}(0)|^2 = 1$.

Regarding the uniqueness question, a given QMF function may generate many different scaling functions. Notice that even in the simplest case, $p(\xi) = \cos^2(\pi\xi)$ and $|\hat{\varphi}(\xi)|^2 = \sin^2(\pi\xi)/(\pi\xi)^2$, the indicator function of an arbitrary unit interval, or Hilbert transform of such an indicator function, is a candidate for $\varphi(t)$. Finally, if $p(\xi)$ is any QMF function (not necessarily a polynomial) such that properties $(\hat{a}), (\hat{b})$, and $(\hat{c})$ hold, it is known that a square root exists (see The Wutam Consortium [24]) and so also a corresponding $\varphi(t)$ that satisfies $(a), (b)$, and (c). For this reason, the object of primary concern is the function $p(\xi)$ and the infinite product $|\hat{\varphi}(\xi)|^2$.

An Infinite Sequence of Games

What has been said about QMF polynomials applies to any periodic QMF $p(\xi)$, expressed as a Fourier series. We can re-express $p(\xi) = P(\cos^2(\pi\xi))$. Let (ξ) be the fractional part of $\xi \in \mathbb{R}$. We can define two quantities, $\alpha = \alpha(\xi) = \cos^2(\pi(\xi)/2)$ and $1 - \alpha(\xi) = \cos^2(\pi((\xi)/2 + 1/2))$ so that $P(\alpha(\xi)) + P(1 - \alpha(\xi)) = 1$. The quantity $P(\alpha(\xi))$ represents the probability that Alice wins a two-person game specified by a parameter (ξ). Our players will play an infinite sequence of such games, and after each play, the parameter (ξ) will be changed by a certain amount, dictated by the QMF condition. In more detail, let us suppose that the two players enter the casino at a time that we arbitrarily call $t = 0$. Since the casino has been running since the beginning of time, the amusement opportunity at $t = 0$ is summarized by the pair $((\xi), p((\xi)/2))$. Here the binary digits for (ξ) give the history of wins for Alice ($\omega_k = 0$) and Bob ($\omega_k = 1$). This pair contains enough information to compute the initial probabilities α_0 and $1 - \alpha_0$; these are determined by the fractional part (ξ) and the binary coefficient ω_0 determining the parity of the integer part $\lfloor \xi \rfloor$: If $\lfloor \xi \rfloor$ is even, Alice wins the initial game ($\omega_0 = 0$) with probability $p((\xi)/2)$; if ($\omega_0 = 1$), Bob wins with probability $p((\xi)/2 + 1/2)$. In any case, the opportunity at $t = 0$ is summarized by (ξ), and $p((\xi)/2)$; the outcome, determined by the parity of $\lfloor \xi \rfloor$, is not known at $t = 0$. In this way, we can compute the probability that Alice wins any finite number of games. The sequence of amusement opportunities is random, depending on Alice's current fortune, and qualifies as a Markov process whose states are numbers in the unit interval. In this context, it is important to note that the sequence of wins and losses, represented by the random sequence of binary digits ω_j, $j \in \mathbb{Z}$, is *not* a two-state Markov process. If it were so, then ω_{-1}, the first binary coefficient of (ξ), would represent "the present". However, it is clear that $\Pr(\omega_0 = 0 \| (\xi)) \neq \Pr(\omega_0 = 0 \| \omega_{-1})$. We have taken the liberty to rescue the Markov property by an expedient definition of "the present" as "the entire history", specified by (ξ). After the outcome of the game at $t = 0$ is revealed, the new state of the process is given by $(\xi)/2 + \omega_0/2$.

The interesting question concerns an infinite sequence of plays after $t = 0$: what is the probability that there is an eventual winner for this sequence of games? The eventual winner is the player who wins every game from some point forward. This can only happen if $\lim_{j\to\infty} \alpha_j = 1$ or $\lim_{j\to\infty} 1 - \alpha_j = 1$, and in this case we will say that the sequence of games is decided. The alternative is an eternal, indecisive combat. In these terms, we can state the following theorem.

Theorem 1. *A continuous QMF function $p(\xi), \xi \in \mathbb{R}$ for dyadic dilation generates a scaling function if and only if, for almost every $(\xi), 0 \leq (\xi) \leq 1$, the infinite sequence of games is decided with probability one. Moreover, there should be a set of (ξ) of positive Lebesgue measure such that with positive probability, Alice is the winner, and a set of (ξ) of positive Lebesgue measure such that Bob is the winner. If (ξ) is a QMF function (that generates a scaling function) with a finite number of zeros, then the above condition can be more simply stated: for almost every (ξ) with probability one, both players have positive probability of being eventual winners.*

Commentary. If Alice finally prevails, winning every game after k trials, the coefficients in the binary expansion of k are eventually zero. So, the probability that she is the eventual winner is $\sum_{k\geq 0} |\hat{\varphi}((\xi) + k)|^2$. The Bob probability is given by the sum over $k < 0$. Of course, if the game is decided (one of the two players is the eventual winner), then $\sum_{k\in\mathbb{Z}} |\hat{\varphi}(\xi + k)|^2 = 1(\xi)$ a.e. Condition $(\hat{c})$ is the expression of the "Moreover" part of the theorem. This second assertion cannot be casually justified at this point. Note that this theorem does not give conditions on $p(\xi)$ that tell us whether or not the game is decided. The bare-bones conditions for a decisive winner are conditions $(\hat{a}), (\hat{b})$, and $(\hat{c})$, conditions that are not easily translated to conditions on $p(\xi)$. However, if we assume that $p(\xi)$ is a polynomial, for example, then there are restrictions on its zeros that translate to necessary and sufficient conditions for the game to be decided. (See the section "Invariant Sets for QMF Functions").

The above discussion suggests that we should transfer our attention from functions of a real variable ξ to functions defined on binary sequences. This is not just a convenience. There is a more compelling reason to do this, described in this section and the following.

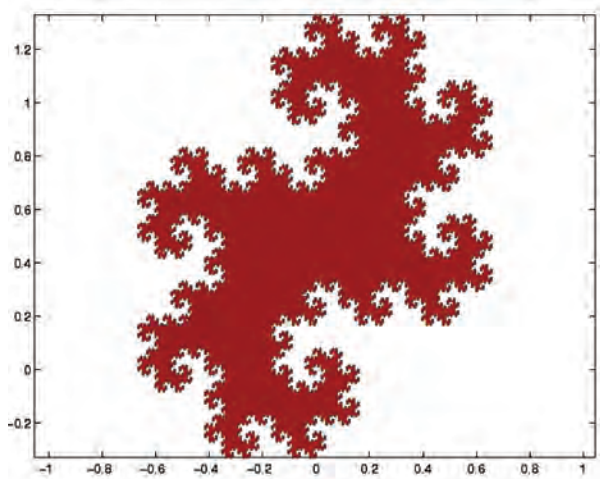


Figure 1: The Twin Dragon

$$\mathbf{T}(B,\mathcal{D})=\sum_{j=1}^{\infty}B^{-j}d_j,\ B=\begin{pmatrix}1&1\\-1&1\end{pmatrix}.$$

Here $d_j=(0,0)$ or $(1,0)$.

The Same Problem for $\mathbb{R}^2$

The time dilations to be considered are given by matrices A with integer entries such that $\det(A)=\pm 2$. In addition, we require all eigenvalues λ to satisfy $|\lambda|>1$. Fortunately, this class of dilations has received much attention in the wavelet literature, and, in particular, they have been completely classified by Lagarias and Wang [17]. These dilations fall into four distinct equivalence classes, where $A\sim A'$ if A is similar to A' by the action of a unimodular matrix U with integer entries. The question is the same as in the one-dimensional case in which $A=2$: Can we give necessary and sufficient conditions for a QMF function (with respect to A) to generate a scaling function $\varphi(t), t\in\mathbb{R}^2$? The problem was posed by Resnikoff and Wells in their book [19]. Here we sketch a solution, based on what has been described above. Complete details may be found in [13]. It will suffice to tell you how this solution emerges in a particular case, one that has been discussed by several authors: the "twin dragon" dilation. (See Gröchenig and Madych [11], Lagarias and Wang [16], Lawton and Resnikoff [17], Cohen and Daubechies [2].)

The *twin dragon* T is a set in the time domain $\mathbb{R}^2$ that is a self-affine tile generated by the matrix (matrices) and digit set

$$\pm A=\pm\begin{pmatrix}1&-1\\1&1\end{pmatrix}$$
$$\text{with } \mathcal{D}=\{d^0=(0,0),d^1=(1,0)\}.$$

These matrices, together with their adjoints $\pm B$, are often referred to as the *quincunx* matrices. The set T is defined in display (2) above. Gröchenig and Madych [11] and Lawton and Resnikoff [17] were the first to prove that T is a self-affine tile. Consequently, the indicator function of T may be viewed as a scaling function of Haar type. The strategy of their proof consists of transferring the problem to the frequency domain where they construct the appropriate QMF function $p(\xi_1,\xi_2)$ and the corresponding infinite product $|\hat{\varphi}(\xi_1,\xi_2)|^2$. The subtle part of the proof lies in showing that $|\hat{\varphi}(\xi_1,\xi_2)|^2$ satisfies $(\hat{b}),(\hat{c})$ of $(\hat{2})$. Clearly, $(\hat{a})$ is automatic, so the difficulty arises in verifying $(\hat{b})$ and $(\hat{c})$. We can view T (rather, $\chi_T(t)$) as an $\mathbb{R}^2$-valued random variable in the time domain that is a *sum of independent variables* of the form $A^{-j}d_j, j\geq 1, i=1,0$, as we pointed out in the section "Some Definitions" in which T was the unit interval in $\mathbb{R}^1$. The random variables d_j take values in the digit set $\mathcal{D}=\{d^0=(0,0),d^1=(1,0)\}$, with probability 1/2 each.

The characteristic function of the two-dimensional random variable $d=(d^0,d^1)$ (or Fourier transform of its probability distribution), written in the notation of the section "Some Definitions", is $(\sqrt{2})^{-1}\hat{c}(\xi)=[1+\exp(-2\pi i\langle d^1,\xi\rangle)]/2, \xi\in\mathbb{R}^2$, so that $p(\xi_1,\xi_2)=\cos^2(\pi\xi_1)$. In contrast to the one-dimensional case, in which $p(\xi)$ vanishes at the single point $\xi=1/2$, the two-dimensional $p(\xi_1,\xi_2)=0$ on the entire line $\xi_1=1/2$. This new element makes verifying $(\hat{b})$, in particular, more difficult if we choose to copy the one-dimensional arguments. The difficulty can be overcome, but this strategy gives no clue as to how to obtain a version of Theorem 1 for general QMF functions. Here is a short historical sketch of the previous arguments, based on a theorem due to A. Cohen [1]: *In order that a polynomial QMF generate a scaling function, it is necessary and sufficient that there exists a tile T (in the sense defined in the section "Some Definitions") consisting of a finite number of disjoint closed sets, one of which contains the origin in the interior, such that $p(B^{-j}\xi)\geq\delta>0, j\geq 1$ for all $\xi\in T$.* We shall refer to this theorem as the *C-tile condition.* In one dimension, $p(\xi)=\cos^2(\pi\xi)$, so we can take $T=\{\xi:|\xi|\leq 1/2\}$ and $\delta=1/4$ since $\cos^2(\pi\xi/2^{-j})\geq 1/4, j\geq 1$. In two dimensions, the inverse matrix $B^{-1}=\begin{pmatrix}1/2&-1/2\\1/2&1/2\end{pmatrix}$ sends the vector $[1/2,-1/2]'$ to $[1/2,0]'$. Consequently, $p(B^{-1}\xi)$ is not uniformly bounded away from 0 on the unit square. Gröchenig and Madych [11] overcome this obstacle by a clever distortion of the unit square to produce a C-tile in frequency domain $\mathbb{R}^2$. This stratagem leads them to a proof that the twin dragon matrix A defines a self-affine tile and a corresponding Haar-like scaling function in the time domain $\mathbb{R}^2$. Incidentally, this distorted square has achieved a degree of artistic recognition: it also appears in Cohen and Daubechies [2], Resnikoff and Wells [19], and Wojtaszczyk [23].

In the next section, we describe *another solution to the two-dimensional problem by direct reduction to the one-dimensional case*, thereby avoiding the difficulty just described. More to the point, we will see that Theorem 1, properly stated, makes no distinction between QMF functions $p(\xi)$ for $\xi \in \mathbb{R}^1$ or $\mathbb{R}^2$ and dilations 2 or A. This may be surprising since, in one dimension, the digit set contains only one linearly independent vector and this situation *persists* in two dimensions. In this case, linear independence is not the right idea. The digits are coset representatives, and it is the equality of the *indices* of the quotient groups $\mathbb{Z}/\, 2\mathbb{Z}$ and $\mathbb{Z}^2/\, A(\mathbb{Z}^2)$ that is the basis of the theorem.

Coding $\mathbb{R}^1$ and $\mathbb{R}^2$ into $2^{\mathbb{Z}}$: Case 1; $\mathbb{Z}^1$ vs. $\mathbb{Z}^2$

In the next two sections, we make a detour into the subject of radix representations for numbers, in both one and two dimensions. While this may seem to be a diversion from the main subject, it is really essential for the constructions that follow.

Here is the description of a mapping between $\mathbb{R}^1$ and $\mathbb{R}^2$ that will allow us to transport QMF functions from one space to the other. The mapping will be accomplished by sending each space into the space of binary sequences $2^{\mathbb{Z}} = \{\omega : \omega = (\dots \omega_{-1}, \omega_0, \omega_1, \dots)\}$. Having designated a zero-coordinate, we split the space into $2^{\mathbb{Z}-} = \{\xi^- = (\dots \omega_{-2}, \omega_{-1})\}$ and $2^{\mathbb{Z}+} = \{\xi^+ = (\omega_0, \omega_1, \dots)\}$. The integers $\mathbb{Z}$ are to be mapped into $2^{\mathbb{Z}+}$ by the following procedure. The nonnegative integers $\mathbb{Z}^+$ are given the usual binary expansion $0 \to (0, 0, \dots)$, and $0 < k \to (\omega_0, \omega_1, \dots, \omega_{n-2}, 1, 0, 0, \dots)$ where $2^{n-1} \le k < 2^n$. The negative integers are given the "two's complement representation". The name says it all; take $k < 0$, $2^n < |k| \le 2^{n+1}$. Let $(\omega_0, \omega_1, \dots, \omega_{n-1})$ be the sequence of binary coefficients for $k' = 2^{n+1} - |k|$, so $\omega_j = 0$, $j \ge n$. Then $k = -2^{n+1} + k'$, and we represent $k \to (\omega_0, \omega_1, \dots, \omega_{n-2}, 1, 0, 1, 1, \dots)$. Notice that $-1 \to (1, 1, \dots)$ and that when $2^n < |k| \le 2^{n+1}$, the coefficients $\omega_{n-1} = 1, \omega_n = 0, \omega_{n+l} \equiv 1, l \ge 1$.

Now check that if we take -2 as the base, with the same digits, we obtain a finite radix expansion for all $k \in \mathbb{Z}$, that is, one in which $d_j \equiv 0$ for all $j \ge j_0$. To rephrase this observation, there is no need to create the two's complement representation if the radix is -2. The proof of this is just an application of the division algorithm. More surprising is the fact that *the same argument can be used to show that the matrix $-B$ also yields a finite radix expansion for every $k \in \mathbb{Z}^2$*. The fundamental fact is that in both cases, the multiplication of the dilations 2 or B by -1 converts each to a radix for "canonical representations" of all integers $\mathbb{Z}$ (or $\mathbb{Z}^2$).

First, we construct a two's complement representation for $\mathbb{Z}^2$ using the adjoint twin dragon matrix B as radix. Given $k \in \mathbb{Z}^2$, apply the division algorithm to obtain $k = Bk_0 + d_0$ where d_0 is one of the digits $d_0 = (0, 0)$ or $d^1 = (1, 0)$. Can we get a B-radix expansion for such $k \in \mathbb{Z}^2$? As was the case for dilation by 2, the answer is "yes" if we admit two kinds of expansions, those that are "finite", $d_j \equiv d^0, j \ge n$, and those that are "infinite", that is, $d_{n-1} = d^1, d_n = d^0, d_{n+1} \equiv d_{n+2} \equiv \dots \equiv d^1$ for some $n \ge 1$. A Gaussian integer $k \in \mathbb{Z}^2$ with the latter one-sided infinite expansion is then uniquely associated with the corresponding negative integer $\tilde{k} \in \mathbb{Z}$, $2^n < |\tilde{k}| \le 2^{n+1}, \tilde{k} \to (\omega_0, \omega_1, \dots, \omega_{n-2}, 1, 0, 1, 1, \dots)$; those $k \in \mathbb{Z}^2$ with one-sided infinite expansions with zero entries after some finite index will correspond to nonnegative integers. One certainly should know which $k \in \mathbb{Z}^2$ corresponds to -1. It is the vector $k = (0, -1)$, the unique solution to $k = Bk + d^1$ and analogous to the equation $\tilde{k} = 2\tilde{k} + 1$, where $\tilde{k} = -1$. Let us assume that the norm $\|k\|$ is large. We apply the Euclidean division algorithm repeatedly to obtain a sequence of vectors $k, k_0, k_1, \dots$, such that the norms $\|k_j\|$, $j \ge 0$, are strictly decreasing. It is easy to verify that the norms will form a decreasing sequence provided $\|k_j\| > \sqrt{2} + 1$ since the norm $|B^{-1}| = \sqrt{2}$, and $|B^{-1}d^1| = 1$. Repeated divisions give a sequence of vectors that eventually converge to one of two fixed points. To verify this, proceed as follows:

There are twenty-one lattice points $k \in \mathbb{Z}^2$ that lie in the circle of radius $\sqrt{2} + 1$; twelve of them are attracted to $k = (0, -1)$ and the rest go to $(0, 0)$. By the way, a verification of this twenty-one count can be done without doing any division. To do it for B, draw the four-by-four square and exclude the four corners to obtain the twenty-one lattice points. In the following manner, construct two disjoint trees, one rooted at the origin, the other at $(0, -1)$, whose vertices are the twenty-one points. Beginning at the base point $(0, -1)$, perform a $-\pi/4$ rotation and dilation by $\sqrt{2}$: $(0, -1) \to (-1, -1) = B(0, -1)'$. From $(-1, -1)$ you have the option of performing another rotation or moving horizontally to the right one unit: the latter option leads us back to $(0, -1)$, so our advice is to rotate. Continue this procedure, rotating and moving to the right by one unit. Lateral moves by a unit must be preceded and followed by a rotation. Stop when you have reached twelve of the points inside the circle. The remaining points can be reached by starting at the origin and moving right to d^1, followed by a rotation, etc. The radix expansions are obtained by reversing the paths.

The same counting argument can be used to show that the matrix $-B$, like the one-dimensional case -2, yields a finite radix expansion for every $k \in \mathbb{Z}^2$. In this case, one only tracks paths from $(0, 0)$ to the boundary of the 4×4 square. This result is also a consequence of the theorem of Kataí and Szabó [15], which covers a much more general class of matrices and does not involve counting.

Also take note of the fact that everything said about B and $-B$ is also true for their adjoints, A and $-A$.

Coding $\mathbb{R}^1$ and $\mathbb{R}^2$ into $2^{\mathbb{Z}}$: Case 2; Unit Interval vs. Twin Dragon

The unit interval is mapped to $2^{\mathbb{Z}-}$ using the usual binary expansion $(\xi) \to \xi^-$. The space $2^{\mathbb{Z}-}$ is thought of as the infinite product of two-point groups under dyadic addition, so it comes equipped with a Haar-measure $d\xi^-$. The probability space $(2^{\mathbb{Z}-}, \mathcal{F}, d\xi^-)$, where $\mathcal{F}$ is the σ-algebra generated by the cylinder sets, is isomorphic to the Borel unit interval $(U, \mathcal{B}, d\xi)$. Therefore, the above map is to be considered as an invertible measure preserving transformation.

Now we are going to prove that the set $T = T(B, \mathcal{D})$ is a self-affine tile in the frequency domain. Recall that $T(B, \mathcal{D})$ is a tile *if* the sum of the indicator functions $\sum_{k\in\mathbb{Z}^n} \chi_T(\xi + k) = 1$ almost everywhere. This implies that T has Lebesgue measure one: if χ_U is the indicator of the unit cube in $\mathbb{R}^n$, then

$$1 = \int \chi_U(\xi)d\xi = \int \chi_U(\xi)\left(\sum \chi_T(\xi + k)\right)d\xi$$
$$= \int \left(\sum \chi_U(\xi - k)\right)\chi_T(\xi)d\xi = \int \chi_T(\xi)d\xi.$$

The following facts are well known to the enthusiasts of this subject. (See all the authors cited above.) We will summarize these facts for the sake of completeness. (i) Any self-affine set T is compact and has positive Lebesgue measure. The compactness is proved by standard arguments. We then check that $\bigcup_{k\in\mathbb{Z}^2} T + k$ is invariant under all dilations $B^n, n \in \mathbb{Z}$, and, therefore, for any fixed ξ we can approximate $B^n\xi, n > 0$ by some $\xi' \in \bigcup_{k\in Z^2} T + k$: we have $|\xi' - B^n\xi| \le c$ and $|B^{-n}\xi' - \xi| \le O(2^{-n/2})$. Thus, the above union is dense in $\mathbb{R}^2$; the Baire category theorem implies that T has positive measure. (ii) The measure $m(T \cap T + d) = 0$ since $m(T \cup T + d^1) = |\det(B)|m(T) = 2m(T)$. The same argument implies that the sets $T, T + d^1$, and $T + d^j + Ad^1, j = 0, 1$, are essentially disjoint. If every $k \in \mathbb{Z}^2$ had a finite radix expansion with respect to B, this argument would prove that all the sets $k + T, k \in \mathbb{Z}^2$, are essentially disjoint, which would imply that $T(B, \mathcal{D})$ is a self-affine tile. However, we saw that only about half of the Gaussian integers have finite B-radix representations. But suppose we had started with the dilation $-B$: in this case, we saw that every $k \in \mathbb{Z}^2$ has a finite radix representation. By the above remark, $-T = T(-B, \mathcal{D})$ is a self-affine tile. Now we must make the transition from $-T$ to T. Here again we use probability, and the first interpretation of $\varphi(t)$ from the section "Some Definitions" to the effect that the indicator function of any tile may be considered as an infinite sum of independent random variables. In particular, the indicator function of $-T$ is the sum of the sequence of independent random variables $(-B)^{-j}d_j, j \ge 1$. Now let us create two sequences $(B^{-j}d_j)'$and$((-B)^{-j}d_j)', j \ge 1$, that are independent of each other and independent of the original (unprimed) sequences. Now consider the two symmetrized sequences $(B^{-j}d_j) - (B^{-j}d_j)'$ and $((-B)^{-j}d_j) - ((-B)^{-j}d_j)'$. These two sequences are identically distributed. Consequently, their characteristic functions are equal. The characteristic functions of the symmetrized variables are exactly the functions $p(B^{-j}\xi)$and $p((-B)^{-j}\xi)$, and these two functions are identical for all $j \ge 0$. Consequently, the infinite products $|\hat{\varphi}_+(\xi)|^2 \equiv |\hat{\varphi}_-(\xi)|^2$ (see display (4) in the section "What Is a Scaling Function?") where $|\hat{\varphi}_\pm(\xi)|^2$ correspond to B and $-B$, respectively. Exactly the same arguments apply to the adjoint matrices A and $-A$. The fact that $-B$ is a self-affine tile means that $(\hat{a})$ and $(\hat{b})$ are satisfied for the matrix $-A$, and, therefore, also for A. But $(\hat{a})$, $(\hat{b})$ for A imply that B is a self-affine tile. Consequently, $T(B, \mathcal{D})$ has Lebesgue measure one.

The important conclusion is that both the Lebesgue unit interval $(T(2, \mathcal{D}), d\xi)$ and the twin dragon pair $(T(B, \mathcal{D}), d\xi)$ are measure-isomorphic to $(2^{\mathbb{Z}-}, d\xi^-)$, and we have the correspondence $[T(2, \mathcal{D}), \mathbb{Z}] \longleftrightarrow [T(B, \mathcal{D}), \mathbb{Z}^2]$ through the intermediate space $2^{\mathbb{Z}} = (2^{\mathbb{Z}-}; 2^{\mathbb{Z}+})$. More important for us is the fact that any QMF $p(\xi)$ with dilation 2 or B generates a QMF on $2^{\mathbb{Z}}$ where the dilation is replaced by the left-shift θ, a two-one transformation defined as $\theta(\ldots, \omega_{-2}, \omega_{-1}) = (\ldots, \omega_{-3}, \omega_{-2})$. The right-shift Θ^{-1} is one-to-one on the two-sided sequence space $2^{\mathbb{Z}}$. When it is followed by the projection onto $2^{\mathbb{Z}-}$, the composition, also denoted by Θ^{-1}, has two branches, just like 2^{-1} and B^{-1}. Now it is easy to interpret Theorem 1 in these terms. The QMF function becomes a Markov transition operator with Θ^{-1} acting as the shift on the path space $2^{\mathbb{Z}}$. That is, for each initial state $\xi^- \in 2^{\mathbb{Z}-}$, the random traveler can proceed to $(\xi^-, 0)$ with probability $p(\xi^-, 0)$ or $(\xi^-, 1)$ with probability $p(\xi^-, 1)$. (As we pointed out in the section "Producing the Scaling Function", the function $p(\xi)$ defines a transition operator for a family of processes with the two-point state space $0, 1$, but the transitions are definitely not Markovian on this state space.)

The periodicity of $p(\xi)$ translates to a condition on $p(\xi^-; \xi^+)$, expressed in these terms: $p(\xi^-; \xi^+) = p(\xi^-)$ and $p(\Theta^{-1}(\xi^-; \xi^+) = p(\xi^-, \omega_0)$. The infinite product $|\hat{\varphi}(\xi^-; \bullet)|^2$ may now be considered as a probability on the path space $2^{\mathbb{Z}}$ for each base point ξ^-. The base points have a natural measure $d\xi^-$. If we have a QMF function $p(\xi^-)$ defined on $(2^{Z-}, d\xi^-)$, the shift serves as a universal model for the various dilations with $\det B = \pm 2$. A QMF function on $2^{\mathbb{Z}-}$ generates a scaling function on both $\mathbb{R}^1$ and $\mathbb{R}^2$, depending on which dilation we choose, provided we can interpret Theorem 1 on the binary sequence space $2^{\mathbb{Z}}$. Moreover, when $2^{\mathbb{Z}}$ is given the product topology, certain QMF functions that are discontinuous on $\mathbb{R}$ or $\mathbb{R}^2$ become continuous. An important example is the Shannon filter $p(\xi)$, the indicator function of the set $[0, 1/4) \cup (3/4, 1]$. (See Hernández and Weiss, [14], page 62.) The restatement of Theorem 1 on the binary sequence space goes as follows:

Theorem 2. *A QMF function $p(\xi)$ generates a scaling function if and only if for $(d\xi^-)$ almost every ξ^-, the paths satisfy $\lim_{n\to\infty}[\Theta^{-n}(\xi^-, \xi^+)]^- = (\ldots, 0, 0)$ or $(\ldots, 1, 1)$ almost everywhere $|\hat{\varphi}(\xi^-; \bullet)|^2$. Moreover, there should exist sets of initial points ξ^- of positive $(d\xi^-)$ measure such that the $(|\hat{\varphi}(\xi^-; \bullet)|^2)$ measure is positive on sequences $\xi^+ = (\omega_0, \omega_1, \ldots)$ such that $\lim_{n\to\infty} \omega_n = 0$ and such that $\lim_{n\to\infty} \omega_n = 1$. If $p(\xi^-)$ has a finite number of zeros, then $p(\xi^-)$ generates a scaling function if and only if from almost every $(d\xi^-)$ initial point (ξ^-), there are two sets of paths, each of positive $(|\hat{\varphi}(\xi^-; \bullet)|^2)$ measure, corresponding to the two limiting sequences.*

Invariant Sets for QMF Functions

Can the probability viewpoint tell us how to recognize which QMF functions generate scaling functions? This question already arose in the discussion of Daubechies' QMF polynomials. As we pointed out above, this question was answered, in part, for certain QMF functions by A. Cohen [1]: if there exists a C-tile such that $p(\xi/2^j) \geq \delta > 0$, $j \geq 1$ for all $\xi \in C$, then $p(\xi)$ generates a scaling function. So, any continuous $p(\xi)$ that vanishes only at $\xi = 1/2$ must generate a scaling function since the interval $\{\xi : |\xi| \leq 1/2\}$ will serve as a C-tile. This covers Daubechies' polynomials as well as the one-dimensional Haar case. (Thus the "big trouble" alluded to earlier is avoided.) The *converse* is also true: if a continuous $p(\xi)$ is also smooth and generates a scaling function, then $p(\xi)$ can be used to create a C-tile. However, there are continuous QMF functions that are smooth except at a few points, for which no C-tile exists, yet that generate scaling functions. In fact, it was the investigation of some contrary claims in the literature that led us to construct a variety of bizarre counterexamples of "good" QMF functions, ones that generate scaling functions, for which no C-tile exists. Here is where the intuition from probability carries the day.

Let us ask the following question, phrased in terms of the process on state space $2^{\mathbb{Z}-}$ generated by $p(\xi)$ and the right shift Θ^{-1}. From the standpoint of a random traveler, starting from ξ^-, directed by $p(\Theta^{-1}(\xi^-, \xi^+))$, what can happen? If the conditions of Theorem 1 do not hold, what goes wrong? Well, the paths from the initial point ξ^- must go somewhere, if they don't go to the 0-sequence $\xi^-(0)$ or the 1-sequence $\xi^-(1)$. The set of limit points for paths from a fixed ξ^- is a closed θ-invariant set: so there is the possibility that some get kidnapped into some more exotic closed invariant subset. This is especially true if the initial point is itself a member of such a finite closed invariant subset of $2^{\mathbb{Z}-}$ and $p(\xi) \equiv 1$ on this set. In that case, the process will remain in the closed set with probability one. On the other hand, for every point at which $p(\xi) = 1$, there is another point at which $p(\xi) = 0$. So, for example, Daubechies' QMF polynomials that only vanish at $\xi = 1/2$ provide no opportunity for the random traveler to wind up in some foreign closed invariant set other than $\xi^-(0)$or $\xi^-(1)$.

We know that, in general, a closed invariant subset, at a positive distance from the points $\xi^-(0)$and $\xi^-(1)$, must have product measure $(d\xi^-)$ zero since the shift is ergodic with respect to this measure. Such sets are, therefore, either finite or perfect and nowhere dense.

Here is the simplest example of a bad invariant set that will be visited by paths created by the QMF function $p(\xi) = \cos^2(3\pi\xi)$. The invariant set consists of two points, $1/3$ and $2/3$, where $p(1/3) = p(2/3) = 1$. The binary sequence representations are $\xi^-(1/3) = (\ldots 1010)$ and $\xi^-(2/3) = (\ldots 0101)$. The simplest pseudo-scaling function obtained from this $p(\xi)$ is the "stretched Haar scaling function", that is, the indicator function of the interval $(0 \leq t \leq 3)$. It turns out that for almost every ξ^-, some of the paths from ξ^- go to $\xi^-(0)$, some to $\xi^-(1)$, and with positive probability, some paths get kidnapped: they converge to $\{\xi^-(1/3), \xi^-(2/3)\}$. In fact, this example is typical in the sense that, if $p(\xi^-) = 1$ on a finite set $\{\theta^j(\xi^-); 0 \leq j \leq n\}$ (that is, ξ^- has a periodic binary expansion), then from every initial point ξ^- in the complement of this finite, shift-invariant set, there will be a set of paths of positive probability that converge to the set *if $p(\xi)$ is smooth at every point*. In general, a necessary and sufficient condition for a polynomial QMF function to generate a scaling function is the requirement that it does not take the value one on a finite shift-invariant set. This is one version of the theorem due to Albert Cohen [1]; this necessary and sufficient condition is equivalent to the C-tile condition mentioned above.

It came as some surprise to find that there was a partial failure of Cohen's theorem when the function $p(\xi)$ was not assumed to be a trigonometric polynomial. In fact, if we start with $p(\xi) = \cos^2(3\pi\xi)$ but modify the values of this function on neighborhoods of $1/3$ and $2/3$ so that the modified function approaches the value 1 along a sharp cusp, the modified function will meet the requirements of Theorem 1 to generate a scaling function. That is, the new function will still take the value 1 on the two-point invariant set, but the $\varphi(t)$ that is generated will be orthogonal to its integer translates. The intuition is as follows: the paths from almost every ξ^- are attracted to the invariant set, as before, but they never accelerate fast enough to converge, that is, to be absorbed. In fact, the typical path will approach the invariant set, but with probability one, fall away from the set finitely often, then succumb to the ultimate attraction of either $\xi^-(0)$ or $\xi^-(1)$. These invariant sets may be called attractors for the paths from initial points: if the initial point is in the set, all paths from this point remain in the set. For initial points ξ^- outside the set, these attractors come in two varieties: accessible and inaccessible. The former are "fatal attractors", toward which a portion of the paths from ξ^- converge. The latter attract paths but with probability one, starting from ξ^- in the complement, the path leaves any neighborhood of such an invariant set. If we assume, as we do, that $\xi^-(0)$and $\xi^-(1)$ are the only fatal attractors, then all paths eventually converge to these points. How bad can nonfatal (inaccessible) attractors be? Given any shift-invariant set that lies at a strictly positive distance from $\xi^-(0)$ and $\xi^-(1)$, can we find a continuous QMF function for which this set is an inaccessible attractor? We don't know the answer to this general question; however, it is possible to construct uncountable inaccessible invariant sets for a class of continuous QMF functions that generate scaling functions. The details of this construction are too involved to relate here, but they can be found in [12], together with a more rigorous account of the phenomena described in this section.

Some More History

The following remarks about the history of the ideas sketched in this article are intended as a guide to further reading.

The Problem of Points

Many authors date the beginning of computational probability to the correspondence between Pascal and Fermat concerning the problem of points. The general version goes as follows: Alice and Bob are playing an independent sequence of zero-sum games, as stated above. The winner of each game is awarded one point. The eventual winner is the player who first wins N points. Now suppose that the game is interrupted before an eventual winner is declared, and at that point, Alice needs n points to win, whereas Bob needs m points to win. The winner would have received a monetary prize of a fixed amount had the game finished. How should this prize be divided, given the incomplete results? The solution, arrived at by both Pascal and Fermat, is the computation of the probability that Alice obtains her points before Bob gets his. The particular case discussed in this article assumes that $n = m = N$.

A reference for the mathematics of the problem of points in the form used here is Ross ([20], page 95), and for a more detailed account of the history of the Pascal-Fermat correspondence, see Devlin [8]. The concept of "an independent sequence of Bernoulli trials, with probabilities $\alpha, 1-\alpha$" was certainly not in the arsenal of Pascal and Fermat, but they obtained the right answer when $\alpha = 1/2$. More important, the idea of using mathematics to make a prediction of the likelihood of a complicated future event was born in their dialogues.

Quadrature Mirror Filters

The concept of a QMF function comes from the electrical engineering literature. Given a function $f(t)$ whose Fourier transform $\hat{f}(\xi)$ is supported in a finite interval $\hat{V}_n = \{\xi{:}|\xi| \le 2^n 2\}$, the problem is to find "filters", $\hat{c}_0(\xi)$, $\hat{c}_1(\xi)$, so that $c_0(\xi)\hat{f}(\xi)$ has low-frequency support $|\xi| \le 2^{n-1}$ and $\hat{c}_1(\xi)\hat{f}(\xi)$ has high-frequency support in $2^{n-1} < |\xi| \le 2^n$. It is enough to consider the case $n = 0$ and to produce two one-periodic functions $\hat{c}_0(\xi), \hat{c}_1(\xi)$. The most obvious example is the Shannon filters: $\hat{c}_0(\xi) = \chi(\xi; |\xi| \le 1/4)$, and $\hat{c}_1(\xi) = 1 - \hat{c}_0(\xi)$. These functions are mirror symmetric around the quadrature phase $1/4 : \hat{c}_0(1/4+\xi) = \hat{c}_1(1/4-\xi)$, so the pair $\hat{c}_0(\xi), \hat{c}_1(\xi)$ are called quadrature mirror filters. However, the coefficients in the Fourier series representing $\hat{c}_0(\xi)$ decay too slowly to allow it to be of practical use in data analysis. But the decomposition of $\hat{f}(\xi)$ into dyadic frequency bands is just one example of multiresolution analysis. Other examples give rise to pairs of filters $c_0(\xi), c_1(\xi)$ that decompose $\hat{f}(\xi) \in \hat{V}_1$ into orthogonal pieces, $\hat{f}_0(\xi) \in \hat{V}_0$ and $\hat{f}_1(\xi) \in \hat{V}_1$. To describe this decomposition, it is enough to consider the functions that generate $V_1 : V_1 = V_0 \oplus W_0$, where W_0 is the closure of all linear combinations of a single function $\psi : \psi \perp \varphi$. Since both functions belong to V_1, we have $\hat{\varphi}(\xi) = \hat{c}_0(\xi/2)\hat{\varphi}(\xi/2)$ and $\hat{\psi}(\xi) = \hat{c}_1(\xi/2)\hat{\varphi}(\xi/2)$. By properties $(\hat{a}\ )$and $(\hat{b})$(see $\hat{2}$ above) and the requirement that $\psi \perp \varphi$, we can show that $\hat{c}_1(\xi) = \exp(-2\pi i\xi)\overline{\hat{c}_0(\xi+1/2)}$. These two filters are not, strictly speaking, quadrature mirror filters; however, $|\hat{c}_0(1/4+\xi)|^2 = |\hat{c}_1(1/4-\xi)|^2$. This follows from an assumption that $\hat{c}_0(\xi)$ has real coefficients, which, in turn, implies that $|\hat{c}_0(1/2+\xi)|^2 = |\hat{c}_0(1/2-\xi)|^2$ for $0 \le \xi < 1/2$. Smith and Barnwell [22] introduced filters $\hat{c}_0(\xi), \hat{c}_1(\xi)$ satisfying these conditions for subband frequency filtering and called them "conjugate quadrature filters". Daubechies ([7], page 163) reports that the CQF label didn't stick, and these filters are called QMF in most of the literature. History seems to have compensated Smith and Barnwell in some measure:

the QMF condition (1) is often referred to as the Smith-Barnwell equation.

The Markov Process with Transition Function $p(\xi)$

As we mentioned in the Introduction, the type of historical Markov process described in this paper arises in connection with the Ising model for $\mathbb{Z}$-lattice systems. In this connection, the function $p(\xi)$ is viewed as the kernel of a "transfer operator". The basic reference for this part of statistical mechanics is Ruelle ([21], Chapter 5).

Other Sources

There are a few references that have not appeared in the text that contributed to the viewpoint expressed in this article: Conze and Raugi [4] view QMF functions as Markov operators on the unit interval and interpret Cohen's theorem in a probabilistic context. The article by Cohen and Conze [3] is another example of the application of ergodic theory to a problem in time-scale analysis. The author was also influenced by the 2005 Ph.D. thesis of E. Curry [5]. In [10], the discussion of radix representations was guided by the fundamental paper by Kataí and Szabó [15]; in particular, their theorem gives necessary and sufficient conditions for radix representations from a class of matrices that include $-B$. Each one of these references deserves study.

Acknowledgments

First of all, I want to acknowledge the contributions of my collaborators, Pavel Hitczenko and Vladimir Dobrić, to [9] and Adam Jonsson to [13]. Second, I would like to extend my warmest thanks to the editorial staff of the *Notices* and the referees of this article for their attention to detail that contributed immensely to the final version of this article. Especially, I want to recognize Mark Pinsky and Hvorje Sikić for their sharp eyes for typos and the many improvements they suggested.

References

[1] A. Cohen, Ondelettes, Analyses multirésolution et filtres miroir en quadrature, *Inst. Henri Poincaré, Anal. Nonlinéaire* **7** (1990), 439–459.

[2] A. Cohen and I. Daubechies, Nonseparable bidimensional wavelet bases, *Revista Mat. Iberoamericana* **7** (1993), 51–137.

[3] J. P. Conze and A. Cohen, Régularité des bases d'ondelettes et mesures ergodiques, *Rev. Mat. Iberoamericana* **8**, no. 3 (1992), 351–365.

[4] J. P. Conze and A. Raugi, Fonctions harmoniques pour un opérateur de transition et applications, *Bull. Soc. Math. France* **118** (1990), 273–310.

[5] E. Curry, *Characterizations of low-pass filters for multivariable wavelets and some related questions*, Ph.D. thesis (2005), Rutgers University, New Brunswick, NJ, 08854.

[6] I. Daubechies, Orthonormal bases of compactly supported wavelets, *Comm. Pure Appl. Math.* **41** (1988), 909–996.

[7] ———, *Ten Lectures on Wavelets*, CBMS-NSF Regional Conference Series in Applied Math., SIAM, Philadelphia, PA, **61** (1992).

[8] K. Devlin, *The Unfinished Game*, Basic Books, New York, NY, 2008.

[9] V. Dobrić, R. F. Gundy, and P. Hitczenko, Characterizations of orthonormal scaling functions: A probabilistic approach, *J. Geometric Analysis* **10**, no. 3 (2000), 413–420.

[10] W. Doeblin and R. Fortêt, Sur les châines à liaisons complètes, *Bull. Soc. Math. France* **65** (1937), 132–148.

[11] K. Gröchenig and W. R. Madych, Multiresolution analyses, Haar bases, and self-similar tilings of $\mathbb{R}^n$, *IEEE Trans. Inform. Theory* **38**, no. 2 (1992), 556–568.

[12] R. F. Gundy, Probability, ergodic theory, and low-pass filters, in Topics in Harmonic Analysis and Ergodic Theory, *Contemporary Math.*, Amer. Math. Soc. **444** (2007), 373–413.

[13] R. F. Gundy and A. L. Jonsson, Scaling functions on $\mathbb{R}^2$ for dilations of determinant ± 2, *Applied and Computational Harmonic Analysis* **29**(1) (2010), 49–62.

[14] E. Hernández and G. Weiss, *A First Course on Wavelets*, CRC Press, Boca Raton, New York, 1966.

[15] I. Kataí and J. Szabó, Canonical number systems for complex integers, *Acta Sci. Math. (Szeged)* **37** (1975), 255–260.

[16] J. C. Lagarias and Y. Wang, Haar-type orthonormal wavelet bases in $\mathbb{R}^2$, *J. Fourier Analysis* **2** (1995), 1–14.

[17] W. Lawton and H. L. Resnikoff, *Multidimensional wavelet bases*, preprint of AWARE, Inc., 1991.

[18] W. R. Madych, Some elementary properties of multiresolution analyses of $L^2(\mathbb{R}^n)$, in *Wavelets: A Tutorial in Theory and Applications* (C. K. Chui, ed.) Academic Press, 1993, 259–294.

[19] H. L. Resnikoff and R. O. Wells Jr., *Wavelet Analysis: The Scalable Structure of Information*, Springer-Verlag, New York, Berlin, Heidelberg, 1998.

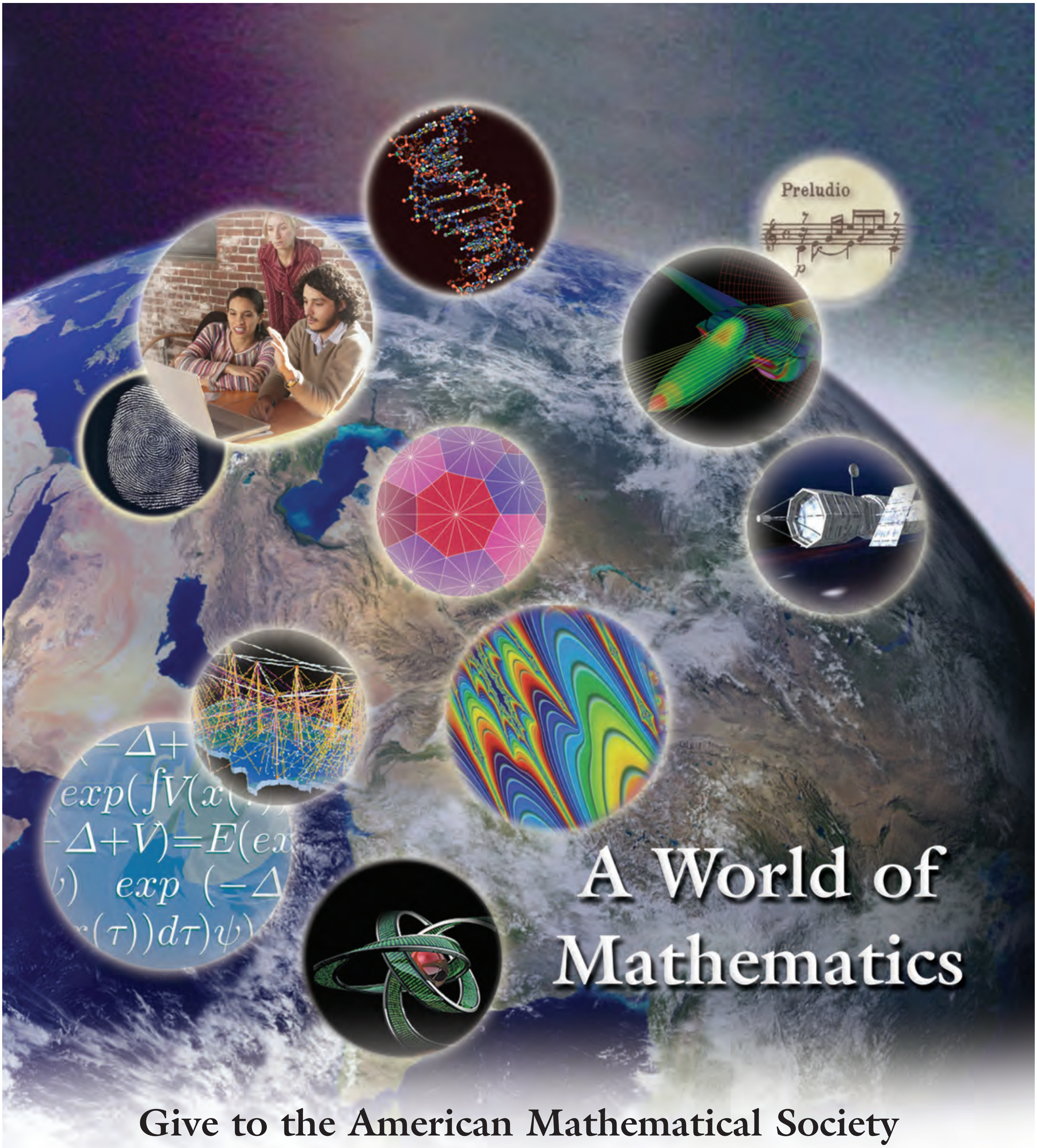
[20] S. Ross, *A First Course in Probability*, 7th ed., Pearson Prentice Hall, Upper Saddle River, N.J., 2006.

[21] D. Ruelle, *Thermodynamic Formalism*, 2nd ed., Cambridge University Press, Cambridge, England, 2004.

[22] M. J. T. Smith and T. P. Barnwell III, Exact reconstruction techniques for tree structured subband coders, *IEEE Trans. Acoust. Signal Speech Process.*, **34** (1986), 434–441.

[23] P. Wojtaszczyk, *A Mathematical Introduction to Wavelets*, London Math. Soc. Student Texts, **37**, Cambridge University Press, Cambridge, UK, New York, Melbourne, Madrid, 1997.

[24] The Wutam Consortium, Basic properties of wavelets, *J. Fourier Anal. Appl.* **4** (1998), 575–594.



Images courtesy of Paul Thiessen, the MITRE Corporation, NASA Ames Data Analysis Group, the National Cable Television Association and TECH CORPS.

Reminiscences of Grothendieck and His School

Luc Illusie, with Alexander Beilinson, Spencer Bloch, Vladimir Drinfeld, et al.

Luc Illusie, an emeritus professor at the Université Paris-Sud, was a student of Alexander Grothendieck. On the afternoon of Tuesday, January 30, 2007, Illusie met with University of Chicago mathematicians Alexander Beilinson, Spencer Bloch, and Vladimir Drinfeld, as well as a few other guests, at Beilinson's home in Chicago. Illusie chatted by the fireside, recalling memories of his days with Grothendieck. What follows is a corrected and edited version of a transcript prepared by Thanos Papaïoannou, Keerthi Madapusi Sampath, and Vadim Vologodsky.

At the IHÉS

Illusie: I began attending Grothendieck's seminars at the IHÉS [Institut des Hautes Études Scientifiques] in 1964 for the first part of SGA 5 (1964–1965).[1] The second part was in 1965–1966. The seminar was on Tuesdays. It started at 2:15 and lasted one hour and a half. After that we had tea. Most of the talks were given by Grothendieck. Usually, he had pre-notes prepared over the summer or before, and he would give them to the potential speakers. Among his many students he distributed the exposés, and also he asked his students to write down notes. The first time I saw him I was scared. It was in 1964. I had been introduced to him through Cartan, who said, "For what you're doing, you should meet Grothendieck." I was indeed looking for an Atiyah-Singer index formula in a relative situation. A relative situation is of course in Grothendieck's style, so Cartan immediately saw the point. I was doing something with Hilbert bundles, complexes of Hilbert bundles with finite cohomology, and he said, "It reminds me of something done by Grothendieck, you should discuss it with him." I was introduced to him by the Chinese mathematician Shih Weishu. He was in Princeton at the time of the Cartan-Schwartz seminar on the Atiyah-Singer formula; there had been a parallel seminar, directed by Palais. We had worked together a little bit on some characteristic classes. And then he visited the IHÉS. He was friendly with Grothendieck and proposed to introduce me.

So, one day at two o'clock I went to meet Grothendieck at the IHÉS, at his office, which is now, I think, one of the offices of the secretaries. The meeting was in the sitting room which was adjacent to it. I tried to explain what I was doing. Then Grothendieck abruptly showed me some naïve commutative diagram and said, "It's not leading anywhere. Let me explain to you some ideas I have." Then he made a long speech about finiteness conditions in derived categories. I didn't know anything about derived categories! "It's not complexes of Hilbert bundles you should consider. Instead, you should work with ringed spaces and pseudocoherent complexes of finite tor-dimension." …(laughter)…It looked very complicated. But what he explained to me then eventually proved useful in defining what I wanted. I took notes but couldn't understand much.

I knew no algebraic geometry at the time. Yet he said, "In the fall I am starting a seminar,

Luc Illusie is professor emeritus of mathematics at the Université Paris-Sud. His email address is luc.illusie@math.u-psud.fr*. Alexander Beilinson is the David and Mary Winton Green University Professor at the University of Chicago. His email address is* sasha@math.uchicago.edu*. Spencer Bloch is R. M. Hutchins Distinguished Service Professor Emeritus at the University of Chicago. His email address is* bloch@math.uchicago.edu*. Vladimir Drinfeld is professor of mathematics at the University of Chicago. His email address is* drinfeld@math.uchicago.edu*.*

[1] *Cohomologie ℓ-adique et fonctions L, Séminaire de Géométrie Algébrique du Bois-Marie 1965/66, dirigé par A. Grothendieck,* Lecture Notes in Math. **589**, *Springer-Verlag, 1977.*

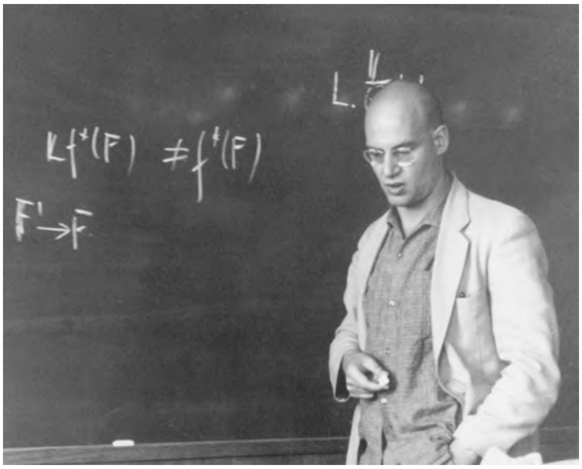


Photo courtesy of Friedrich Hirzebruch.

Alexander Grothendieck around 1965.

a continuation of SGA 4”,[2] which was not called “SGA 4”, it was “SGAA”, the “Séminaire de géométrie algébrique avec Artin”. He said, “It will be on local duality. Next year we will reach ℓ-adic cohomology, trace formulas, L-functions.” I said, “Well, I will attend, but I don’t know if I’ll be able to follow.” He said, “But in fact I want you to write down the notes of the first exposé.” However, he gave me no pre-notes. I went to the first talk.

He spoke with great energy at the board but taking care to recall all the necessary material. He was very precise. The presentation was so neat that even I, who knew nothing of the topic, could understand the formal structure. It was going fast but so clearly that I could take notes. He started by briefly recalling global duality, the formalism of $f^!$ and $f_!$. By that time, I had learned a little bit of the language of derived categories, so I was not so afraid of distinguished triangles and things like that. Then he moved to dualizing complexes, which was much harder. After a month, I wrote down notes. I was very anxious when I gave them to him. They were about fifty pages. For Grothendieck it was a reasonable length. Once, Houzel, who had been my teaching assistant at the École Normale, at the end of the seminar said to Grothendieck, “I have written something I’d like to give you.” It was something on analytic geometry, about ten pages. Grothendieck said, “When you have written fifty pages, then come back” …(laughter)…Anyway, the length was reasonable, but I was still very anxious. One reason is that, meanwhile, I had written some notes about my idea on complexes of Hilbert bundles. I had a final version which seemed to me to be good. Grothendieck said, “Maybe I’ll have a look at that.” So I gave them to him. Not too long afterward, Grothendieck came to me and said, “I have a few comments on your text. Could you please come to my place, I will explain them to you.”

At Grothendieck’s Place

When I met him, to my surprise, my text was blackened with penciled annotations. I thought it was in final form, but everything had to be changed. In fact, he was right all the time, even for questions of French language. He proposed modifications in the style, the organization, everything. So, for my exposé on local duality, I was very afraid. However, a month later or so, he said, “I’ve read your notes. They are okay, but I have a few comments, so could you please come to my place again?” That was the beginning of a series of visits to his place. At the time he lived at Bures-sur-Yvette, rue de Moulon, in a little white pavilion, with a ground floor and one story. His office there was austere and cold in the winter. He had a portrait of his father in pencil, and also on the table there was the mortuary mask of his mother. Behind his desk he had filing cabinets. When he wanted some document, he would just turn back and find it in no time. He was well organized. We sat together and discussed his remarks on my redactions. We started at two and worked until maybe four o’clock, then he said, “Maybe we could take a break.” Sometimes we took a walk, sometimes we had tea. After that we came back and worked again. Then we had dinner around seven, with his wife, his daughter, and his two sons. The dinner didn’t last long. Afterward we met again in his office, and he liked to explain some maths to me. I remember, one day, he gave me a course on the theory of the fundamental group from several viewpoints, the topological approach, the scheme-theoretic one (with the enlarged fundamental group of SGA 3), the topos-theoretic one. I tried to catch up, but it was hard.

He was improvising, in his fast and elegant handwriting. He said that he couldn’t think without writing. I, myself, would find it more convenient first to close my eyes and think, or maybe just lie down, but he could not think this way, he had to take a sheet of paper, and he started writing. He wrote $X \to S$, passing the pen several times on it, you see, until the characters and arrow became very thick. He somehow enjoyed the sight of these objects. We usually finished at half past eleven, then he walked with me to the station, and I took the last train back to Paris. All afternoons at his place were like that.

Walks in the Woods

Among the people coming to the seminar, I remember Berthelot, Cartier, Chevalley, Demazure, Dieudonné, Giraud, Jouanolou, Néron, Poitou, Raynaud and his wife Michèle, Samuel, Serre, Verdier. Of course we also had foreign visitors, some for

[2]*Théorie des topos et cohomologie étale des schémas, Séminaire de géométrie algébrique du Bois-Marie 1963-64, dirigé par M. Artin, A. Grothendieck, J.-L. Verdier,* Lecture Notes in Math. **269***,* **270***,* **305***, Springer-Verlag, 1972, 1973.*

long periods (Tits; Deligne, who attended the seminars since 1965; Tate; and later Kleiman, Katz, Quillen…). Then we had tea at four in the drawing room of the IHÉS. That was a place to meet and discuss. Another one was the lunch at the IHÉS, to which I decided to come after some time. There you could find Grothendieck, Serre, Tate discussing motives and other topics that passed well over my head. SGA 6,[3] the seminar on Riemann-Roch, started in 1966. A little before, Grothendieck said to Berthelot and me, "You should give the talks." He handed me some pre-notes on finiteness conditions in derived categories and on K-groups. So Berthelot and I gave several talks, and we wrote down notes. In this time, we usually met for lunch, and after lunch—that was very nice—Grothendieck would take us for a walk in the woods of the IHÉS and just casually explain to us what he had been thinking about, what he'd been reading. I remember, once he said, "I'm reading Manin's paper on formal groups[4] and I think I understand what he's doing. I think one should introduce the notion of slope, and Newton polygon," then he explained to us the idea that the Newton polygon should rise under specialization, and for the first time he envisioned the notion of crystal. Then at the same time, maybe, or a little later, he wrote his famous letter to Tate: "… Un cristal possède deux propriétés caractéristiques : la rigidité, et la faculté de croître, dans un voisinage approprié. Il y a des cristaux de toute espèce de substance: des cristaux de soude, de soufre, de modules, d'anneaux, de schémas relatifs, etc." ("A crystal possesses two characteristic properties: rigidity, and the ability to grow in an appropriate neighborhood. There are crystals of all kinds of substances: sodium, sulfur, modules, rings, relative schemes, etc.")

Künneth

Bloch: What about you? What about your part? You must have been thinking about your thesis.

Illusie: It was not working so well, I must say. Grothendieck had proposed to me some problems, of course. He said, "The second part of EGA III[5] is really lousy, there are a dozen spectral sequences abutting to the cohomology of a fiber product. It's a mess, so, please, clean this up by introducing derived categories, write the Künneth formula in the general framework of derived categories." I thought about that and was fairly rapidly stuck. Of course, I could write some formula, but only in the tor-independent situation. I'm not sure that there is even now in the literature a nice general formula in the non-tor-independent situation.[6] For this you need homotopical algebra.

You have two rings, and you have to take the derived tensor product of the rings; what you get is an object in the derived category of simplicial rings, or you can view it as a differential graded algebra in the characteristic 0 case, but the material was not available at the time. In the tor-independent case, the usual tensor product is good. In the general one I was stuck.

SGA 6

I was therefore happy to work with Grothendieck and Berthelot on SGA 6. At the time you didn't have to finish your thesis in three years. The completion of a thèse d'État could take seven, eight years. So the pressure was not so great. The seminar, SGA 6, went well, we eventually proved a Riemann-Roch theorem in a quite general context, and Berthelot and I were quite happy. I remember that we tried to imitate Grothendieck's style. When Grothendieck handed me his notes on the finiteness conditions in derived categories, I said, "This is only over a point. We should do that in a fibered category over some topos…" (laughter). It was a little naïve, but, anyway, it proved to be the right generalization.

Drinfeld: What is written in the final version of SGA 6? Is it in this generality?

Illusie: Yes, of course.

Drinfeld: So, it was your suggestion, not Grothendieck's.

Illusie: Yes.

Drinfeld: Did he approve it?

Illusie: Of course, he liked it. As for Berthelot, he brought original contributions to the K-theory part. Grothendieck had calculated the K_0 of a projective bundle. We did not call it "K_0" at the time; there were a $K^\bullet$ made with vector bundles and a $K_\bullet$ made with coherent sheaves, which are now denoted K_0 and K'_0. Grothendieck had proved that the K_0 of a projective bundle P over X is generated over $K_0(X)$ by the class of $\mathcal{O}_P(1)$. But he was not happy with that. He said, "Sometimes you're not in a quasi-projective situation, you don't have any global resolutions for coherent sheaves. Then it's better to work with the K-group defined using perfect complexes." However, he didn't know how to prove the similar result for this other K group. Berthelot thought about the problem, and, adapting to complexes some constructions of Proj made in EGA II for modules, he solved it. He showed that to Grothendieck and then Grothendieck told me, "Berthelot est encore plus

[3] *Théorie des intersections et théorème de Riemann-Roch, Séminaire de Géométrie Algébrique du Bois-Marie 1966/67, dirigé par P. Berthelot, A. Grothendieck, L. Illusie,* Lecture Notes in Math. **225**, *Springer-Verlag, 1971.*

[4] *Yu. I. Manin, Theory of commutative formal groups over fields of finite characteristic,* Uspehi Mat. Nauk. **18** *(1963), no. 6 (114), 3–90. (Russian)*

[5] *Éléments de Géométrie Algébrique, par A. Grothendieck, rédigés avec la collaboration de J. Dieudonné, Pub. Math. IHÉS 4, 8, 11, 17, 20, 24, 28, 32, and Grundlehren 166, Springer-Verlag, 1971.*

[6] *This issue is discussed again in the section under the heading "Cartier, Quillen".*

fonctorisé que moi!"[7]…(laughter). Grothendieck had given us detailed notes on lambda operations, which he had written before 1960. Berthelot discussed them in his exposés and solved several questions that Grothendieck had not thought about at the time.

Bloch: Why did you choose this topic? There was this earlier paper, by Borel and Serre, based on Grothendieck's ideas about Riemann-Roch. I'm sure he wasn't happy with that!

Illusie: Grothendieck wanted a relative formula over a general base and for fairly general morphisms (locally complete intersection morphisms). Also, he didn't want to move cycles. He preferred to do intersection theory using K-groups.

Bloch: But he didn't forget his program of trying to prove the Weil conjectures?

SGA 7

Illusie: No, but he had several irons in the fire. In 1967–1968 and 1968–1969, there was another seminar, SGA 7,[8] about monodromy, vanishing cycles, the $R\Psi$ and $R\Phi$ functors, cycle classes, Lefschetz pencils. Certainly he had already thought about the formalism of nearby cycles a few years before. Also, he had read Milnor's book on singularities of hypersurfaces. Milnor had calculated some examples and observed that for these all the eigenvalues of the monodromy of the cohomology of what we now call the Milnor fiber of an isolated singularity are roots of unity. Milnor conjectured that that was always the case, that the action was quasi-unipotent. Then Grothendieck said, "What are the tools at our disposal? Hironaka's resolution. But then you leave the world of isolated singularities, you can no longer take Milnor fibers, you need a suitable global object." Then he realized that the complex of vanishing cycles that he had defined was what he wanted. Using resolution of singularities, he calculated, in the case of quasi-semistable reduction (with some multiplicities), the vanishing cycles, and then the solution came out quite easily in characteristic zero. He also obtained an arithmetic proof in the general case: he found this marvelous argument showing that when the residue field of your local field is not so big, in the sense that no finite extension of it contains all roots of unity of order a power of ℓ, then ℓ-adic representations are quasi-unipotent. He decided to make a seminar on that, and that was this magnificent seminar, SGA 7. It's in it that Deligne gave his beautiful exposés on the Picard-Lefschetz formula (at the request of Grothendieck, who couldn't understand Lefschetz's arguments) and Katz his marvelous lectures on Lefschetz pencils.

Cotangent Complex and Deformations

However, my thesis was still empty, I had just attended SGA 7, written up no notes. I had given up long ago this question on Künneth formulas. I had published a little paper in *Topology* on finite group actions and Chern numbers, but that was not much. One day, Grothendieck came to me and said, "I have a few questions for you on deformations." So we met on one afternoon, and he proposed several problems on deformations with similar answers: deformations of modules, groups, schemes, morphisms of schemes, etc. Every time the answer involved an object he had recently constructed, the cotangent complex. In his work with Dieudonné in EGA IV, there appears a differential invariant of a morphism, called the *module of imperfection*. Grothendieck realized that Ω^1 and the module of imperfection were in fact the cohomology objects of a finer invariant in the derived category, a complex of length one, which he called the cotangent complex. He wrote this up in his Lecture Notes, *Catégories cofibrées additives et complexe cotangent relatif* (SLN 79). Grothendieck observed that to get to the obstructions, which involved H^2 groups, his theory was probably insufficient, because a composition of morphisms didn't give rise to a nice distinguished triangle for his cotangent complexes. It happens that at the same time, independently, Quillen had been working on homotopical algebra and, a little later, had constructed, in the affine case, a chain complex of infinite length, which had Grothendieck's complex as a truncation, and which behaved well with respect to composition of morphisms. Independently, too, Michel André had defined similar invariants. I got interested in their work and realized that in André's construction, the classical lemma of Whitehead, which played a key role, could easily be sheafified. In a few months, I obtained the main results of my thesis, except for deformation of group schemes, which came much later (the commutative ones required much more work).

After May 1968

In May 1968 Grothendieck was seduced by the leftist ideology. He admired *Mao's thought* and the Cultural Revolution. He had also started thinking about other topics: physics (he told me he had been reading books by Feynman), then biology (especially embryology). I have the impression that from that time, mathematics was slowly drifting away from his main focus of interest, though he was still very active (e.g., the second part of SGA 7 was in 1968–1969). He had contemplated giving a seminar on abelian schemes after that but finally decided to go on studying Dieudonné's theory for

[7] *"Berthelot is still more functorized than I am!"*

[8] *Groupes de monodromie en géométrie algébrique, Séminaire de Géométrie Algébrique du Bois-Marie 1967–1969, I dirigé par A. Grothendieck, II par P. Deligne et N. Katz,* Lecture Notes in Math. **288**, **340**, *Springer-Verlag 1972, 1973.*

p-divisible groups, in the continuation of his work on crystalline cohomology.

His lectures on this (in 1966) had been written up by Coates and Jussila, and he let Berthelot develop a full-fledged theory. One can regret he didn't give a seminar on abelian schemes. I'm sure it would have produced a beautiful, unified presentation of the theory, much better than the scattered references we can find in the literature. In 1970 he left the IHÉS and founded the ecological group *Survivre* (renamed later *Survivre et Vivre*). At the Nice congress, he was doing propaganda for it, offering documents taken out of a small cardboard suitcase. He was gradually considering mathematics as not being worthy of being studied, in view of the more urgent problems of the survival of the human species. He carelessly dispatched around him many of his documents (papers, private notes, etc.). Yet, in 1970–1971 he gave a beautiful course (together with a seminar) at the Collège de France on Barsotti-Tate groups and lectured later in Montreal on the same topic.

Working with Grothendieck

Many people were afraid of discussing with Grothendieck, but, in fact, it was not so difficult. For example, I could call him anytime, provided that it was not before noon, because he would get up at that time. He worked late in the night. I could ask him any question, and he would very kindly explain to me what he knew about the problem. Sometimes, he had afterthoughts. He would then write me a letter with some complements. He was very friendly with me. But some students were not so happy. I remember Lucile Bégueri-Poitou, who had asked for a topic for her thesis from Grothendieck. It was a bit like with my Künneth formula. I think he proposed to her to write down the theory of coherent morphisms for toposes, finiteness conditions in toposes. That was hard and thankless, things didn't go well, and she eventually decided to stop working with him. Years later she wrote a thesis solving a totally different question of his.[9] He was more successful with Mme Raynaud, who produced a beautiful thesis.[10]

I said that when I handed him some notes, he would correct them heavily and suggest many modifications. I liked it because his remarks were almost always quite up to the point, and I was happy to improve my writing. But some didn't like it, some thought that what they had written was good and there was no need to improve it. Grothendieck gave a series of lectures on motives at the IHÉS. One part was about the standard conjectures. He asked John Coates to write down notes. Coates did it, but the same thing happened: they were returned to him with many corrections. Coates was discouraged and quit. Eventually, it was Kleiman who wrote down the notes in *Dix exposés sur la cohomologie des schémas*.[11]

Drinfeld: But it's not so good for many people, giving a thesis on coherent morphisms of toposes; it's bad for most students.

Illusie: I think these were good topics for Grothendieck himself.

Drinfeld: Yes, sure.

Illusie: But not for students. Similarly with Monique Hakim, *Relative schemes over toposes*. I am afraid this book[12] was not such a success.

Unknown: But the logicians like it very much.

Illusie: I heard from Deligne that there were problems in some parts.[13] Anyway, she was not so happy with this topic, and she did quite different mathematics afterward. I think that Raynaud also didn't like the topic that Grothendieck had given him. But he found another one by himself.[14] That impressed Grothendieck, as well as the fact that Raynaud was able to understand Néron's construction of Néron models. Grothendieck of course had quite brilliantly used the universal property of Néron models in his exposés in SGA 7, but he could not grasp Néron's construction.

Verdier

For Verdier it's a different story. I remember Grothendieck had a great admiration for Verdier. He admired what we now call the Lefschetz-Verdier trace formula and Verdier's idea of defining $f^!$ first as a formal adjoint, and then calculating it later.

Bloch: I thought, maybe, that was Deligne's idea.

Illusie: No, it was Verdier's. But Deligne in the context of coherent sheaves used this idea afterward. Deligne was happy to somehow kill three hundred pages of Hartshorne's seminar in eighteen pages. (laughter)

Drinfeld: Which pages do you mean?

---

[9] *L. Bégueri, Dualité sur un corps local à corps résiduel algébriquement clos,* Mém. Soc. Math. France (N. S.) *1980/81, n. 4, 121 pp.*

[10] *M. Raynaud, Théorèmes de Lefschetz en cohomologie cohérente et en cohomologie étale,* Bull. Soc. Math. France, *Mém. n. 41, Supplément au* Bull. Soc. Math. France, *t. 103, 1975, 176 pp.*

[11] *S. Kleiman, Algebraic cycles and the Weil conjectures, in Dix exposés sur la cohomologie des schémas, A. Grothendieck and N. Kuiper, eds., North Holland Pub. Co., Masson et Co., 1968, 359-386.*

[12] *M. Hakim, Topos annelés et schémas relatifs, Ergebnisse der Mathematik und ihrer Grentzgebiete, Bd 64, Springer-Verlag, 1972.*

[13] *Added in April 2010: Deligne doesn't think there was anything wrong but remembers that the objects she defined over analytic spaces were not the desired ones.*

[14] *M. Raynaud, Faisceaux amples sur les schémas en groupes et les espaces homogènes,* Lecture Notes in Math. **119**, Springer-Verlag, *1970.*

Illusie: In the appendix to Hartshorne's seminar *Residues and Duality*,[15] I say "Hartshorne's seminar", but in fact it was Grothendieck's seminar. Pre-notes had been written up by Grothendieck. Hartshorne gave the seminar from these.

Coming back to Verdier, who had written such a nice "fascicule de résultats" on triangulated and derived categories,[16] one can ask why he did not embark on writing a full account. In the late 1960s and early 1970s, Verdier got interested in other things, analytic geometry, differential equations, etc. When Verdier died in 1989, I gave a talk on his work, at a celebration for him in his memory, and I had to understand this issue: *Why didn't he publish his thesis?* He had written some summary, but not a full text. Probably one of the main reasons is simply that in the redaction of his manuscript he had not yet treated derived functors. He had discussed triangulated categories, the formalism of derived categories, the formalism of localization, but not yet derived functors.[17] At the time he was already too busy with other things. And presumably he did not want to publish a book on derived categories without derived functors. It's certainly a pity.[18]

Drinfeld: And the *Astérisque* volume, how much does it correspond to?

Illusie: It corresponds to what Verdier had written, up to derived functors.[19] This volume is quite useful, I think, but for derived functors, you have to look at other places.[20]

Filtered Derived Categories

Drinfeld: Did the notion of differential graded category ever appear in Verdier's work? Another potential source of dissatisfaction with derived categories was that the cones were defined only up to isomorphism; there are many natural constructions which do not work naturally in derived categories as defined by Verdier. Then you need differential graded categories or go to "stable categories", but these formally have been developed only recently. In hindsight, the idea of the differential graded category seems very natural. Did you have this idea in the discussion of the derived category?

Illusie: Quillen found that differential graded algebras would give you a similar but in general inequivalent category to the derived category defined by simplicial algebras, but this was done in the late 1960s or early 1970s and did not appear in discussions with Grothendieck. However, I know the story about the filtered derived category. Grothendieck thought that if you have an endomorphism of a triangle of perfect complexes, then the trace of the middle part should be the sum of the traces of the right-hand side and the left-hand side. In SGA 5, when he discussed traces, he explained that on the board. One of the persons attending the seminar was Daniel Ferrand. At the time, nobody saw any problem with that, it was so natural. But then Grothendieck gave Ferrand the task of writing the construction of the determinant of a perfect complex. This is a higher invariant than the trace. Ferrand was stuck at one point. When he looked at the weaker version, he realized that he could not show that the trace of the middle part was the sum of the two extremes, and then he built a simple counterexample. The problem was: *How can we restore that?* The person who at the time could repair anything that went wrong was Deligne. So, we asked Deligne. Deligne came up with the construction of a category of *true triangles*, finer than usual triangles, obtained by a certain process of localization, from pairs of a complex and a subcomplex. In my thesis I wanted to define Chern classes, using an Atiyah extension. I needed some additivity of Chern classes, hence additivity of traces, and algebraic complements; I also needed tensor products, which increase lengths of filtrations. So I thought: why not just take filtered objects and localize with respect to maps inducing quasi-isomorphisms on the associated graded objects? It was very natural. So I wrote it up in my thesis, and everybody was happy. At the time, only finite filtrations were considered.

Photo courtesy of Luc Illusie.

Luc Illusie

Drinfeld: So it is written in your Springer Lecture Notes volumes on cotangent complex and deformations?

Illusie: Yes, in SLN 239, Chapter V. Deligne's category of true triangles was just $DF^{[0,1]}$, the filtered derived category with filtrations of length 1. That was the beginning of the theory. However, Grothendieck said, "In triangulated categories we have the octahedron axiom, what will replace that in filtered derived categories?" Maybe the situation is not yet fully understood today. Once, Grothendieck told me, it must have been in 1969: "We have the K-groups defined by vector bundles, but we could take vector bundles with a filtration of

---

[15] *R. Hartshorne, Residues and Duality,* Lecture Notes in Math. **20**, Springer-Verlag, *1966.*

[16] *Catégories dérivées, Quelques résultats (État 0) in [SGA 4 1/2, Cohomologie étale, par P. Deligne,* Lecture Notes in Math. **569**, Springer-Verlag, *1977], pp. 266–316.*

[17] *Derived functors were defined and studied in the above mentioned "fascicule de résultats", II* §2.

[18] *Added in April 2010: According to Deligne, Verdier was also plagued by sign problems, for which he had not found a satisfactory treatment.*

[19] *J.-L. Verdier, Des catégories dérivées des catégories abéliennes, édité par G. Maltsiniotis,* Astérisque **239** *(1996).*

[20] *E.g., in Deligne's exposé XVII in SGA 4, where a better definition of derived functors is given.*

length one (with quotient a vector bundle), vector bundles with filtrations of length 2, length n, with associated graded still vector bundles…. Then you have operations such as forgetting a step of the filtration, or taking a quotient by one step. This way you get some simplicial structure which should deserve to be studied and could yield interesting homotopy invariants."

Independently, Quillen had worked out the Q-construction, which is a substitute for the filtration approach. But, I think, if Grothendieck had had more time to think about it, he would have defined the higher K-groups.

Drinfeld: But this approach looks more like Waldhausen's one.

Illusie: Yes, of course.

Drinfeld: Which appeared much later.

Illusie: Yes.

Cartier, Quillen

Drinfeld: During the SGA 6 seminar, was it known that the λ-operations have something to do with Witt rings?

Illusie: Yes. In fact, I think that G. M. Bergman's appendix to Mumford's book on surfaces[21] was already available at that moment.

Drinfeld: Are there λ-operations in this appendix?

Illusie: No, but I gave a talk in Bures on universal Witt rings and lambda operations. I remember I was going to the Arbeitstagung in Bonn. Having missed the night train I took an early morning train. Surprise: Serre and I were in the same compartment. I told him about the talk I had to prepare, and he generously helped me. During the whole trip, he improvised in a brilliant way, explaining to me several beautiful formulas, involving the Artin-Hasse exponential and other miracles of Witt vectors. This was discussed toward the end of the SGA 6 seminar, in June 1967. I wonder, Cartier's theory should have existed at the time. *Tapis de Cartier*, I think, existed.

Drinfeld: What is *Tapis de Cartier*?

Illusie: *Tapis de Cartier* was how Grothendieck called Cartier's theory of formal groups. *Tapis* (= rug) was a (slightly derogatory) expression used by some Bourbaki members, comparing those who advocated for a theory to rug merchants.

Bloch: But still, if you look back, Cartier made a lot of contributions.

Illusie: Yes, Cartier's theory is powerful and had a strong impact later. But I don't think that Grothendieck used much of it. On the other hand, at the time, Grothendieck was impressed by Quillen, who had brilliant new ideas on many topics. About the cotangent complex, I don't remember well now, but Quillen had a way of calculating the Ext^i of the cotangent complex and $\mathcal{O}$ as the cohomology of the structural sheaf of a certain site, which looked like the crystalline site, but with the arrows reversed. That surprised Grothendieck.

Unknown: Apparently, this idea was rediscovered later by Gaitsgory.[22]

Bloch: In Quillen's notes on the cotangent complex it was the first time I'd ever seen a derived tensor product *over* a derived tensor product.

Illusie: Yes, in the relation between the (derived) self-intersection complex and the cotangent complex.

Bloch: I think it was something like $B \otimes^L_{B \otimes^L_A B} B$. I remember studying for days, puzzling over exactly what that meant.

Illusie: But when I said I couldn't do my Künneth formula, one reason was that such an object didn't exist at the time.

Drinfeld: I am afraid that even now it doesn't exist in the literature (although it may exist in somebody's head). I needed the derived tensor product of algebras over a ring a few years ago when I worked on the article on DG categories. I was unable either to find this notion in the literature or to define it neatly. So I had to write something pretty ugly.

Grothendieck's Tastes

Illusie: I realize I didn't say much about Grothendieck's tastes. For example, do you know the piece of music he would like most?

Bloch: Did he like music at all?

Illusie: Grothendieck had a very strong feeling for music. He liked Bach, and his most beloved pieces were the last quartets by Beethoven.

Also, do you know what his favorite tree was? He liked nature, and there was one tree he liked more than the others. It was the olive tree, a modest tree, but which lives long, is very sturdy, is full of sun and life. He was very fond of the olive tree.

In fact, he always liked the south very much, long before he went to Montpellier. He had been a member of the Bourbaki group, and he had visited *La Messuguière*, where some congresses were held.

He tried to get me to go to that place, but it didn't work out. It is a beautiful estate on the heights above Cannes. You have Grasse a little higher, and still a little higher you have a small village called Cabris, where there is this estate, with eucalyptus trees, olive trees, pine trees, and a magnificent view. He liked it very much. He had a fancy for this sort of landscape.

Drinfeld: Do you know what Grothendieck's favorite books were? You mentioned his favorite music…

[21] *D. Mumford, Lectures on curves on an algebraic surface. With a section by G. M. Bergman.* Annals of Mathematics Studies*, No. 59,* Princeton University Press*, Princeton, N.J. 1966.*

[22] *D. Gaitsgory, Grothendieck topologies and deformation theory II.* Compositio Math. **106** *(1997), no. 3, 321–348.*

Illusie: I don't remember. I think he didn't read much. There are only twenty-four hours in a day…

Automorphic Forms, Stable Homotopy, Anabelian Geometry

Illusie: In retrospect, I find it strange that representation theory and automorphic forms theory were progressing well in the 1960s but somehow ignored in Bures-sur-Yvette. Grothendieck knew algebraic groups quite well.

Bloch: Well, as you said, there are only twenty-four hours in a day.

Illusie: Yes, but he might have constructed the ℓ-adic representations associated with modular forms like Deligne did, but he didn't. He really was very interested in arithmetic, but maybe the computational aspect of it was not so appealing to him. I don't know.

He liked putting different pieces of mathematics together: geometry, analysis, topology… so automorphic forms should have appealed to him. But for some reason he didn't get interested in that at the time. I think the junction between Grothendieck and Langlands was realized only in 1972 at Antwerp. Serre had given a course on Weil's theorem in 1967–1968. But after 1968 Grothendieck had other interests. And before 1967 things were not ripe. I'm not sure.

Beilinson: What about stable homotopy theory?

Illusie: Of course Grothendieck was interested in loop spaces, iterated loop spaces; n-categories, n-stacks were at the back of his mind, but he didn't work it out at the time.

Beilinson: When did it actually come about? Picard category is probably about 1966.

Illusie: Yes, it was related to what he did with the cotangent complex. He conceived the notion of Picard category at that time, and then Deligne sheafified it into Picard stacks.

Beilinson: And higher stacks…?

Illusie: He had thought about the problem, but it's only long afterwards that he wrote his manuscript *Pursuing stacks*. Also, $\pi_1(\mathbb{P}^1 - \{0, 1, \infty\})$ was always at the back of his mind. He was fascinated by the Galois action, and I remember once he had thought about possible connections with that and Fermat's problem. Already in the 1960s he had some ideas about anabelian geometry.

Motives

Illusie: I regret that he was not allowed to speak on motives at the Bourbaki seminar. He asked for six or seven exposés, and the organizers considered it was too much.

Bloch: It was kind of unique then; nobody else was lecturing on their own work.

Illusie: Yes, but you see, FGA (Fondements de la Géométrie Algébrique) consists of several exposés. He was thinking of doing for motives what he had done for the Picard scheme, the Hilbert scheme, etc. There are also three exposés on the Brauer group which are important and useful, but seven exposés on motives would have been even more interesting. However, I don't think they would have contained things which have not been worked out by now.

Weil and Grothendieck

Bloch: I once asked Weil about nineteenth-century number theory and whether he thought that there were any ideas there that had not yet been worked out. He said, "No." (*laughter*)

Illusie: I discussed with Serre what he thought were the respective merits of Weil and Grothendieck. Serre places Weil higher. But though Weil's contributions are fantastic, I myself think Grothendieck's work is still greater.

Drinfeld: But it was Weil who revived the theory of modular forms in his famous article.[23] Probably Grothendieck couldn't have done it.

Illusie: Yes, this is certainly a great contribution. As for Weil's books, *Foundations of Algebraic Geometry* is hard to read. Serre the other day told me that Weil was unable to prove theorem A for affine varieties in his language. And even Weil's book on Kähler varieties,[24] I find it a little heavy.

Bloch: That book in particular was very influential.

Grothendieck's Style

Illusie: Yes, but I'm not so fond of Weil's style. Grothendieck's style had some defects also. One that was barely perceptible at the beginning and became enormous later is his habit of afterthoughts and footnotes. *Récoltes et Semailles* is incredible in this respect. So many, so long footnotes! Already in his beautiful letter to Atiyah on de Rham cohomology there are many footnotes, which contain some of the most important things.

Bloch: Oh, I remember seeing photocopies, early photocopies, when photocopy machines didn't work all that well. He would type a letter and then add handwritten comments which were *illegible*.

Illusie: Well, I was used to his handwriting, so I could understand.

Bloch: We would sit around and puzzle…

Illusie: To him no statement was ever the best one. He could always find something better, more general or more flexible. Working on a problem, he said he had to sleep with it for some time. He liked mechanisms that had oil in them. For this you had to do scales, exercises (like a pianist), consider special cases, functoriality. At the end you obtained a formalism amenable to dévissage.

[23] *A. Weil, Über die Bestimmung Dirichletscher Reihen durch Funktionalgleichungen,* Math. Ann. **168** *(1967), 149–156.*

[24] *A. Weil, Introduction à l'étude des variétés kählériennes. Publications de l'Institut de Mathématique de l'Université de Nancago, VI. Actualités Sci. Ind. no. 1267,* Hermann, *Paris, 1958.*

I think one reason why Grothendieck, after Serre's talk at the Chevalley seminar in 1958, was confident that étale localization would give the correct H^i's is that once you had the correct cohomology of curves, then by fibration in curves and dévissage you should also reach the higher H^i's.

I think he was the first one to write a map vertically instead of from left to right.[25]

Drinfeld: It was he who put the X over S. Before that X was on the left and S was on the right.

Illusie: Yes. He was thinking over a base. The base could be a scheme, a topos, anything. The base had no special properties. It's the relative situation that was important. That's why he wanted to get rid of Noetherian assumptions.

Bloch: And I remember, in the early days schemes, morphisms were separated, but then they became quasi-separated.

Commutative Algebra

Illusie: At the time of Weil, you looked at fields, and then valuations, and then valuation rings, and normal rings. Rings were usually supposed to be normal. Grothendieck thought it was ridiculous to make such systematic restrictions from the beginning. When defining Spec A, A should be any commutative ring.

Drinfeld: Sorry, but how did people treat the nodal curve if the rings were supposed to be normal? Non-normal varieties appear…

Illusie: Of course, but they often looked at the normalization. Grothendieck was aware of the importance of normality, and I think Serre's criterion of normality was one of the motivations for his theory of depth and local cohomology.

Bloch: I wonder whether today such a style of mathematics could exist.

Illusie: Voevodsky's work is fairly general. Several people tried to imitate Grothendieck, but I'm afraid that what they did never reached that "oily" character dear to Grothendieck.

But it is not to say that Grothendieck was not happy to study objects having rich structures. As for EGA IV, it is of course a masterpiece of local algebra, a domain in which he was extremely strong. We owe a lot to EGA IV, though maybe some rewriting could be possible now, using the cotangent complex.

Relative Statements

Illusie: Certainly we're now so used to putting some problem into relative form that we forget how revolutionary it was at the time. Hirzebruch's proof of Riemann-Roch is very complicated, while the proof of the relative version, Grothendieck-Riemann-Roch, is so easy, with the problem shifted to the case of an immersion. This was fantastic.[26]

Grothendieck was the father of K-theory, certainly. But it was Serre's idea to look at χ. I think the people in the olden days, they had no idea of the right generalization of Riemann-Roch for curves. For surfaces, both sides of the formula were quite intricate. It's Serre who realized that the Euler-Poincaré characteristic, the alternate sum of the dimensions of the $H^i(\mathcal{O})$ or the $H^i(E)$ was the invariant you should look for. That was in the early 1950s. And then Grothendieck saw that the universal χ was in the K-group…

The Thèse d'État

Drinfeld: So when Grothendieck chose problems for his students he didn't care very much about the problem being solvable.

Illusie: Of course, he cared about the problem, and when he didn't know how to solve it, he left it to his students. The *thèses d'état* were like that…

Drinfeld: And how many years did it take to write the thesis? For example, how many years did you spend? You had to change the subject once or twice, and then in between you worked on SGA, which had nothing to do with the thesis. It was very helpful for humanity and very good practice for you, but it had nothing to do with your thesis. So how many years did you spend?

Illusie: I started working on the cotangent complex in the end of 1967, and the whole thing was finished in two years, somehow.

Drinfeld: But before this, there were some attempts which were not so successful due to the nature of the problem. When did you begin working on your thesis? As far as I understand, even now the standard amount of time in the U.S. is five years.

Illusie: In fact, I did it in two years, essentially. In 1968 I sent a letter to Quillen sketching what I had done. He said, "It's fine." And then I wrote up my thesis very quickly.

Drinfeld: Were you a graduate student before that (when you began attending Grothendieck's seminar)?

Illusie: I was at the CNRS [Centre National de la Recherche Scientifique].

Drinfeld: Oh, you were already…

Illusie: Yes, it was like paradise. You entered the École Normale …

Drinfeld: Yes, sure, I understand.

Illusie: Then you worked reasonably well so Cartan spotted you, saying, "Well, this student

[25] *Added in April 2010: Cartier observes that vertical lines had been commonly used to denote field extensions since long ago, especially in the German school.*

[26] *Added in April 2010: as Deligne observes, equally revolutionary—and intimately linked to the relative viewpoint—was Grothendieck's idea of thinking of a scheme in terms of the functor it represents, thus recovering a geometric language somewhat concealed in the ringed spaces approach.*

should go to the CNRS." Once at the CNRS, you were there for the rest of your life. Which is not quite true. A position at the CNRS at that time was not one of "fonctionnaire" (civil servant). But as I was not idle, my contract was renewed from year to year.

Of course, we were maybe fifteen people at the École Normale doing mathematics, and there were not that many positions at the CNRS. Others could get positions as "assistants", which were not so good as the CNRS, but still reasonable.

Drinfeld: And did somebody tell you from time to time that it is time to finish your thesis?

Illusie: Well, after seven years, it could become a problem. As I had started at the CNRS in 1963, and had finished my thesis by 1970, I was safe.

Drinfeld: And the fact that you spent seven years didn't diminish your chances for future employment?

Illusie: No. From 1963 to 1969 I was attaché de recherche, then, from 1969 to 1973, chargé de recherche, and promoted maître de recherche in 1973 (the equivalent of directeur de deuxième classe today). Nowadays if a student after five years has not defended his thesis, it's a problem.

Drinfeld: What has changed…?

Illusie: The thèse d'État was suppressed, replaced by the standard thesis, following the American model.

Drinfeld: I see.

Illusie: Typically, a student has three years to finish his thesis. After three years, the fellowship ends, and he has to find a position somewhere, either a permanent one or a temporary one (like ATER = attaché d'enseignement et de recherche, or a postdoc).

For a few years we had a transitional system with the nouvelle thèse (new thesis), similar to the thesis we have now, followed by the thèse d'État. Now the thèse d'État is replaced by the habilitation. It's not the same kind of thing. It's a set of papers that you present at the defense. You need the habilitation for applying for a position of professor.

Grothendieck Today

Unknown: Maybe you told me, but where is Grothendieck now? Nobody knows?

Illusie: Maybe some people know. I myself don't know.

Bloch: If we were to go to Google and type in "Grothendieck"…

Illusie: We'd find the Grothendieck site.

Bloch: Yes, the website. He has a web topos …[27]

Unknown: What happened to his son? Did he become a mathematician?

Illusie: He has four sons. I heard the last one studied at Harvard.

[27] *Grothendieck Circle.*

EGA

Bloch: You can't tell a student now to go to EGA and learn algebraic geometry…

Illusie: Actually, students want to read EGA. They understand that for specific questions they have to go to this place, the only place where they can find a satisfactory answer. You have to give them the key to enter there, explain to them the basic language. And then they usually prefer EGA to other expository books. Of course, EGA or SGA are more like dictionaries than books you could read from A to Z.

Bloch: One thing that always drove me crazy about EGA was the excessive back referencing. I mean there would be a sentence and then a seven-digit number…

Illusie: No… You're exaggerating.

Bloch: You never knew whether behind the veiled curtain was something very interesting that you should search back in a different volume to find; or whether in fact it was just referring to something that was completely obvious and you didn't need to…

Illusie: That was one principle of Grothendieck: every assertion should be justified, either by a reference or by a proof. Even a "trivial" one. He hated such phrases as "It's easy to see," "It's easily checked." When he was writing EGA, you see, he was in unknown territory. Though he had a clear general picture, it was easy to go astray. That's partly why he wanted a justification for everything. He also wanted Dieudonné to be able to understand!

Drinfeld: What was Dieudonné's contribution to the EGA?

Illusie: He did rewriting, filling in details, adding complements, polishing the proofs. But Grothendieck's first drafts (*État 000*), some of which I have seen, were already quite elaborate. Nowadays you have such efficient TEX systems, manuscripts look very nice. In Grothendieck's time the presentation was not so beautiful, maybe, but Dieudonné-Grothendieck's manuscripts were still fantastic.

I think Dieudonné's most important contribution was on the part of EGA IV dealing with differential calculus in positive characteristic, with complete local rings, which is basic in the theory of excellent rings.

Also, Grothendieck was not thrifty. He thought that some complements, even if they were not immediately useful, could prove important later and therefore should not be removed. He wanted to see all the facets of a theory.

Unknown: When Grothendieck started working on EGA, did he already have a vision of what would come later, étale cohomology… Did he have in mind some applications?

Illusie: The plan he gives for EGA in the first edition of EGA I (in 1960) amply shows the vision he had at that time.

Alice Turner Schafer (1915–2009): Remembrances*

edited by Anne Leggett

Georgia Benkart

Alice Turner Schafer, one of the founders of the Association for Women in Mathematics (AWM) and its second president, died September 27, 2009, at the age of ninety-four. As early as her high school years, Alice Turner demonstrated a deep love of mathematics and teaching. She attended the University of Richmond, where back in the early 1930s, the men's and women's colleges stood on opposite sides of Westhampton Lake, and women were not allowed in the campus library. Female students had never enrolled in advanced mathematics classes there until a dean advised Alice to "take mathematics courses on the boys' side of the lake". No one could have predicted how symbolic and significant a crossing that would be.

Photo courtesy of Richard Schafer.

Alice Schafer, Washington, D.C., 1987.

As a senior in college, Alice applied for a fellowship to attend graduate school in mathematics at the University of Chicago, but despite her stellar undergraduate record, her application was denied. After receiving her undergraduate degree from the University of Richmond's Westhampton College in 1936, Alice taught secondary-school mathematics for three years to earn enough money to pursue graduate study. It was at the University of Chicago that she received her M.S. and Ph.D. degrees. She married fellow mathematics graduate student Richard (Dick) Schafer as they were completing their doctoral work in 1942. Her dissertation on projective differential geometry was supervised by E. P. Lane, and she published papers based on it in the *Duke Mathematical Journal* and the *American Journal of Mathematics*.

Alice held positions at eight different colleges or universities before moving to Wellesley College in 1962 (a successful solution to the "two-body problem", as by then Dick was a professor at MIT). At Wellesley, she soon became department head and the Helen Day Gould Professor of Mathematics. In 1964, her alma mater, the University of Richmond, recognized Alice with an honorary D.Sc. degree.

Following her first retirement from teaching in 1980, Alice stayed two more years at Wellesley, serving as chair of its Affirmative Action Program. She then resumed teaching at Simmons College and in the management program in the Radcliffe College Seminars. When Dick retired from MIT in 1988, they moved to Arlington, Virginia, and for the next seven years, Alice taught mathematics at Marymount University until retiring for the final time at the age of eighty-one.

In 1985 Alice Schafer was elected a fellow of the American Association for the Advancement of Science. In 1990, to commemorate all she had done for the organization and for women in mathematics, AWM established its annual Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman. The MAA honored Alice in 1998 with its Yueh-Gin Gung and Dr. Charles Y. Hu Distinguished Service to Mathematics Award,

Anne Leggett is associate professor at Loyola University Chicago. Her email address is amcdona@luc.edu.

Georgia Benkart is professor emerita at the University of Wisconsin-Madison. Her email address is benkart@math.wisc.edu.

**Revised versions of material from "President's report" and "A tribute to Alice Turner Schafer", AWM* Newsletter*, Vol. 40, No. 1, January–February 2010.*

citing her work as a mathematics educator and as a champion of the full participation of women in mathematics.

The hiring of women mathematicians, a constant concern to Alice, is reflected extensively in her 1991 *Notices* article, "Mathematics and Women: Perspectives and Progress. Women in Mathematics". In it she notes that at the time there were 303 faculty members in the "top ten" mathematics departments but only five women, four tenured and one nontenured. Always the advocate, she relates the following encounter:

> *... when I was talking to a mathematician at another of the "top ten", I asked why there were no women on the faculty. His answer was that if the department could find anyone as good as "X", a woman at a less prestigious university, that his department would hire her. "What about hiring X?" I asked. No response—end of conversation.*

Under the auspices of the People to People Ambassador Program, Alice Schafer led three different delegations to China to promote the equal treatment of women in mathematics and science. She had fearless determination, boundless enthusiasm, and an unwavering commitment to the equal treatment of *all* mathematicians. She lived the word "inclusiveness" long before it became part of the standard terminology for statements on diversity.

Alice stayed in touch with many of her former students until recent years, when she was confined to a nursing facility and age diminished her ability to communicate. When former student Ellen Maycock, who is associate executive director of AMS, visited Alice and Dick two years ago, she mentioned to Alice that I had just become president-elect of AWM. Alice broke into a broad grin. The story meant a lot to me when Ellen told me about the visit. I'd like to think Alice is still smiling on us all.

Bhama Srinivasan

The 1970s were the heady days of the "second wave of feminism", as it was sometimes called. Betty Friedan's classic *The Feminine Mystique* had recently been published. I was living in the Boston area and teaching at Clark University in Worcester, Massachusetts. Academic women in Cambridge were forming consciousness-raising groups that met weekly, and I joined one. By coincidence, Linda Rothschild was in it, too. Change was in the air; women were energized, asking why they were ignored and marginalized. And only 7 percent of Ph.D.s in mathematics were awarded to women.

Bhama Srinivasan is professor emerita at the University of Illinois at Chicago. Her email address is srinivas@uic.edu.

Photo courtesy of Sylvia Wiegand.

Olga Taussky Todd Celebration of Careers in Mathematics for Women, MSRI, 1999. Past presidents of AWM. Left to right: Mary Gray, Bhama Srinivasan, Carol Wood, Alice T. Schafer, Jean Taylor, and Sylvia Wiegand.

This was the setting when Alice Schafer started a group of women mathematicians in the Boston area that included myself, Linda Rothschild, Vera Pless, Betty Salzburg, and others. This group became a part of AWM, which was founded in 1971. Mary Gray was the first president of AWM, to be followed by Alice and then Lenore Blum and Judy Roitman. Alice approached me in 1980 to ask if I would agree to be the next president; I was, understandably, anxious about accepting what I perceived as a demanding job. One evening she called me and said, "That's it, girl. You are it. Now have a drink and go to bed!" This was vintage Alice; how could one refuse? The next day she told me that she and others would help me if I accepted the position. Thus I had the honor of serving as the president of AWM, 1981–83. During this time AWM sponsored the Emmy Noether Symposium at Bryn Mawr College, the brainchild of Rhonda Hughes, who was on the faculty there. Alice, Rhonda, and I were on the organizing committee of this highly enjoyable event.

With all Alice's career moves and her positions at colleges that were geared mainly to teaching, it is not surprising that she did not pursue a research career. She was a dedicated teacher, and her political activism, especially directed toward women's issues and human rights, is well known. She and Mary Gray were the "mothers of AWM", always ready to help with advice and action.

Alice and I had endless conversations about women's issues and about AWM, and I regarded her as a mentor. An anecdote from Gail Collins's book *When Everything Changed: The Amazing Journey of American Women from 1960 to the Present* gives the story of a woman who went to

Photo courtesy of Richard Schafer.

Dick and Alice Schafer, Chicago, 1944.

court to pay her boss's speeding ticket—and was sent home by the judge to change her clothes because she was wearing slacks. This reminded me of Alice saying to me (around 1971), "It is now OK for women to teach wearing pantsuits." (Yes, there was a time when it was not OK.)

Now everything has changed, and American women mathematicians have made an amazing journey from 1970 to the present. AWM has played a big role in this movement, and Alice has been a primary player, indeed one of the movers and shakers. We will miss her.

Mary Gray

Great minds think alike, especially if we consider "great minds" to be those attuned to a strong feminism, politely (well, usually) and relentlessly pursued. AWM began operation from a corner of my desk; the organization's newsletter was written, printed, and distributed with a little help from my mathematician husband. Boston area women mathematicians had also decided that "something must be done" about the position of women in mathematics: we needed more of us, and we needed recognition and encouragement once we chose to do mathematics. Inspired by Alice Schafer, the Boston group had been gathering for support and, yes, plotting how to succeed in these goals. We joined forces, and we never looked back. Alice became the second president of AWM and moved the enterprise to Wellesley, where it flourished, gaining thousands of members and widespread influence.

In 1981 *Science* chose to publish a study done at Johns Hopkins purporting to show that females really aren't cut out to be mathematicians. My tendency was to shrug it off as just another annoyance, but Alice was indignant. She flew into Washington and demanded an audience for us (the atmosphere in the upper echelons of AAAS was pretty imperial) with the editor. He was totally unprepared for a little lady, as he put it, with a charming Virginia accent to be challenging the magazine to publish an editorial refuting the conclusion that had been drawn in the article. But we triumphed with a nice piece, "Sex and Mathematics". Too bad Larry Summers didn't read it before he ventured his opinion.

We, Alice most of all, were determined that no longer should women with Ph.D.s in mathematics face the exclusion from the faculties of major universities that she had. Alice also understood that we need to start with young girls and helped AWM get organized to do such events as Sonya Kovalevskaya days and to reach out to teachers in the K–12 system.

My husband and I often found ourselves at the opera with Dick while Alice was home with the cats and at math conferences with Alice while Dick was home with the cats. Maybe opera would have become less sexist if the cats had fended for themselves and Alice had decided to take on the operatic establishment.

Mary Gray is professor of mathematics and statistics at American University. Her email address is mgray@american.edu.

Ellen Maycock

I was exceptionally fortunate to have had Alice T. Schafer as a classroom teacher and as an advisor at Wellesley College. I took the second semester of Abstract Algebra from her and went on to work independently with her on several topics. During my senior year, I worked with her on my honors thesis in group theory. After my graduation from Wellesley in 1972, I continued to stay in touch with her over the years. I last saw her in February 2009.

Alice was a strong and remarkable woman. She had a vision about the role of women in mathematics, and her efforts have made a huge difference. I went to college imagining that I would major in mathematics, but many students who excel in high school mathematics feel that way, and most don't continue. Alice's energy and her commitment to and excitement about mathematics made a big difference to me: the combination of her high expectations and the support she gave me was crucial. I'm quite sure that I would not have become a mathematician if I hadn't gone to Wellesley, and Alice's role was key. For my graduation, she gave me a Wedgwood plate that has a drawing of Founders Hall, where I took my mathematics courses; this plate still has an honored place on my dining room buffet. Alice continued to support me throughout

Ellen Maycock is the Associate Executive Director, Meetings and Professional Services, at the American Mathematical Society. Her email address is ejm@ams.org.

my career as a college mathematics professor and as an administrator at the American Mathematical Society. I am very grateful.

Linda Rothschild

It was with great sadness that I heard about Alice Schafer's death. But what a life she had! I did not realize that she was ninety-four years old. Now I know that she was already over fifty in 1966, the year I first met her when I was a new graduate student at MIT and she was on the faculty at Wellesley. Alice was introduced to me at an MIT function as the spouse of an MIT faculty member. At that time she was not yet a household name. As the only woman among thirty-six new math graduate students at MIT, I was already heavily engaged in my mathematical studies and future research (as a graduate student was supposed to be), and although Alice and I exchanged brief words at later functions, we did not really talk until several years later. By then, the women's movement was picking up steam!

The first meeting of women in science and engineering I attended was held by Vera Pless at her home in suburban Boston in 1969. A wonderful group of women scientists of all ages gathered there, the first of several meetings to discuss the situation of women scientists and engineers. If my memory serves me right (no guarantee), it was from this group that some of us in mathematics, egged on by Alice, decided to meet from time to time to discuss problems particular to our field. Alice was a leading force of this group from the start. She had the vision to see that although we were just a small group, we could be part of a larger movement. We continued to meet for a couple of years while we were all still in the Boston area.

Photo courtesy of Barbara Victor.

Alice at the Great Wall of China on her 75th birthday.

As the story has been told many times over, AWM was created following the annual AMS-MAA meeting in 1971 in Atlantic City, through the considerable efforts of Alice, Mary Gray, and others. The continuation of Bhama's story above is that when a new president-elect for AWM was needed in 1982, Alice turned her sights on me. I had been less involved in AWM since the early years, and I had many excuses. Indeed, in the bad job market of the 1970s I held five different postdoc positions before obtaining a permanent position at Wisconsin, after which my life was further complicated by the arrival of two children. Alice, however, was not accepting any excuses! She told me in no uncertain terms that I had to be the next AWM president. She offered to give me all the assistance I needed as president, and after I got the job she was incredibly helpful. Both AWM and I survived my presidency, and I would like to think that both came out stronger, thanks to Alice's wise counsel.

Photo courtesy of Sylvia Wiegand.

1998 JMM, Baltimore. Back row: Deborah Hughes Hallett (Hay Award winner), Cora Sadosky (AWM past president), Sylvia Wiegand (AWM president), Jessica Shepherd (Schafer Prize co-winner), Cathleen Morawetz (AMS past president), and Sharon Lozano (Schafer Prize co-winner). Front row: Martha Siegel (MAA secretary), Anne Leggett (AWM newsletter editor), and Alice T. Schafer (AWM past president).

After I moved to California I saw Alice less frequently, usually at the annual meetings. In her quiet way, she was always bubbling over with new ideas and projects for AWM. In fact, AWM had no need for a formal executive director until age caught up with Alice, who had really held the post without the title. Alice was like that: always giving away her ideas and doing the hard work, but never asking for the credit.

Alice Schafer was a force of nature: strong, steady, lasting through many seasons. She was persistent and persuasive, but never angry or perturbed. She was fortunate to have the support of her wonderful husband, Dick. AWM would not be what it is today without her energy, enthusiasm, and commitment. Women mathematicians of all generations owe her a great debt.

Linda Rothschild is professor of mathematics at the University of California San Diego. Her email address is `lrothschild@ucsd.edu`.

American Mathematical Society

AMS RESEARCH JOURNALS DIGITAL ARCHIVE

The American Mathematical Society (AMS) has established a complete digital archive of its mathematical research journals. Over 34,000 articles are available from over 100 years of high-quality mathematical research in *Journal of the AMS*, *Mathematics of Computation*, *Proceedings of the AMS*, *Transactions of the AMS*, and *Bulletin of the AMS*. All back issues, starting with each journal's inaugural issue through 2005, are now freely available in electronic format.

Researchers can browse the contents of each journal to find articles and authors in each volume and issue, and can search across the entire archive by journal *or group of journals* at **http://www.ams.org/joursearch/**. View the abstract, references (with links to MathSciNet), bibliographic information, Mathematics Subject Classifications for each article, or view a PDF of the full article.

Each journal is unique in its offering of articles, book reviews, and reports. AMS journals have consistently been managed by editors prominent in their fields.

Journal of the AMS, founded in 1988 in celebration of the AMS Centennial, maintains the highest standards in mathematical research. Its first editors, Michael Artin, H. Blaine Lawson, Jr., Richard Melrose, Wilfried Schmid, and Robert E. Tarjan, along with a distinguished group of associate editors, launched one of the most respected and valued research journals in mathematics.

Mathematics of Computation was founded in 1943 to serve as a clearing-house for information concerning mathematical tables and other aids to computation. The journal continues to focus on research articles of the highest quality in computational mathematics. The journal also includes reviews of books in related areas.

Proceedings of the AMS is devoted to research in all areas of pure and applied mathematics, and contains significant and peer-reviewed research of interest to mathematicians across many specialties. The entire archive of 18,295 articles, dating from 1950, has been digitized.

Transactions of the AMS, founded in 1900 originally to foster the work of American mathematicians, includes significant and peer-reviewed research—generally lengthier papers—in pure and applied mathematics.

The earlier digitization of the back issues of the *Bulletin of the AMS* from 1891 to 1991 was made possible with the generous support of the Gordon and Betty Moore Foundation through a grant to the Mathematical Sciences Research Institute. The AMS makes the digitized archive of these other important research journals freely available to all mathematicians through the generosity of an anonymous donor.

AMS
American Mathematical Society
www.ams.org

Speaking with the Natives: Reflections on Mathematical Communication

Gerald B. Folland

As an amateur student of both theoretical physics and languages, I have had many occasions to contemplate the problems of transmission of mathematical information between people in different disciplines. What follows is a loosely connected series of observations based on my experience—and a few other things.

It is a truth universally acknowledged that almost all mathematicians are Platonists, at least when they are actually doing mathematics rather than philosophizing about it. As Hardy [8, §22] said, "I believe that mathematical reality lies outside us, that our function is to discover or *observe* it, and that the theorems which we prove, and which we describe grandiloquently as our 'creations', are simply the notes of our observations." One might maintain that mathematicians can create new structures within mathematical reality just as engineers can create new structures within the physical world, but most of us have no trouble with the idea that there *is* such a reality and that our job consists of studying it. Moreover, we are all trained to believe that the universe that encompasses this reality consists of *sets*, and that every respectable mathematical object should possess a precise definition as a set.[1]

It can therefore take the working mathematician by surprise to discover that most nonmathematicians who use mathematics are not Platonists. Nor are they intuitionists or constructivists, eager though people of the latter persuasions might be to claim their allegiance. They are formalists. For them mathematics is the discipline of manipulating symbols according to certain sophisticated rules, and the external reality to which those symbols refer lies not in an abstract universe of sets but in the real-world phenomena that they are studying. As Dirac put it in the first edition of his classic book on the principles of quantum mechanics [5, §7], discussing the symbols that represent the states of a quantum system: "One does not anywhere specify the exact nature of the symbols employed, nor is such specification at all necessary. They are used all the time in an abstract way, the algebraic axioms that they satisfy and the connexion between equations involving them and physical conditions being all that is required."[2]

This point of view has consequences that can cause some perplexity when mathematicians and scientists try to talk to one another. The algebraic axioms to which Dirac refers, for example, amount to the condition that the symbols representing states are the names of vectors in a Hilbert space $\mathcal{H}$ and that other symbols representing observables are the names of self-adjoint operators on $\mathcal{H}$. Mathematicians would usually prefer to have the state space for a specific quantum system identified as a specific concrete Hilbert space, with the important observables described by explicit formulas, and they are disconcerted when these ingredients are missing from the recipe. Physicists, on the other hand, would maintain that committing oneself to such a specific choice at the

Gerald B. Folland is professor of mathematics at the University of Washington. His email address is `folland@math.washington.edu`.

[1] *Some recent developments such as topos theory take a broader view, but they are not part of the standard conceptual toolkit.*

[2] *In later editions of* [5] *Dirac did not make the point quite so baldly. I imagine he had been softened up by conversations with mathematicians, but his basic attitude remained unchanged.*

outset is a tactical error, like committing oneself to a specific coordinate system for describing phenomena on a manifold. If one is studying specific phenomena, one may wish to *represent* $\mathcal{H}$ (that is, to set up an isomorphism between $\mathcal{H}$ and a concrete Hilbert space) in a way that makes the analysis more transparent, but $\mathcal{H}$ itself is just what it is: the state space. (Even introducing the notation $\mathcal{H}$ for the set of state vectors reflects my bias toward the language of set theory; most physics books don't give it a name.)

In a similar vein, when asked to describe a Lie algebra, physicists will usually say something like "a set of generators $X_1, \dots, X_n$ that satisfy the Lie algebra $[X_i, X_j] = \sum_k c_{ij}^k X_k$". This seems decidedly off-key: the "generators" are what we would call basis elements, and the "Lie algebra" is what we would call the structure equations for the Lie algebra. But it makes sense when one realizes that it is meant as a description not of a set with some additional structure, as mathematicians would expect, but of an algebraic structure unattached to any particular set. Again, one can *represent* it by particular sets (of matrices, for example) if one wishes, but the essence of the structure is independent of such a representation.

There is also a sociological aspect to such dialectal differences. The phrase quoted in the preceding paragraph may prejudice a mathematical reader against the writer in the same way that the statement "I ain't workin' there no more" may lower the speaker in the estimation of one whose normal dialect is standard American English. I believe it works the other way, too: a definition such as "a set equipped with the structure of a vector space together with a bilinear product that is skew-symmetric and satisfies the Jacobi identity" might induce a sentiment in some readers that is the scientific equivalent of "Upper-class twit!" Needless to say, such instinctive responses are an impediment to effective communication.

It must be admitted that there are many situations in which the mathematicians' insistence that mathematical objects should be precisely defined as sets becomes a mere dogma rather than an aid to understanding what is going on. When we are working with the real numbers—solving calculus problems, say—it is rarely helpful to think of a number such as π as a subset of the rationals (the appropriate Dedekind cut) or an equivalence class of Cauchy sequences. Everything that we really need to know in order to use the real numbers is contained in the axioms for a complete ordered field, and the intuitive picture of numbers as points on a line suffices as a concrete model. In a similar vein, if we are thinking about points in the Cartesian plane, most of us would dismiss the assertion that $(1,3) \cap (3,1) = \{1,3\}$ as nonsense, although it is quite correct according to the standard definition of an ordered pair: $(a,b) = \{\{a\},\{a,b\}\}$. People from other disciplines are right to dismiss the invocation of formal set-theoretic definitions in such situations as an exotic tribal ritual with which they need not concern themselves.

On the other hand, scientists' willingness to mathematize on the formal level can sometimes lead them into very murky waters. Perhaps the most egregious examples at present come from quantum field theory. Sixty years after the development of quantum electrodynamics as a successful physical theory, a satisfactory mathematical model for the field operators on which it is based is still lacking, and the non-Abelian gauge field theories that complete the current "standard model" of the elementary particles are no better off. One can treat the much simpler theory of free (noninteracting) fields in a mathematically respectable way, although that is harder than one might expect—the fields are linear maps from the Schwartz space of rapidly decreasing smooth functions on $\mathbb{R}^4$ to the set of unbounded operators on a Hilbert space—but interacting fields in four-dimensional space-time remain in the realm of mathematical fiction. This does not stop the physicists from writing down symbols for them and performing formal calculations at great length to investigate their properties. There is also another approach to quantum field theory through certain "functional integrals" (integrals over infinite-dimensional spaces of classical fields), which also lack a mathematically respectable definition (so far), although they bear some kinship to genuine integrals that are familiar to probabilists. One of the Millennium Prize Problems is, in essence, to rectify this situation; see [10]. But, meanwhile, the mathematician who wants to learn more about elementary particle physics has a problem. My attempts in this direction were frustrated for many years by my getting stuck in the morass of ill-defined concepts, although eventually I found a way to pick out a path around the edges of the swamp. An account of the route can be found in [7].

Other forms of nonrigorousness may cause annoyance and frustration, but they are usually not so unnerving. The most common sort involves the use of informal reasoning that can be made airtight by any competent mathematician who wishes to take the trouble. Arguments involving infinitesimals in calculus are generally of this type, and the opprobrium with which they are regarded in some circles may fairly be regarded as a sort of mathematical prudery. More serious is the use of approximation procedures without proper mathematical justification—that is, without the derivation of error estimates that would guarantee that the claimed approximation is really good enough. But here the appliers of mathematics have a different criterion for success: they ask whether their approximated quantities are close not to some "true" mathematical quantity but to the real-world quantities that they are studying. If so, they are happy, and the approximation must be regarded simply as part of the model. In this connection one must keep reminding oneself that, in applied analysis, even on the fundamental level, approximations and simplifications are *always* part of the picture. Newton's laws of motion, for example, are valid only in inertial frames of reference, and the latter are mythical beasts if one insists on arbitrarily high precision. (A laboratory on the surface of the earth does not qualify because of the nonuniform motion of the planet on which it sits.)

Even pure mathematicians' standards of rigor are not as strict as popular belief would have it; logicians find our claims about insisting on formal proofs quite amusing. (The word "formal," by the way, is slippery. A "formal proof" is supposed to be logically sound, but a "formal calculation" may not be.) In particular, the language in which we couch our arguments has its share of idioms and peculiarities like any other language. Learning these idioms is part of becoming a mathematician, and an unfamiliarity with them is part of the reason why people in other disciplines have trouble. To introduce an example, let me give a quote from V. I. Arnold [1, p. 14]: "An author, claiming that A implies B, must say whether the inverse holds, otherwise the reader who is not spoiled by mathematical slang would understand the claim as 'A is equivalent to B.' If mathematicians do not follow this rule, they are wrong." Arnold may be overstating the case; perhaps the Russian word for "implies" has a slightly different flavor. (He is speaking, in English, about having a paper rejected by a Russian physics journal.) But the fact is that there is a situation in which mathematicians routinely say "if" when they mean "if and only if": in definitions. "A number is called *perfect* if it is the sum of its proper divisors," we say, and we expect the reader to understand that a number is *not* called perfect otherwise.

Another situation in which we commonly suppress part of an assertion is in implications involving variables. When we say

(*) If $x > 2$ then $x^2 > 4$,

we are not talking about a particular number x; the statement implicitly contains a universal quantifier "for all real numbers x". Such unspoken quantifiers generally remain in the background without giving any trouble, but they can cause confusion in interpreting statements like (*), and their ubiquity has even led some people who should know better [4, p. 29] to suggest that the words "if … then" are a way of expressing universal quantification. The way to force the universal quantifiers out of the shadows is to consider negations, for the resulting existential quantifiers cannot be elided: the negation of (*) is "There is an x such that $x > 2$ and $x^2 \leq 4$." (I could go on for pages about the perils of expressing quantifications, implications, and negations in ordinary language, but that is another essay.)

Every technical discipline has its own specialized vocabulary, but mathematical jargon is distinguished by its propensity for adopting common words as technical terms. Many people have observed that the discrepancies between common and technical usages of words such as "limit", "group", and "series" present an obstacle (not the only one) to students' mastery of mathematical terminology; see, for example, Boas [2], Edwards and Ward [6], and Hersh [9]. But they can also have unintended consequences for the perception of mathematics by the general public. On April 9, 1975, Congressman Robert Michel addressed the House of Representatives on the possible misuse of taxpayers' money by the National Science Foundation, and he cited several recently approved grants whose significance he found dubious. One of them was a grant for US$27,400 entitled "Studies in complex analysis".[3] To the mathematical reader this title seems innocuous enough, but Michel's reaction [3] was, "Well, for that amount of money I certainly hope it is complex. 'Simple analysis' would, hopefully, be cheaper."

Michel also cited a grant entitled "Measurement of the stratospheric distribution of the fluorocarbons and other constituents of interest in the effect of chlorine pollutants in the ozone layer". He said, "At least in that title there was one word I understood: constituents. And so the thought occurs to me, if one of my constituents should ask me my feelings about [this] project—which I implicitly approve when I vote the NSF appropriation—what in the world could I possibly say?"

Well, what can *I* possibly say? One might have hoped that Michel would have read about holes in the ozone layer in the newspaper. I suppose we should just be grateful that none of the NSF grants that year had to do with perverse sheaves. As far as I know, that unfortunate bit of whimsical nomenclature has not caused us any serious embarrassment yet, but if it does, I suggest that its perpetrators be sentenced to a year of hard labor teaching remedial algebra.

Goethe once quipped that "mathematicians are a sort of Frenchmen; they translate whatever you say into their own language, and forthwith it is something entirely different." At times we may have the same feeling about what others do with the things *we* say. The problems of communication can produce annoyance and frustration, but to an inquisitive mind they offer entertainment and illumination, too.

---

[3] *I was one of the junior investigators on it.*

References

[1] V. I. Arnold, From Hilbert's superposition problem to dynamical systems, in E. Bierstone et al. (eds.), *The Arnoldfest: Proceedings of a Conference in Honour of V. I. Arnold for his Sixtieth Birthday*, American Mathematical Society, Providence, RI, 1999, pp. 1–18.

[2] R. P. Boas, Can we make mathematics intelligible?, *Amer. Math. Monthly* **88** (1981), 727–731.

[3] *Congressional Record* **121** (1975), 9510.

[4] J. P. D'Angelo and D. B. West, *Mathematical Thinking: Problem Solving and Proofs* (2nd ed.), Prentice-Hall, Upper Saddle River, NJ, 2000.

[5] P. A. M. Dirac, *The Principles of Quantum Mechanics* (1st ed.), Oxford University Press, Oxford, U.K., 1930.

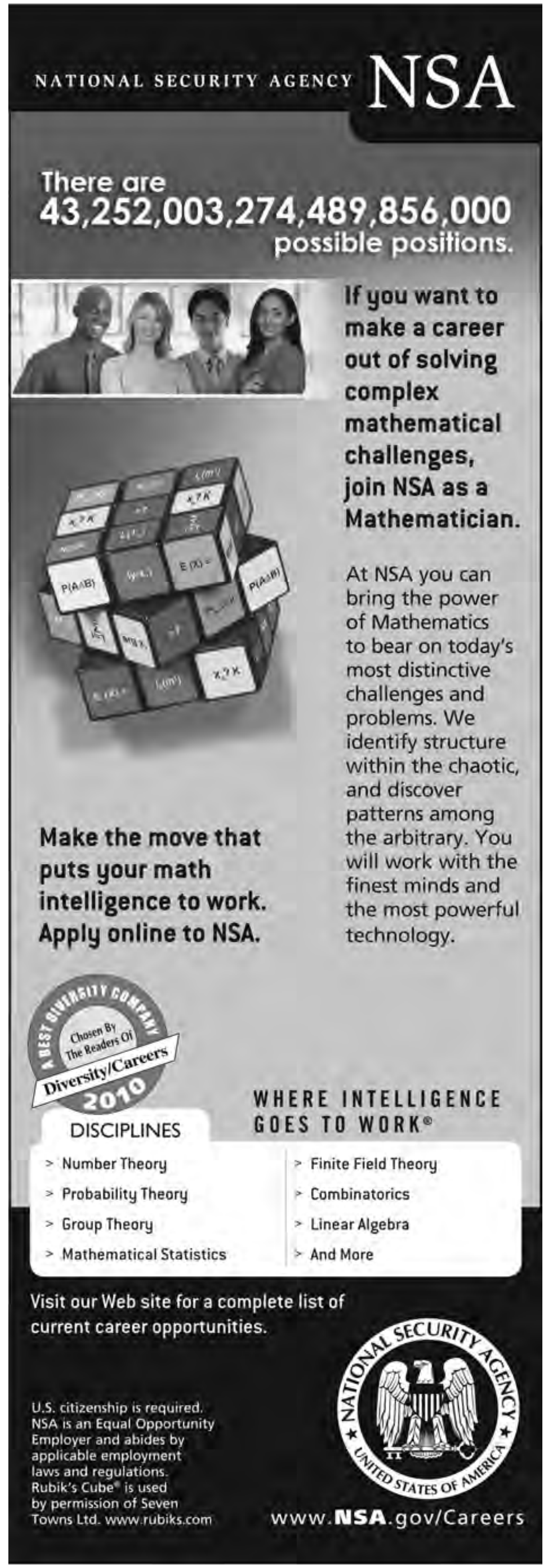
[6] B. S. Edwards and M. B. Ward, Surprises from mathematics education research: Student (mis)use of mathematical definitions, *Amer. Math. Monthly* **111** (2004), 411–424.

[7] G. B. Folland, *Quantum Field Theory: A Tourist Guide for Mathematicians*, American Mathematical Society, Providence, RI, 2008.

[8] G. H. Hardy, *A Mathematician's Apology*, Cambridge University Press, Cambridge, U.K., 1940.

[9] R. Hersh, Math lingo vs. plain English: Double entendre, *Amer. Math. Monthly* **104** (1997), 48–51.

[10] A. Jaffe and E. Witten, Quantum Yang-Mills theory, in *The Millennium Prize Problems*, J. Carlson, A. Jaffe, and A. Wiles (eds.), American Mathematical Society, Providence, RI, 2006, pp. 129–152.



WHAT IS...

a Linear Algebraic Group?

Skip Garibaldi

From a marketing perspective, algebraic groups are poorly named. They are not the groups you met as a student in abstract algebra, which I will call *concrete groups* for clarity. Rather, an algebraic group is the analogue in algebra of a topological group (from topology) or a Lie group (from analysis and geometry).

Algebraic groups provide a unifying language for apparently different results in algebra and number theory. This unification can not only simplify proofs, it can also suggest generalizations and bring new tools to bear, such as Galois cohomology, Steenrod operations in Chow theory, etc.

Definitions

A *linear algebraic group over a field F* is a smooth affine variety over F that is also a group, much like a topological group is a topological space that is also a group and a Lie group is a smooth manifold that is also a group. (For nonexperts: it is useful to think of an affine variety G as a natural assignment—i.e., a functor—that takes any field extension K of F and gives the set $G(K)$ of common solutions over K of some fixed family of polynomials with coefficients in F.)

Properly speaking, for each of the three types of groups in the previous paragraph, one needs to require that the group operations are morphisms in the appropriate category, so, e.g., for a topological group G, the multiplication $G \times G \to G$ and inversion $G \to G$ are required to be continuous. In more categorical language, a linear algebraic group over F, a Lie group, or a topological group is a "group object" in the category of affine varieties over F, smooth manifolds, or topological spaces, respectively. For algebraic groups, this implies that the set $G(K)$ is a concrete group for each field K containing F.

Examples

The basic example is the general linear group GL_n for which $\mathrm{GL}_n(K)$ is the concrete group of invertible n-by-n matrices with entries in K. It is the collection of solutions (t, X)—with $t \in K$ and X an n-by-n matrix over K—to the polynomial equation $t \cdot \det X = 1$. Similar reasoning shows that familiar matrix groups such as SL_n, orthogonal groups, and symplectic groups can be viewed as linear algebraic groups. The main difference here is that instead of viewing them as collections of matrices over F, we view them as collections of matrices over every extension K of F.

Roughly, the theory of linear algebraic groups generalizes that of linear Lie groups over the real or complex numbers to give something that makes sense over an arbitrary field. The category of linear algebraic groups over $\mathbb{R}$ contains a full subcategory equivalent to the compact Lie groups; see [3, §5]. And the parameterization of the irreducible finite-dimensional representations of a complex reductive Lie group in terms of dominant weights holds more generally for so-called "split reductive" groups over any field.

Algebraic groups allow one to deal systematically with familiar matrix groups and their generalizations in a way that works over arbitrary fields, whether they are the rationals for number theory, finite fields for finite group theory, or the real or complex numbers for geometry. This is not just a language. There is enough theory available that one can often avoid computing with actual

---

Skip Garibaldi is Winship Professor of Mathematics at Emory University. His email address is skip@member.ams.org.

The author thanks B. Conrad, G. McNinch, R. Parimala, G. Prasad, and J.-P. Serre for their valuable suggestions.

matrices, or at least with matrices larger than 2-by-2!

Local-Global Principles

Quadratic forms and division algebras over a global field[1] F are determined by their properties at the completions F_v of F; this is roughly the content of the Hasse-Minkowski theorem and the Albert-Brauer-Hasse-Noether theorem, respectively. These theorems can be viewed as saying that the natural map

$$(*) \qquad H^1(F, G) \to \prod_{\text{places } v \text{ of } F} H^1(F_v, G)$$

in Galois cohomology is injective, where G is an orthogonal group or PGL_n. This reformulation of the problem in terms of algebraic groups has two advantages. First, we see that the two theorems are two faces of the same phenomenon, and second, we get a natural general question: *For which linear algebraic groups G is $(*)$ injective for every global field F?* The Hasse principle (proved by Kneser, Harder, and Chernousov) says that $(*)$ is injective if G is connected and absolutely simple. (A linear algebraic group is *absolutely simple* if, when viewed as an algebraic group over an algebraic closure of F, it is not commutative and does not contain any proper, connected, and normal algebraic subgroups besides the identity.) This broadly generalizes the two results mentioned at the start of the paragraph.

If we weaken our request that $(*)$ be injective, we arrive at a substantial result due to Borel and Serre (early 1960s) that $(*)$ has finite kernel for every linear algebraic group G in the case in which F is a number field. This result has recently been extended to global fields of prime characteristic by Brian Conrad. Because these latter fields are not perfect, this extension relies on the classification of "pseudo-reductive" linear algebraic groups recently completed by Conrad, Ofer Gabber, and Gopal Prasad.

Another way to generalize the local-global question is to weaken the hypotheses on F, for example, to assume that F has cohomological dimension at most 2, which holds for totally imaginary number fields and $\mathbb{C}(x, y)$. For such fields and G simply connected, Serre's "Conjecture II" (1962) asserts that $H^1(F, G)$ is zero. This is known to hold if F is the function field of a complex surface (de Jong, He, and Starr, 2008) or G is a classical group (Bayer and Parimala, 1995). There are many other results on this conjecture and generalizations such as the Hasse principle conjecture II; Google can provide details.

[1] *A* global field *is a finite extension of $\mathbb{Q}$ or $k(t)$ for k a finite field.*

Group Theory

In the list of finite simple (concrete) groups, most are *of Lie type*. That is, take a linear algebraic group G that is absolutely simple, simply connected, and defined over a finite field F that is not very small. Then the concrete group $G(F)$ modulo its center is finite and simple. This is helpful because one can use the general framework of algebraic groups to prove theorems about these finite groups. One example of this is Deligne-Lusztig theory, which is the most effective approach to the complex representations of the finite groups of Lie type.

The construction of simple concrete groups in the previous paragraph works for many algebraic groups G and many fields F, not just for finite fields. But for precisely which G does it work? The *Kneser-Tits problem* (1964) asks: *Let G be a linear algebraic group that is simply connected, is absolutely simple, and contains* GL_1*. Is $G(F)$ modulo its center simple?* Much like the Hasse principle discussed above, Kneser-Tits is a generalization in terms of algebraic groups of earlier problems—such as the Tannaka-Artin problem—regarding more classical algebraic structures.

The answer to Kneser-Tits seems to depend on the arithmetic complexity of the field F. The answer can be "no" for fields of dimension at least 4 (Platonov, 1975).

In contrast, the answer is "yes" for global fields, which "are 2-dimensional". This was an open question for some time, until Philippe Gille settled the last remaining case in 2007 by discovering the following interesting criterion that works over every field F: for a group G as in Kneser-Tits, the concrete group $G(F)$ modulo its center is simple (a purely algebraic criterion) if and only if the variety G is, roughly speaking, "path connected" (a purely geometric criterion). See [1] for details.

We still don't know the answer to Kneser-Tits for other fields of dimension 2 and don't even have strong indications of what the answer should be for dimension 3.

In closing, I urge you: Please do not be misled by the short list of topics in this article. There are many other areas of mathematics in which algebraic groups play an essential role, such as the Langlands program, geometric invariant theory and Schubert varieties in algebraic geometry, Tits's theory of buildings... Algebraic groups deserve more attention.

References

[1] P. Gille, Le problème de Kneser-Tits, *Astérisque* **326** (2009), 39–82.

[2] V. P. Platonov and A. Rapinchuk, *Algebraic Groups and Number Theory*, Academic Press, Boston, 1994.

[3] J.-P. Serre, Gèbres, *L'Enseignement Math.* **39** (1993), 33–85. (Reprinted in *Oeuvres*, vol. IV, pp. 272–324.)

The Doctor Is In

Robert Borrelli

Until the late nineteenth century, mathematics was regarded as part of science and not as a separate discipline. Indeed, people such as Newton, Gauss, and Poincaré were comfortable in using high-level mathematics to explain phenomena in science. But eventually mathematics began to develop with little regard for applications, and departments of mathematics were founded at universities throughout the world. Mathematics returned to more practical concerns in the 1970s when traditional academic jobs in mathematics declined precipitously and math grads turned more and more toward jobs in industry.

Mathematicians in industry need skills different from those encountered in academia. Indeed, mathematicians in industry

- rarely choose their own problems to work on and are often not experts in problems they are assigned;
- almost always work in teams with engineers and scientists not of their own choosing, and must communicate across technical boundaries;
- are expected to take poorly defined problems and make sense out of them; and
- never have the luxury of unlimited time to work on a problem because projects in industry always have deadlines.

In 1973 the Mathematics Department at Harvey Mudd College (HMC) started an academic program to address the needs of industry-bound math grads. Its name, *Mathematics Clinic*, was borrowed from the HMC Engineering Department, which in the early 1960s created a program they called the *Engineering Clinic*. The name was chosen because they imagined it to be like the one in which medical interns get practice treating patients in a controlled and supervised environment. Although the word "clinic" has a remedial connotation, our *Clinic* program solicits real-world open-ended problems (called projects) from industrial concerns or government agencies that require hands-on teamwork by faculty and students over an academic year. Projects are tasks that require modeling, analysis, and validation and that offer significant educational value to students. Projects are assigned to a faculty member and a team of three or four students. Students do the work; the faculty member acts as an advisor. The "sponsor" is the industrial organization for whom we are consulting. A sponsor representative acts as liaison to the team. A team member acts as the project manager, who gives regular written and oral reports to the sponsor liaison. All *Clinic* project work takes place on campus, but sometimes the team travels to visit the sponsor.

In 1974 the Claremont Graduate University (CGU) established a *Mathematics Clinic* program, and these two Claremont Clinic programs cooperate in many ways for the benefit of all students in the Claremont Consortium. In the late 1970s the *Mathematics Clinics* were awarded a three-year NSF grant to train twelve postdocs to do *Clinic* projects; they all found jobs at year's end. Over two years in the mid-1980s, the Sloan Foundation supported eleven liberal arts math professors for a year-long *Math Clinic* experience. Currently, the norm is four projects per year at HMC and two projects per year at CGU. Since my knowledge concerns HMC *Clinic* operations, I will describe that program; CGU's program is similar.

Because "interns" in a *Math Clinic* project are undergrads, work is spread over an academic year—giving students time to learn the material required for their problem. Every *Clinic* project is a course, so students earn academic credit (but no pay), and the faculty advisor receives release time. HMC math students are required to do a capstone course of either a *Math Clinic* project or a senior

Robert Borrelli is emeritus professor of mathematics at Harvey Mudd College. His email address is `borelli@hmc.edu`.

thesis. Often students from other majors join *Math Clinic* teams. Because *Clinic* projects are such low-enrollment courses, the sponsor is required to pay a substantial fee (currently a standard $45K per project), and all rights to the project's results are assigned to the sponsor. The college receives 33% overhead per project to cover some college overhead costs and some faculty release time. Otherwise, the *Clinic* must cover its own expenses.

The *Clinic* is staffed part-time with a director, an administrative assistant, and a computer systems administrator. Operation of the program is aided by

- a detailed *Mathematics Clinic Handbook* for all participants;
- a carefully written and signed *Letter of Understanding*, which describes the project in enough detail to determine when it is completed (i.e., a "stopping rule");
- a signed *Confidentiality Agreement* to protect both the sponsor and the college;
- a *Clinic Advisory Committee* composed of representatives from industry, the *Clinic* directors, and the Director of Corporate Relations. This committee advises the directors on the operation of the *Clinic* program and, most importantly, aids the directors and the HMC Advancement Office in recruiting suitable projects.

Projects selected for the *Clinic* program must be educationally valuable to mathematics students; must not be of urgent value to the sponsor; must meet a reasonable prediction of success; and must be such that the sponsor can allocate a few hours per week for liaison time. Projects must also fit the time and resource constraints of an academic year. Prospective sponsors are asked to submit a list of three rank-ordered possible projects that they would support. The *Clinic* director and faculty make the final selection of projects using the criteria above. The *Clinic* always avoids half-year projects and is careful about accepting a software project that involves rewriting someone else's software code.

An organizational meeting at the beginning of the school year allows sponsors to present their projects so that students can see what mathematics is involved (statistics, operations research, computing, differential equations, etc.). Afterward, students express preferences before being assigned to particular projects. Each team reviews its work schedule often in order to finish the project by the academic year's end. *Clinic* teams must present weekly progress reports.

Clinic projects fall roughly into the categories listed below (along with examples):

- Algorithm Development
  - **Fair, Isaac** (Rule-based neural nets)
  - **Aerojet** (Multiple hypothesis testing)
- Optimal Design
  - **Teledyne** (Design of a hybrid microprocessor)
  - **AlliedSignal** (Design of a turbocharger blade)
- Modeling/Optimization
  - **B2 Division Northrop** (Maximization of EM energy absorption)
  - **Chevron** (Prediction of abnormally high underground water pressures)
- Smart Software
  - **Jet Propulsion Laboratory** (Formal verification methods based on math logic)
  - **Texas Instruments** (Synthetic Speech Listener)
- Software Design
  - **Bank of America** (Design of contact-sensitive GUI components)
  - **CODEE Consortium** (Design of a Java version of an ODE solver)

The *Clinic* director passes along this advice to faculty advisors:

- be professional in all relations with the sponsor;
- don't expect the sponsor to always follow your advice;
- be aware of the realities of student commitments;
- be careful to adhere to the Confidentiality Policy; and
- expect to have personnel problems (it happens in industry, too).

Clinic projects benefit sponsors in many ways. The *Clinic* can be regarded as an extension of in-house R & D at a much more reasonable cost. *Clinic* work provides the sponsor's staff contact with academic applied mathematicians (resulting sometimes in consulting opportunities). Teams have access to all library facilities and all computer facilities at HMC. And last but not least, the *Clinic* provides sponsors with a chance to see how possible employees might perform on the job.

The *Clinic* also benefits students in many ways. For example, students learn valuable techniques they may not have seen in a course and learn how to work together in teams to accomplish a common objective. Students learn how to work under time and resource constraints and how to set realistic schedules. They also learn how to write clear and concise technical reports and how to give professional-level talks and briefings. By planning day-to-day activities for the team, project managers gain valuable management experience.

Students often receive job offers from the sponsor at the project's conclusion.

The academic year ends with all the forty or so Mathematics and Engineering Clinics projects presenting their results at a professional-level meeting called Projects Day. Projects Day attracts some 400 people and presents a great opportunity to recruit projects for the following year.

To create a viable *Clinic* program, these questions must be answered:

- What makes a good *Clinic* project?
- How well can undergrads handle open-ended projects?
- What exactly is the role of the faculty advisor?
- How are faculty advisors recruited?
- How are sponsors recruited?

Several indicators show that HMC has successfully answered these questions: To date (1973 –2010), the HMC *Mathematics Clinic* has had 130 projects from 58 sponsors involving 553 students. A large number of sponsors return year after year, and the Math Clinic has inspired other institutions to create similar programs, among them San Jose State University, the University of South Australia, and the Institute for Pure and Applied Mathematics (IPAM) at UCLA.

For detailed project abstracts and other information about the HMC *Math Clinic* program, visit `http://www.math.hmc.edu/clinic`. For further information contact the HMC *Math Clinic* director, Susan Martonosi, at `martonosi@math.hmc.edu` (or at CGU contact Ellis Cumberbatch at `ellis.cumberbatch@cgu.edu`). Institutions wanting to start a *Clinic* program are invited to contact either *Math Clinic* director for advice. Of course the best introduction is for an interested faculty member to go through a complete *Clinic* cycle while on sabbatical leave for a year!

Book Review

The Cult of Statistical Significance

Reviewed by Olle Häggström

The Cult of Statistical Significance: How the Standard Error Costs Us Jobs, Justice, and Lives
S.T. Ziliak and D. McCloskey
University of Michigan Press, 2008
US$26.95, 352 pages
ISBN-13: 978-0472050079

There are excellent evolutionary reasons why we humans have far-reaching abilities to observe the world around us and to draw sensible conclusions about it. But evolution is very far from a perfect optimization algorithm, so it should come as no surprise that our cognitive capacities, too, are far from perfect. One example is our strong tendency to deduce patterns from meaningless noise. Another is our inclination toward overconfidence in our conclusions, as evidenced by studies showing how in certain kinds of situations we are wrong about 40 percent of the time about conclusions we claim to be 98 percent sure about [AR].

The scientific method can be seen as an organized attempt to overcome such "bugs" in our search for accurate knowledge about the world around us. One ingredient, which during the course of the twentieth century has permeated all of science to the extent that it is nowadays recognized as indispensable, is mathematical statistics, which helps researchers distinguish between pattern and noise and to quantify how much confidence in our conclusions the data warrant.

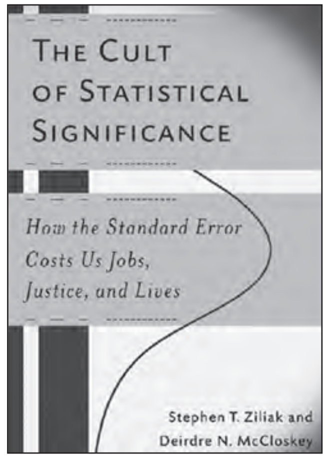
There can hardly be any doubt that this development has been of immense benefit to science. All the more interesting, then, that two prominent economists, Stephen Ziliak and Deirdre McCloskey, claim in their recent book *The Cult of Statistical Significance* [ZM] that the reliance on statistical methods has gone too far and turned into a ritual and an obstacle to scientific progress.

A typical situation is the following. A scientist formulates a *null hypothesis*. By means of a *significance test*, she tries to falsify it. The analysis leads

Olle Häggström is professor of mathematical statistics at Chalmers University of Technology in Gothenburg, Sweden. His email address is `olleh@chalmers.se`.

to a *p-value*, which indicates how likely it would have been, if the null hypothesis were true, to obtain data at least as extreme as those she actually got. If the *p-value* is below a certain prespecified threshold (typically 0.01 or 0.05), the result is deemed *statistically significant*, which, although far from constituting a definite disproof of the null hypothesis, counts as evidence against it.

Imagine now that a new drug for reducing blood pressure is being tested and that the fact of the matter is that the drug does have a positive effect (as compared with a placebo) but that the effect is so small that it is of no practical relevance to the patient's health or well-being. If the study involves sufficiently many patients, the effect will nevertheless with high probability be detected, and the study will yield statistical significance. The lesson to learn from this is that in a medical study, statistical significance is not enough—the detected effect also needs to be large enough to be *medically significant*. Likewise, empirical studies in economics (or psychology, geology, etc.) need to consider not only statistical significance but also economic (psychological, geological, etc.) significance.



A major point in *The Cult of Statistical Significance* is the observation that many researchers are so obsessed with statistical significance that they neglect to ask themselves whether the detected discrepancies are large enough to be of any subject-matter significance. Ziliak and McCloskey call this neglect *sizeless science*. They exemplify and discuss instances of sizeless science in, among other disciplines, medicine and psychology, but for obvious reasons they focus most of their attention on economics. In one study, they have gone over all of the 369 papers published in the prestigious journal *American Economic Review* during the 1980s and 1990s that involve regression analysis. In the 1980s, 70 percent of the studied papers committed sizeless science, and in the 1990s this alarming figure had increased to a stunning 79 percent. A number of other kinds of misuse of statistics are considered in the same study, with mostly equally depressing results.

One particular error, which every teacher of mathematical statistics is painfully familiar with, is to conflate the probability of the observed data given the null hypothesis with the probability of the null hypothesis given the data (the latter cannot, of course, be obtained unless we resort to Bayesian statistics, a framework that is still rare in the fields under study). This error, known as the fallacy of the transposed conditional, is discussed in the book but does not appear as a separate item in the *American Economic Review* literature study.

The Cult of Statistical Significance is written in an entertaining and polemical style. Sometimes the authors push their position a bit far, such as when they ask themselves: "If null-hypothesis significance testing is as idiotic as we and its other critics have so long believed, how on earth has it survived?" (p. 240). Granted, the single-minded focus on statistical significance that they label sizeless science is bad practice. Still, to throw out the use of significance tests would be a mistake, considering how often it is a crucial tool for concluding with confidence that what we see really is a pattern, as opposed to just noise. For a data set to provide reasonable evidence of an important deviation from the null hypothesis, we typically need *both* statistical *and* subject-matter significance.

The book also offers a short history of the significance test. Here Ziliak and McCloskey take their polemical style to even further heights in their portrayal of William Gossett (inventor of Student's t-test, the most widely used of all significance tests) as a hero and an angel and of Ronald Fisher (the father of modern mathematical statistics, who arguably did more than anyone else to give significance testing the central role it has today) as pretty much the devil himself. For instance, they make no attempt at concealing their schadenfreude when quoting what Robert Oppenheimer (allegedly) had said upon Fisher's arrival in Berkeley in 1936: "I took one look at him and decided I did not want to meet him" (p. 222).

To sum up, if statistical practice in the empirical sciences is as bad as the authors say, what should be done? No easy fix is offered, but they do advocate a larger degree of pluralism among statistical methods. Here, one would have liked to see them address the danger that this might lead to an increase in a particular kind of misuse of statistics: to tune the choice of statistical approach to the particular data that were obtained. Many of the authors' comments seem to imply a commitment to the Bayesian paradigm, but it is not clear whether they are really aware of this. In any case they never explicitly step out of the Bayesian closet.

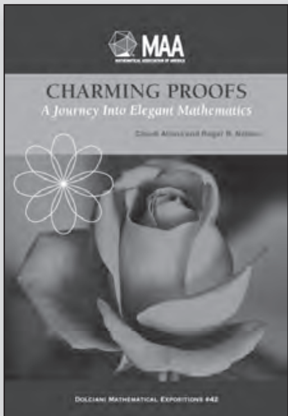
References

[AR] M. Alpert and H. Raiffa, A progress report on the training of probability assessors, *Judgment under Uncertainty: Heuristics and Biases* (D. Kahneman, P. Slovic, and A. Tversky, eds.), Cambridge University Press, 1982.

[ZM] S. T. Ziliak and D. McCloskey, *The Cult of Statistical Significance: How the Standard Error Costs Us Jobs, Justice, and Lives*, The University of Michigan Press, Ann Arbor, MI, 2008.

Two New Books From the Mathematical Association of America

MAA
MATHEMATICAL ASSOCIATION OF AMERICA



Catalog Code: DOL-42
328 pp., Hardbound 2010
ISBN 9780-88385-348-1
List: $59.95
MAA Member: $49.95

Charming Proofs
A Journey into Elegant Mathematics

Claudi Alsina and Roger Nelsen

Theorems and their proofs lie at the heart of mathematics. In speaking of the purely aesthetic qualities of theorems and proofs, G. H. Hardy wrote that in beautiful proofs "there is a very high degree of **unexpectedness**, combined with **inevitability and economy**." ***Charming Proofs*** present a collection of remarkable proofs in elementary mathematics that are exceptionally elegant, full of ingenuity, and succinct. By means of a surprising argument or a powerful visual representation, the proofs in this collection will invite readers to enjoy the beauty of mathematics, to share their discoveries with others, and to become involved in the process of creating new proofs.

Charming Proofs is organized as follows. Following a short introduction about proofs and the process of creating proofs, the authors present, in 12 chapters, a wide and varied selection of proofs they consider charming, Topics include the integers, selected real numbers, points in the plane, triangles, squares, and other polygons, curves, inequalities, plane tilings, origami, colorful proofs, three-dimensional geometry, etc. At the end of each chapter are some challenges that will draw the reader into the process of creating charming proofs. There are over 130 such challenges.

Catalog Code: ICA
336 pp., Hardbound, 2010
ISBN 978-0-88385-764-9
List: $63.95
MAA Member: $50.95

Invitation to Complex Analysis | Second Edition

Ralph P. Boas | Second Edition revised by Harold P. Boas

Written in an informal style by a master expositor, the book distills more than half a century of experience with the subject into a lucid, engaging, yet rigorous account. The book reveals both the power of complex analysis as a tool for applications and the intrinsic beauty of the subject as a fundamental part of pure mathematics.

Written at the level of courses commonly taught in American universities to seniors and beginning graduate students, the book is suitable for readers acquainted with advanced calculus or introductory real analysis. The treatment goes beyond the standard material of power series, Cauchy's theorem, residues, conformal mapping, and harmonic functions by including accessible discussions of many intriguing topics that are uncommon in a book at this level. Readers will encounter notions ranging from Landau's notation to overconvergent series to the Phragmén-Lindelöf theorem. The flexibility afforded by the supplementary topics and applications makes the book adaptable either to a short, one-term course or to a comprehensive, full-year course.

The writing is user-friendly in many ways. Each topic is discussed in a typical, commonly encountered situation rather than in the most general, abstract setting. There are no numbered equations. Numerous exercises interspersed in the text encourage readers to test their understanding of new concepts and techniques as they are presented. Detailed solutions of the exercises, included at the back of the book, both serve as models for students and facilitate independent study. Supplementary exercises at the ends of sections, not solved in the book, provide an additional teaching tool.

To order
or to inquire about examination copies: Call **1-800-331-1622**.
These books are available at **www.maa.org**, and through Amazon.com.

Meta-Morphism: From Graduate Student to Networked Mathematician

Andrew Schultz

While the stereotypical mathematician is a hermit locked alone in his office, the typical mathematician is far from a solitary explorer. A great amount of the mathematics produced today is created collaboratively, spurred into existence during those quintessentially mathematical social interactions: on chalkboards following a seminar talk, on napkins during a coffee break at a conference, on the back of a coaster at a pub. Though it often isn't clear to those wading through graduate programs, one of the key metamathematical skills one should develop while working on a master's or Ph.D. is the ability to participate in this social network. What follows is a rough guide to how you can use graduate school to build the professional relationships that will shape your career.

The Hungry Caterpillar

Stepping into the mathematical social network begins by getting to know your graduate student cohort. It's likely that some of the friendships you form during graduate school will be among the closest in your life, and even those fellow students who aren't your best friends are likely to be professional colleagues long after you've received your degree. It's worth the investment of time and energy to foster these relationships as your first semester begins.

When arriving on campus to start your graduate career, you'll likely convene with the new graduate students in your department and a handful of the faculty for a kind of informal orientation. Ph.D. programs often draw students from a wide variety of backgrounds, so don't be surprised to find people whose professional experience, familial status, or country of origin doesn't match your own. Despite any differences you might notice at first, this group has a common bond with you that you've probably never experienced: shared professional passion and the dedication to pursue an advanced degree over the course of several years. Use this commonality to bridge social or cultural gaps that your classmates might settle into upon arrival. Fortunately your busy class schedule will leave you with plenty of excuses for convening *en masse*: to tackle lengthy homework assignments, to review topics covered in class, to prepare for qualifying exams. As you work toward your degree, you will rely on the various skills and perspectives that your fellow classmates can offer, so it is in your best interest to meet and spend some time with as many in your incoming class as possible. As you progress through the program, you might be surprised to find your ideal study partner, your favorite office mates, and your mathematical siblings aren't the people you might have guessed when you first arrived.

Although mathematics and the novelty of graduate school are convenient starting points for meeting other incoming graduate students, don't rely on math to be the only tie that binds you: meet people for pizza at the end of a long week; organize a hike at a local nature preserve; or set up an informal, weekly grad student happy hour. Chances are good that graduate students who are further along in the program will be organizing various social events to which you'll be invited, and these will provide you with a good opportunity for meeting people whose experience can be of great benefit to you, both within the program and in your extra-mathematical life. Again, it is

Andrew Schultz is assistant professor of mathematics at Wellesley College. His email address is `andrew.c.schultz@gmail.com`.

to your benefit to meet as many of the graduate students in your department as possible, so band together with a few first-year students and jump into this wider social pool. This larger community will also give you a chance to find people whose nonacademic interests match your own, and your department's graduate student email list can be a boon for collecting people together to join in your favorite sport, play your favorite game, or take in a local theatrical performance. You can also consider broadening your social circle outside the math department by looking for university-wide student groups organized around your particular interests; being a mathematician certainly doesn't oblige you to spend time only with other mathematicians, and the break from an otherwise mathematically centered life could be a welcome respite.

Once you've established yourself among the graduate students, you'll next want to get to know your local faculty. Departments typically have a number of social activities planned through the course of the year, from annual get-togethers like a fall barbecue to weekly afternoon tea breaks. These give you a good opportunity for interacting with faculty members outside of the classroom, and you should take advantage of this opportunity. Chat with your algebra professor about where the course is going, talk to your analysis professor about the REU project you worked on, or try to find some nonmathematical interests you share with other faculty. These conversations will give you an indication of which professors you most easily relate to, and this is an important factor to keep in consideration when choosing your thesis adviser. If you don't give yourself the chance to interact with a faculty member who is a candidate for becoming your Ph.D. supervisor, you might find yourself spending an hour each week with someone you can't talk to. Also, when considering a candidate for your supervisor, you will want to take advantage of the connections you've made with older graduate students by asking them about experiences they may have had in working with this person; for obvious reasons, it is particularly helpful if you can get an honest assessment from a current advisee.

Pupal Growth

Once you've gotten through your first year of graduate school, you are likely to have gravitated toward one research group or another within your department, and it's important that you become an active part of this community. Some of this will happen in the traditional classroom, where you already know the rules of engagement, though seminars will play an increasingly important role as you develop as a mathematician. Generally speaking, a seminar talk is a fifty-minute presentation to mathematicians in a specific discipline about recent developments in their field; often, but not always, the speaker at a seminar will be visiting from another mathematics department.

Once you've decided on your dissertation topic, you should start attending local seminars in your research area. Before attending, though, you'll need to adjust your expectations from those you have of a typical class. Seminar speakers have a limited time in which to introduce their topics, discuss connections to larger problems in the area, and then present specific results. Since the target audience is almost always specialists in the field, speakers often don't spend time bringing nonspecialists up to speed. As a graduate student who might have limited background in the discipline, you could very well find that many (if not all) of the seminars you attend are mostly incomprehensible to you. Not only is this okay, but it's the experience of nearly every graduate student who attends a seminar; it's hard to drink from a fire hose. Don't let this discourage you from attending future seminars, and don't turn the seminar into your personal fifty-minute nap session.

Your job when attending seminars is to focus on understanding as much of the talk as you can. Bring along a notepad and write down any questions you think of. Don't expect that your questions will sound as fancy as those being asked by the senior faculty member you're sitting next to; you're just starting in the area, and you're not expected to be making esoteric connections. Instead, bullet point the big ideas of the talk: what were the basic objects under investigation? What qualitative information did the stated theorems give about these objects? How do the stated theorems depend on or diverge from each other? When the talk is over, you should feel free to participate in the question-and-answer session even if your questions don't sound as sophisticated as others. Afterward you should certainly speak with an experienced faculty member—if at all possible, the seminar speaker—about some of the questions you had. This adds an additional ten minutes to your seminar experience but can put the fifty minutes you've already invested into perspective. What's more, by attending seminars you'll be training yourself to learn mathematics in an important way: contrary to the foundation-building, semester-long methodology used in teaching known mathematics, this result-focused, hour-long seminar approach is how you're most likely to hear about (and personally disseminate) new developments in your area for the rest of your career. For this reason, it's important to keep attending seminars even if you feel as though you're not understanding all of the talks. Each additional seminar will fill out your understanding of the discipline as a whole, and soon you'll find that a talk you've just attended reminds you of another talk you heard two months before; you'll be weaving your own mathematical tapestry.

The other benefit of attending seminars is that they are occasionally preceded by a seminar lunch or followed by a seminar dinner. Graduate students are always encouraged to attend these informal gatherings, and oftentimes their meals are subsidized. What graduate student doesn't like a cheap meal? These get-togethers are a golden opportunity to interact with faculty members outside of your department (think "future postdoc mentors", "future coauthors", etc.), so you should make a regular habit of attending. Striking up conversations in these settings is usually very easy. Questions like "Where did you attend graduate school?" and "What made you start researching…?" seem obvious, but they are great places to begin. As always, don't feel obliged to stay within the bounds of mathematics when making conversation; after a long day of focusing on work, a nonmathematical topic of conversation could be a welcome change. Without prying or excluding others from the conversation, explore connections that you might have: perhaps the speaker hails from somewhere you've been meaning to visit, or one of your undergraduate professors went to the speaker's graduate school. Remember that these meals are meant to be fun; relax, be yourself, and make a good-faith effort at participating in the conversation.

The Emerging Butterfly

As you progress in your graduate career, you'll likely have the opportunity to speak about mathematics to an audience of mathematicians, either on your own work or on some theory you've been studying for your dissertation. If you are offered such an opportunity, take advantage of it. One doesn't develop the ability to give an interesting mathematics talk without experience, and you'll want to give yourself as many opportunities as possible to hone this critically important craft.

There are a number of excellent guides for how you can give a good mathematics talk (see [1, 2, 3, 4], or talk to someone whose presentation style you admire), but don't forget the interpersonal component of talking to an audience. Do the basics well: make eye contact regularly, gauge the audience's understanding and make necessary adjustments. The audience will sense and respond to your attitude, so you can help encourage an enthusiastic response by projecting your own interest when describing your results. Along these same lines, avoid self-deprecating humor and resist the urge to downplay the importance of your results because they don't seem as profound as topics you might have heard while attending past seminars. The increased accessibility you detect in your talk comes from the fact that you have spent a lot of time developing the mathematics which bolsters it, and most of your audience won't have the benefit of this prolonged exposure to your topic. In other words: what seems obvious to you is often not immediately obvious to those in attendance. Help the audience follow your talk by providing them with interpretations of the results you present, such as how a certain lemma will be used in developing a later theory, or why a particular result is connected to previous work in the area.

Don't feel that you need to give your first talk in a research seminar filled with faculty. Instead, see if the graduate students in your department have a student-run, general-interest seminar that you can speak in. If no such seminar exists, take the lead and start one. Graduate-student colloquia can be a tremendous opportunity for you and your cohort to sharpen a critical professional skill in a low-stakes, friendly environment, and your department will be stronger for the introduction of such a seminar. Approach your department chair or the director of your graduate program and see if you can get some nominal funding to support the seminar, and use the money to entice student attendance with that siren song of graduate life: free food. Presenting in such a seminar will force you to boil your technical results down into an understandable form, and you'll reap the benefits of seeing how your classmates perform this same reduction. As you go on to present in seminars with faculty attendees or with a more specialized focus, you'll rely on this same skill (though you'll need to adjust the parameters of "understandable" depending on your target audience). Even if you don't plan to keep research as an active part of your professional life after you finish graduate school, this skill remains applicable for the many times you have to talk about mathematics to nonmathematicians: when explaining the importance of a subject to a class of undergraduates, or when justifying some mathematical program to administrators at your college.

After you've had a chance to present work locally, you'll want to take advantage of any opportunities which arise for presenting talks at nearby meetings or at far-flung conferences. There is often support for graduate student travel, either from your department or the conference's organizing body, so don't assume that an empty bank account will prevent you from participating. Occasionally you can also receive support even when you aren't presenting at a given conference, or you might have the opportunity to attend a conference which won't require outside support (if it's at a local university, say). If you are given financial backing, or if the out-of-pocket expenses are manageable, it's always a good idea to attend conferences which cover mathematics of interest to you when you have the opportunity. Don't feel obliged to limit your participation to conferences organized around your specific research area; your mathematical interests are likely varied, and your professional life will be richer by fostering this breadth.

Once you've arrived at a conference, don't forget that there's more to do than simply attend talks (or deliver your own). Conferences represent an opportunity to further your social sphere and make contacts with some of the movers and shakers in your field, or at least a handful of mathematicians who are a bit further along in their mathematical careers than you. This will likely be the first time in a while that you've felt like you truly know no one around, but don't let that be an excuse for making a quick retreat to your room at the end of each talk. Don't be shy about introducing yourself to people during coffee breaks or in the ten-minute pauses between talks or presentations. Again, basic introductions can take you very far, so feel free to start with your name and institution and see where things go. At the beginning of a conference, you can always ask if the person will be presenting later in the week; if you've already seen their talk, you can ask them something you didn't get a chance to ask during the question-and-answer period (you're still writing questions down during talks, right?). Take advantage of this opportunity to establish yourself as an inquisitive, approachable person to a large group of people outside your home institution.

Life as a Pollinator

Life as a professional mathematician requires participation in a social network, and graduate school represents an ideal setting for you to gradually develop the skills and connections which will help you thrive in this web: first with your classmates, then local faculty, and later with the wide mathematical world. Regardless of where you end up after graduate school, continue to take advantage of the opportunities you have to further your own connections, and do your part to help budding mathematicians at your institution join this network: foster their interest in exploring and presenting their own mathematical questions, encourage their attendance in colloquia or seminars (or help organize a student-targeted colloquium), and convince your department to set aside funds so they can attend conferences to meet other mathematicians. By placing value on the interpersonal aspects of practicing math, we ultimately increase the quality of mathematical content and discourse for those we seek to serve: our institutions, our students, our colleagues, and ourselves.

Acknowledgments

Thanks to Anne Brubaker and the referees of this article for carefully reading through drafts and making helpful suggestions. Thanks to Ravi Vakil for teaching me to get the most out of seminars and conferences, even when I didn't know what the speaker was talking about. Thanks to Project NExT for helping me extend my own mathematical network.

References

[1] C. T. Bennett and F. Sottile, Math talks, *Starting Our Careers: A Collection of Essays and Advice on Professional Development from the Young Mathematicians' Network*, American Mathematical Society, Providence, RI, 1999.

[2] P. Halmos, How to talk mathematics, *AMS Notices* **21** (1974), 155–158.

[3] J. E. McCarthy, How to give a good colloquium, *Canadian Mathematical Society Notes* **31**, no. 5 (1999), 3–4.

[4] J. Swallow, Proving yourself: How to develop an interview lecture, *AMS Notices* **56** (2009), 948–951.

Lovász Receives Kyoto Prize

László Lovász, director of the Mathematical Institute at Eötvös Loránd University in Budapest, Hungary, and president of the International Mathematics Union, has been awarded the twenty-sixth annual Kyoto Prize for Lifetime Achievement in Basic Sciences. The prize this year focused on the field of mathematical sciences. He was honored for his outstanding contributions to the advancement of both the academic and technological possibilities of the mathematical sciences. He will be presented with the award, which consists of a diploma, a Kyoto Prize medal of twenty-karat gold, and a cash prize totaling 50 million yen (approximately US$550,000). The presentation ceremony will be held at the Kyoto International Conference Center on November 10, 2010. In the Advanced Technology category, the prize goes to medical scientist Shinya Yamanaka, and in the Arts and Philosophy category, to visual artist William Kentridge.

The Work of László Lovász

László Lovász is considered to be one of the world's preeminent contemporary mathematicians. He has provided a link among numerous branches of mathematics through his advanced research on discrete structures. Many of his concrete research results are presented in the form of elucidated properties of graphs and their algorithmic designs. However, his methodologies go beyond the framework of graph theory to exert significant influence on a broad spectrum of mathematical sciences, including discrete mathematics, combinatorial optimization, and theoretical computer science.

Lovász has solved several outstanding problems, including the "weak perfect graph conjecture", a well-known open problem in graph theory, and the famous and long-standing open problem on Shannon capacity in the field of information theory. In this work he introduced quadratic forms to express discrete structures. It has served as the very first instance of semidefinite programming, which went on to become one of the central topics in mathematical optimization. By further advancing those pioneering achievements, he played a role in developing the geometric methodology of algorithms based on the ellipsoid method, which led to the solution of a major open problem on submodular function minimization. His contributions are significant in clarifying the deeper relationship between computation theory and optimization theory.

However, he is perhaps best known for the widely used Lovász local lemma, which provided a fundamental probabilistic tool for the analysis of discrete structures and contributed to the creation of a framework for probabilistically checkable proofs. The basis algorithm, commonly known as the "LLL algorithm", has also contributed to the construction of important algorithms and has become a fundamental tool in the theory of cryptography.

Lovász was born in 1948 in Budapest and is a citizen of both Hungary and the United States. He received his Dr. Math. Sci. degree from the Hungarian Academy of Sciences in 1977 and has held a number of prestigious positions, including professor and chair of geometry at József Attila University (1978–1982), professor and chair of computer science at Eötvös Loránd University (1983–1993), professor of computer science at Yale University (1993–2000), and senior researcher at Microsoft Research (1999–2006). His honors include the George Pólya Prize of the Society for Industrial and Applied Mathematics (1979), the Delbert Ray Fulkerson Prize of the AMS and the Mathematical Programming Society (1982), the Brouwer Medal of the Dutch Mathematical Society (1993), the Bolzano Medal of the Czech Mathematical Society (1998), the Knuth Prize of ACM-SIGACT (1999), the Gödel Prize of ACM-SIGACT-EATCS (2001), and the 1999 Wolf Prize.

About the Prize

The Kyoto Prize is Japan's highest private award for global achievement, honoring significant contributions to the betterment of society. The Inamori Foundation is a nonprofit organization established in 1984 by Kazuo Inamori, founder and chairman emeritus of Kyocera and KDDI Corporation. The activities of the Inamori Foundation reflect the lifelong belief of its founder that a human being has no higher calling than to strive for the greater good of society and that the future of humanity can be assured only when there is a balance between scientific progress and spiritual depth. The Kyoto Prize is presented not only in recognition of outstanding achievements but also in honor of the excellent personal characteristics that have shaped those achievements.

Previous Kyoto Prize winners who have made contributions to the mathematical sciences are: Rudolf E. Kalman (1985), Claude E. Shannon (1985), John McCarthy (1988), I. M. Gelfand (1989), Edward Lorenz (1991), André Weil (1994), Donald E. Knuth (1996), Kyosi Itô (1998), Mikhael Gromov (2002), Simon A. Levin (2005), and Hirotugu Akaike (2006).

—From Inamori Foundation announcements

Mathematics People

Nagel and Wainger Receive 2007–2008 Bergman Prize

Alexander Nagel and Stephen Wainger of the University of Wisconsin-Madison have been awarded the 2007–2008 Stefan Bergman Prize. Established in 1988, the prize recognizes mathematical accomplishments in the areas of research in which Stefan Bergman worked. The prize consists of one year's income from the prize fund. Because the prize is given for the years 2007 and 2008, Nagel and Wainger will each receive US$26,950.

The previous Bergman Prize winners are: David W. Catlin (1989), Steven R. Bell and Ewa Ligocka (1991), Charles Fefferman (1992), Yum Tong Siu (1993), John Erik Fornæss (1994), Harold P. Boas and Emil J. Straube (1995), David E. Barrett and Michael Christ (1997), John P. D'Angelo (1999), Masatake Kuranishi (2000), László Lempert and Sidney Webster (2001), M. Salah Baouendi and Linda Preiss Rothschild (2003), Joseph J. Kohn (2004), Elias M. Stein (2005), and Kengo Hirachi (2006). On the selection committee for the 2007–2008 prize were Raphael Coifman, Linda Preiss Rothschild, and Elias M. Stein (chair).

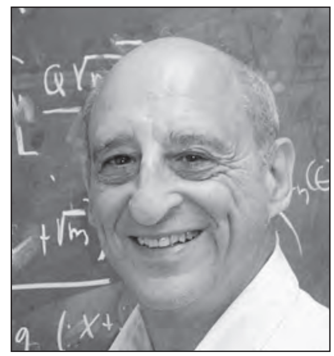
Citation

The 2007–2008 Bergman Prize is shared by Alexander Nagel and Stephen Wainger of the University of Wisconsin for their fundamental contributions in collaborative work in the study of Bergman and Szegö kernels, the geometry of control (Carnot-Carathéodory) metrics associated with vector fields, and the initial breakthroughs for singular integrals on curves, culminating in a general theory of singular Radon transforms.

Biographical Sketch: Alexander Nagel

Alexander Nagel was born in New York City in 1945. He received his B.A. from Harvard College in 1966 and his Ph.D. from Columbia University in 1971, where he wrote his thesis under the direction of Lipman Bers. He joined the faculty at the University of Wisconsin-Madison in 1970, serving as chair of the mathematics department from 1991 to 1993 and as associate dean for the natural sciences in the College of Letters and Science from 1993 to 1998. He was named Steenbock Professor of Mathematical Sciences in 2004.

Alexander Nagel



Stephen Wainger

Nagel held a National Science Foundation Graduate Fellowship (1996–1970), an H. I. Romnes Faculty Fellowship at the University of Wisconsin (1980–1985), and a Guggenheim Fellowship (1987–88). He received the Wisconsin Distinguished Teaching Award from the Mathematical Association of America in 2004 and was elected a Fellow of the American Association for the Advancement of Science in 2009.

Biographical Sketch: Stephen Wainger

Stephen Wainger was born in Schenectady, New York, in 1936. He received his Ph.D. from the University of Chicago in 1961, writing his thesis under the direction of Elias M. Stein. He then had short stints at De Paul University and Cornell University. Since 1966 he has been on the faculty at the University of Wisconsin-Madison. He is currently the Antoni Zygmund Professor of Mathematics at the University of Wisconsin.

About the Prize

The Bergman Prize honors the memory of Stefan Bergman, best known for his research in several complex variables, as well as the Bergman projection and the Bergman kernel function that bear his name. A native of Poland, he taught at Stanford University for many years and died in 1977 at the age of eighty-two. He was an AMS member for thirty-five years. When his wife died, the terms of her will stipulated that funds should go toward a special prize in her husband's honor.

The American Mathematical Society was asked by Wells Fargo Bank of California, the managers of the Bergman Trust, to assemble a committee to select recipients of the prize. In addition, the Society assisted Wells Fargo in interpreting the terms of the will to assure sufficient breadth in the mathematical areas in which the prize may be given. Awards are made every one or two years in the following areas: (1) the theory of the kernel function and its applications in real and complex analysis and (2) function-theoretic methods in the theory of partial differential equations of elliptic type with attention to Bergman's operator method.

—Allyn Jackson

AMS Menger Awards at the 2010 ISEF

AMS Menger Award winners. Left to right: Ed Connors (judge), Yale Fan, Almas Abdulla, Evgeniia Alekseeva, Anirudha Balasubramanian, Joshua Pfeffer, Jacob Hurwitz, and Kate Geschwind.

The 2010 Intel International Science and Engineering Fair (ISEF) was held May 9–14, 2010, in San Jose, California. This was the sixtieth year of the ISEF competition. More than fifteen hundred students in grades 9 through 12 from more than fifty countries participated in the fair. Student finalists who competed at the ISEF went through a multistep process to qualify and won an all-expenses-paid trip to the fair. They qualified by winning local, regional, and state fairs in the United States or national science fairs abroad. In addition to numerous grand awards presented by the ISEF, sixty-seven federal agencies and professional and educational organizations, including the American Mathematical Society (AMS), participated by giving special awards. Prizes given by the AMS included cash, certificates, books, and tote bags.

For the AMS, this was the twenty-third year of participation, and it was the twenty-first year of the presentation of the Karl Menger Awards. The members of the 2009–2010 AMS Menger Prize Committee and AMS Special Awards judges were Edward Connors, University of Massachusetts (chair); Doron Levy, University of Maryland; and Greg Fasshauer, Illinois Institute of Technology. The panel of judges initially reviewed all sixty-nine projects in mathematics, as well as mathematically oriented projects in computer science, physics, and engineering. From these entries they interviewed several students selected for further consideration for a Menger Award. In the mathematics category fifty-nine entries were submitted by individuals, and ten were submitted by teams of two or three students. The AMS gave awards to one first-place winner, two second-place winners, four third-place winners, and honorable mentions to two others.

The Karl Menger Memorial Prize winners for 2010 are as follows:

First-Place Award (US$1,000): "Adiabatic Quantum Evolution for NP-Complete and Physical Problems", Yale Wang Fan, The Catlin Gabel School, Portland, Oregon.

Second-Place Awards (US$500): "Super Kähler-Ricci Flow", Joshua W. Pfeffer, North Shore Hebrew Academy High School, Great Neck, New York; and "On the Lower Central Series Quotients of a Graded Associative Algebra", Anirudha Balasubramanian, Saint Albans School, Washington, DC.

Third-Place Awards (US$250): "Explaining Wind Farm Output Using Regression Analysis", Kate A. Geschwind, Mayo High School, Rochester, Minnesota; "Universal Law for the Distribution of Odd Periodic Cycles within Chaos in Nonlinear Dynamical Systems: A Fine Classification of Odd Cycles (Year III)", Almas Abdulla, West Shore Junior/Senior High School, Melbourne, Florida; "Decycling Densities of Tessellations", Jacob B. Hurwitz, Montgomery Blair High School, Silver Spring, Maryland; and "Hyperbolic Triangles of the Maximum Area and Two Fixed Sides", Evgeniia I. Alekseeva, GOU Lyceum "Vtoraiia shkola", Moscow, Russia.

Honorable Mention Awards: "Deligne Categories and Representation Theory in Complex Rank", Akhil Mathew, Madison High School, Madison, New Jersey; and "Effects of Motility and Contact Inhibition on Tumor Viability: A Discrete Simulation Using the Cellular Potts Model", Jonathan F. Li, Saint Margaret's Episcopal School, San Juan Capistrano, California.

The Society for Science and the Public (SSP), a nonprofit organization based in Washington, DC, owns and has administered the ISEF since 1950. Intel became the title sponsor of ISEF in 1996. The Intel ISEF is the premiere science competition in the world and annually provides a forum for more than fifteen hundred high school students from more than fifty countries.

The panel of judges was impressed by the quality, breadth, and originality of the work and by the dedication and enthusiasm of the students. The projects covered a wide range of topics, somewhat indicated by the titles of the award-winning projects.

As mentioned, the classification of mathematics attracted fifty-nine individual entries and ten team entries. In all there were fifty-nine male and twenty-one female entrants. Of the monetary award winners (first, second, and third place), three are female and six are male. Yale

Fan (first place) and Almas Abdulla (third place) were the only 2010 winners to have also placed in 2009.

The AMS's participation in the Intel-ISEF is supported in part by income from the Karl Menger Fund, which was established by the family of the late Karl Menger. The income from the donation by the Menger family covers less than the amount of the awards. The balance, including the travel expenses of the judges, comes from the AMS's general fund. For more information about this program or to make contributions to this fund, contact the AMS Development Office, 201 Charles Street, Providence, RI, 02904-2294; or send email to `development@ams.org`; or phone 401-455-4103.

—Ed Connors, University of Massachusetts, Amherst

Gupta and Grattan-Guinness Awarded May Prize

Radha Charan Gupta of Ganita Bharati Institute and Ivor Grattan-Guinness, emeritus professor at Middlesex University, have been named the recipients of the 2009 Kenneth O. May Prize for the History of Mathematics by the International Commission for the History of Mathematics.

Gupta was honored for his contributions to the understanding of the development of Indian mathematics. He has analyzed many unknown mathematical formulas in Sanskrit. He also published several papers on the mathematical discoveries of the Jaina tradition, many of which had been almost inaccessible to anyone except specialists in Prakrit. He has also traced the influence of Indian mathematical discoveries in foreign traditions. His major contributions in the field include work on the history of the development of trigonometry in India.

Grattan-Guinness received his Ph.D. in 1969 and his D.Sc. in 1978 from the University of London in the history of science. From 1974 to 1981 he was editor of *Annals of Science*. In 1979 he founded the journal *History and Philosophy of Logic* and edited it until 1992. He was an associate editor of *Historia Mathematica* from its inception in 1974 till 1994 and again from 1996 to the present. He specializes in Euclid, the development of the calculus and mathematical analysis and their applications to mechanics and mathematical physics, and in the rise of set theory and mathematical logic. He has been especially interested in characterizing how past thinkers viewed their findings differently from the way we see them now.

The May Prize is given once every four years in appreciation of a mathematician's scholarly work in the history of mathematics.

—Elaine Kehoe

Buchweitz Receives Humboldt Research Award

Ragnar-Olaf Buchweitz of the University of Toronto, Scarborough, has been awarded a Humboldt Research Award in recognition of a lifetime of achievement in research. His research focuses on the mathematical fields of commutative algebra and algebraic geometry. He mainly uses tools from homological algebra, which some describe as the most abstract form of pure mathematics. The prize, which is awarded by the Alexander von Humboldt Foundation, carries a cash prize of 60,000 euros (roughly C$80,000) and the opportunity to spend up to one year cooperating on long-term research projects with colleagues at German research institutes.

—From a University of Toronto announcement

Prizes of the Royal Society

Graeme Segal of the University of Oxford has been awarded the Sylvester Medal of the Royal Society "for his highly influential and elegant work on the development of topology, geometry and quantum field theory, bridging the gap between physics and pure mathematics." His work extends the machinery of algebraic topology to quantum field theories. He also studies how smooth manifolds can be modeled algebraically, essentially as quadratic objects in the homotopy category.

David Cox, formerly of Oxford University, has been awarded a Copley Medal for his seminal contributions to numerous areas of statistics and applied probability, of which the best known may be the proportional hazards model, which is used in the analysis of survival data. He gave his name to the Cox process, a stochastic process that is a generalization of a Poisson process.

—Elaine Kehoe

SIAM Prizes Awarded

The Society for Industrial and Applied Mathematics (SIAM) awarded a number of prizes at its annual meeting in July 2010 in Pittsburgh, Pennsylvania.

Emmanuel Candés of Stanford University and Terence Tao of the University of California, Los Angeles, were awarded the George Pólya Prize. The prize is awarded every two years (1) for a notable application of combinatorial theory or (2) for a notable contribution in another area of interest to George Pólya, such as approximation theory, complex analysis, number theory, orthogonal polynomials, probability theory, or mathematical discovery and learning. Each prizewinner receives a cash award of US$10,000.

John A. Burns of the Virginia Institute of Technology was awarded the W. T. and Idalia Reid Prize in Mathematics, given for research in or other contributions to the broadly defined areas of differential equations and control theory.

Colin B. Macdonald of the University of Oxford was awarded the Richard C. DiPrima Prize. The prize is awarded to a young scientist who has done outstanding research in applied mathematics and carries a cash award of US$1,000.

Martin Grötschel of the Konrad-Zuse-Zentrum für Informationstechnik Berlin, Germany, was awarded the SIAM Prize for Distinguished Service to the Profession.

Bernd Sturmfels of the University of California, Berkeley, was named the John von Neumann Lecturer. This lectureship is given for outstanding and distinguished contributions to the field of applied mathematical sciences and for the effective communication of these ideas to the community. It carries a cash award of US$5,000.

Dmitri Tymoczko of Princeton University was selected as the I. E. Block Community Lecturer. The lectureship is intended to encourage public appreciation of the excitement and vitality of science. Tymoczko's lecture was titled "The Geometry of Music". It carries an honorarium of US$1,500.

John R. King of the University of Nottingham, United Kingdom, was honored with the Julian Cole Lectureship. This lectureship is awarded for an outstanding contribution to the mathematical characterization and solution of a challenging problem in the physical or biological sciences or in engineering or for the development of mathematical methods for the solution of such problems. It carries a cash award of US$1,000.

Suzanne Lenhart of the University of Tennessee was named the AWM-SIAM Sonia Kovalevsky Lecturer. This lectureship highlights significant contributions of women to applied or computational mathematics.

The SIAM Student Paper Prizes were awarded to the following students: Bubacarr Bah, University of Edinburgh, for "Improved Restricted Isometry Constant Bounds for Gaussian Matrices"; Russell Carden of Rice University for "A Simple Algorithm for the Inverse Field of Values Problem"; and Karin Leiderman of the University of Utah for "Grow with the Flow: A Spatial-Temporal Model of Platelet Deposition and Blood Coagulation under Flow". The prize carries a cash award of US$1,000 per paper.

The SIAM Awards in the Mathematical Contest in Modeling were awarded to the following students: For Problem A, the Continuous Problem: The Sweet Spot, the awardees were Zhe Xiong, Qipei Mei, and Fei Han of Huazhong University of Science and Technology (HUST), PRC School of Civil Engineering and Mechanics, for "An Optimal Model of the 'Sweet Spot' Effect". Their faculty advisor was Liang Gao. For Problem B, the Discrete Problem: Criminology, the awardees were Joseph H. Gibney, Emily P. Meissen, and Yonatan Naamad of Rensselaer Polytechnic Institute for "Following the Trail of Data". Their faculty advisor was Peter Kramer. Each student member of the winning teams receives a cash award of US$300.

—From a SIAM announcement

Prizes of the London Mathematical Society

The London Mathematical Society (LMS) has awarded several prizes for 2010.

Keith W. (Bill) Morton of Oxford University received the DeMorgan Medal in recognition of his seminal contributions to the field of numerical analysis of partial differential equations and its applications and for services to his discipline.

Jonathan Keating of the University of Bristol was awarded the Fröhlich Prize in recognition of his seminal work on the modeling of zeta functions via random matrix theory.

Dusa McDuff of Barnard College was awarded the Senior Berwick Prize for her papers "Symplectic embeddings of 4-dimensional ellipsoids" and "Some 6-dimensional Hamiltonian S^1-manifolds", published in the *Journal of Topology*, volume 2, 2009.

Four Whitehead Prizes were awarded. Harald Helfgott of the University of Bristol was honored for his varied contributions to number theory, including work on Möbius sums in two variables, integral points on elliptic curves, and, in particular, his groundbreaking work on growth and expansion of multiplication of sets in $SL_2(F_p)$. Jens Marklof of the University of Bristol was recognized for his work on quantum chaos, random matrices and number theory. Lasse Rempe of the University of Liverpool was honored for his work in complex dynamics, in particular his research on the escaping set for entire functions. Françoise Tisseur of the University of Manchester was recognized for outstanding research achievements in numerical linear algebra, including polynomial eigenvalue and structured matrix problems.

—From an LMS announcement

Prizes of the Canadian Mathematical Society

The Canadian Mathematical Society has made several awards for 2010.

Bálint Virág of the University of Toronto has been awarded the Coxeter-James Prize for outstanding research by a young mathematician. The prize citation reads in part: "As a relatively young probabilist, Bálint Virág has produced significant high quality research. This award recognizes the research excellence of his substantive early career research contribution to the area of probability." He is well known for his research on random walks, random matrices, random polynomials, and probabilistic methods in group theory.

Vladimir Manuilov of Moscow State University and Klaus Thomsen of Aarhus University were awarded the G. de B. Robinson Prize for their joint paper "On the lack of inverses to C^*-extensions related to property T groups", published in the *Canadian Mathematical Bulletin* **50**, no. 2 (2007), pp. 268–283. The prize recognizes the publication of excellent papers in the *Canadian Journal of Mathematics* and the *Canadian Mathematical Bulletin*.

Walter Whiteley of York University was honored with the Adrien Pouliot Award for his "noteworthy and influential contribution to research and development of tasks in visual reasoning (broadly and within mathematics) as well as in the teaching and learning of geometry." The Pouliot Award is for individuals, or teams of individuals, who have made significant and sustained contributions to mathematics education in Canada.

Jennifer Hyndman of the University of Northern British Columbia received the Excellence in Teaching Award for her "proven excellence as a teacher, her unusual effectiveness in the classroom, and her commitment and dedication to teaching and to students." The award recognizes sustained and distinguished contributions in teaching at the undergraduate level at a Canadian postsecondary education institution.

Christiane Rousseau of the University of Montreal was awarded the Graham Wright Public Service award for her "outstanding service to CMS and to world recognition of Canadian mathematics; her numerous mathematical outreach activities, ranging from delivering lectures in schools and CEGEPs, to organizing student conferences, math camps or public lectures, all of which aim to stimulate public or student engagement with mathematics." The award recognizes individuals who have made sustained and significant contributions to the Canadian mathematical community and, in particular, to the Canadian Mathematical Society.

—From a CMS announcement

2010 International Mathematical Olympiad

The fifty-first International Mathematical Olympiad (IMO) was held July 2–14 in Astana, Kazakhstan. The IMO is the preeminent mathematical competition for high school-age students from around the world. This year 517 young mathematicians from 97 countries competed. The IMO consists of solving six extremely challenging mathematical problems in a nine-hour competition administered over two days.

The team from China finished first for the third straight year, with 197 points out of a possible 252. Each team member earned a gold medal. Russia finished second, with 169 points. The team from the United States finished third with 168 points and three gold medals.

The U.S. team consisted of Calvin Deng, (William G. Enloe High School, Raleigh, North Carolina); Ben Gunby (Georgetown Day School, Washington, D. C.); Xiaoyu He (Acton-Boxborough Regional High School, Acton, Massachusetts); In Sung Na (Northern Valley Regional High School, Old Tappan, New Jersey); Evan O'Dorney (Berkeley Math Circle, Berkeley, California); and Allen Yuan (Detroit Country Day School, Beverly Hills, Michigan). Gunby, Na, and O'Dorney won gold medals; and Deng, Na, and Yuan won silver medals. O'Dorney, winner of the 2010 national Who Wants to Be a Mathematician competition, as well as of the 2007 Scripps National Spelling Bee, finished with a score of 39 (out of a possible 42 points), the second highest individual score overall. Zipei Nie of China was the highest scoring individual, earning a perfect score of 42.

The Mathematical Association of America sponsors the U.S. team through its American Mathematics Competitions program, with travel support provided by a grant from the Army Research Office. Training for the team at the University of Nebraska, Lincoln, is aided by a grant from the Akamai Foundation. Additional support for the team is provided by the National Council of Teachers of Mathematics.

—Elaine Kehoe

SIAM Fellows Elected

The Society for Industrial and Applied Mathematics (SIAM) has elected its class of fellows for 2010. Fellowship is an honorific designation conferred on members distinguished for their outstanding contributions to the fields of applied mathematics and computational science. The names, institutions, and brief citations of the new fellows follow.

Uri M. Ascher (University of British Columbia), for contributions to numerical solution of differential equations and numerical software; Andrea L. Bertozzi (University of California, Los Angeles), for contributions to the application of mathematics in incompressible flow, thin films, image processing, and swarming; Susanne C. Brenner (Louisiana State University), for advances in finite element and multigrid methods for the numerical solution of partial differential equations; John C. Butcher (University of Auckland), for developing the foundations of the modern theory of Runge-Kutta methods; Stephen L. Campbell (North Carolina State University), for contributions to analysis and algorithms for differential algebraic equations; Carlos Castillo-Chavez (Arizona State University), for contributions to the mathematical modeling of infectious diseases and for leadership as a mentor and teacher; Tony F. Chan (Hong Kong University of Science and Technology), for contributions to numerical analysis and image processing and for service to the mathematical community; Peter Constantin (University of Chicago), for contributions to the mathematical analysis of nonlinear partial differential equations, fluid dynamics, and turbulence; John E. Dennis Jr. (Rice University and University of Washington), for contributions to the theory and applications of nonlinear optimization; Iain S. Duff (Rutherford Appleton Laboratory, United Kingdom, and CERFACS, France), for contributions to sparse matrix computations; Paul Dupuis (Brown University), for contributions to stochastics and control; Bjorn E. Engquist (University of Texas, Austin), for contributions to numerical analysis and multiscale modeling; Donald Geman (Johns Hopkins University), for contributions to stochastic processes, image analysis, and statistical learning; John R. Gilbert (University of California, Santa Barbara), for contributions to the development and analysis of algorithms for sparse matrix problems; Michael T. Heath (University of Illinois), for contributions in computational science and engineering, especially parallel computing; T. C. Hu (University of California, San Diego), for contributions to network flows, integer programming, and combinatorial algorithms; George Karniadakis (Brown University), for contributions to stochastic modeling, spectral elements, and fluid mechanics; William L. Kath (Northwestern University), for contributions to wave propagation, nonlinear dynamics, optical fibers and waveguides, and computational neuroscience; Ioannis G. Kevrekidis (Princeton University), for research contributions in chemical engineering, applied mathematics, and the computational sciences; Barbara Lee Keyfitz (Ohio State University), for advances in hyperbolic conservation laws and the study of shock waves; Randall J. LeVeque (University of Washington), for contributions to numerical analysis and scientific computing, particularly for conservation laws; Anders G. Lindquist (KTH–Royal Institute of Technology), for contributions to systems and control; Steve McCormick (University of Colorado, Boulder), for contributions to numerical partial differential equations, especially multigrid and first-order system least-squares methods; Carl D. Meyer (North Carolina State University), for contributions to theory and applications of linear algebra; Jorge Nocedal (Northwestern University), for contributions to the theory and practice of continuous optimization; Yousef Saad (University of Minnesota, Twin Cities), for contributions in numerical linear algebra and its applications; Fadil Santosa (University of Minnesota, Twin Cities), for contributions to the mathematics of inverse problems and for advancing the application of mathematics in industry; Robert Schreiber (Hewlett-Packard Corporation), for contributions to parallel and high-performance computing and algorithms for matrix computations; Mitchell D. Smooke (Yale University), for the development of new methods in computational combustion and their application to problems involving hydrocarbon chemistry; Danny C. Sorensen (Rice University), for contributions to numerical linear algebra, optimization, and model reduction; Gunther Uhlmann (University of Washington), for contributions to the analysis of inverse problems and partial differential equations; Frederic Y. M. Wan (University of California, Irvine), for contributions to the theory of elasticity and to developmental biology and for outstanding service to the mathematical sciences; Michael I. Weinstein (Columbia University), for contributions to the analysis and applications of nonlinear waves; Olof B. Widlund (Courant Institute of Mathematical Sciences, New York University), for contributions to the theory of domain decomposition methods.

—From a SIAM announcement

Mathematics Opportunities

NSF Postdoctoral Research Fellowships

The National Science Foundation (NSF) awards Mathematical Sciences Postdoctoral Research Fellowships (MSPRF) for appropriate research in areas of the mathematical sciences, including applications to other disciplines. A program announcement is available from the website http://www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=5301&ods_key=nsf08582.The deadline for proposals is **October 20, 2010**.

—From an NSF announcement

NSF Conferences and Workshops in the Mathematical Sciences

The National Science Foundation (NSF) supports conferences, workshops, and related events (including seasonal schools and international travel by groups). Proposals for conferences, workshops, or conference-like activities may request funding of any amount and for durations of up to three years. Proposals may be submitted only by universities and colleges and by nonprofit nonacademic institutions. For full information, including deadlines for each disciplinary program, see the website http://www.nsf.gov/pubs/2010/nsf10578/nsf10578.htm?WT.mc_id=USNSF_25&WT.mc_ev=click.

—From an NSF announcement

NSF Research Networks in the Mathematical Sciences

The National Science Foundation (NSF) has initiated the Research Networks in Mathematical Sciences (RNMS) Program to provide support over five to ten years for research collaborations that will cross intellectual, institutional, national, or other boundaries. The goals of the RNMS program are (1) to support coordinated research and training collaborations that link together researchers addressing significant challenges in the mathematical sciences and (2) to broaden participation in the mathematical sciences by creating new opportunities for research involvement and support. It will complement existing research award mechanisms to promote disciplinary progress in mathematics and statistics and to promote progress on multidisciplinary research agendas. It will create a new class of rich and stimulating environments for recruiting, educating, and training the next generation of mathematicians and statisticians, and it will help to form effective connections among academic researchers and researchers in government, industry, and international institutions.

Proposals may be submitted only by universities and colleges. The deadline for full proposals is **November 9, 2010.** For more information, see the website http://www.nsf.gov/pubs/2010/nsf10584/nsf10584.htm?WT.mc_id=USNSF_25&WT.mc_ev=click.

—From an NSF announcement

Visiting Positions at CIRM

The Centro Internazionale per la Ricerca Matematica (CIRM), the Fondazione Bruno Kessler, is seeking applications for its Visiting Scholars and Professors and its Research in Pairs programs. CIRM Visiting Scholars will perform mathematical research in cooperation with scientists and researchers at the University of Trento or, more generally, of the Trento area and will present some research seminars. CIRM Visiting Professors will give short Ph.D. courses, summer courses, or series of seminars. Visits will usually be for between fifteen days and three months. Applications and proposals may be sent at any time to FBK, Centro Internazionale per la Ricerca Matematica, Via Sommarive n. 14-Povo, 38123 Trento, Italy, by postal mail or via electronic mail to micheletti@fbk.eu.

The Research in Pairs (RIP) Program provides for the presence of two or three partners from universities located in different towns who intend to work on a definite research project and for a well-specified period of time (ranging from one to six weeks). Applicant partners must submit a scientific project in the field of mathematics with a detailed research program. Participants in the program will also give occasional research seminar talks at the CIRM or at the University of Trento. Applications may be sent at any time to FBK, Centro Internazionale per la Ricerca Matematica, Via Sommarive n. 14-Povo, 38123 Trento, Italy, by postal mail or via electronic mail to micheletti@fbk.eu.

For more details about these positions and requirements for submission, see the website http://science.unitn.it/cirm/PosizPostDocEn.html.

—Fabrizio Catanese, Director, CIRM

PIMS Call for Proposals

The Pacific Institute for the Mathematical Sciences (PIMS) welcomes applications for support of conferences, workshops, seminars, collaborative research groups, and related activities in the mathematical sciences to occur after April 1, 2011. Proposals may be made for general scientific activities and major education and industrial outreach events. Letters of intent are required for collaborative research groups; successful groups will be invited to submit full proposals. The deadline for submissions is **October 1, 2010**. Pacific Northwest Seminars are scientific meetings of one to two days in length. Funding of up to US$1,000, together with administrative support, is available from PIMS. Proposals for these may be submitted to the deputy director at any time.

For complete information and submission requirements, see the website http://www.pims.math.ca/scientific/call-proposals.

—From a PIMS announcement

News from IPAM

The Institute for Pure and Applied Mathematics (IPAM), located at the University of California, Los Angeles, holds long- and short-term research programs and workshops throughout the academic year for junior and senior mathematicians and scientists who work in academia, the national laboratories, and industry. IPAM sponsors two summer programs. IPAM's upcoming programs are listed below. See the website www.ipam.ucla.edu for detailed information and to find online application and registration forms. IPAM's Science Advisory Board meets in November, when it considers workshop and program proposals. Proposals from the community are encouraged; instructions are available on our website.

Registration and applications for support for all programs are available at the website.

Currently, IPAM is in the midst of its long program on optimization. Researchers from mathematics, computer science, operations research, engineering, and other fields are in residence at IPAM this fall. A series of workshops focus on current trends and applications of optimization.

IPAM's Tenth Anniversary Conference. November 2–4, 2010. The conference will focus on the current state and the future of interdisciplinary mathematics and science. Speakers from academia, government, and industry will present current research results related to programs from IPAM's first ten years. Two public lectures, given by Josh Tenenbaum (Massachusetts Institute of Technology) and Tony Chan (president, Hong Kong University of Science and Technology), and a panel discussion will provide an overview of interdisciplinary mathematics and science and IPAM's role in this exciting endeavor. For details see www.ipam.ucla.edu/programs/ann2010/.

Winter 2011 Short Programs.

Algorithmic Game Theory. January 10–14, 2011.

Efficiency of the Simplex Method: Quo Vadis Hirsch Conjecture? January 18–21, 2011.

Random Media: Homogenization and Beyond. January 24–28, 2011.

Women in Mathematics Symposium. February 24–26, 2011.

Mathematics of Information—Theoretic Cryptography. February 28–March 4, 2011.

Navigating Chemical Compound Space for Materials and Bio Design. March 14–June 17, 2011. This long program includes the following workshops that are also open for participation. You may apply online for support to be core participants for the entire program or to attend any of the following individual workshops.

Tutorials. March 15–18, 2011.

Workshop I: Design of Drugs and Chemicals That Influence Biology. April 4–8, 2011.

Workshop II: Optimization, Search and Graph-Theoretical Algorithms for Chemical Compound Space. April 11–15, 2011.

Workshop III: Materials Design in Chemical Compound Space. May 2–6, 2011.

Workshop IV: Physical Frameworks for Sampling Chemical Compound Space. May 16–20, 2011.

Mathematical and Computational Approaches in High-Throughput Genomics. September 12–December 16, 2011. This long program includes the following workshops that are also open for participation. You may apply online for support to be core participants for the entire program or to attend any of the following individual workshops.

Tutorials. September 13–16, 2011.

Workshop I: Next-Generation Sequencing Technology and Algorithms for Primary Data Analysis. October 3–6, 2011.

Workshop II: Transcriptomics and Epigenomics. October 25–28, 2011.

Mini-Workshop: Cancer Genomics. October 31–November 1, 2011.

Workshop III: Evolutionary Genomics. November 15–18, 2011.

Workshop IV: Coancestry, Association, and Population Genomics. November 29–December 2, 2011.

Seventeenth Annual Conference for African American Researchers in the Mathematical Sciences (CAARMS). June 1–4, 2011.

Computational Methods in High Energy Density Plasmas. March 12–June 15, 2012. This long program will include tutorials and four workshops. You may apply online for support to be core participants for the entire program or to attend individual workshops. See the website for workshop titles and dates.

IPAM will host a summer school in 2011 tentatively titled "Probabilistic Models of Cognition". The dates and more information will be announced soon.

—From an IPAM announcement

For Your Information

Report: Considering the Future of K–12 STEM Curricula and Instructional Design

The rapid growth in features and use of educational media (from e-books to applets) makes it possible to envision dramatic changes in the kinds of instructional materials and environments that can support STEM (science, technology, engineering, mathematics) learning. Questions that emerge when the field considers new tools and technology-rich environments include:

What will a high-impact, technology-intensive STEM learning environment look like in the near and long-term future?

What materials development and research are required to make this vision possible?

What design, development, and diffusion processes are most likely to produce new, effective approaches to STEM education?

To address these questions, two workshops were convened to identify and analyze the needs and opportunities for innovative work. Participants included education futurists, researchers in the STEM content and education disciplines, and specialists in instructional technology, cognitive psychology, policy, museum and educational media. Workshop discussions provided a rich source of ideas for examination by those interested in promoting and strengthening STEM learning. The Workshop Series report *Considering the Future of K–12 STEM Curricula and Instructional Design: Stimulating and Supporting Innovative Research and Development* identifies critical research and development activities and calls on funding agencies and the field to focus attention on these activities. The fifty-page report is free and available for download at: `http://www.mathcurriculumcenter.org/conferences/stem/index.php`.

—Robert Reys, University of Missouri

Correction

I thank Marius Stefan for commenting on some typographical errors in my column "WHAT IS …a Wilf-Zeilberger Pair?", which appeared in the April 2010 *Notices*. The corrections are as follows.

(1) In the paragraph **Doubling the fun!** $F(n,k)$ in the equation

$$\sum_k F(n,k) = r(n), (n \geq n_0)$$

should be replaced by $h(n,k)$, and $G(n,L)$ in condition (ii) should be replaced by $G(n,-L)$.

(2) In the last column of the article, the recurrence equation $\sum_{j=0}^{J} a_j(n)S(n) = 0$ should be replaced by $\sum_{j=0}^{J} a_j(n)S(n+j) = 0$.

—Akalu Tefera

Inside the AMS

National *Who Wants to Be a Mathematician*

The second national contest of *Who Wants to Be a Mathematician* will take place Friday, January 7, 2011, at the Joint Mathematics Meetings in New Orleans. All meeting attendees are invited. Any U.S. high school student is eligible for the top prize of US$10,000. Pictured is the 2010 winner, Evan O'Dorney of the Berkeley Math Circle, with the championship trophy. Find out more at `www.ams.org/wwtbam/wwtbamnational`.

Deaths of AMS Members

T. A. C. Adamson, of Nedlands, Australia, died on June 9, 2010. Born on June 17, 1928, he was a member of the Society for 59 years.

Herbert Federer, of North Scituate, Rhode Island, died on April 21, 2010. Born on July 23, 1920, he was a member of the Society for 67 years.

K. S. Ghent, of Eugene, Oregon, died on January 12, 2008. Born on June 29, 1911, he was a member of the Society for 72 years.

Kathryn A. Powers, of Jerseyville, Illinois, died on January 7, 2010. Born on December 6, 1923, she was a member of the Society for 40 years.

Richard P. Stauduhar, of Kailua Kona, Hawaii, died on March 24, 2010. Born on May 28, 1940, he was a member of the Society for 3 years.

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.*

Contacting the *Notices*

The preferred method for contacting the *Notices* is electronic mail. The editor is the person to whom to send articles and letters for consideration. Articles include feature articles, memorial articles, communications, opinion pieces, and book reviews. The editor is also the person to whom to send news of unusual interest about other people's mathematics research.

The managing editor is the person to whom to send items for "Mathematics People", "Mathematics Opportunities", "For Your Information", "Reference and Book List", and "Mathematics Calendar". Requests for permissions, as well as all other inquiries, go to the managing editor.

The electronic-mail addresses are notices@math.wustl.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 314-935-6839 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

September 30, 2010: Nominations for ICTP Ramanujan Prize. See http://prizes.ictp.it/Ramanujan/.

September 30, 2010: Nominations for 2010 Sacks Prize. See http://www.aslonline.org/Sacks_nominations.html.

September 30, 2010: Full proposals for NSF Integrative Graduate Education and Research Training (IGERT) program; by invitation only. See http://www.nsf.gov/pubs/2010/nsf10523/nsf10523.htm?WT.mc_id=USNSF_25.

October 1, 2010: Proposals for PIMS support for research activities. See "Mathematics Opportunities" in this issue.

October 1, 2010: Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html; telephone: 703-934-0163; email: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 4, 2010: Proposals for minisymposia for ICIAM 2011. See the website http://www.iciam2011.com/.

October 15, 2010: Proposals for NSA Grants for Research in Mathematics. See http://www.nsa.gov/research/math_research/index.shtml.

October 20, 2010: Applications for NSF Mathematical Sciences Postdoctoral Research Fellowships. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5301.

October 30, 2010: Nominations for Clay Research Fellowships. See the website http://www.claymath.org/research_fellows. For more information telephone Alagi Patel, 617-995-2602; e-mail patel@claymath.org.

November 1, 2010: Nominations for CRM-Fields-PIMS Prize. Submit nominations to crm-fields-pims-prize@fields.utoronto.ca.

November 1, 2010: Applications for November review for National Academies Postdoctoral and Senior Research Associateship Program. See http://sites.

Where to Find It

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

nationalacademies.org/PGA/RAP/PGA_050491 or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; email rap@nas.edu.

November 9, 2010: Proposals for NSF Research Networks in the Mathematical Sciences. See "Mathematics Opportunities" in this issue.

November 19, 2010: Proposals for research programs at CRM. See http://www.crm.cat/RPapplication.

December 1, 2010: Letters of intent for proposals for thematic programs at the Bernoulli Center. See the website http://bernoulli.epfl.ch/new/index.php.

December 3, 2010: Entries for Ferran Sunyer i Balaguer Prize. See http://ffsb.iec.cat.

December 15, 2010: Abstracts for contributed papers for ICIAM. See the website http://www.iciam2011.com/.

December 15, 2010: Applications for PIMS Postdoctoral Fellowships. See http://www.pims.math.ca/scientific/postdoctoral.

February 1, 2011: Applications for AWM Mentoring Travel Grants. See http://www.awm-math.org/travelgrants.html#standard.

February 1, 2011: Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html#standard.

May 1, 2011: Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html#standard.

October 1, 2011: Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html#standard.

October 1, 2011: Nominations for the 2012 Emanuel and Carol Parzen Prize. Contact Thomas Wehrly, Department of Statistics, 3143 TAMU, Texas A&M University, College Station, Texas 77843-3143.

DoD Mathematics Staff

The following agencies of the Department of Defense and the Department of Energy fund research in the mathematical sciences. The names, addresses, and telephone numbers of the pertinent staff members are listed.

Defense Advanced Research Projects Agency
Defense Sciences Office
3701 North Fairfax Drive
Arlington, VA 22203-1714
703-526-6630
http://www.darpa.mil/dso

Applied and Computational Mathematics Program

Predicting Real Optimized Materials
Judah Goldwasser, Program Manager
571-218-4293
judah.goldwasser@darpa.mil

Fundamental Mathematics Program

Focus Areas in Theoretical Mathematics
Mark A. Neifeld, Program Manager
(571) 218-4210
mark.neifeld@darpa.mil

Fundamental Laws of Biology
Christian Macedonia, Program Manager
(571) 526-4115
christian.macedonia@darpa.mil

Sensor Topology for Minimal Planning
Mark A. Neifeld, Program Manager
(571) 218-4210
mark.neifeld@darpa.mil

Air Force Office of Scientific Research
Directorate of Mathematics, Information, and Life Sciences
AFOSR/NM
875 North Randolph Street, Suite 325, Room 3112
Arlington, VA 22203-1768
Fax: 703-696-8450
http://www.afosr.af.mil/
Frederica Darema, Director

Bioenergy
Walt Kozumbo
(703) 696-7720
walter.kozumbo@afosr.af.mil

Collective Behavior and Sociocultural Modeling
Terence Lyons
703-696-9542
terence.lyons@afosr.af.mil

Complex Networks
Robert Bonneau
703-696-9545
robert.bonneau@afosr.af.mil

Computational Mathematics
Fariba Fahroo
703-696-8429
fariba.fahroo@afosr.af.mil

Dynamics and Control
Fariba Fahroo
703-696-8429
fariba.fahroo@afosr.af.mil

Information Fusion
Douglas Cochran
(703) 696-7796
douglas.cochran@afosr.af.mil

Information Operations and Security
Robert L. Herklotz
703-696-6565
robert.herklotz@afosr.af.mil

Mathematical Modeling of Cognition and Decision
Jun Zhang
703-696-8421
jun.zhang@afosr.af.mil

Natural Materials and Systems
Hugh C. De Long
(703) 696-7722
hugh.delong@afosr.af.mil

Optimization and Discrete Mathematics
Donald Hearn
703-696-1142
donald.hearn@afosr.af.mil

Robust Computational Intelligence
David J. Atkinson

Sensory Information Systems
Willard Larkin
703-696-7793
willard.larkin@afosr.af.mil

Systems and Software
David Luginbuhl
703-696-6207
david.luginbuhl@afosr.af.mil

Physics and Electronics Directorate
Patrick Carrick, Director

Electromagnetics
Arje Nachman
703-696-8427
arje.nachman@afosr.af.mil

Multiscale Modeling
Arje Nachman
703-696-8427
arje.nachman@afosr.af.mil

Sensing, Surveillance, and Navigation
Jon Sjogren
703-696-6564
jon.sjogren@afosr.af.mil

Army Research Office
Mathematical and Information Sciences Directorate
ATTN: RDRL-ROI-M
P.O. Box 12211
Research Triangle Park, NC
27709-2211 919-549-4206
http://www.arl.army.mil/www/default.cfm?Action=29&Page=216

Program in Mathematics

Biomathematics
Virginia Pasour
919-549-4254

Modeling of Complex Systems
John Lavery
919-549-4253
john.lavery2@arl.army.mil

Probability and Statistics
Mou-Hsiung (Harry) Chang, Acting Division Chief
919-549-4229
mouhsiung.chang@arl.army.mil

Numerical Analysis
Joe Myers
919-549-4245
josephd.myers@arl.army.mil

Program in Computing Sciences

Computational Architectures and Visualization
Joseph (Michael) Coyle, Program Manager
919-549-4256
joseph.michael.coyle@arl.army.mil

Information Processing and Fusion
Liyi Dai, Program Manager
919-549-4350
liyi.dai@arl.army.mil

Information and Software Assurance
Cliff Wang, Acting Division Chief
919-549-4330
cliff.wang@arl.army.mil

National Security Agency
Mathematical Sciences Program
Attn: R1, Suite 6557
Ft. George G. Meade, MD 20755-6557
http://www.nsa.gov/research/math_research/index.shtml
301-688-0400
MSPgrants@nsa.gov

Office of Naval Research
Mathematics, Computer, and Information Sciences Division
Office of Naval Research
One Liberty Center, Suite 1425
875 North Randolph Street
Arlington, VA 22203-1995
http://www.onr.navy.mil

Computational Analysis
Reza Malek-Madani
703-696-0195
reza.malekmadani@navy.mil

Command and Control
Gary Toth
703-696-4961
gary.toth@navy.mil

Image Analysis and Understanding
Behzad Kamgar-Parsi
703-696-5754
behzad.kamgarparsi@navy.mil

Information Integration
Tristan Nguyen
703-588-2360
tristan.nguyen@navy.mil

Intelligent and Autonomous Systems
Behzad Kamgar-Parsi
703-696-5754
behzad.kamgar-parsi@.navy.mil

Mathematical Optimization and Operations Research
Donald Wagner
703-696-4313
don.wagner@navy.mil

Signal Processing for Networked Sensing
Rabinder Madan
703-696-4217
rabinder.madan@navy.mil

Software and Computing Systems
Ralph Wachter
703-696-4304
ralph.wachter@navy.mil

DoE Mathematics Program
Office of Advanced Scientific Computing Research
Office of Science
U.S. Department of Energy
SC-21.1, Germantown Building
1000 Independence Avenue, SW
Washington, DC 20585-1290
http://www.sc.doe.gov/ascr/index.html

Michael Strayer
Associate Director
301-903-7486
michael.strayer@science.doe.gov

Computational Science Research and Partnerships Division
Walter M. Polansky, Acting Director
301-903-5800
walt.polansky@science.doe.gov

Computer Science
Dan Hitchcock
301-903-9958
daniel.hitchcock@science.doe.gov

Computer Science SciDAC Centers and Institutes
Osni Marques
301-903-9925
oamarques@ascr.doe.gov

Data and Visualization
Lucy Nowell
301-903-3191
lucy.nowell@science.doe.gov

Barbara Helland
301-903-3127
barbara.helland@science.doe.gov

High Performance Computing (HPC) Science and Applications
Sonia Sachs
301-903-0060
sonia.sachs@science.doe.gov

Network Research
Thomas D. Ndousse-Fetter
301-903-9960
tndousse@ascr.doe.gov

Multiscale Mathematics
Sandy Landsberg
301-903-8507
landsberg@ascr.doe.gov

Steven Lee
301-903-5710
slee@ascr.doe.gov

Karen Pao
301-903-5384
appliedmath@ascr.doe.gov

SciDAC Centers and Institutes
Bill Spotz
301-903-8268
wfspotz@ascr.doe.gov

Book List

The Book List highlights books that have mathematical themes and are aimed at a broad audience potentially including mathematicians, students, and 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* notices-booklist@ams.org.

*Added to "Book List" since the list's last appearance.

The Archimedes Codex: How a Medieval Prayer Book Is Revealing the True Genius of Antiquity's Greatest Scientist, by Reviel Netz and William Noel. Da Capo Press, October 2007. ISBN-13: 978-03068-1580-5. (Reviewed September 2008.)

Bright Boys: The Making of Information Technology, by Tom Green. A K Peters, April 2010. ISBN-13: 978-1-56881-476-6.

The Calculus of Friendship: What a Teacher and Student Learned about Life While Corresponding about Math, by Steven Strogatz. Princeton University Press, August 2009. ISBN-13: 978-0-691-13493-2. (Reviewed June/July 2010.)

The Cult of Statistical Significance: How the Standard Error Costs Us Jobs, Justice, and Lives, by Stephen T. Ziliak and Deirdre N. McCloskey, University of Michigan Press, February 2008. ISBN-13: 978-04720-500-79. (Reviewed in this issue.)

Duel at Dawn: Heroes, Martyrs, and the Rise of Modern Mathematics, by Amir Alexander. Harvard University Press, April 2010. ISBN-13: 978-06740-466-10.

Here's Looking at Euclid: A Surprising Excursion through the Astonishing World of Math, by Alex Bellos. Free Press, June 2010. ISBN-13: 978-14165-882-52.

The Housekeeper and the Professor, by Yoko Ogawa. Picador, February 2009. ISBN-13: 978-03124-278-01. (Reviewed May 2010.)

How to Read Historical Mathematics, by Benjamin Wardhaugh. Princeton University Press, March 2010. ISBN-13: 978-06911-401-48.

Isaac Newton on Mathematical Certainty and Method, by Niccolò Guicciardini. MIT Press, October 2009. ISBN-13: 978-02620-131-78.

Logicomix: An Epic Search for Truth, by Apostolos Doxiadis and Christos Papadimitriou. Bloomsbury USA, September 2009. ISBN-13: 978-15969-145-20.

Logic's Lost Genius: The Life of Gerhard Gentzen, by Eckart Menzler-Trott, Craig Smorynski (translator), Edward R. Griffor (translator). AMS-LMS, November 2007. ISBN-13: 978-0-8218-3550-0.

The Mathematical Mechanic: Using Physical Reason to Solve Problems, by Mark Levi. Princeton University Press, 2009. ISBN-13: 978-0691140209.

Mathematicians: An Outer View of the Inner World, by Mariana Cook. Princeton University Press, June 2009. ISBN-13: 978-0-691-13951-7. (Reviewed August 2010.)

Mathematicians Fleeing from Nazi Germany: Individual Fates and Global Impact, by Reinhard Siegmund-Schultze. Princeton University Press, July 2009. ISBN-13: 978-0-691-14041-4.

Mathematics in Ancient Iraq: A Social History, by Eleanor Robson. Princeton University Press, August 2008. ISBN-13: 978-06910-918-22. (Reviewed March 2010.)

Mathematics in India, by Kim Plofker. Princeton University Press, January 2009. ISBN-13: 978-06911-206-76. (Reviewed March 2010.)

The Mathematics of Egypt, Mesopotamia, China, India, and Islam: A Sourcebook, by Victor J. Katz et al. Princeton University Press, July 2007. ISBN-13: 978-0-6911-2745-3.

The Millennium Prize Problems, edited by James Carlson, Arthur Jaffe, and Andrew Wiles. AMS, June 2006. ISBN-13: 978-08218-3679-8. (Reviewed December 2009.)

More Mathematical Astronomy Morsels, by Jean Meeus. Willmann-Bell, 2002. ISBN 0-943396743.

Mrs. Perkins's Electric Quilt: And Other Intriguing Stories of Mathematical Physics, Paul J. Nahin, Princeton University Press, August 2009. ISBN-13: 978-06911-354-03.

Naming Infinity: A True Story of Religious Mysticism and Mathematical Creativity, by Loren Graham and Jean-Michel Kantor. Belknap Press of Harvard University Press, March 2009. ISBN-13: 978-06740-329-34.

Numbers Rule: The Vexing Mathematics of Democracy, from Plato to the Present, by George G. Szpiro. Princeton University Press, April 2010. ISBN-13: 978-06911-399-44.

The Numerati, by Stephen Baker. Houghton Mifflin, August 2008. ISBN-13: 978-06187-846-08. (Reviewed October 2009.)

Our Days Are Numbered: How Mathematics Orders Our Lives, by Jason Brown. Emblem Editions, April 2010. ISBN-13: 978-07710-169-74.

A Passion for Discovery, by Peter Freund. World Scientific, August 2007. ISBN-13: 978-9-8127-7214-5

Perfect Rigor: A Genius and the Mathematical Breakthrough of the Century, by Masha Gessen. Houghton Mifflin Harcourt, November 2009. ISBN-13: 978-01510-140-64.

Pioneering Women in American Mathematics: The Pre-1940 Ph.D.'s, by Judy Green and Jeanne LaDuke. AMS, December 2008. ISBN-13:978-08218-4376-5.

Plato's Ghost: The Modernist Transformation of Mathematics, by Jeremy Gray. Princeton University Press, September 2008. ISBN-13: 978-06911-361-03. (Reviewed February 2010.)

The Princeton Companion to Mathematics, edited by Timothy Gowers (June Barrow-Green and Imre Leader, associate editors). Princeton University Press, November 2008. ISBN-13: 978-06911-188-02. (Reviewed November 2009.)

Probabilities: The Little Numbers That Rule Our Lives, by Peter Olofsson. Wiley, March 2010. ISBN-13: 978-04706-244-56.

Proofs from THE BOOK, by Martin Aigner and Günter Ziegler. Expanded fourth edition, Springer, October 2009. ISBN-13: 978-3-642-00855-9

Pythagoras' Revenge: A Mathematical Mystery, by Arturo Sangalli. Princeton University Press, May 2009. ISBN-13: 978-06910-495-57. (Reviewed May 2010.)

Recountings: Conversations with MIT Mathematicians, edited by Joel Segel. A K Peters, January 2009. ISBN-13: 978-15688-144-90.

Roger Boscovich, by Radoslav Dimitric (Serbian). Helios Publishing Company, September 2006. ISBN-13: 978-09788-256-21.

Sacred Mathematics: Japanese Temple Geometry, by Fukagawa Hidetoshi and Tony Rothman. Princeton University Press, July 2008. ISBN-13: 978-0-6911-2745-3.

**The Shape of Inner Space: String Theory and the Geometry of the Universe's Hidden Dimensions,* by Shing-Tung Yau (with Steve Nadis). Basic Books, September 2010. ISBN-13: 978-04650-202-32.

The Solitude of Prime Numbers, by Paolo Giordano. Pamela Dorman Books, March 2010. ISBN-13: 978-06700-214-82. (Reviewed September 2010.)

Solving Mathematical Problems: A Personal Perspective, by Terence Tao. Oxford University Press, September 2006. ISBN-13: 978-0-199-20560-8. (Reviewed February 2010.)

Sphere Packing, Lewis Carroll, and Reversi, by Martin Gardner. Cambridge University Press, July 2009. ISBN-13: 978-0521756075.

The Strangest Man, by Graham Farmelo. Basic Books, August 2009. ISBN-13: 978-04650-182-77.

Street-Fighting Mathematics: The Art of Educated Guessing and Opportunistic Problem Solving, by Sanjoy Mahajan. MIT Press, March 2010. ISBN-13: 978-0-262-51429-3.

Symmetry in Chaos: A Search for Pattern in Mathematics, Art, and Nature, by Michael Field and Martin Golubitsky. Society for Industrial and Applied Mathematics, second revised edition, May 2009. ISBN-13: 978-08987-167-26.

Teaching Statistics Using Baseball, by James Albert. Mathematical Association of America, July 2003. ISBN-13: 978-08838-572-74. (Reviewed April 2010.)

Tools of American Math Teaching, 1800–2000, by Peggy Aldrich Kidwell, Amy Ackerberg-Hastings, and David Lindsay Roberts. Johns Hopkins University Press, July 2008. ISBN-13: 978-0801888144. (Reviewed January 2010.)

The Unfinished Game: Pascal, Fermat, and the Seventeenth-Century Letter That Made the World Modern, by Keith Devlin. Basic Books, September 2008. ISBN-13: 978-0-4650-0910-7.

Zeno's Paradox: Unraveling the Ancient Mystery behind the Science of Space and Time, by Joseph Mazur. Plume, March 2008 (reprint edition). ISBN-13: 978-0-4522-8917-8.

About the cover

The French Quarter

The cover illustration for this issue is an ink and felt pen sketch of Royal Street in the Vieux Carré of New Orleans, site of this year's Joint Mathematics Meetings. It was drawn in 1998 by Karl Hofmann, faculty member at both Tulane University and the University of Darmstadt. His tools were a Staedtler calligraphic pen and a few felt pens.

Karl says, "New Orleanians call the French Quarter, the oldest part of their town, the 'Vieux Carré', indicating at the same time its old history and its European flavor, preserved to this day: bustling with tourists and locals alike, with jazz musicians, artists, tarot readers, and other performers in Royal Street and around Jackson Square. A friend of mine commented that the black-and-white rendition conjured up in him the impression of yesterday's authenticity of the time of black-and-white photographs."

Karl was also responsible for the *Notices* cover associated with the last annual meeting in New Orleans (2007). We are grateful to him for both.

—Bill Casselman
Graphics Editor
(notices-covers@ams.org)

Officers and Committee Members

Numbers to the left of headings are used as points of reference in an index to AMS committees which follows this listing. Primary and secondary headings are:

Terms of members expire on January 31 following the year given unless otherwise specified.

1. Officers

President	George E. Andrews	2010
President Elect	Eric M. Friedlander	2010
Vice Presidents	Sylvain Cappell	2012
	Frank Morgan	2011
	Bernd Sturmfels	2010
Secretary	Robert J. Daverman	2010
Associate Secretaries	Georgia Benkart	2011
	Michel L. Lapidus	2011
	Matthew Miller	2010
	Steven Weintraub	2010
Treasurer	John M. Franks	2010
Associate Treasurer	Linda Keen	2010

1.1. Liaison Committee

All members of this committee serve *ex officio*.

Chair	George E. Andrews
	Robert J. Daverman
	John M. Franks
	Carol S. Wood

2. Council

2.0.1. Officers of the AMS

President	George E. Andrews	2010
President Elect	Eric M. Friedlander	2010
Vice Presidents	Sylvain Cappell	2012
	Frank Morgan	2011
	Bernd Sturmfels	2010
Secretary	Robert J. Daverman	2010
Associate Secretaries*	Georgia Benkart	2011
	Michel L. Lapidus	2011
	Matthew Miller	2010
	Steven Weintraub	2010
Treasurer	John M. Franks	2010
Associate Treasurer	Linda Keen	2010

2.0.2. Representatives of Committees

Bulletin	Susan J. Friedlander	2011
Colloquium	Paul J. Sally, Jr.	2011
Executive Committee	Ruth M. Charney	2010
	Craig Huneke	2011
Journal of the AMS	Karl Rubin	2013
Mathematical Reviews	Ronald M. Solomon	2012
Mathematical Surveys and Monographs	Ralph L. Cohen	2012
Mathematics of Computation	Chi-Wang Shu	2011
Proceedings	Ken Ono	2013
Transactions and Memoirs	Robert Guralnick	2012

2.0.3. Members at Large

Alejandro Adem	2012	Joseph H. Silverman	2010
Aaron Betram	2011	Panagiotis E. Souganidis	2011
Rebecca F. Goldin	2010	Janet Talvacchia	2012
Richard Hain	2012	Christoph Thiele	2012
Bryna Kra	2010	Michelle L. Wachs	2011
William A. Massey	2011	Sarah J. Witherspoon	2010
Irena Peeva	2010	David Wright	2011
Jennifer Schultens	2012		

*Only one Associate Secretary at a time is a voting member of the Council, namely the cognizant Associate Secretary for the scientific sessions.

2.1. Executive Committee of the Council

	George E. Andrews	*ex officio*
	Ruth M. Charney	2010
	Robert J. Daverman	*ex officio*
	Eric M. Friedlander	*ex officio*
	Craig L. Huneke	2011
	Bryna Kra	2013
	Joseph H. Silverman	2012

3. Board of Trustees

	George E. Andrews	*ex officio*
	John B. Conway	2010
	John M. Franks	*ex officio*
	Mark L. Green	2014
	Linda Keen	*ex officio*
	Ronald J. Stern	2013
Secretary	Karen Vogtmann	2012
Chair	Carol S. Wood	2011

4. Committees

4.1. Committees of the Council

Standing Committees

4.1.1. Editorial Boards

	Robert J. Daverman	*ex officio*
	Sergei Gelfand	*ex officio*
	Michael T. Lacey	2011
	Anatoly S. Libgober	2012
Chair	Alan W. Reid	2010
	Michael F. Singer	2011
	Catherine Sulem	2010
	Simon Tavener	2012

4.1.2. Fellows Program Revision

	George E. Andrews	2010
	James G. Arthur	2010
	Susan J. Friedlander	2010
Chair	James G. Glimm	2010

4.1.3. Nominating Committee

Terms begin on January 1 and expire on December 31 of the year listed.

	William Beckner	2012
	Percy Alec Deift	2010
	Richard T. Durrett	2012
	Irene Fonseca	2011
Chair	Sheldon H. Katz	2011
	Ellen E. Kirkman	2011
	Louise A. Raphael	2010
	Carla D. Savage	2012
	Richard A. Wentworth	2010

Policy Committees

4.1.4. Employment Services, Advisory Board on

	Laura G. DeMarco	2011
	Patrick Barry Eberlein	2012
	Richard M. Hain	2010

4.1.5. Mathematics Research Communities Advisory Board

	David Aldous	2010
	Robert J. Daverman	2012
Chair	David Eisenbud	2010
	William M. Goldman	2012
	Ken Ono	2012
	Hal Schenck	2010
	Frank Sottile	2010
	Alejandero Uribe	2012
	Genevieve Walsh	2010

Special Committees

4.1.6. Editor for Bulletin, Search Committee for

	George E. Andrews	2011
	Robert J. Daverman	2011
	Donald E. McClure	2011
	Ken Ono	2011
	Michelle Wachs	2011

4.1.7. Associate Treasurer, Search Committee for

	John M. Franks	2011
Chair	Jane Hawkins	2011
	Linda Keen	2011

4.1.8. Treasurer, Search Committee for the

Chair	John M. Franks	2010
	Linda Keen	2010
	B. A. Taylor	2010
	Carol S. Wood	2010

4.2. Editorial Committees

4.2.1. Abstracts Editorial Committee

All members of this committee serve *ex officio*.

	Georgia Benkart
Chair	Robert J. Daverman
	Michel L. Lapidus
	Matthew Miller
	Steven Weintraub

4.2.2. Bulletin (New Series)

Consultant	Gerald L. Alexanderson	2010
Book Reviews Editor	Robert L. Devaney	2011
Chief Editor	Susan J. Friedlander	2011
Consultant	Jane Kister	2010

Associate Editors for Bulletin Articles

David J. Benson	2011	Gregory Lawler	2011
Daniel S. Freed	2011	Barry Mazur	2011
Edward Frenkel	2011	Paul H. Rabinowitz	2011
Mark Goresky	2011	Panagiotis E. Souganidis	2010
Andrew J. Granville	2011	Yuri Tschinkel	2011
Bryna R. Kra	2011	Michael Wolf	2011

Associate Editors for Book Reviews

Jonathan L. Alperin	2011	Ken Ono	2011
Steven G. Krantz	2011	Philip E. Protter	2011
Peter Kuchment	2011	Lisa Traynor	2011

4.2.3. Collected Works

Chair	Dusa McDuff	2012
	Elias M. Stein	2012
	William A. Veech	2011

4.2.4. Colloquium

	Yuri Manin	2013
Chair	Paul J. Sally, Jr.	2011
	Peter Sarnak	2012

4.2.5. Contemporary Mathematics

	George E. Andrews	2011
Chair	Dennis DeTurck	2011
	Abel Klein	2011
	Martin Strauss	2011

4.2.6. Graduate Studies in Mathematics

Chair	David A. Cox	2012
	Rafe Mazzeo	2011
	Martin G. Scharlemann	2011
	Gigliola Staffilani	2013

4.2.7. Journal of the AMS

	Weinan E	2013
	Sergey Fomin	2012
	Gregory Lawler	2012
	Tom Mrowka	2013
Chair	Karl Rubin	2013
	Terence Tao	2011

Associate Editors

Noga Alon	2011	Elon Lindenstrauss	2011
Alexei Borodin	2011	Jacob Lurie	2012
Robert L. Bryant	2011	Haynes R. Miller	2012
Emanuel Candes	2011	Assaf Naor	2011
Sun-Yung Alice Chang	2013	Sorin T. Popa	2011
Brian Conrad	2013	Thomas Scanlon	2012
Pavel I. Etingof	2011	Freydoon Shahidi	2012
Mark Goresky	2011	Karen Vogtmann	2013
Christopher Hacon	2012	Avi Wigderson	2012
Peter Kronheimer	2012	Lia-Sang Young	2011

4.2.8. Mathematical Reviews

AMS staff contact: Graeme Fairweather

	Cameron Gordon	2011
	Barbara Keyfitz	2013
	Peter Maass	2012
	Shigefumi Mori	2013
Chair	Ronald M. Solomon	2012
	Trevor D. Wooley	2012

4.2.9. Mathematical Surveys and Monographs

Chair	Ralph L. Cohen	2012
	Eric M. Friedlander	2010
	Michael Singer	2013
	Benjamin Sudakov	2011
	Michael Weinstein	2013

4.2.10. Mathematics of Computation

	Susanne C. Brenner	2012
	Ronald F. Cools	2011
	Igor Shparlinski	2011
Chair	Chi-Wang Shu	2011

Associate Editors

Rémi Abgrall	2013	Gilles Pagès	2013
Daniela Calvetti	2011	Cheryl Praeger	2012
Zhiming Chen	2013	Renate Scheidler	2013
Jean-Marc Couveignes	2011	Christoph Schwab	2011
Ricardo G. Duran	2013	Jie Shen	2011
Ivan P. Gavrilyuk	2011	Chris J. Smyth	2013
Viviette Girault	2012	Michael Stillman	2012
Ernst Hairer	2011	Daniel B. Szyld	2013
Fred J. Hickernell	2011	Tao Tang	2012
Gregor Kemper	2012	Paul Tseng	2012
Michael J. Mossinghoff	2013	Hans W. Volkmer	2011
Francis J. Narcowich	2011	Ya-Xiang Yuan	2013
Marian Neamtu	2011	Zhimin Zhang	2012
Stanley Osher	2011		

4.2.11. Notices Editorial Board

Terms begin on January 1 and expire on December 31 of the year listed.

Editor	Steven G. Krantz	2012

Associate Editors

Krishnaswami Alladi	2012	Robion C. Kirby	2012
David H. Bailey	2012	Rafe Mazzeo	2012
Jonathan M. Borwein	2012	Harold R. Parks	2012
Susanne Brenner	2012	Peter C. Sarnak	2012
William Casselman	2012	Mark E. Saul	2012
Robert J. Daverman	*ex officio*	Edward L. Spitznagel	2012
Lisette de Pillis	2012	John R. Swallow	2012
Susan J. Friedlander	2012		

4.2.12. Proceedings

	Mario Bonk	2011
	Lev Borisov	2011
	Richard Bradley	2010
	Kathrin Bringmann	2013
	Jianguo Cao	2013
Coordinating	Peter A. Clarkson	2010
	Walter Craig	2012
	Harm Derksen	2013
	Alexander N. Dranishnikov	2011
	Franc Forstneric	2012
	Matthew J. Gursky	2010
	James Haglund	2013
	Jonathan I. Hall	2010
Coordinating	Birge Huisgen-Zimmermann	2013
	Marius Junge	2010
	Nigel Kalton	2011
	Julia Knight	2012
	Bryna Kra	2011
	Michael T. Lacey	2012
	Gail R. Letzter	2010
Chair	Ken Ono	2013
	Matthew Papanikolas	2013
	Irena Peeva	2013
	Richard H. Rochberg	2013
Coordinating	Daniel Ruberman	2013
Coordinating	Mei-Chi Shaw	2012
	Brooke E. Shipley	2012
	Hart F. Smith	2010
Coordinating	Chuu-Lian Terng	2013
	Tatiana Toro	2010
	Walter Van Assche	2012
	Mathai Varghese	2011
	Edward C. Waymire	2011
	Michael Wolf	2013
	Yingfei Yi	2012

4.2.13. Proceedings of Symposia in Applied Mathematics

	Mary C. Pugh	2013
	Leonid Ryzhik	2011
Chair	Eitan Tadmor	2011

4.2.14. Transactions and Memoirs

	Dan Abramovich	2010
	Alejandro Adem	2012
	Luchezar L. Avramov	2012
	Richard Bass	2011
	Mark Feighn	2011
Chair	Robert Guralnick	2012
	Yunping Jiang	2011
	Alexander Kleshchev	2012
	Steffan Lempp	2011
	William P. Minicozzi II	2010
	Alexander Nagel	2010
	Peter Polacik	2010
	Gustavo Alberto Ponce	2013
	Jonathan Rogawski	2011
	Shankar Sen	2012
	Dimitri Shlyakhtenko	2010
	John R. Stembridge	2013
	Daniel I. Tartaru	2010
	Mina Teicher	2012
	Erik P. Van Den Ban	2013
	Christopher Woodward	2012

4.2.15. Translation from Chinese

	Sun-Yung Alice Chang
	S.-Y. Cheng
Chair	Tsit-Yuen Lam
	Tai-Ping Liu
	Chung-Chun Yang

4.2.16. Translation from Japanese

Chair	Shoshichi Kobayashi
	Masamichi Takesaki

Standing Committees

4.2.17. Conformal Geometry and Dynamics

	Francois Berteloot	2011
	Mario Bonk	2013
	Sun-Yung Alice Chang	2010
	Pekka Koskela	2012
Chair	Gaven Martin	2011
	Susan Mary Rees	2011
	Caroline Series	2012

4.2.18. History of Mathematics

	Joseph W. Dauben	2011
	Peter L. Duren	2011
	Robin Hartshorne	2012
Chair	Karen H. Parshall	2011

4.2.19. Pure and Applied Undergraduate Texts

Chair	Paul J. Sally, Jr.	2012
	Joseph H. Silverman	2012
	Francis Edward Su	2012
	Susan Tolman	2012

4.2.20. Representation Theory

	Jens Carsten Jantzen	2012
	Nicolai Reshetikhin	2012
Chair	Henrik Schlichtkrull	2012
	Freydoon Shahidi	2012
	Peter E. Trapa	2012
	David A. Vogan	2013

4.2.21. Student Mathematics Library

	Gerald B. Folland	2012
	Robin Forman	2011
Chair	Brad G. Osgood	2011
	John Stillwell	2013

4.2.22. University Lecture Series

Chair	Eric M. Friedlander	2010
	William P. Minicozzi II	2013
	Benjamin Sudakov	2010
	Tatiana Toro	2013

4.3. Committees of the Board of Trustees

4.3.1. Agenda and Budget

All members of this committee serve *ex officio.*
AMS staff contact: Ellen H. Heiser

Chair	George E. Andrews
	Robert J. Daverman
	John M. Franks
	Linda Keen
	Carol S. Wood

4.3.2. Audit

All members of this committee serve *ex officio.*

Chair	John M. Franks
	Linda Keen
	Karen Vogtmann
	Carol S. Wood

4.3.3. Investment

Chair	John M. Franks	*ex officio*
	Linda Keen	*ex officio*
	Ronald J. Stern	*ex officio*
	Rob Taylor	2012

4.3.4. Salary

All members of this committee serve *ex officio.*
AMS staff contact: Donald E. McClure.

Chair	John M. Franks
	Linda Keen
	Carol S. Wood

4.4. Committees of the Executive Committee and Board of Trustees

4.4.1. Long Range Planning

All members of this committee serve *ex officio.*
AMS staff contact: Ellen H. Heiser.

Chair	George E. Andrews
	Robert J. Daverman
	John M. Franks
	Craig L. Huneke
	Donald E. McClure
	Joseph H. Silverman
	Carol S. Wood

4.4.2. Nominating

All members of this committee serve *ex officio.*

	Craig L. Huneke
	Sheldon H. Katz
Chair	Karen Vogtmann

4.5. Internal Organization of the American Mathematical Society

Standing Committees

4.5.1. Archives

	Bruce C. Berndt	2011
	Thomas W. Hawkins	2012
Chair	Kenneth R. Meyer	2010

4.5.2. Books and Journal Donations Steering Committee

	Toka Diagana	2012
Chair	Huaxin Lin	2011
	Nageswari Shanmugalingam	2010

4.5.3. Committee on Committees

Chair	Krishnaswami Alladi	2010
	George E. Andrews	*ex officio*
	Steven Damelin	2010
	Robert J. Daverman	*ex officio*
	Charles L. Epstein	2010
	Eric M. Friedlander	*ex officio*
	Johnny L. Henderson	2010
	Chawne M. Kimber	2010
	Bryna Kra	2010
	Steven G. Krantz	2010
	R. James Milgram	2010
	Ken Ono	2010
	Kim Ruane	2010
	Mei-Chi Shaw	2010

4.5.4. Library Committee

	Jonathan M. Borwein	2011
	Roger Chalkley	2010
	Sherry Chang	2010
	Silvio Levy	2009
	Joseph Rosenblatt	2012
	Linda Y. Yamamoto	2011
	Yunliang Yu	2010
	Smilka Zdravkovska	2012

4.5.5. Publications

AMS staff contact: Erin Buck.

	George E. Andrews	*ex officio*
	Aaron J. Bertram	2011
	Richard Brualdi	2012
	Robert J. Daverman	*ex officio*
	Roman J. Dwilewicz	2010
	Sergei Gelfand	*ex officio*
	Mark Goresky	2011
	Richard M. Hain	2012
	Gregory F. Lawler	2011
	Donald E. McClure	*ex officio*
	Andrew M. Odlyzko	2011
	Alan Reid	2010
Chair	Joseph H. Silverman	2010
	Carol S. Wood	2010

4.6. Program and Meetings

Standing Committees

4.6.1. Meetings and Conferences

AMS staff contact: Ellen Maycock

	Daljit S. Ahluwalia	2011
	George E. Andrews	*ex officio*
	Robert J. Daverman	*ex officio*
	David W. Farmer	2012
	Ryan Garibaldi	2010
	Mark Green	2010
Chair	Aloysius G. Helminck	2010
	Alex Iosevich	2011
	William A. Massey	2011
	Donald E. McClure	*ex officio*
	Irena Peeva	2010
	Janet Talvacchia	2013
	Ann Trenk	2010

4.6.2. Program Committee for National Meetings

	J. P. Buhler	2012
	Suncica Canic	2011
	Robert J. Daverman	*ex officio*
	Vaughan F. R. Jones	2010
Chair	Dana Randall	2010
	K. Soundararajan	2012
	Gigliola Staffilani	2011
	Steven H. Weintraub	*ex officio*

4.6.3. Short Course Subcommittee

	Yuliy M. Baryshnikov	2011
	Robert W. Ghrist	2012
	Charles M. Grinstead	2012
	Jonathan C. Mattingly	2011
Chair	Daniel Rockmore	2010
	Chi-Wang Shu	2010
	John Sylvester	2012

4.6.4. Central Section Program Committee

	Scott Ahlgren	2011
	Georgia Benkart	*ex officio*
Chair	Joseph G. Conlon	2010
	Brendan E. Hassett	2011
	Russell D. Lyons	2010

4.6.5. Eastern Section Program Committee

Chair	Bruce A. Kleiner	2010
	John E. Meier	2011
	Robert C. Vaughan	2011
	Michael Vogelius	2010
	Steven Weintraub	*ex officio*

4.6.6. Southeastern Section Program Committee

	Matthew Boylan	2011
Chair	John Etnyre	2010
	Ian Knowles	2010
	Matthew Miller	*ex officio*
	Chris Rodger	2011

4.6.7. Western Section Program Committee

	Thomas Y. Hou	2010
	Michel L. Lapidus	*ex officio*
	Daniel Tataru	2011
	Chuu-Lian Terng	2011
Chair	Rekha Thomas	2010

4.6.8. Agenda for Business Meetings

	Robert J. Daverman	*ex officio*

4.6.9. Arnold Ross Lecture Series Committee

Chair	Thomas C. Hull	2010
	Jonathan M. Kane	2012
	David Pollack	2012
	Daniel B. Shapiro	2011

4.6.10. Colloquium Lecture

Chair	Peter Sarnak	2010
	Gilbert Strang	2011
	Efim I. Zelmanov	2012

4.6.11. Gibbs Lecturer for 2011 and 2012, Committee to Select

	Robet Calderbank	2011
Chair	James G. Glimm	2011
	James A. Sethian	2011

4.7. Status of the Profession

Standing Committees

4.7.1. Academic Freedom, Tenure, and Employment Security

	William K. Allard	2010
	Lisa Carbone	2011
Chair	Ronald G. Douglas	2010
	John B. Garnett	2012
	Joseph M. Landsberg	2011
	Michael K. May	2010
	Margaret M. Robinson	2012

4.7.2. Education

AMS staff contact: Samuel M. Rankin III.

	George E. Andrews	*ex officio*
	Ralph L. Cohen	2011
	Robert J. Daverman	*ex officio*
	Beverly E. J. Diamond	2011
	Michael E. Gage	2010
	Rebecca F. Goldin	2010
Chair	Lawrence Firman Gray	2010
	Kenneth I. Gross	2012
	Deborah Hughes Hallett	2010
	Donald E. McClure	*ex officio*
	Harriett S. Pollatsek	2012
	Catherine Roberts	2012
	Ronald J. Stern	2010
	Christopher Theile	2012
	Sarah J. Witherspoon	2010
	David Wright	2011

4.7.3. Fan Fund

Chair	Tsit-Yuen Lam	2010
	Jinchao Xu	2011
	Tonghai Yang	2012

4.7.4. Human Rights of Mathematicians

	Mark Alber	2012
	Augustin Banyaga	2012
	Margaret Bayer	2010
	Raul E. Curto	2011
	Wilfrid Gangbo	2011
	Parimala Raman	2010
	Tanush Shaska	2012
	Yakov Sinai	2011
Chair	Joseph C. Watkins	2010

4.7.5. Profession

AMS staff contact: Ellen J. Maycock.

	George E. Andrews	*ex officio*
	Bruce Blackadar	2010
	John B. Conway	2010
	Robert J. Daverman	*ex officio*
	Ron Y. Donagi	2012
	Charles L. Epstein	2010
	Lorelei Koss	2012
	Bryna Kra	2010
Chair	Susan Loepp	2010
	Donald E. McClure	*ex officio*
	Christopher K. McCord	2011
	Rick Miranda	2011
	Jennifer Schultens	2012
	Jeffrey Vaaler	2012
	Michelle Wachs	2011
	Julius Zelmanowitz	2011

4.7.6. Professional Ethics

	Miklos Bona	2012
	Petra Bonfert-Taylor	2012
	David B. Leep	2010
	John Roe	2012
Chair	William Trotter	2010
	Dana P. Williams	2011

4.7.7. Science Policy

AMS staff contact: Samuel M. Rankin III.

	Alejandro Adem	2012
	George E. Andrews	*ex officio*
	Gunnar Carlsson	2010
	Robert J. Daverman	*ex officio*
	James W. Demmel	2010
	Eric M. Friedlander	*ex officio*
	Kenneth M. Golden	2012
Chair	Rebecca F. Goldin	2010
	Lawrence Firman Gray	2010
	David C. Manderscheid	2012
	Donald E. McClure	*ex officio*
	Konstantin Mischaikow	2010
	George C. Papanicolaou	2011
	Panagiotis Souganidis	2011
	Karen Votgman	2010

4.7.8. Young Scholars Awards

Terms expire on June 30.

	Brian R. Hunt	2013
Chair	Irwin Kra	2011
	Rafe Mazzeo	2012
	Zvezdelina E. Stankova	2013
	Jeremy T. Teitelbaum	2010

4.8. Prizes and Awards

Standing Committees

4.8.1. AMS Public Policy Award Selection Committee

	George E. Andrews	2010
	Eric M. Friedlander	2010
	Rebecca F. Goldin	2010

4.8.2. Award for Distinguished Public Service, Committee to Select the Winner of the

	Richard A. Askey	2013
	C. Herbert Clemens	2013
	Richard A. Tapia	2011
	________	2014
	________	2014

4.8.3. The Stefan Bergman Trust Fund

	Carlos Kenig	2012
	Linda Preiss Rothschild	2011
Chair	Elias M. Stein	2010

4.8.4. Bôcher Prize, Committee to Select the Winner of

	Alberto Bressan	2010
	Reese Harvey	2010
Chair	David Jerison	2010

4.8.5. Centennial Fellowships

Terms expire on June 30.

	Adebisi Agboola	2010
	Abel Klein	2011
Chair	Peter B. Kronheimer	2011
	Loredana Lanzani	2011
	David R. Larson	2010
	Judith A. Packer	2010
	Zinovy Reichstein	2010

4.8.6. Conant Prize, Committee to Select the Winner of the

Chair	Georgia Benkart	2010
	Jerry Bona	2012
	Ronald M. Solomon	2011

4.8.7. Joseph L. Doob Prize

	Harold Boas	2015
	Andrew J. Granville	2012
	Robin C. Hartshorne	2012
Chair	Neal I. Koblitz	2015
	John H. McCleary	2015

4.8.8. Leonard Eisenbud Prize for Mathematics and Physics

	Barry Simon	2010
	Yakov G. Sinai	2010
Chair	Craig Tracy	2010

4.8.9. Math in Moscow Progam—Travel Support

Terms expire on June 30.

Chair	Vladimir V. Chernov	2010
	Leonid Koralov	2010
	Alexander Varchenko	2011

4.8.10. Menger Prize, Committee to Select the Winner of the

Terms expire on May 31.

	Moon Duchin	2012
Chair	Gregory E. Fasshauer	2012
	Jonathan King	2013

4.8.11. E. H. Moore Research Article Prize, Committee to Select the Winner of the

	Sergiu Klainerman	2014
	Kenneth A. Ribet	2014
	Richard M. Schoen	2014
	________	2014
	________	2014

4.8.12. National Awards and Public Representation

Chair	George E. Andrews	*ex officio*
	Robert J. Daverman	*ex officio*
	Eric M. Friedlander	*ex officio*
	Arthur M. Jaffe	2010
	Richard M. Schoen	2011

4.8.13. David P. Robbins Prize

	Louis J. Billera	2011
	Carol E. Fan	2011
	David J. Saltman	2011
	John R. Stembridge	2011
	Peter Winkler	2011

4.8.14. Satter Prize, Committee to Select the Winner of the

	Victor Guillemin	2013
Chair	Jane M. Hawkins	2011
	Sijue Wu	2011

4.8.15. Steele Prizes

	Peter S. Constantin	2011
	Yakov Eliashberg	2012
	John Erik Fornaess	2012
	Barbara Keyfitz	2012
Chair	Gregory F. Lawler	2010
	Richard M. Schoen	2010
	Joel A. Smoller	2011
	Terence Chi-Shen Tao	2011
	Akshay Venkatesh	2012

Special Committees

4.8.16. Cole Prize, Committee to Select the Winner of the

	Manjul Bhargava	2010
Chair	Henryk Iwaniec	2010
	Richard L. Taylor	2010

4.8.17. Exemplary Program or Achievement by a Mathematics Department, Committee to Select the Winner of the Prize for

	Carlos Castillo-Chavez	2012
Chair	Amy Cohen	2010
	Annalisa Crannell	2012
	William Burkley Jacob	2010
	Phil Kutzko	2012

4.8.18. Prizes, Task Force on

	Alejandro Adem	2010
	Eric Friedlander	2010
	Robert M. Guralnick	2010
Chair	William H. Jaco	2010
	Chawne Kimber	2010
	Bryna Kra	2010
	Francis Edward Su	2010

4.8.19. Veblen Prize

	Yakov Eliashberg	2010
Chair	Bruce Kleiner	2010
	Peter Steven Ozsvath	2010

4.9. Institutes and Symposia

Standing Committees

4.9.1. Liaison Committee with AAAS

	Edward F. Aboufadel	*ex officio*
	Jerry L. Bona	2011
	Robert Calderbank	*ex officio*
Chair	Keith Devlin	*ex officio*
	David Donoho	2010
	John Ewing	*ex officio*
	Lawrence Firman Gray	*ex officio*
	Kenneth C. Millett	*ex officio*
	Julie C. Mitchell	2011
	Jack Morava	2011
	Shmuel Weinberger	2011

4.9.2. Von Neumann Symposium Selection Committee

	Ronald A. DeVore	2011
	James Sethian	2011
Chair	Joel H. Spencer	2011

4.10. Joint Committees

4.10.1. AMS-ASA-AWM-IMS-MAA-NCTM-SIAM Committee on Women in the Mathematical Sciences

	Indrani Basak (ASA)	2012
Co-chair	Sandra Clarkson (ASA)	2010
	Carolyn Connell (MAA)	2010
	K. Renee Fister (SIAM)	2012
	Priscilla Greenwood (IMS)	2012
	Terrell Hodge (AWM)	2011
	Amy Langville (AMS)	2011
	Nicole Lazar (ASA)	2011
	Tanya Leise (MAA)	2011
	Xihong Lin (IMS)	2010
Co-chair	Maura Mast (AWM)	2010
	Gerald Porter (MAA)	2011
	Mary Silber (SIAM)	2011
	Lynda Wiest (NCTM)	2010
	________(AMS)	2012
	________(AMS)	2012

4.10.2. AMS-ASA-MAA-SIAM Data Committee

AMS staff contact: James W. Maxwell.

	Pam Arroway (ASA)	2012
Chair	Richard J. Cleary (MAA)	2011
	Steven R. Dunbar (AMS)	2012
	Susan Geller (MAA)	2011
	Abbe H. Herzig (AMS)	2011
	Ellen Kirkman (MAA)	2010
	James W. Maxwell (AMS)	*ex officio*
	Joanna B. Mitro (AMS)	2010
	Bart S. Ng (SIAM)	2012
	Douglas C. Ravenel (AMS)	2010
	Marie A. Vitulli (AMS)	2010

4.10.3. AMS-ASA-MAA-SIAM Joint Policy Board for Mathematics

ASA and SIAM members' terms expire December 31 of the year given.

	George E. Andrews (AMS)	2010
	Douglas Arnold (SIAM)	2010
	David M. Bressoud (MAA)	2010
	James Crowley (SIAM)	2010
	Robert J. Daverman (AMS)	2010
	Reinhard Laubenbacher (SIAM)	2010
	Donald E. McClure (AMS)	2012
	Sastry Pantula (ASA)	2010
	Tina H. Straley (MAA)	2010
	Philippe Tondeur (MAA)	2010
	Ronald Wasserstein (ASA)	2010

4.10.4. AMS-ASL-IMS-SIAM Committee on Translations from Russian and Other Slavic Languages

Chair	James D. Stasheff (AMS)

AMS Subcommittee Members

Consultant	V. I. Arnol′d
	Luchezar Avramov
	Igor Dolgachev
Consultant	S. G. Gindikin
Consultant	Askol′d Georgievič Khovanskiĭ
	Robert D. MacPherson
	Grigorii A. Margulis
Consultant	N. K. Nikol′skiĭ
Chair	James D. Stasheff

ASL Subcommittee Members

Chair	Veronica Becher	2011
	Max Dickmann	2011
	Andrei Morozov	2011
	Hiroakira Ono	2011
	Kai Wehmeier	2011
	Feng Ye	2011

IMS Subcommittee Members

Chair	M. I. Freidlin
	B. Pittel
	A. Rukhin
	W. J. Studden

4.10.5. AMS-MAA Committee on Cooperation

All members of this committee serve *ex officio*.

George E. Andrews (AMS)
David Bressoud (MAA)
Robert J. Daverman (AMS)
Barbara T. Faires (MAA)
Eric M. Friedlander (AMS)
Donald E. McClure (AMS)
Tina H. Straley (MAA)
Paul Zorn (MAA)

4.10.6. AMS-MAA Committee on Mathematicians with Disabilities

	Lawrence Baggett (AMS)	2011
	Bradford Chin (MAA)	2012
	Benson S. Farb (AMS)	2010
	David M. James (MAA)	2011
Chair	Judith Miller (MAA)	2011
	Amanda W. Peet (AMS)	2010

4.10.7. AMS-MAA Committee on Teaching Assistants and Part-time Instructors (TA/PTI)

	David C. Carothers (MAA)	2010
	Delaram Kahrobaei (AMS)	2012
	Janet McShane (MAA)	2011
	Calvin C. Moore (AMS)	2010
	Dennis Pence (MAA)	2010
	Stephen Robinson (AMS)	2010
	James Sellers (AMS)	2012
	George T. Yates (MAA)	2010

4.10.8. AMS-MAA Joint Archives Committee

	Bruce C. Berndt (AMS)	2011
	William W. Dunham (MAA)	2011
	Thomas W. Hawkins (AMS)	2012
Chair	Kenneth R. Meyer (AMS)	2010
	James J. Tattersall (MAA)	2010
	David Zitarelli (MAA)	2012

4.10.9. AMS-MAA Joint Meetings Committee

All members of this committee serve *ex officio*.

Chair	Robert J. Daverman
	Donald E. McClure
Consultant	Penny Pina
	Tina H. Straley
	Gerard Venema

4.10.10. AMS-MAA Exhibits Advisory Subcommittee

	Robert J. Daverman
	Christine Davis
	Rebecca Elmo
	Robert Fathauer
	Norma Flores
	Elizabeth Huber
	Linda Larusso
Chair	Penny Pina
	Gale Portwine
	Kady Safar
	Sandi Lynn Scherer
	Inez van Korlaar
	Gerard Venema
	Audra Weaver
	Joan Weiss

4.10.11. AMS-MAA Joint Program Committee for the New Orleans, Meeting January 5–8, 2011

Chair	Scott Ahlgren (AMS)
	Ronald L. Graham (MAA)
	Jennifer J. Quinn (MAA)
	Karen Vogtmann (AMS)

4.10.12. AMS-MAA-SIAM Joint Committee on Employment Opportunities

AMS staff contact: Ellen Maycock.

	Thomas C. Craven (AMS)	2010
	Sue Geller (MAA)	2011
Chair	E. McKay Hyde (SIAM)	2010
	Ellen Maycock (AMS)	*ex officio*
	Michael Pearson (MAA)	*ex officio*
	Margaret Robinson (MAA)	2012
	Leon H. Seitelman (SIAM)	2011
	Sarah Ann Stewart (AMS)	2012
	James Tattersall (MAA)	2010
	Linda Thiel (SIAM)	*ex officio*
	Dana P. Williams (AMS)	2011

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

	Georgia M. Benkart (MAA)	2010
	Anna L. Mazzucato (SIAM)	2011
	Maeve L. McCarthy (SIAM)	2010
Chair	Michael E. Orrison, Jr. (AMS)	2010
	Kannan Soundararjan (MAA)	2012
	Sergei Tabachnikov (AMS)	2012

Special Committees

4.10.14. AMS-Chile Joint Program Committee, December 2010

C. Herbert Clemens
Gustavo Alberto Ponce
Robert S. Rumely
Steven Weintraub

4.10.15. AMS-South Africa Mathematical Society Joint Program Committee, November 29–December 3, 2011

	Percy Deift
Chair	Doron Lubinsky
	Matthew Miller
	Neville Robbins

4.10.16. Committee to Choose a Joint AMS-MAA Invited Speaker for the 2011 MAA Mathfest (August 4–6, 2011, Lexington, KY)

Bruce C. Berndt
Jean Taylor

5. Representatives

5.0.1. American Association for the Advancement of Science

Terms expire on February 21.

Section A	Robert Calderbank	2013
Section Q	Lawrence Firman Gray	2013

5.0.2. Canadian Mathematical Society

David Wright 2010

5.0.3. Conference Board of the Mathematical Sciences

George E. Andrews 2010

5.0.4. Delbert Ray Fulkerson Prize Selection Committee

Richard P. Stanley 2011

5.0.5. MAA Committee on the American Mathematics Competition

Term expires on June 30.

Kiran S. Kedlaya 2012

5.0.6. MAA Committee on Undergraduate Program in Mathematics (CUPM)

Randy McCarthy 2011
Alan Tucker 2011

5.0.7. Professionals in Science and Technology, Commission on

Sam Rankin 2012

5.0.8. U.S. National Committee on Theoretical and Applied Mechanics

Term expires on October 31.

Russel Caflisch	2012

6. Index

Officers and Committee Members

Statistics on Women Mathematicians Compiled by the AMS

At its August 1985 meeting the Council of the AMS approved a motion to regularly assemble and report in the *Notices* information on the relative numbers of men versus women in at least the following categories: membership in the AMS, invited hour addresses at AMS meetings, speakers at Special Sessions at AMS meetings, percentage of women speakers in AMS Special Sessions by gender of organizers, and members of editorial boards of AMS journals.

It was subsequently decided that this information would be gathered by determining the sex of the individuals in the above categories based on name identification if no other means was available and that additional information on the number of Ph.D.s granted to women would also be collected using the AMS-ASA-IMS-MAA-SIAM Annual Survey. Since name identification was used, the information for some categories necessitated the use of three classifications:

Male: names that were obviously male

Female: names that were obviously female

Unknown: names that could not be identified as clearly male or female (e.g., only initials given, non-gender-specific names, etc.)

The following is the twenty-fourth reporting of this information. Updated reports will appear annually in the *Notices*.

Invited Hour Address Speakers at AMS Meetings (2000–2009)

Male:	382	85%
Female:	67	15%
Unknown:	0	0%
Total:	449	

Speakers at Special Sessions at AMS Meetings (2005–2009)

Male:	10,364	80%
Female:	2,461	19%
Unknown:	167	1%
Total:	12,992	

Percentage of Women Speakers in AMS Special Sessions by Gender of Organizers (2009)

Special Sessions with at Least One Woman Organizer

Male:	879	74%
Female:	307	26%
Unknown:	8	1%
Total:	1,194	

Special Sessions with No Women Organizers

Male:	1,569	84%
Female:	290	15%
Unknown:	15	1%
Total:	1,874	

2009 Members of the AMS Residing in the U.S.

Male:	14,380	67%
Female:	3,703	17%
Unknown:	3,438	16%
Total:	21,521	

Trustees and Council Members

	2006		2007		2008		2009	
Male:	27	66%	27	66%	26	63%	29	67%
Female:	14	34%	14	34%	15	37%	14	33%
Total:	41		41		41		43	

Members of AMS Editorial Committees

	2000		2001		2002		2003		2004		2005		2006		2007		2008		2009	
Male:	186	85%	190	85%	195	85%	189	84%	180	84%	184	83%	193	84%	194	84%	168	83%	178	84%
Female:	33	15%	34	15%	35	15%	35	16%	34	16%	38	17%	36	16%	36	16%	35	17%	34	16%
Total:	219		224		230		224		214		222		229		230		203		212	

Ph.D.s Granted to U.S. Citizens

	2000		2001		2002		2003		2004		2005		2006		2007		2008		2009	
Male:	379	71%	343	69%	291	70%	341	68%	347	68%	355	72%	399	72%	396	69%	431	69%	515	69%
Female:	158	29%	151	31%	127	30%	158	32%	166	32%	141	28%	153	28%	180	31%	191	31%	227	31%
Total:	537		494		418		499		513		496		552		576		622		742	

Mathematics Calendar

October 2010

* 21–22 **Workshop on Algebra and Its Applications**, Faculty of Basic Sciences, Department of Pure Mathematics, Ardebil, Islamic Republic of Iran.

Description: The organizing committee cordially invite you to participate in the Workshop on Algebra and Its Applications which will be held in Ardebil, Iran, from October 21–22, 2010. The primary goal of this workshop is to bring together researchers from all fields of algebra. Secondary goal is to provide graduate students and junior researchers with a rich and interesting set of new problems to work on.

Information: `http://www.uma.ac.ir/enalgwork`.

* 25–29 **Workshop 2: Circadian Clocks in Plants and Fungi**, Mathematical Biosciences Institute, The Ohio State University, Columbus, Ohio.

Description: Circadian (24-hour) rhythms control the timing of many biological processes including leaf movements in plants and sporulation in fungi. Advances in understanding the biological mechanism of plant and fungal clocks have also helped inspire clock research in higher organisms. This workshop brings together theorists and experimentalists to better understanding timekeeping in plants and fungi and how they relate to clocks in higher organisms.

Information: `http://www.mbi.osu.edu/2010/ws2description.html`.

November 2010

* 5–6 **Current Topic Workshop: Blackwell-Tapia Conference**, Mathematical Biosciences Institute, The Ohio State University, Columbus, Ohio.

Description: This is the sixth in a series of biannual conferences honoring David Blackwell and Richard Tapia, two seminal figures who inspired a generation of African-American, Native American and Latino/Latina students to pursue careers in mathematics. 2010 Blackwell-Tapia Prize: The National Blackwell-Tapia Committee is pleased to announce that the 2010 Blackwell-Tapia Prize will be awarded to Dr. Trachette Jackson (Department of Mathematics, University of Michigan). This prize is awarded every second year in honor of the legacy of David H. Blackwell and Richard A. Tapia. Special Event: Dr. Richard Tapia will give a public lecture at the Columbus Science Museum (COSI) on Thursday evening, November 4, at 7:00 pm. Admission is free and the public is welcome.

Information: `http://www.mbi.osu.edu/2010/ctwdescription.html`.

* 17–21 **International conference on functional analysis dedicated to the 90th anniversary of Professor V. E. Lyantse**, Lviv National University, Lviv, Ukraine.

Description: The conference will be focused on (but not limited to) the following areas of functional analysis: Operator Theory, Methods

---

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 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. 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 **eight 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/July, 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 the AMS website on the World Wide Web. To access the AMS website, use the URL: `http://www.ams.org/`.

of Nonstandard Analysis, Banach Space Theory, Infinite-Dimensional Holomorphy, Topological Methods in Functional Analysis.
Languages: The official languages of the conference are English, Ukrainian, and Russian.
Fee: The conference fee is UHR 150 for participants from Ukraine and the former CIS and EUR 100 for foreign participants, to be paid in cash upon registration.
Deadline: For the registration form and abstract of report: October 1, 2010.
Information: Further particulars can be found on the webpages: http://www.franko.lviv.ua/faculty/mechmat/Departments/cf/index.html or http://topos.if.ua/conference/index.html.

December 2010

* 4–5 **Palmetto Number Theory Series XIV**, University of South Carolina, Columbia, South Carolina.
Description: The Palmetto Number Theory Series (PANTS) is a series of number theory meetings held in South Carolina, the Palmetto State, and other places in the Southeast. The core members of the PANTS consortium are Clemson University University of South Carolina.
Information: http://www.math.sc.edu/~boylan/seminars/pantshome.html.

* 6–10 **34ACCMCC: The 34th Australasian Conference on Combinatorial Mathematics & Combinatorial Computing**, The Australian National University, Canberra, Australia.
Description: The Australasian Conference on Combinatorial Mathematics and Combinatorial Computing is the annual conference of the Combinatorial Mathematics Society of Australasia. This year it will be held at the Australian National University in Canberra, Australia. The conference covers all areas of combinatorics in mathematics and computer science. The first two days of the conference will run concurrently with the Annual Australian Statistical Mechanics Meeting.
Information: http://www.maths.anu.edu.au/events/34accmcc/34accmcc.html.

* 10–14 **School on Information and Randomness 2010**, Universidad de la Frontera, Pucón, Chile.
Topics: This school will cover topics in random processes, ergodic theory, heat kernel and potential theory, Lévy processes, coalescent and fragmentation theory, stochastic differential equations, percolation theory, finance, probabilistic algorithms and particle systems, and we look forward to seeing the latest developments in these areas.
Support: There are a few fellowships, travel support, and living expenses, especially for Chilean and Latin-American students. Qualifying individuals need to fill out the Online Registration Form and send their curriculum vitae to the secretary of the school before October 31, 2010.
Courses: 1. Julien Berestycki (Univ. Paris VI) "Universality of the Bolthausen-Sznitman coalescent: conjectures, challenges and results", 2. David Damanik (Rice Univ.) "Ergodic Schrödinger Operators", 3. Renming Song (Univ. Illinois at Urbana-Champaign) "Sharp estimates on the heat kernels and Green functions of symmetric Levy processes in open sets".
Information: http://www.ir2010.dim.uchile.cl/.

January 2011

* 14–16 **2011 International Conference on Intelligent Structure and Vibration Control (ISVC 2011)**, Chongqing, China.
Description: Only original and unpublished papers will be considered.
Information: email: icisvc2011@gmail.com; http://www.theiast.org/isvc2011.

* 31–March 4 **Complex and Riemannian Geometry**, CIRM, Marseille, France.
Description: This thematic month—five weeks of conferences and courses—focuses on complex and riemannian geometry. It is located at CIRM, International Center for Mathematical Meetings, which offers very comfortable facilities in a beautiful frame. Program: Week 1: Komplex Analysis Winterschool/Workshop & Applications. Week 2: Extremal metrics: evolution equations and stability. Week 3: Analytic aspects of complex algebraic geometry. Week 4: Non Kählerian aspects of complex geometry. Week 5: Geometric flows in finite or infinite dimension. In order to encourage Ph.D. students, postdocs and young researchers to participate in these events, we have special fundings for those who would like to attend several weeks of conferences. If you are interested in participating or wish to have more information, contact us using the link below.
Information: http://www.latp.univ-provence.fr/geom2011/index.php/welcome.

February 2011

* 18–20 **Second International Conference on Emerging Applications of Information Technology (EAIT 2011)**, Kolkata, India.
Organizer: Computer Society of India, Kolkata Chapter; Technically Co-Sponsored by IEEE Computer Chapter, Calcutta Section. Conference Proceedings to be published by IEEE Computer Society Conference Publishing Services and digitally available in IEEE Xplore.
Deadline: Last date of full paper submission: August 15, 2010.
Information: Please check conference website regularly for updates and announcements. Conference url for contacts and latest updates: http://sites.google.com/site/csieait2011. Paper submission website: http://cmt2.research.microsoft.com/csieait2011. For queries, please send email: csieait2011@gmail.com. http://sites.google.com/site/csieait2011/.

* 19–20 **Palmetto Number Theory Series XV**, Clemson University, Clemson, South Carolina.
Description: The Palmetto Number Theory Series (PANTS) is a series of number theory meetings held in South Carolina, the Palmetto State, and other places in the Southeast. The core members of the PANTS consortium are Clemson University and University of South Carolina.
Information: http://www.math.clemson.edu/~jimlb/PANTS/PANTS15/pants15.html.

March 2011

* 17–19 **The 45th Annual Spring Topology and Dynamical Systems Conference**, University of Texas at Tyler, Tyler, Texas.
Sessions: In addition to 18 invited speakers, there will be special sessions in Continuum Theory, Dynamical Systems, Geometric Group Theory, Geometric Topology, and Set-theoretic Topology.
Information: http://www.math.uttyler.edu/sgraves/STDC2011/.

* 28–April 1 **International workshop: Unlikely intersections in algebraic groups and Shimura varieties**, Scuola Normale Superiore, Centro di Ricerca Matematica Ennio De Giorgi, Pisa, Italy.
Description: This workshop, sponsored by AIM, Scuola Normale Superiore, and the NSF, will explore the recent conjectures on "unlikely intersections" due to Zilber, Pink, and Bombieri-Masser-Zannier, and related or analogous problems in model theory, diophantine geometry, and arithmetic dynamics.
Information: http://aimath.org/ARCC/workshops/zilberpink.html.

April 2011

* 2–3 **Midwest Graduate Student Topology and Geometry Conference**, Michigan State University, East Lansing, Michigan.
Description: This is the 9th Annual Graduate Student Topology and Geometry Conference. Plenary talks will be given by Ralph Cohen, John Etnyre, and Karsten Grove, and open problem sessions will be led by Matthew Hedden, Teena Gerhardt, Jean-Francois Lafont, and Dave Futer. Most of the conference will consist of graduate student talks from many different fields of topology and geometry. This conference provides a chance for graduate students to gain experience

giving conference presentations, learn about disciplines not represented at their schools, learn about open problems in the field, and meet a community of researchers.

June 2011

* 13–16 **2011 International Conference on Applied Mathematics and Interdisciplinary Research**, Nankai University, Tianjin, China.
Second Location: June 16, 2011: Computational Science Research Center, Beijing, China.
Description: Interdisciplinary interaction has emerged as an important mode of research as the boundaries between traditional disciplines are evolving, emerging, and redefining. This is especially true in applied and computational mathematics, medicine, sciences and engineering community. Applied and computational mathematics has traditionally maintained a strong tie with science and engineering communities. They have permeated into medicine and social sciences in the past half century as well. Now, with the rapidly changing landscape in scientific territory, they are facing new challenges so that the community must actively engage in and adopt the interdisciplinary research paradigm. This conference aims at bridging applied and computational mathematics with some well selected scientific and engineering disciplines, especially, computational sciences, physical sciences, biomedical sciences and engineering, and facilitating cross-disciplinary research activities.
Themes: • Analytic methods for partial differential equations, applied analysis, and applied dynamical systems. • Numerical methods for computational sciences, numerical optimization, and high performance computing. • Modeling and computation of condense matter materials, soft matter and complex fluids. • Modeling and computation of complex systems in biological and medical sciences. • Stochastic methods for science and engineering. The conference features a group of invited speakers with expertise in an area of the conference themes and solicits contributed papers as well to provide a scientifically stimulating environment for participants to showcase their state-of-the-art research in applied and computational mathematics and interdisciplinary research.
Sponsors: Chern Institute of Mathematics; School of Mathematical Sciences, Nankai University; Nankai Institute of Scientific Computing; Beijing Computational Science Research Center; State Key Laboratory of Scientific and Engineering Computing (LSEC), CAS.

July 2011

* 4–10 **International Conference on Topology and its Applications (ICTA), 2011**, Department of Mathematics, COMSATS Institute of Information Technology (CIIT), Islamabad, Pakistan.
Aim: To bring together experts and young researchers in the field of topology from Pakistan and abroad. In this way it is hoped to foster ties between topologists in different countries and further the study of topology and its applications. There will be 50-minute key note lectures and 25-minute contributory talks in the first 4 working days. There will be an excursion to the beautiful Kaghan Valley in the last 3 days.
Information: For further details contact any of the emails: `icta@comsats.edu.pk` and `icta2011pk@gmail.com`; `http://ww2.ciit-isb.edu.pk/math/`.

* 12–15 **The 6th SEAMS-GMU 2011 International Conference on Mathematics and Its Applications; Workshop on Financial Mathematics and Workshop on Dynamical System in Biology**, Gadjah Mada University, Yogyakarta, Indonesia.
Description: Following the commitment in mathematical activities to SEAMS (South East Asian Mathematical Society), once in every four years Gadjah Mada University in cooperation with SEAMS organize an International Conference on Mathematics and its Applications in Yogyakarta, Indonesia. The first SEAMS-GMU Conference was held in 1991 and the last (fifth) conference was held in 2007. The scientific program will include invited lectures, contributed presentation and workshops.
Information: `http://seams2011.fmipa.ugm.ac.id/`.

September 2011

* 7–9 **IMA Hot Topics Workshop: Instantaneous Frequencies and Trends for Nonstationary Nonlinear Data**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
Description: In this workshop, we will explore the issues involved in trend determination and instantaneous frequency. This workshop will bring together experts from these areas to exchange ideas and identify new research opportunities for this emerging research area. One of the main objectives of the workshop is to promote research that leads to the discovery and understanding of the underlying processes in order to provide a base for building predictive models. An extension of the trend study is the problem of regression, which is also of great interest to a broad research community, including the econometrics/finance community.
Information: See `http://www.ima.umn.edu/2011-2012/SW9.7-9.11/`.

* 19–23 **IMA Workshop: High Dimensional Phenomena**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
Description: The time is ripe to foster a direct cross-fertilization between the communities in geometric functional analysis, high dimensional geometry and probability and various information theory communities. This workshop will bring together researchers from these communities, including those already at work at the interface, as well as young investigators entering one of the fields.
Information: See `http://www.ima.umn.edu/2011-2012/W9.19-23.11/`.

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.

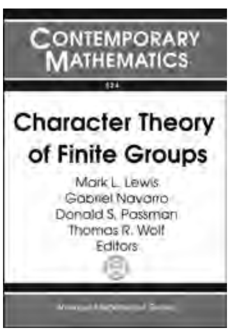
October 2011

* 24–28 **IMA Workshop: Large Graphs: Modeling, Algorithms and Applications**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
Description: The focus of the workshop will be on the mathematical, algorithmic, and statistical questions that arise in graph-based machine learning and data analysis, with an emphasis on graphs that arise in the above settings, as well as the corresponding algorithms and motivating applications. Thus, this workshop will be an opportunity for researchers from diverse fields to get together and share problems and techniques for handling these graph structures. The connections " mathematical, computational, and practical" that arise between these seemingly diverse problems and approaches will be emphasized.
Information: See `http://www.ima.umn.edu/2011-2012/W10.24-28.11/`.

New Publications Offered by the AMS

To subscribe to email notification of new AMS publications, please go to http://www.ams.org/bookstore-email.

Algebra and Algebraic Geometry



Character Theory of Finite Groups

Mark L. Lewis, *Kent State University, OH*, **Gabriel Navarro**, *Universitat de València, Spain*, **Donald S. Passman**, *University of Wisconsin, Madison, WI*, and **Thomas R. Wolf**, *Ohio University, Athens, OH*, Editors

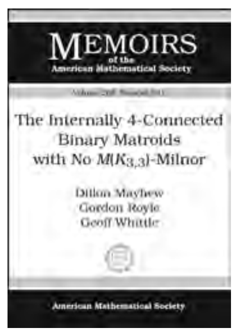
This volume contains a collection of papers from the Conference on Character Theory of Finite Groups, held at the Universitat de València, Spain, on June 3–5, 2009, in honor of I. Martin Isaacs.

The topics include permutation groups, character theory, p-groups, and group rings. The research articles feature new results on large normal abelian subgroups of p-groups, construction of certain wreath products, computing idempotents in group algebras of finite groups, and using dual pairs to study representations of cross characteristic in classical groups. The expository articles present results on vertex subgroups, measuring theorems in permutation groups, the development of super character theory, and open problems in character theory.

Contents: V. A. Belonogov, On character tables and abstract structure of finite groups; **N. Boston**, Large transitive groups with many elements having fixed points; **J. P. Cossey**, Vertex subgroups and vertex pairs in solvable groups; **P. Diaconis**, Threads through group theory; **S. M. Gagola, Jr.**, Tate's theorem, and other oddities, via transfer; **G. Glauberman**, A p-group with no normal large abelian subgroup; **A. Goren** and **M. Herzog**, General measuring arguments for finite permutation groups; **R. M. Guralnick**, Commutators and wreath products; **T. M. Keller**, Gaps in character degrees for groups with many conjugacy classes; **A. Mann**, The number of subgroups of metacyclic groups; **G. Navarro**, Problems in character theory; **T. Okuyama** and **T. Wada**, Eigenvalues of Cartan matrices of blocks in finite groups; **D. S. Passman**, Character theory and group rings; **G. R. Robinson**, Lifting theorems and applications to group algebras; **M. C. Slattery**, Character degrees of normally monomial maximal class 5-groups; **P. H. Tiep**, Dual pairs of finite classical groups in cross characteristic.

Contemporary Mathematics, Volume 524

October 2010, 179 pages, Softcover, ISBN: 978-0-8218-4827-2, LC 2010013663, 2000 *Mathematics Subject Classification:* 20B05, 20B40, 20C05, 20C15, 20C20, 20D15, 20D20, 20F12, 60J20, **AMS members US$55.20**, List US$69, Order code CONM/524



The Internally 4-Connected Binary Matroids with No $M(K_{3,3})$-Minor

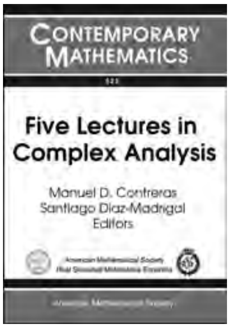
Dillon Mayhew, *Victoria University of Wellington, New Zealand*, **Gordon Royle**, *University of Western Australia, Crawley, Western Australia*, and **Geoff Whittle**, *Victoria University of Wellington, New Zealand*

Contents: Introduction; Preliminaries; Möbius matroids; From internal to vertical connectivity; An R_{12}-type matroid; A connectivity lemma; Proof of the main result; Appendix A. Case-checking; Appendix B. Sporadic matroids; Appendix C. Allowable triangles; Bibliography; Index.

Memoirs of the American Mathematical Society, Volume 208, Number 981

October 2010, 95 pages, Softcover, ISBN: 978-0-8218-4826-5, 2000 *Mathematics Subject Classification:* 05B35, **Individual member US$40.20**, List US$67, Institutional member US$53.60, Order code MEMO/208/981

Analysis



Five Lectures in Complex Analysis

Manuel D. Contreras and **Santiago Díaz-Madrigal**, *Universidad de Sevilla, Spain*, Editors

This volume contains state-of-the-art survey papers in complex analysis based on lectures given at the Second Winter School on Complex Analysis and Operator Theory held in February 2008 at the University of Sevilla, Sevilla, Spain.

Complex analysis is one of the most classical branches of mathematical analysis and is closely related to many other areas of mathematics, including operator theory, harmonic analysis, probability theory, functional analysis and dynamical systems. Undoubtedly, the interplay among all these branches gives rise to very beautiful and deep results in complex analysis and its neighboring fields. This interdisciplinary aspect of complex analysis is the central topic of this volume.

This book collects the latest advances in five significant areas of rapid development in complex analysis. The papers are: *Local holomorphic dynamics of diffeomorphisms in dimension one*, by F. Bracci, *Nonpositive curvature and complex analysis*, by S. M. Buckley, *Virasoro algebra and dynamics in the space of univalent functions*, by I. Markina and A. Vasil′ev, *Composition operators* ♥ *Toeplitz operators*, by J. H. Shapiro, and *Two applications of the Bergman spaces techniques*, by S. Shimorin.

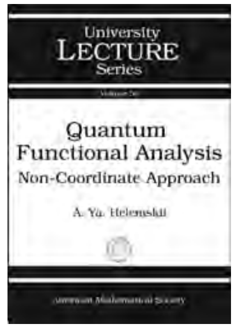
The papers are aimed, in particular, at graduate students with some experience in basic complex analysis. They might also serve as introductions for general researchers in mathematical analysis who may be interested in the specific areas addressed by the authors. Indeed, the contributions can be considered as up-to-the-minute reports on the current state of the fields, each of them including many recent results which may be difficult to find in the literature.

A co-publication of the AMS and Real Sociedad Matemática Española (RSME).

Contents: F. Bracci, Local holomorphic dynamics of diffeomorphisms in dimension one; **S. M. Buckley**, Nonpositive curvature and complex analysis; **I. Markina** and **A. Vasil′ev**, Virasoro algebra and dynamics in the space of univalent functions; **J. H. Shapiro**, Composition operators ♥ Toeplitz operators; **S. Shimorin**, Two applications of the Bergman spaces techniques.

Contemporary Mathematics, Volume 525

October 2010, 161 pages, Softcover, ISBN: 978-0-8218-4809-8, LC 2010014488, 2000 *Mathematics Subject Classification:* 30Cxx, 30Hxx, 30Jxx, 37Fxx, 47Bxx, 76-XX, **AMS members US$47.20**, List US$59, Order code CONM/525



Quantum Functional Analysis

Non-Coordinate Approach

A. Ya. Helemskii, *Moscow Lomonosov State University, Russia*

This book contains a systematic presentation of quantum functional analysis, a mathematical subject also known as operator space theory. Created in the 1980s, it nowadays is one of the most prominent areas of functional analysis, both as a field of active research and as a source of numerous important applications.

The approach taken in this book differs significantly from the standard approach used in studying operator space theory. Instead of viewing "quantized coefficients" as matrices in a fixed basis, in this book they are interpreted as finite rank operators in a fixed Hilbert space. This allows the author to replace matrix computations with algebraic techniques of module theory and tensor products, thus achieving a more invariant approach to the subject.

The book can be used by graduate students and research mathematicians interested in functional analysis and related areas of mathematics and mathematical physics. Prerequisites include standard courses in abstract algebra and functional analysis.

Contents: Three basic definitions and three principal theorems; *The beginning: Spaces and operators:* Preparing the stage; Abstract operator (= quantum) spaces; Completely bounded operators; The completion of abstract operator spaces; *Bilinear operators, tensor products and duality:* Strongly and weakly completely bounded bilinear operators; New preparations: Classical tensor products; Quantum tensor products; Quantum duality; *Principal theorems, revisited in earnest:* Extreme flatness and the extension theorem; Representation theorem and its gifts; Decomposition theorem; Returning to the Haagerup tensor product; Miscellany: More examples, facts and applications; Bibliography; Index.

University Lecture Series, Volume 56

December 2010, approximately 257 pages, Softcover, ISBN: 978-0-8218-5254-5, LC 2010023811, 2000 *Mathematics Subject Classification:* 46H25, 46L07, 47L25, **AMS members US$40.80**, List US$51, Order code ULECT/56

Complex Interpolation between Hilbert, Banach and Operator Spaces

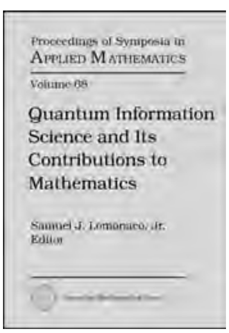
Gilles Pisier, *Texas A&M University, College Station, TX, and Université Paris VI, France*

Contents: Introduction; Preliminaries. Regular operators; Regular and fully contractive operators; Remarks on expanding graphs; A duality operators/classes of Banach spaces; Complex interpolation of families of Banach spaces; θ-Hilbertian spaces; Arcwise versus not arcwise; Fourier and Schur multipliers; A characterization of uniformly curved spaces; Extension property of regular operators; Generalizations; Operator space case; Generalizations (Operator space case); Examples with the Haagerup tensor product; References.

Memoirs of the American Mathematical Society, Volume 208, Number 978

October 2010, 78 pages, Softcover, ISBN: 978-0-8218-4842-5, 2000 *Mathematics Subject Classification:* 46B70, 47B10, 46M05, 47A80, **Individual member US$38.40**, List US$64, Institutional member US$51.20, Order code MEMO/208/978

Applications



Quantum Information Science and Its Contributions to Mathematics

Samuel J. Lomonaco, Jr., *University of Maryland Baltimore County, MD*, Editor

This volume is based on lectures delivered at the 2009 AMS Short Course on Quantum Computation and Quantum Information, held January 3–4, 2009, in Washington, D.C.

Part I of this volume consists of two papers giving introductory surveys of many of the important topics in the newly emerging field of quantum computation and quantum information, i.e., quantum information science (QIS). The first paper discusses many of the fundamental concepts in QIS and ends with the curious and counter-intuitive phenomenon of entanglement concentration. The second gives an introductory survey of quantum error correction and fault tolerance, QIS's first line of defense against quantum decoherence.

Part II consists of four papers illustrating how QIS research is currently contributing to the development of new research directions in mathematics. The first paper illustrates how differential geometry can be a fundamental research tool for the development of compilers for quantum computers. The second paper gives a survey of many of the connections between quantum topology and quantum computation. The last two papers give an overview of the new and emerging field of quantum knot theory, an interdisciplinary research field connecting quantum computation and knot theory. These two papers illustrate surprising connections with a number of other fields of mathematics.

In the appendix, an introductory survey article is also provided for those readers unfamiliar with quantum mechanics.

This item will also be of interest to those working in geometry and topology.

Contents: *Quantum information science:* **P. Hayden**, Concentration of measure effects in quantum information; **D. Gottesman**, An introduction to quantum error correction and fault-tolerant quantum computation; *Contributions to mathematics:* **H. E. Brandt**, Riemannian geometry of quantum computation; **L. H. Kauffman** and **S. J. Lomonaco, Jr.**, Topological quantum information theory; **S. J. Lomonaco, Jr.** and **L. H. Kauffman**, Quantum knots and mosaics; **S. J. Lomonaco, Jr.** and **L. H. Kauffman**, Quantum knots and lattices, or a blueprint for quantum systems that do rope tricks; *Appendix:* **S. J. Lomonaco, Jr.**, A Rosetta Stone for quantum mechanics with an introduction to quantum computation.

Proceedings of Symposia in Applied Mathematics, Volume 68

November 2010, approximately 345 pages, Hardcover, ISBN: 978-0-8218-4828-9, LC 2010019765, 2000 *Mathematics Subject Classification:* 81P15, 81P40, 81P45, 81P68, 68Q12, 57M25, 57M27, 20C35, **AMS members US$71.20**, List US$89, Order code PSAPM/68

Differential Equations

Selected Papers on Analysis and Differential Equations

This volume contains translations of papers that originally appeared in the Japanese journal *Sūgaku*. These papers range over a variety of topics in ordinary and partial differential equations and in analysis. Many of them are survey papers presenting new results obtained in the last few years.

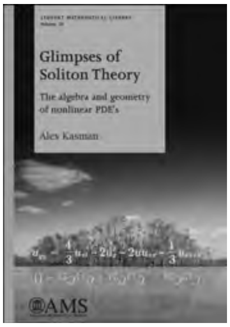
This volume is suitable for graduate students and research mathematicians interested in analysis and differential equations.

This item will also be of interest to those working in analysis.

Contents: **K. Nakanishi**, Asymptotic analysis of nonlinear dispersive equations; **N. Hayashi**, Asymptotics of nonlinear dispersive-type evolution equations; **K. Takemura**, Heun's differential equation; **H. Isozaki**, Scattering theory and inverse problems; **Y. Komori**, Nondoubling measure and harmonic analysis; **S. Saitoh**, Theory of reproducing kernels; **H. Izeki** and **S. Nayatani**, An approach to superrigidity and fixed-point theorems via harmonic maps; **H. Sumi**, Rational semigroups, random complex dynamics and singular functions on the complex plane; **K. Oguiso**, Salem polynomials and the bimeromorphic automorphism group of a hyperkähler manifold; **S. Yamagami**, Tensor categories in operator algebras.

American Mathematical Society Translations—Series 2, Volume 230

November 2010, approximately 248 pages, Hardcover, ISBN: 978-0-8218-4881-4, LC 2010022951, 2000 *Mathematics Subject Classification:* 35-06, 37-06, 43-06, **AMS members US$95.20**, List US$119, Order code TRANS2/230



Glimpses of Soliton Theory

The Algebra and Geometry of Nonlinear PDEs

Alex Kasman, *College of Charleston, SC*

Solitons are explicit solutions to nonlinear partial differential equations exhibiting particle-like behavior. This is quite surprising, both mathematically and physically. Waves with these properties were once believed to be impossible by leading mathematical physicists, yet they are now not only accepted as a theoretical possibility but are regularly observed in nature and form the basis of modern fiber-optic communication networks.

Glimpses of Soliton Theory addresses some of the hidden mathematical connections in soliton theory which have been revealed over the last half-century. It aims to convince the reader that, like the mirrors and hidden pockets used by magicians, the underlying algebro-geometric structure of soliton equations provides an elegant and surprisingly simple explanation of something seemingly miraculous.

Assuming only multivariable calculus and linear algebra as prerequisites, this book introduces the reader to the KdV Equation and its multisoliton solutions, elliptic curves and Weierstrass $\wp$-functions, the algebra of differential operators, Lax Pairs and their use in discovering other soliton equations, wedge products and decomposability, the KP Equation and Sato's theory relating the Bilinear KP Equation to the geometry of Grassmannians.

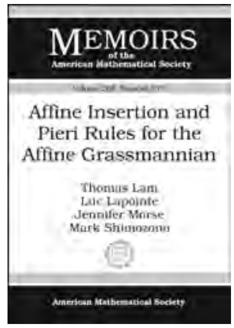
Notable features of the book include: careful selection of topics and detailed explanations to make this advanced subject accessible to any undergraduate math major, numerous worked examples and thought-provoking but not overly-difficult exercises, footnotes and lists of suggested readings to guide the interested reader to more information, and use of the software package *Mathematica*® to facilitate computation and to animate the solutions under study. This book provides the reader with a unique glimpse of the unity of mathematics and could form the basis for a self-study, one-semester special topics, or "capstone" course.

Contents: Differential equations; Developing PDE intuition; The story of solitons; Elliptic curves and KdV traveling waves; KdV n-solitons; Multiplying and factoring differential operators; Eigenfunctions and isospectrality; Lax form for KdV and other soliton equations; The KP equation and bilinear KP equation; The Grassmann cone $\Gamma_{2,4}$ and the bilinear KP equation; Pseudo-differential operators and the KP hierarchy; The Grassman cone $\Gamma_{k,n}$ and the bilinear KP hierarchy; Concluding remarks; Mathematica guide; Complex numbers; Ideas for independent projects; References; Glossary of symbols; Index.

Student Mathematical Library, Volume 54

December 2010, approximately 312 pages, Softcover, ISBN: 978-0-8218-5245-3, LC 2010024820, 2000 *Mathematics Subject Classification:* 35Q53, 37K10, 14H70, 14M15, 15A75, **AMS members US$36.80**, List US$46, Order code STML/54

Discrete Mathematics and Combinatorics



Affine Insertion and Pieri Rules for the Affine Grassmannian

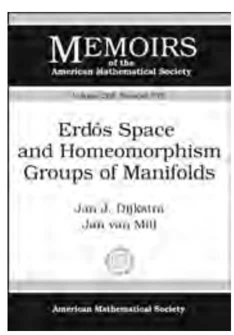
Thomas Lam, *Harvard University, Cambridge, MA*, **Luc Lapointe**, *Universidad de Talca, Chile*, **Jennifer Morse**, *Drexel University, Philadelphia, PA*, and **Mark Shimozono**, *Virginia Polytechnic Institute and State University, Blacksburg, VA*

Contents: Schubert bases of Gr and symmetric functions; Strong tableaux; Weak tableaux; Affine insertion and affine Pieri; The local rule $\phi_{u,v}$; Reverse local rule; Bijectivity; Grassmannian elements, cores, and bounded partitions; Strong and weak tableaux using cores; Affine insertion in terms of cores; Bibliography.

Memoirs of the American Mathematical Society, Volume 208, Number 977

October 2010, 82 pages, Softcover, ISBN: 978-0-8218-4658-2, 2000 *Mathematics Subject Classification:* 05E05, 14N15, **Individual member US$40.20**, List US$67, Institutional member US$53.60, Order code MEMO/208/977

Geometry and Topology



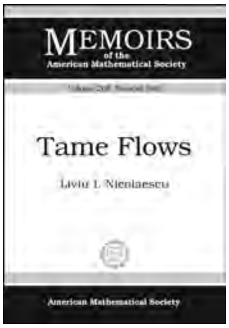
Erdős Space and Homeomorphism Groups of Manifolds

Jan J. Dijkstra and **Jan van Mill**, *Vrije Universiteit, Amsterdam, The Netherlands*

Contents: Introduction; Erdős space and almost zero-dimensionality; Trees and $\mathbb{R}$-trees; Semi-continuous functions; Cohesion; Unknotting Lelek functions; Extrinsic characterizations of Erdős space; Intrinsic characterizations of Erdős space; Factoring Erdős space; Groups of homeomorphisms; Bibliography.

Memoirs of the American Mathematical Society, Volume 208, Number 979

October 2010, 62 pages, Softcover, ISBN: 978-0-8218-4635-3, 2000 *Mathematics Subject Classification:* 57S05, **Individual member US$34.80**, List US$58, Institutional member US$46.40, Order code MEMO/208/979



Tame Flows

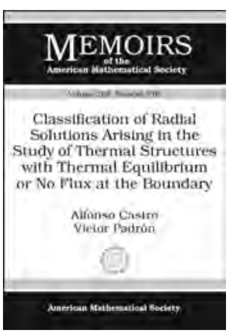
Liviu I. Nicolaescu, *University of Notre Dame, IN*

Contents: Introduction; Tame spaces; Basic properties and examples of tame flows; Some global properties of tame flows; Tame Morse flows; Tame Morse-Smale flows; The gap between two vector subspaces; The Whitney and Verdier regularity conditions; Smale transversality and Whitney regularity; The Conley index; Flips/flops and gradient like tame flows; Simplicial flows and combinatorial Morse theory; Tame currents; Appendix A. An "elementary" proof of the generalized Stokes formula; Appendix B. On the topology of tame sets; Bibliography; Index.

Memoirs of the American Mathematical Society, Volume 208, Number 980

October 2010, 130 pages, Softcover, ISBN: 978-0-8218-4870-8, 2000 *Mathematics Subject Classification:* 03C64, 06F30, 37B30, 58A07, 58A10, 58A17, 58A25, 58A35, 58E05; 55P05, 55U10, 57Q05, 57R05, **Individual member US$41.40**, List US$69, Institutional member US$55.20, Order code MEMO/208/980

Mathematical Physics



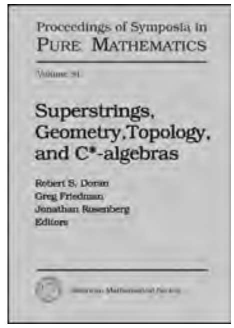
Classification of Radial Solutions Arising in the Study of Thermal Structures with Thermal Equilibrium or No Flux at the Boundary

Alfonso Castro, *Harvey Mudd College, Claremont, CA*, and **Víctor Padrón**, *Normandale Community College, Bloomington, MN*

Contents: Introduction; Bifurcation diagrams; Oscillation properties; Ground states; Stability of thermal structures; Proof of main theorems; The degenerate case, $k = -1$; Appendix 1. The conservative case ($N = 1$); Appendix 2. Pohozaev identity; Bibliography.

Memoirs of the American Mathematical Society, Volume 208, Number 976

October 2010, 72 pages, Softcover, ISBN: 978-0-8218-4726-8, 2000 *Mathematics Subject Classification:* 35J60, 85A25, 35K60; 80A20, 34B16, **Individual member US$38.40**, List US$64, Institutional member US$51.20, Order code MEMO/208/976



Superstrings, Geometry, Topology, and C^*-algebras

Robert S. Doran and **Greg Friedman**, *Texas Christian University, Fort Worth, TX*, and **Jonathan Rosenberg**, *University of Maryland, College Park, MD*, Editors

This volume contains the proceedings of an NSF-CBMS Conference held at Texas Christian University in Fort Worth, Texas, May 18–22, 2009. The papers, written especially for this volume by well-known mathematicians and mathematical physicists, are an outgrowth of the talks presented at the conference. Topics examined are highly interdisciplinary and include, among many other things, recent results on D-brane charges in K-homology and twisted K-homology, Yang-Mills gauge theory and connections with non-commutative geometry, Landau-Ginzburg models, C^*-algebraic non-commutative geometry and ties to quantum physics and topology, the rational homotopy type of the group of unitary elements in an Azumaya algebra, and functoriality properties in the theory of C^*-crossed products and fixed point algebras for proper actions. An introduction, written by Jonathan Rosenberg, provides an instructive overview describing common themes and how the various papers in the volume are interrelated and fit together. The rich diversity of papers appearing in the volume demonstrates the current interplay between superstring theory, geometry/topology, and non-commutative geometry. The book will be of interest to graduate students, mathematicians, mathematical physicists, and researchers working in these areas.

This item will also be of interest to those working in geometry and topology and analysis.

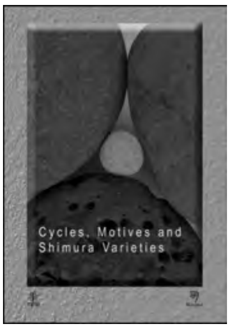
Contents: **J. Rosenberg**, Introduction; **A. an Huef**, **I. Raeburn**, and **D. P. Williams**, Functoriality of Rieffel's generalised fixed-point algebras for proper actions; **M. Ando**, **A. J. Blumberg**, and **D. Gepner**, Twists of K-theory and TMF; **J. C. Baez** and **J. Huerta**, Division algebras and supersymmetry I; **P. Baum**, K-homology and D-branes; **A. L. Carey** and **B.-L. Wang**, Riemann-Roch and index formulae in twisted K-theory; **K. C. Hannabuss** and **V. Mathai**, Noncommutative principal torus bundles via parametrised strict deformation quantization; **S. Kang**, A survey of noncommutative Yang-Mills theory for quantum Heisenberg manifolds; **J. R. Klein**, **C. L. Schochet**, and **S. B. Smith**, From rational homotopy to K-theory for continuous trace algebras; **M. A. Rieffel**, Distances between matrix algebras that converge to coadjoint orbits; **H. Sati**, Geometric and topological structures related to M-branes; **E. Sharpe**, Landau-Ginzburg models, Gerbes, and Kuznetsov's homological projective duality.

Proceedings of Symposia in Pure Mathematics, Volume 81

November 2010, 249 pages, Hardcover, ISBN: 978-0-8218-4887-6, LC 2010027233, 2000 *Mathematics Subject Classification:* 81-06, 55-06, 46-06, 46L87, 81T30, **AMS members US$50.40**, List US$63, Order code PSPUM/81

New AMS-Distributed Publications

Algebra and Algebraic Geometry



Cycles, Motives and Shimura Varieties

V. Srinivas, *Tata Institute of Fundamental Research, Mumbai, India*, Editor

This is the proceedings of the international colloquium organized by the Tata Institute of Fundamental Research in January 2008, one of a series of colloquia going back to 1956. It covers a wide spectrum of mathematics, ranging over algebraic geometry, topology, automorphic forms, and number theory.

Algebraic cycles form the basis for the construction of motives, and conjectures about motives depend ultimately on important problems related to algebraic cycles, such as the Hodge and the Tate conjectures. Shimura varieties provide interesting, nontrivial instances of these fundamental problems. On the other hand, the motives of Shimura varieties are of great interest in automorphic forms and number theory.

This volume features refereed articles by leading experts in these fields. The articles contain original results as well as expository material.

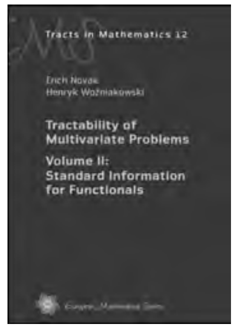
A publication of the Tata Institute of Fundamental Research. Distributed worldwide except in India, Bangladesh, Bhutan, Maldavis, Nepal, Pakistan, and Sri Lanka.

Contents: **D. Arapura**, Mixed Hodge structures associated to geometric variations; **M. Asakura** and **K. Sato**, Beilinson's Tate conjecture for K_2 of elliptic surface: Survey and examples; **E. Ghate**, On the freeness of the integral cohomology groups of Hilbert-Blumenthal varieties as Hecke modules; **P. Griffiths**, Singularities of admissible normal functions; **G. Harder**, Arithmetic aspects of rank one Eisenstein cohomology; **K. Kimura**, A remark on the second Abel-Jacobi map; **A. Krishna** and **V. Srinivas**, Zero cycles on singular affine varieties; **M. Levine**, Tate motives and the fundamental group; **S.-J. Kang** and **J. D. Lewis**, Beilinson's Hodge conjecture for K_1 revisited; **S. Kimura** and **J. P. Murre**, On natural isomorphisms of finite dimensional motives and applications to the Picard motives; **A. Miller**, Chow motives of mixed Shimura varieties; **A. Neeman**, Dualizing complexes—the modern way; **A. Rosenschon** and **V. Srinivas**, The Griffiths group of the generic abelian 3-fold; **R. Sreekantan**, Non-Archimedean regulator maps and special values of L-functions; **T. Terasoma**, The Artin-Schreier DGA and the $\mathbf{F}_p$-fundamental group of an $\mathbf{F}_p$ scheme.

Tata Institute of Fundamental Research

August 2010, 540 pages, Hardcover, ISBN: 978-81-8487-085-5, 2000 *Mathematics Subject Classification:* 14C25, 14F42, 19E15, 14G35, 11G18; 14C30, 14C35, 19F27, 11F46, 11F41, **AMS members US$40**, List US$50, Order code TIFR/16

Applications



Tractability of Multivariate Problems

Volume II: Standard Information for Functionals

Erich Novak, *University of Jena, Germany*, and **Henryk Woźniakowski**, *Columbia University, New York, NY*

This is the second volume of a three-volume set comprising a comprehensive study of the tractability of multivariate problems. The second volume deals with algorithms using standard information consisting of function values for the approximation of linear and selected nonlinear functionals. An important example is numerical multivariate integration.

The proof techniques used in volumes I and II are quite different. It is especially hard to establish meaningful lower error bounds for the approximation of functionals by using finitely many function values. Here, the concept of decomposable reproducing kernels is helpful, allowing it to find matching lower and upper error bounds for some linear functionals. It is then possible to conclude tractability results from such error bounds.

Tractability results, even for linear functionals, are very rich in variety. There are infinite-dimensional Hilbert spaces for which the approximation with an arbitrarily small error of all linear functionals requires only one function value. There are Hilbert spaces for which all nontrivial linear functionals suffer from the curse of dimensionality. This holds for unweighted spaces, where the role of all variables and groups of variables is the same. For weighted spaces one can monitor the role of all variables and groups of variables. Necessary and sufficient conditions on the decay of the weights are given to obtain various notions of tractability.

The text contains extensive chapters on discrepancy and integration, decomposable kernels and lower bounds, the Smolyak/sparse grid algorithms, lattice rules and the CBC (component-by-component) algorithms. This is done in various settings. Path integration and quantum computation are also discussed.

This volume is of interest to researchers working in computational mathematics, especially in approximation of high-dimensional problems. It is also well suited for graduate courses and seminars. There are 61 open problems listed to stimulate future research in tractability.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: Discrepancy and integration; Worst case: General linear functionals; Worst case: Tensor products and decomposable kernels; Worst case: Linear functionals on weighted spaces; Average case setting; Probabilistic setting; Smolyak/Sparse grid algorithms; Multivariate integration for Korobov and related spaces; Randomized setting; Nonlinear functionals; Further topics; Summary: Uniform integration for three Sobolev spaces; Appendices: List of open problems and Errata for volume I; Bibliography; Index.

EMS Tracts in Mathematics, Volume 12

June 2010, 675 pages, Hardcover, ISBN: 978-3-03719-084-5, 2000 *Mathematics Subject Classification:* 65Y20, 68Q17, 68Q25, 41A63, 65-02, 46E22, 28C20, 46E30, 11K38, 65D32, **AMS members US$102.40**, List US$128, Order code EMSTM/12

Number Theory

Séminaire Bourbaki

Volume 2008/2009 Exposés 997–1011

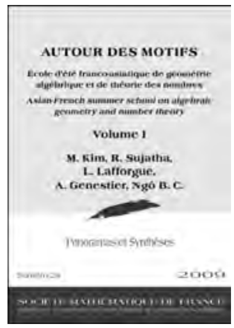
As in the preceding volumes of this seminar, at which more than one thousand talks have been presented, this volume contains fifteen survey lectures on topics of current interest: four lectures on algebraic geometry, two on analysis, one on harmonic analysis, two on probability, five on differentiable geometry, and one on new links between number theory and theoretical physics.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: *NOVEMBRE 2008:* **R. Cerf**, Dimères et surfaces aléatoires; **C. Favre**, Le groupe de Cremona et ses sous-groupes de type fini; **J.-F. Quint**, Convexes divisibles; **J.-P. Serre**, Le groupe de Cremona et ses sous-groupes finis; **C. Villani**, Paradoxe de Scheffer-Shnirelman revu sous l'angle de l intégration convexe; *MARS 2009:* **D. Auroux**, La conjecture de Weinstein en dimension 3; **G. Besson**, Le théorème de la sphère différentiable; **E. Giroux**, Sur la géométrie et la dynamique des transformations de contact; **P. G. Goerss**, Topological modular forms; **T. Szamuely**, Corps de classes des schémas arithmétiques; *JUIN 2009:* **F. Barthe**, Un théorème de la limite centrale pour les ensembles convexes; **E. Breuillard**, Équidistribution des orbites toriques sur les espaces homogènes; **A. Figalli**, Regularity of optimal transport maps; **E. Frenkel**, Gauge theory and Langlands duality; **S. Maillot**, Variétés hyperboliques de petit volume; Table par noms d'auteurs.

Astérisque, Number 332

July 2010, 463 pages, Softcover, ISBN: 978-2-85629-291-4, 2000 *Mathematics Subject Classification:* 11E99, 11G99, 11Gxx, 11R37, 11R39, 14D24, 14E07, 14Exx, 14G25, 14H50, 14H52, 14K10, 20F55, 20F67, 20Fxx, 20G20, 20H15, 20J06, 22E40, 22E45, 30C65, 32H50, 35B65, 35B99, 35J60, 37A17, 37A45, 37D20, 37D40, 49Q20, 51M10, 51M25, 52A20, 52A38, 53A20, 53C20, 53C21, 53C23, 53C44, 53D10, 53D35, 53D40, 53D50, 55N22, 55N34, 55Q10, 57M50, 57N10, 57R17, 57R57, 57R58, 57S30, 58A05, 58J99, 60D05, 60F05, 81T13, 82B23, **Individual member US$121.50**, List US$135, Order code AST/332



Autour des Motifs

Asian-French Summer School on Algebraic Geometry and Number Theory: Volume 1

M. Kim, *University College London, England*, **R. Sujatha**, *Tata Institute of Fundamental Research, Mumbai, India*, **L. Lafforgue**, *Institut des Hautes Études Scientiques, Bures-sur-Yvette, France*, **A. Genestier**, *Université Henri Poincaré Nancy, France*, and **Ngô B. C.**, *Université Paris-Sud, Orsay, France*

This volume contains the first part of the lecture notes of the Asian-French Summer School on Algebraic Geometry and Number Theory, which was held at the Institut des Hautes Études Scientifiques (Bures-sur-Yvette) and the Université Paris-Sud XI (Orsay) in July 2006. This summer school was devoted to the theory of motives and its recent developments and to related topics, notably Shimura varieties and automorphic representations.

The contributions in this first part are expanded versions of the talks introducing the theory of motives by M. Kim and R. Sujatha, the lecture notes “Quelques remarques sur le principe de fonctorialité” by L. Lafforgue and “Lectures on Shimura varieties” by A. Genestier and Ngô B. C.

This item will also be of interest to those working in algebra and algebraic geometry.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: M. Kim, Classical motives and motivic L-functions; **R. Sujatha**, Motives from a categorical point of view; **L. Lafforgue**, Quelques remarques sur le principe de fonctorialité; **A. Genestier** and **Ngô B. C.**, Lectures on Shimura varieties; References.

Panoramas et Synthèses, Number 29

July 2009, 236 pages, Softcover, ISBN: 978-2-85629-292-1, 2000 *Mathematics Subject Classification:* 11Fxx, 11Gxx, 11R39, 14Fxx, 14Gxx, 14Kxx, 19E15, **Individual member US$46.80**, List US$52, Order code PASY/29

Classified Advertisements

Positions available, items for sale, services available, and more

CALIFORNIA

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Harry Bateman Research Instructorships in Mathematics

Description: Appointments are for two years. The academic year runs from approximately October 1 to June 1. Instructors are expected to teach one course per term for the full academic year and to devote the rest of their time to research. During the summer months there are no duties except research.

Eligibility: Open to persons who have recently received their doctorates in mathematics.

Deadline: January 1, 2011.

Application information: Please apply online at: `http://mathjobs.org`. To avoid duplication of paperwork, your application may also be considered for an Olga Taussky and John Todd Instructorship.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, Minorities, Veterans and Disabled Persons are encouraged to apply.

000050

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Scott Russell Johnson Senior Postdoctoral Scholar in Mathematics

Description: There are three terms in the Caltech academic year. The fellow is expected to teach one course in two terms each year, and is expected to be in residence even during terms when not teaching. The initial appointment is for three years with an additional three-year terminal extension expected.

Eligibility: Offered to a candidate within six years of having received the Ph.D. who shows strong research promise in one of the areas in which Caltech's mathematics faculty is currently active

Deadline: January 1, 2011.

Application information: Please apply online at: `http://mathjobs.org`. To avoid duplication of paperwork, your application will also be considered for an Olga Taussky and John Todd Instructorship and a Harry Bateman Research Instructorship.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, Minorities, Veterans and Disabled Persons are encouraged to apply.

000051

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Olga Taussky and John Todd Instructorships in Mathematics

Description: Appointments are for three years. There are three terms in the Caltech academic year, and instructors are expected to teach one course in all but two terms of the total appointment. These two terms will be devoted to research. During the summer months there are no duties except research.

Eligibility: Offered to persons within three years of having received the Ph.D. who show strong research promise in one of the areas in which Caltech's mathematics faculty is currently active.

Deadline: January 1, 2011.

Application information: Please apply online at: `http://mathjobs.org`. To avoid duplication of paperwork, your application will also be considered for a Harry Bateman Research Instructorship.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, Minorities, Veterans and Disabled Persons are encouraged to apply.

000052

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 2010 rate is $3.25 per word. 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 ads.

Upcoming deadlines for classified advertising are as follows: November 2010 issue–August 30, 2010; December 2010 issue–September 28, 2010; January 2011 issue–October 28, 2010; February 2011 issue–November 29, 2010; March 2011 issue–December 28, 2010; April 2011 issue–January 30, 2011.

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 email to `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 20904. Advertisers will be billed upon publication.

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
The Division of Physics, Mathematics, and Astronomy

The Division of Physics, Mathematics, and Astronomy at the California Institute of Technology invites applications for a possible tenure-track position in Mathematics at the assistant professor level. We are particularly interested in the following research areas: Algebraic Geometry/Number Theory, Analysis/Dynamics, Combinatorics, Finite and Algebraic Groups, Geometry/Topology, Logic/Set Theory, and Mathematical Physics, but other fields may be considered. The term of the initial appointment is normally four years for a tenure-track assistant professor (with a possible to extension to as much as seven years). Appointment is contingent upon completion of the Ph.D. Exceptional candidates may also be considered at the associate or full professor level. We are seeking highly qualified applicants who are committed to a career in research and teaching. Applicants should apply online at: `http://mathjobs.org`.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women and minorities are encouraged to apply.

000053

MATHEMATICAL SCIENCES RESEARCH INSTITUTE
Berkeley, CA

MSRI invites applications for 40 Research Professors, 200 Research Members, and 30 semester-long Post-Doctoral Fellows in the following programs: Quantitative Geometry (August 15 to December 16, 2011), and Random Spatial Processes (January 09, 2012 to May 18, 2012). In addition a very small number of positions may be available as part of our Complementary Program. Research Professorships are intended for senior researchers who will be making key contributions to a program, including the mentoring of postdoctoral fellows, and who will be in residence for three or more months. Research Memberships are intended for researchers who will be making contributions to a program and who will be in residence for one or more months. Post-Doctoral Fellowships are intended for recent Ph.D.s. Interested individuals should carefully describe the purpose of their proposed visit, and indicate why a residency at MSRI will advance their research program. To receive full consideration, application must be complete, including all letters of support by the following deadlines: Research Professorships, October 01, 2010; Research Memberships, December 01, 2010; Postdoctoral Fellowships, December 01, 2010. Application information: `http://www.msri.org/propapps/applications/application_material`. The Institute is committed to the principles of Equal Opportunity and Affirmative Action.

000031

UNIVERSITY OF CALIFORNIA, DAVIS
Department of Mathematics

The Department of Mathematics at the University of California, Davis, is soliciting applications for the following positions to begin July 1, 2011. Applications will be accepted until the positions are filled. To receive full consideration, the application should be received by December 1, 2010. To apply, submit the AMS Cover Sheet and supporting documentation electronically through: `http://www.mathjobs.org/`.

1. An Assistant Professor in the area of Mathematical Biology. Applicants should have demonstrated excellence in mathematical modeling of biological phenomena, and the ability to reach across traditional boundaries in the life sciences and mathematics. Minimum qualifications for this position include a Ph.D. degree or its equivalent in the Mathematical Sciences and great promise in research and teaching. Duties include mathematical research, undergraduate and graduate teaching, and departmental and university service.

2. One or more Arthur J. Krener Assistant Professor positions, subject to budgetary and administrative approval. The Department seeks applicants with excellent research potential in areas of faculty interest and effective teaching skills. The annual salary of this position is $52,350. Applicants for the Krener Assistant Professorship are required to have completed their Ph.D. by the time of their appointment, but no earlier than July 1, 2007. The appointment is renewable for a total of up to three years, assuming satisfactory performance in research and teaching. Additional information may be found at: `http://math.ucdavis.edu/`.

Postal address: Department of Mathematics, University of California, One Shields Avenue, Davis, CA 95616-8633.

The University of California is an Affirmative Action/Equal Opportunity Employer.

000044

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Department of Mathematics
Faculty Positions Academic Year 2011-2012

The Department of Mathematics solicits applications at the level of tenure-track/tenure faculty with particular emphasis in applied mathematics. Salary is commensurate with the level of experience.

We also plan to make temporary and visiting appointments in the categories 1-5 below. Depending on the level, candidates must give evidence of potential or demonstrated distinction in scholarship and teaching.

(1) E.R. Hedrick Assistant Professorships. Salary is $61,200 and appointments are for three years. The teaching load is four-quarter courses per year.

(2) Computational and Applied Mathematics (CAM) Assistant Professorships. Salary is $61,200, and appointments are for three years. The teaching load is normally reduced by research funding to two quarter courses per year.

(3) Program in Computing (PIC) Assistant Adjunct Professorships. Salary is $65,500. Applicants for these positions must show very strong promise in teaching and research in an area related to computing. The teaching load is four one-quarter programming courses each year and one seminar every two years. Initial appointments are for one year and possibly longer, up to a maximum service of four years.

(4) Assistant Adjunct Professorships and Research Postdocs. Normally appointments are for one year, with the possibility of renewal. Strong research and teaching background required. The salary range is $53,200-$59,500. The teaching load for Adjuncts is six-quarter courses per year.

(5) Simons Postdoctoral Fellows. Salary is $70,000 increased by 3% each year. Appointments are for three years. The teaching load is four courses over the three year period. Candidates must show exceptional research promise. Simons Postdoctoral Fellowships will be restricted to candidates who receive the Ph.D. in the academic year immediately preceding that in which they would become Simons Postdoctoral Fellows. This position is funded by the Simons Foundation.

If you wish to be considered for any of these positions you must submit an application and supporting documentation electronically via: `http://www.mathjobs.org`.

For fullest consideration, all application materials should be submitted on or before, December 8, 2010. Ph.D. is required for all positions.

UCLA and the Department of Mathematics have a strong commitment to the achievement of excellence in teaching and research and diversity among its faculty and staff. The University of California is an Equal Opportunity/Affirmative Action Employer. The University of California asks that applicants complete the Equal Opportunity Employer survey for, Letters and Science, at the following URL: http://cis.ucla.edu/facultysurvey. Under Federal law, the University of California may employ only individuals who are legally authorized to work in the United States as established by providing documents specified in the Immigration Reform and Control Act of 1986.

000042

CONNECTICUT

UNIVERSITY OF CONNECTICUT
Department of Mathematics
Assistant Professor

The Department of Mathematics at the University of Connecticut invites applicants for a tenure-track position at the Assistant Professor level starting in Fall 2011. Highly qualified candidates in all mathematical disciplines are encouraged to apply, but logic, geometry and topology, and numerical linear algebra and numerical analysis are areas of particular, but not exclusive, focus of the search.

Minimum Qualifications: A completed Ph.D. in Mathematics by August 23, 2011; and demonstrated evidence of excellent teaching ability and outstanding research potential.

Preferred Qualifications: Research focus of logic, geometry and topology, and numerical linear algebra and numerical analysis; and the ability to contribute through research, teaching and/or public engagement to the diversity and excellence of the learning experience.

Position is at the Storrs campus. Candidates may have the opportunity to work at the campuses at Avery Point, Hartford, Stamford, Torrington, Waterbury, and West Hartford.

Review of applications will begin on November 15, 2010, and continue until the position is filled. Applications and at least 3 letters of reference should be submitted online at: `http://www.mathjobs.org/jobs`. Questions or requests for further information should be sent to the Hiring Committee at: email: `mathhiring@uconn.edu`.

The University of Connecticut is an Equal Opportunity and Affirmative Action Employer. We enthusiastically encourage applications from underrepresented groups, including minorities, women, and people with disabilities.

000062

ILLINOIS

THE UNIVERSITY OF CHICAGO
Department of Mathematics

The University of Chicago Department of Mathematics invites applications for the following positions: 1. L.E. Dickson Instructor: This is open to mathematicians who have recently completed or will soon complete a doctorate in mathematics or a closely related field,and whose work shows remarkable promise in mathematical research and teaching. The appointment typically is for two years, with the possibility of renewal for a third year. The teaching obligation is up to four one-quarter courses per year. 2. Simons Fellow (at the rank of Dickson Instructor): This is open to candidates who receive the Ph.D. within the period September 1, 2010 through August 31, 2011. The duration of the fellowship is three years, and the teaching obligation is four one-quarter courses during the three year fellowship. This appointment would be at the University's rank of Dickson Instructor but would also carry the title of Simons Fellow within the Department of Mathematics. 3. Assistant Professor: This is open to mathematicians who are further along in their careers, typically two or three years past the doctorate. These positions are intended for mathematicians whose work has been of outstandingly high caliber. Appointees are expected to have the potential to become leading figures in their fields. The appointment is generally for three years, with a teaching obligation of three one-quarter courses per year. Applicants will be considered for any of the positions above which seem appropriate. Complete applications consist of (a) a cover letter, (b) a curriculum vitae, (c) three or more letters of reference, at least one of which addresses teaching ability, and (d) a description of previous research and plans for future mathematical research. Applicants are strongly encouraged to include information related to their teaching experience, such as a teaching statement or evaluations from courses previously taught, as well as an AMS cover sheet. If you have applied for an NSF Mathematical Sciences Postdoctoral Fellowship, please include that information in your application, and let us know how you plan to use it if awarded. If you are eligible for the Simons Fellowship and wish to be considered for it, please indicate this in your cover letter. Applications must be submitted online through: `http://www.mathjobs.org`. Questions may be directed to: `apptsec@math.uchicago.edu`. We will begin screening applications on December 1, 2010. Screening will continue until all available positions are filled. The University of Chicago is an Equal Opportunity/Affirmative Action Employer.

000041

MASSACHUSETTS

BOSTON COLLEGE
Department of Mathematics
Post-doctoral Position

The Department of Mathematics at Boston College invites applications for a post-doctoral position beginning September 2011. This position is intended for a new or recent Ph.D. with outstanding potential in research and excellent teaching. This is a 3-year Visiting Assistant Professor position, and carries a 2-1 annual teaching load. Research interests should lie within Number Theory or Representation Theory or related areas. Candidates should expect to receive their Ph.D. prior to the start of the position and have received the Ph.D. no earlier than Spring 2010.

Applications must include a cover letter, description of research plans, curriculum vitae, and four letters of recommendation, with one addressing the candidate's teaching qualifications. Applications received no later than January 1, 2011 will be assured our fullest consideration. Please submit all application materials through: `http://MathJobs.org`.

Applicants may learn more about the department, its faculty and its programs and about Boston College at `http://www.bc.edu/math`. Email inquiries concerning this position may be directed to: `postdoc-search@bc.edu`. Boston College is an Affirmative Action/Equal Opportunity Employer. Applications from women, minorities and individuals with disabilities are encouraged.

000056

BOSTON COLLEGE
Department of Mathematics
Tenure-Track Positions

The Department of Mathematics at Boston College invites applications for four tenure-track positions at the level of Assistant Professor beginning in September 2011, two in Number Theory or related areas, including Algebraic Geometry and Representation Theory; and two in Geometry/Topology or related areas. In exceptional cases, a higher level appointment may be considered. The teaching load for each position is three semester courses per year.

Requirements include a Ph.D. or equivalent in Mathematics awarded in 2009 or earlier, a record of very strong research combined with outstanding research potential, and demonstrated excellence in teaching mathematics.

A completed application should contain a cover letter, a description of research plans, a statement of teaching philosophy, curriculum vitae, and at least four letters of recommendation. One or more of the letters of recommendation should directly comment on the candidate's teaching credentials.

Applications completed no later than November 1, 2010 will be assured our fullest consideration. Please submit all application materials through: `http://MathJobs.org`.

Applicants may learn more about the department, its faculty and its programs, and about Boston College at: `http://www.bc.edu/math`. Electronic inquiries concerning these positions ma y be directed to: `math-search@bc.edu`. Boston College is an Affirmative Action/Equal Opportunity Employer. Applications from women, minorities and individuals with disabilities are encouraged.

000055

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
Positions for Faculty and Instructors

The Mathematics Department at MIT is seeking to fill positions in Pure and Applied Mathematics and Statistics, at the level of Simons Postdoctoral Fellow, Instructor, Assistant Professor and higher, beginning September 2011. Appointments are based primarily on exceptional research qualifications. Appointees will be expected to fulfill teaching duties and to pursue their own research program. A Ph.D. is required by the employment start date.

For more information, and to apply, please visit www.mathjobs.org.

To receive full consideration, please submit applications by December 1, 2010. Recommendations should be submitted through: `http://mathjobs.org` but may also be sent as PDF attachments to: email: `hiring@math.mit.edu`, or as paper copies mailed to: Mathematics Search Committee, Room 2-345, Department of Mathematics, MIT, 77 Massachusetts Ave., Cambridge, MA 02139-4307.

Please do not mail or e-mail duplicates of items already submitted via `http://mathjobs`.

MIT is an Equal Opportunity, Affirmative Action Employer.

000058

NEW JERSEY

PRINCETON UNIVERSITY
School of Mathematics
Institute for Advanced Study

The School of Mathematics has a limited number of memberships some with financial support for research in mathematics and computer science at the Institute during the 2011-2012 academic year.

During the 2011-2012 academic year, Professors Helmut Hofer of the Institute and John Mather of Princeton University will lead a program on symplectic dynamics. There will be weekly seminars and a couple of workshops.

The mathematical theory of dynamical systems provides tools to understand the complex behavior of many important physical systems. Of particular interest are Hamiltonian systems. Since Poincare's fundamental contributions, many mathematical tools have been developed to understand such systems. Surprisingly these developments led to the creation of two seemingly unrelated mathematical disciplines: the field of dynamical systems and the field of symplectic geometry. In view of the significant advances in both fields, it seems timely to have a program that aims at the development of the common core, which potentially should lead to a new field with highly integrated ideas from both disciplines. Of particular interest will be the study of dynamics of area-preserving disk maps, the ramifications of new symplectic techniques in three-dimensional hydrodynamics, as well as questions about the utility of the symplectic pseudoholomorphic curve techniques in questions related to KAM and Aubry-Mather theory.

Recently the School established the von Neumann Fellowships, and up to six of these fellowships will be available for the 2011-2012 year. To be eligible for a von Neumann Fellowship, applicants should be at least five, but no more than fifteen, years following the receipt of their Ph.D.

The Veblen Research Instructorship is a three-year position which the School of Mathematics and the Department of Mathematics at Princeton University established in 1998. Three-year instructorships will be offered each year to candidates in pure and applied mathematics who have received their Ph.D. within the last three years. The first and third year of the instructorship will be spent at Princeton University and will carry regular teaching responsibilities. The second year will be spent at the Institute and dedicated to independent research of the instructor's choice.

Application materials may be requested from Applications, School of Mathematics, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540; email: `applications@math.ias.edu`. After June 1, 2010 applications may be made online at: `http://applications.ias.edu/login.php`. Application deadline is December 1, 2010. You can also see our listing on `http://www.mathjobs.org`.

The Institute for Advanced Study is committed to diversity and strongly encourages applications from women. and minorities.

000035

NEW YORK

CORNELL UNIVERSITY
Department of Mathematics
HC Wang Assistant Professor

The Department of Mathematics at Cornell University invites applications for two or more H.C. Wang Assistant Professors, non-renewable, 3-year position beginning July 1, 2011, pending administrative approval. Successful candidates are expected to pursue independent research at Cornell and teach three courses per year. A Ph.D. in mathematics is required. The Department actively encourages applications from women and minority candidates.

Applicants must apply electronically at: `http://www.mathjobs.org`.

For information about our positions and application instructions, see: `http://www.math.cornell.edu/Positions/facpositions.html`. Applicants will be automatically considered for all eligible positions. Deadline December 1, 2010. Early applications will be regarded favorably. Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

000046

CORNELL UNIVERSITY
Department of Mathematics
RTG NSF Postdoctoral Positions

The probability group at Cornell invites applications from recent PhD recipients for postdoc positions (Visiting Assistant Professors) beginning July 1, 2011. These positions are funded each year by Cornell University and a Research Training Grant from the National Science Foundation. The usual term is two years, with a two course teaching load each year. The salary is $50,000 plus $10,000 supplemental summer support per year.

All applicants must be US citizens, nationals or permanent residents, who have had their Ph.D.'s for less than 18 months or are graduate students who will complete their PhD requirements by the position start date. The Department actively encourages applications from women and minority candidates.

Applicants are required to apply electronically at: `http://www.mathjobs.org`.

For information about these positions and application instructions, see: `http://www.math.cornell.edu/Positions/facpositions.html`.

For full consideration, please submit application by January 1, 2011. Successful candidates will be invited for interviews in late January, early February.

Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

000048

CORNELL UNIVERSITY
Department of Mathematics
Tenure/Tenure-Track Position

The Department of Mathematics at Cornell University invites applications for a tenure-track Assistant Professor position, or higher rank, pending administrative approval, starting July 1, 2011. Applications in all areas of Mathematics will be considered with a priority given to probability. The Department actively encourages applications from women and minority candidates.

Applicants are strongly encouraged to apply electronically at: `http://www.mathjobs.org`.

For information about our positions and application instructions, see: `http://www.math.cornell.edu/Positions/facpositions.html`. Applicants will be automatically considered for all eligible positions. Deadline November 1, 2010. Early applications will be regarded favorably. Cornell University is an Affirmative

Action/Equal Opportunity Employer and Educator.

000045

CORNELL UNIVERSITY
Department of Mathematics
Visiting Professor Positions

The Department of Mathematics at Cornell University invites applications for possible visiting positions, academic year or one semester teaching positions (rank based on experience) beginning August 16, 2011. We are seeking candidates who have excellent teaching skills. The teaching load varies from 1-4 courses per year, depending on the individual and the availability of courses. Candidates with teaching and research interests compatible with current faculty are sought. The Department actively encourages applications from women and minority candidates.

Applicants are strongly encouraged to apply electronically at: `http://www.mathjobs.org`.

For information about our positions and application instructions, see: `http://www.math.cornell.edu/Positions/facpositions.html`. Applicants will be automatically considered for all eligible positions. Deadline December 1, 2010. Early applications will be regarded favorably. Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

000047

NORTH CAROLINA

NORTH CAROLINA STATE UNIVERSITY
Department of Mathematics

The Mathematics Department at North Carolina State University invites applications for a tenure-track position in applied analysis beginning Fall 2011, depending on the availability of funding. We are seeking an exceptionally well-qualified individual with research interests compatible with those in the department. Candidates must have a Ph.D. in the mathematical sciences, an outstanding research program, a commitment to effective teaching at the undergraduate and graduate levels and demonstrated potential for excellence in both research and teaching. She or he will likely have had successful post-doctoral experience. The Department of Mathematics has strong research programs in both pure and applied mathematics. Many members of the department participate in interdisciplinary programs and research groups on campus and in the broader Research Triangle community. More information about the department can be found at http://www.math.ncsu.edu.

To submit your application materials, go to: `http://www.mathjobs.org/jobs/ncsu`. Include a vita, at least three letters of recommendation, and a description of current and planned research. To be considered for this position please also go to: `http://jobs.ncsu.edu/applicants/Central?quickFind=87399` and complete a Faculty Profile for the position.

Write to: email: `math-jobs@math.ncsu.edu` for questions concerning this position.

AA/EOE. In addition, NC State welcomes all persons without regard to sexual orientation. The College of Physical and Mathematical Sciences welcomes the opportunity to work with candidates to identify suitable employment opportunities for spouses or partners. For ADA accommodations, please contact Human Resources by email at employment@ncsu.edu or by calling (919) 515-2135. Applications received by November 15, 2010 will be given priority.

000059

NORTH CAROLINA STATE UNIVERSITY
Department of Mathematics

The Mathematics Department at North Carolina State University invites applications for one or more tenure-track position beginning Fall 2011, depending on the availability of funding. We are seeking exceptionally well-qualified individuals with research interests compatible with those in the department. All areas of pure and applied mathematics will be considered. Candidates must have a Ph.D. in the mathematical sciences, an outstanding research program, a commitment to effective teaching at the undergraduate and graduate levels and demonstrated potential for excellence in both research and teaching. She or he will likely have had successful post-doctoral experience. The Department of Mathematics has strong research programs in both pure and applied mathematics. Many members of the department participate in interdisciplinary programs and research groups on campus and in the broader Research Triangle community. More information about the department can be found at: `http://www.math.ncsu.edu`.

To submit your application materials, go to: `http://www.mathjobs.org/jobs/ncsu`. Include a vita, at least three letters of recommendation, and a description of current and planned research. To be considered for this position please also go to: `http://jobs.ncsu.edu/applicants/Central?quickFind=87396` and complete a Faculty Profile for the position.

Write to: email: `math-jobs@math.ncsu.edu` for questions concerning this position.

AA/EOE. In addition, NC State welcomes all persons without regard to sexual orientation. The College of Physical and Mathematical Sciences welcomes the opportunity to work with candidates to identify suitable employment opportunities for spouses or partners. For ADA accommodations, please contact Human Resources by email at: `employment@ncsu.edu` or by calling (919) 515-2135. Applications received by November 15, 2010 will be given priority.

000060

NORTH CAROLINA STATE UNIVERSITY
Department of Mathematics

The Mathematics Department at North Carolina State University invites applications for the LeRoy Martin Professorship in Mathematics. We are seeking exceptionally well-qualified individuals with research interests compatible with those in the department. All areas of pure and applied mathematics will be considered. Candidates must have a Ph.D. in the mathematical sciences. The successful applicant will have an internationally recognized research program, a commitment to effective teaching at the undergraduate and graduate levels, a strong record of mentoring PhD students, and demonstrated ability to attract external funding. The Department of Mathematics has strong research programs in both pure and applied mathematics. Many members of the department participate in interdisciplinary programs and research groups on campus and in the broader Research Triangle community. More information about the department can be found at: `http://www.math.ncsu.edu`.

To submit your application materials, go to: `http://www.mathjobs.org/jobs/ncsu`. Include a vita, at least four letters of recommendation, and a description of current and planned research.

Write to: email: `math-jobs@math.ncsu.edu` for questions concerning this position.

AA/EOE. In addition, NC State welcomes all persons without regard to sexual orientation. The College of Physical and Mathematical Sciences welcomes the opportunity to work with candidates to identify suitable employment opportunities for spouses or partners. For ADA accommodations, please contact Human Resources by email at: `employment@ncsu.edu` or by calling (919) 515-2135.

000061

OREGON

UNIVERSITY OF OREGON
Department of Mathematics

The University of Oregon department of mathematics seeks applicants for a full-time tenure-related position in the area of probability at the rank of Assistant Professor. Minimum qualifications are a Ph.D. in mathematics or closely related field. An outstanding research record, and active participation and excellence in teaching at the undergraduate and graduate levels will be the most important criteria for selection. Please see `http://hr.uoregon.edu/jobs/` for a full position announcement. Applicants should provide a standard AMS cover page, CV, research statement, and three letters of recommendation and apply online at: http://mathjobs.org. Deadline for applications: December 15, 2010. Candidates should have the ability to work effectively with a diverse community. The University of Oregon is an EO/AA/ADA institution committed to cultural diversity.

000063

PENNSYLVANIA

PENN STATE UNIVERSITY
Assistant Professor of Math Education

Penn State Lehigh Valley invites applications for Assistant Professor of Math Education (tenure-track). Teach three courses each semester, including math methods course, for elementary education majors, and lower level math courses for education majors, using traditional and hybrid delivery modes. Publish in refereed journals. Participate in service activities. Ph.D./Ed.D. in mathematics, math education, or related field (will consider ABD candidates) and preschool, elementary, or middle school teaching experience required. Expect evidence of potential in research and publication. To learn more about the campus and Penn State, visit http://www.psu.edu/ur/cmpcoll.html. To learn more about the position and how to apply, visitL http://www.psu.jobs/Search/Opportunities.html; follow "Faculty" link. AA/EOE.

000036

SOUTH CAROLINA

COLLEGE OF CHARLESTON
Department of Mathematics

Applications are invited for at least one tenure-track position at the Assistant Professor level beginning August 16, 2011. The Mathematics Department at the College of Charleston when fully-staffed has 34 full-time faculty members and offers the B.S. and M.S. degrees in mathematics. Candidates must have a Ph.D. in one of the mathematical sciences, potential for continuing research, and commitment to excellence in teaching. Some preference will be given to individuals in the broad area of analysis and who have the potential to contribute to interdisciplinary offerings, however exceptionally strong candidates in all areas will be considered. The normal teaching load is nine hours per week, and the salary is competitive. A minimal application will consist of a vita, narratives on research and teaching, and at least three letters of recommendation which, combined, must address both teaching and research. All materials should be submitted to the College of Charleston at: http://mathjobs.org. For demographic purposes only, candidates must respond yes or no to the Citizen/Residency field. Additional information about the department and its programs, including the interdisciplinary Discovery Informatics program, is available at: http://math.cofc.edu and http://discovery.cofc.edu. Review of applications for on-campus interviews will begin as applications are received, and applications will be accepted until the position is filled. The College of Charleston is an Equal Opportunity / Affirmative Action Employer and encourages applications from minority and women candidates.

000054

TEXAS

TEXAS A&M UNIVERSITY
The Department of Mathematics

The Department of Mathematics anticipates up to six openings for postdoctoral positions at the level of Visiting Assistant Professor, subject to budgetary approval. Our Visiting Assistant Professor positions are three-year appointments and carry a three-course-per-year teaching load. They are intended for those who have recently received their Ph.D.s and preference will be given to mathematicians whose research interests are close to those of our regular faculty members. We also anticipate up to six short-term (semester or year-long) visiting positions at various ranks, depending on budget. A complete dossier should be received by December 15, 2010. Early applications are encouraged since the department will start the review process in October 2010. Applicants should send the completed "AMS Application Cover Sheet", a vita, a summary statement of research and teaching experience, and arrange to have letters of recommendation sent to: Faculty Hiring, Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, Texas 77843-3368. Further information can be obtained from: http://www.math.tamu.edu/hiring.

Texas A&M University is an Equal Opportunity Employer. The university is dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment, and strongly encourages applications from women, minorities, individuals with disabilities, and veterans. The university is responsive to the needs of dual career couples.

000034

TEXAS A&M UNIVERSITY-KINGSVILLE
Department of Mathematics
Department Chair

The Department of Mathematics at Texas A&M University-Kingsville invites applications for Department Chair, beginning August 2010 and pending budgetary approval. The position will be filled at the rank of Associate or Professor based on experience. Candidates must have a Ph.D. in mathematics, Mathematics Education or Statistics and must demonstrate a history of excellence in teaching, scholarly research and excellent English communication skills. Experience in academic administration at the department level or higher is desirable. Review of applications will begin December 1 2010, although application will be accepted until the position is filled. Submit letter of application, C.V., statement of teaching and administrative philosophy, research interests, graduate transcripts and three letters of reference online at: http://javjobs.tamuk.edu/ and to Wanda Badger, Administrative Assistant II, Department of Mathematics, MSC 172, 700 University Blvd., Kingsville Tx. 78363. Inquiries can be made to 361-593-3517 or w-badger@tamuk.edu. For review of application, applicants may submit unofficial transcripts to http://Javjobs. However, prior to issuing a letter of appointment, official transcripts must be received directly from each regionally accredited degree granting institution by the office of the Provost. If transcripts are from an international institution, it is the responsibility of the prospective faculty member to have the transcripts translated and evaluated by an approved credential evaluator (AACRAO). EEO/AA/ADA.

000066

TRINITY UNIVERSITY
Department of Mathematics
Chair and Tenured Faculty Appointment

The Department of Mathematics at Trinity University in San Antonio, Texas invites applications for the position of departmental chair. Appointment will be at the rank of associate or full professor with tenure in an area of applied mathematics. The position requires extensive experience in undergraduate education, and a record of excellence in teaching, research and service. We seek an individual with vision who is a skilled leader, a supportive colleague and an accomplished educator/scholar. Experience in fiscal affairs is desirable. The department recently received an institutional five-year NSF-UBM grant and an NIH research grant. For further information on our department, please visit our web page at: http://www.trinity.edu/math. Review of applications will begin October 15, 2010 and continue until the position is filled.

To apply, please submit curriculum vita and a letter addressing all desired attributes indicated in the paragraph above to:

Trinity University
Department of Mathematics
Attn: Dr. Saber Elaydi

One Trinity Place
San Antonio, TX 78212
or: email: selaydi@trinity.edu.

Trinity University is an Equal Opportunity Employer. Women and minority candidates are strongly encouraged to apply.

000049

UTAH

UNIVERSITY OF UTAH
Department of Mathematics

The Department of Mathematics at the University of Utah invites applications for the following positions:

Full-time tenure-track or tenured appointments at the level of assistant, associate, or full professor in all areas of mathematics and statistics.

Three-year Scott, Wylie, and Burgess Assistant Professorships.

Please see our website at: http://www.math.utah.edu/positions for information regarding available positions, application requirements and deadlines. Applications must be completed through the website: http://www.mathjobs.org.

The University of Utah is an Equal Opportunity, Affirmative Action Employer and encourages applications from women and minorities, and provides reasonable accommodation to the known disabilities of applicants and employees.

The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and possess a strong commitment to improving access to higher education for historically underrepresented students.

000057

WASHINGTON

UNIVERSITY OF WASHINGTON
Department of Mathematics

Applications are invited for a non-tenure-track Acting Assistant Professor position. The appointment is for a period of up to three years to begin in September 2011. Applicants are required to have a Ph.D. by the starting date, and to be highly qualified for undergraduate and graduate teaching and independent research.

Applications should include should include the American Mathematical Society's Cover Sheet for Academic Employment, a curriculum vitae, statements of research and teaching interests, and three letters of recommendation. We prefer applications and supporting materials to be submitted electronically via: http://www.mathjobs.org. Application materials may also be mailed to: Appointments Committee Chair (AAP position), Department of Mathematics, Box 354350, University of Washington, Seattle, WA 98195-4350. Priority will be given to applicants whose complete applications, including recommendations, are received by December 15, 2010.

The University of Washington is building a culturally diverse faculty and strongly encourages applications from female and minority candidates. The University is an Equal Opportunity/Affirmative Action employer.

000043

WISCONSIN

UNIVERSITY OF WISCONSIN–MADISON
Department of Mathematics

The Department of Mathematics is accepting applications for an assistant professor (tenure-track) position beginning August 29, 2011. Applications are invited in all areas of mathematics. Candidates should exhibit evidence of outstanding research potential, normally including significant contributions beyond the doctoral dissertation. A strong commitment to excellence in instruction is also expected. Additional departmental information is available on our website: http://www.math.wisc.edu.

An application packet should include a completed AMS Standard Cover Sheet, a curriculum vitae which includes a publication list, and brief descriptions of research and teaching to. Application packets should be submitted electronically to: http://www.mathjobs.org. Applicants should also arrange to have sent, to the above URL address, three to four letters of recommendation, at least one of which must discuss the applicant's teaching experiences, capabilities and potential. To ensure full consideration, application packets must be received by November 8, 2010. Applications will be accepted until the position is filled. The Department of Mathematics is committed to increasing the number of women and minority faculty. The University of Wisconsin is an affirmative action, equal opportunity employer and encourages applications from women and minorities. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality. A background check may be required prior to employment.

000064

BRAZIL

INSTITUTO DE MATÉMATICA PURA E APLICADA
IMPA
Rio de Janeiro, Brasil

The Instituto de Matématica Pura e Aplicada (IMPA), invites applications for the S.S. Chern Chair in Geometry, and the J. Simons Chair in Geometry, sponsored by the Simons Foundation and the Brazilian Ministry of Science and Technology. The first recruitment for these chairs will be in Differential Geometry as two tenure-track positions. Tenure will be considered during the first four years. The monthly salary will be between R$ 11,300 and R$ 15,000 (about US$ 6,250 and US$ 8,300 respectively at the June 23, 2010 exchange rate). During the first four years there will be also a monthly research allotment of R$ 2,500 (about US$1,400). Applications should be sent to: chair@impa.br until October 31, 2010. The decisions will be made by January 10, 2011. The appointees should begin their engagement at IMPA any time between March 1, 2011 and September 1, 2011. Further inquiries should be addressed to the same e-mail address. For information on application submissions, see: http://www.impa.br/opencms/en/pesquisa/chairsopening.html.

INSTITUTO DE MATÉMATICA PURA E APLICADA
IMPA
Rio de Janeiro, Brasil

The Instituto de Matématica Pura e Aplicada (IMPA), invites applications for six two-year post-doctoral positions, with a monthly take-home salary of R$ 7.500 (about US$ 4,200 at the June 28, 2010 exchange rate). Two of these positions are a donation of João Moreira Salles and Pedro Moreira Salles, and are open to candidates in mathematics. Two additional positions are open to candidates in any field of mathematics. One position is reserved for candidates working on Mathematical Economics, and the remaining one is targeted on candidates able to build a bridge between IMPA research and the industrial sector (this position is open to candidates with doctorates in fields other than mathematics). Candidates must have obtained their Ph.D. degrees after March 31, 2007. IMPA, located in Rio de Janeiro, Brazil, is widely recognized as one of the leading mathematical research centers worldwide. Its main goal is the generation of high-level mathematical research. It offers also graduate level programs at the Ph.D. and MSc level. Currently, its faculty includes specialists in Real and Complex Dynamical Systems, Analysis, Algebra, Geometry, Probability, Fluid Dynamics, Optimization, Mathematical Economics and Computer Graphics. Applications should be sent to: pdopen@impa.br until December 31, 2010. Decision will be announced around March 1, 2011. Accepted candidates should start their activities at IMPA between May 1, 2011 and September 1, 2011. Further inquiries should be addressed to the same e-mail address. For information on application submissions, see: http://www.impa.br/opencms/en/pesquisa/pdopen.html.

000038

INSTITUTO DE MATÉMATICA PURA E APLICADA
IMPA
Rio de Janeiro, Brazil

The Instituto de Matématica Pura e Aplicada (IMPA), invites applications for two tenure-track positions in any field of mathematics, with a monthly salary between R$ 11.500 and R$ 15.000 (about US$ 6,250 and US$ 8300 at the June 23, 2010 exchange rate). IMPA, located in Rio de Janeiro, Brazil, is widely recognized as one of the leading mathematical research centers worldwide. Its main goal is the generation of high-level mathematical research. It offers also graduate level programs at the Ph.D. and MSc level. Currently, its faculty includes specialists in Real and Complex Dynamical Systems, Analysis, Algebra, Geometry, Probability, Fluid Dynamics, Optimization, Mathematical Economics and Computer Graphics. Applications should be sent to: `opening@impa.br` until December 31, 2010. The decisions will be made by early March, 2011. Further inquiries should be addressed to the same e-mail address. For information on application submissions, see: `http://www.impa.br/opencms/en/pesquisa/opening.html`.

000039

INDIA

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH (IISER)
Mohali, India

Indian Institute of Science Education and Research (IISER), Mohali invites applications for faculty positions in mathematics at all levels. Applicants should have a Ph.D in mathematics with proven research record and a strong commitment to teaching and reseach. For details see: `http://www.iisermohali.ac.in/faculty_openings.html`. IISER Mohali also invites applications for the positions of Research Associates/Post-doctoral fellows. Applicants should have a recent Ph.D in Mathematics with a flair for research and teaching.

The applications may be sent either as a soft or a hard copy to:

Director
IISER
Mohali MGSIPA Complex, Sector 26
Chandigarh-160019 India;
email: `director@iisermohali.ac.in`.

IISER Mohali is funded by the Ministry of Human Resource Development, Government of India and is located near the foothills of the Shivalik range of the Himalayas in Northwest India.

000040

SINGAPORE

NATIONAL UNIVERSITY OF SINGAPORE (NUS)
Department of Mathematics

The Department of Mathematics at the National University of Singapore (NUS) invites applications for tenured, tenure-track and visiting positions at all levels, beginning in August 2011.

NUS is a research intensive university that provides quality undergraduate and graduate education. The Department of Mathematics, which is one of the largest in the university, has about 70 faculty members and teaching staff whose expertise cover major areas of contemporary mathematical research.

We seek promising scholars and established mathematicians with outstanding track records in any field of pure and applied mathematics. The Department offers internationally competitive salaries with start-up grants for research. The teaching load is particularly light for young scholars, in an environment conducive to research with ample opportunities for career development.

The Department is particularly interested in, but not restricted to, considering applicants specializing in any of the following areas:

· Analysis, Probability, and Ergodic Theory.

· Computational Science, including but not restricted to, Computational Biology, Medical Imaging, Computational Materials Science and Nanoscience.

· Financial Mathematics.

Application materials should be sent to Search Committee via email (as PDF files) to: email: `search@math.nus.edu.sg`.

Please include the following supporting documentation in the application:

1. an American Mathematical Society Standard Cover Sheet;

2. a detailed CV including publications list;

3. a statement (max. of 3 pages) of research accomplishments and plan;

4. a statement (max. of 2 pages) of teaching philosophy and methodology. Please attach evaluation on teaching from faculty members or students of your current institution, where applicable;

5. at least three letters of recommendation including one which indicates the candidate's effectiveness and commitment in teaching. Please ask your referees to send their letters directly to: `search@math.nus.edu.sg`.

Enquires may also be sent to this email address.

Review process will begin on October 15, 2010, and will continue until positions are filled.

For further information about the department, please visit: `http://www.math.nus.edu.sg`.

000065

Mathematical Sciences Employment Center

New Orleans Marriott, New Orleans, Louisiana
January 6–9, 2011

The Employment Center offers a convenient, safe, and practical meeting place for employers and applicants attending the Joint Meetings. The focus of the Employment Center is on Ph.D.-level mathematical scientists and those that seek to hire them from academia, business, and government.

Employment Center Web Services

All resume and job forms will be submitted and accessed electronically on the Web. In addition, registered attendees will also be able to utilize a basic scheduling tool in advance on the Web. The website and all information will be available beginning in mid-August, 2010, and will remain accessible through the period of the Employment Center. The same applicant and job information available on the Employment Center/EIMS website during the months preceding the event in New Orleans will be accessible during the JMM on computer terminals available at the Employment Center. While some schools may delay appointment setting until late December, virtually all scheduling will be done before travel takes place, so applicants should expect few or no further appointments after arrival. Registering on site, for applicants, serves no real purpose.

There will be no printed books or paper forms. Also, there will be no paper message center since the new electronic system allows for interview arrangements. Computer scheduling is no longer provided at the Employment Center.

2011 Employment Center Schedule:

November 1, 2010–Suggested deadline for electronic forms submission to allow for advanced scheduling.

December 15, 2010–Advance registration deadline for JMM. Meeting badge will be required for admittance. After this date, meeting registration fees go up and meeting registration may only happen on site in New Orleans.

OPEN HOURS (NO access before opening time):

Thursday, January 6, 2011–8:00 a.m.–7:00 p.m.

Friday, January 7, 2011–8:00 a.m.–7:00 p.m.

Saturday, January 8, 2011–8:00 a.m.–7:00 p.m.

Sunday, January 9, 2011–9:00 a.m.–12:00 noon.

Location: Marriott Preservation Hall, Second Floor, New Orleans Marriott, 555 Canal Street, New Orleans

Do not schedule an interview to begin until 15 minutes after opening.

Note: When deciding on travel dates, keep in mind that employers may wish to conduct interviews on any of the days listed above.

No Admittance Without a JMM Badge

All applicants and employers planning to enter the Employment Center—even just for one interview—must present a 2011 Joint Meeting Registration badge or they will be denied admittance. This is not a new policy, but it is now strictly enforced. Meeting badges are obtained by registering for the Joint Mathematics Meetings and paying a meeting registration fee. See the JMM website at: http://ams.org/meetings/national/jmm/2125_intro.html for registration instructions and rates.

Employers: Choose a Table

There are two table types available for employers, based on the number of interviewers who will be present at any one time:

• one or two interviewers per table in the "Quiet Area" (US$295), additional table (US$105).

• three to six interviewers per table in the "Committee Table" area (US$400), additional table (US$105).

• If a table ONLY is desired, without an ad submission, just enter the Web system, look for pricing under "Career Fair", purchase any table/ad combination, and then do not post the ad. Ad submission is not required, however, prices are the same whether the ad is used or not.

• All tables include the option to set appointments on the EIMS system where schools and employers can access the information.

The fee includes one ad, which will run in EIMS and serve as the Employment Center ad through January. Please note that the traditional advertising site on the AMS website, EIMS, now also serves as the ad placement site for the Employment Center. Employers should be sure and place their ad through the "Career Fair" tab which will be available on the EIMS website by mid-August. There is no point in placing an EIMS ad and an Employment Center ad separately; one ad will serve both purposes, but it MUST be placed using the Employment Center table purchase options.

All fees are to be paid at the EIMS ad website; fees are no longer paid through the JMM registration form. However, individual registration for the JMM is required for all interviews and no admittance is possible without a JMM badge.

Employers: How to Register

• Registration runs mid-August 2010 through January 6, 2011, at the following website: www.eims.ams.org. The suggested deadline is November 1 if possible.

• Use your existing EIMS account or create a new Employer account at eims.ams.org. Look under "Career Fair" to find the right table option and complete the purchase. Once a table is reserved, the ad can be placed at any time (or never) and will run until late January.

• Each person who will need to enter the Employment Center area must have a meeting badge (obtained by registering for the JMM and paying a meeting registration fee).

Once registered, employers will gain access to applicant data as it is submitted to the site. There will be applicant resumes on the site, but employers will want to notice especially the resumes marked "Employment Center" (EC logo). Also, employers can review the requests for interviews submitted by applicants on the system. To respond to a request, employers will be able to access the applicant's pre-approved schedule and fill in the desired slot or slots. In this way, employers will build their own schedule, which is also viewable on the system.

To display an ad on site, and use no Employment Center services at all, submit your one page paper ad on site to the Employment Center staff. There is no fee for this service.

For complete information, visit http://www.ams.org/emp-reg/.

Applicants: Making the Decision to Attend

• The Employment Center offers no guarantees of interviews or jobs. Hiring decisions are not made during or immediately following interviews. In the current job market, the ratio of applicants to employers is about 10:1, and many applicants go completely unnoticed.

• There will ordinarily be no research-oriented postdoctoral positions listed or discussed at the Employment Center.

• Interviews will go to applicants who applied to jobs during the fall and are now being sought out by the institutions for in person meetings during the JMM.

• There will be no opportunity to speak to employers without a pre-arranged interview, and no walk-up job information tables.

In the current job market, the majority of Employment Center employers are academic departments of mathematical sciences seeking to meet a short list of applicants who applied for their open positions during the fall. Each year, a few government or industry employers are present. Often, they are seeking U.S. citizens only due to existing contracts.

All job postings and interview request arrangements are available on the website in advance, and now that this electronic service is in place, there is no other messaging conducted on paper. Please note, also, that there is no connection between Mathjobs.org and the Employment Center. The Employment Center shares web software with the EIMS ads on the AMS website, but not with Mathjobs.org.

Past attendees have pointed out that all interviews are arranged in advance, and there is no opportunity to make connections on site if it has not happened before the meeting. In a recent survey, fifty percent of applicants responding reported being invited for at least one on-campus visit to an employer they had interviewed with at the Employment Center. Please visit the Employment Center website for further advice, information, and program updates at www.ams.org/emp-reg/.

Applicants: How to Register

• Early registration is vital since most employers will finalize schedules before arriving in New Orleans.

• Register for the JMM by completing a meeting registration form and paying a meeting registration fee. No admittance without a meeting badge.

• Create an Applicant account on the Employment Center/EIMS website. Review job ads with the "EC" logo, upload documents, and request interviews.

After submitting information and a limited number of documents on the Employment Center/EIMS website, applicants should mark their hours of availability on their interview schedule/calendar. Applicants can then review the jobs ads marked "Employment Center" (EC logo) and, if desirable, click the "request an interview" button to show interest in the job. This may appear at times like making a job application, but it really only serves as an interview request with backup documentation. If an application has already been made separately (as is often the case) applicants should indicate that in a brief cover letter. Employers may, at any time, respond to your "request for interview" by filling in an interview slot on your schedule. Employers are usually happy if you then send a quick email agreeing to the appointment.

There are no Employment Center fees for applicants; however, admission to the Employment Center room requires a 2011 JMM badge, obtainable by registering (and paying a fee) for the Joint Mathematics Meetings. To register for the meeting, go to http://ams.org/meetings/national/jmm/2125_intro.html.

It is possible to attend one or more privately arranged interviews without official Employment Center registration, however, a meeting badge is required to access the interview room.

For complete information, visit http://www.ams.org/emp-reg/.

Questions about the Employment Center registration and participation can be directed to Steve Ferrucci, AMS Membership and Programs Department, at 800-321-4267, ext. 4113, or by e-mail to emp-info@ams.org.

AMS Short Courses

AMS Short Courses

Two Short Course proposals have beeen selected for presentation just before the Joint Mathematics Meetings begin. These Short Courses will take place on January 4 and 5, 2011 (Tuesday and Wednesday).

The cost to participate is the same for both courses. Advance registration fees are: member of the AMS or MAA, US$100; nonmembers are US$134; students, unemployed, or emeritus are US$48. These fees are in effect until December 15. If you choose to register at the meeting, the fees are US$140 for members of the AMS or MAA, US$170 for nonmembers, and US$69 for students, unemployed, or emeritus.

Evolutionary Game Dynamics

Karl Sigmund, University of Vienna, organizer

Evolutionary game theory studies basic types of social interactions in populations of players. It is the ideal mathematical tool for methodological individualism, i.e., the reduction of social phenomena to the level of individual actions. Evolutionary game dynamics combines the strategic viewpoint of classical game theory (independent, rational players trying to outguess each other) with population dynamics (successful strategies increase their frequencies).

A substantial part of the appeal of evolutionary game theory comes from its highly diverse applications, such as social dilemmas, evolution of language, or mating behavior in animals. Moreover, its methods are becoming increasingly popular in computer science, engineering, algorithmic game theory, network analysis, machine learning, statistical procedures, and control theory. They help to design and control multi-agent systems, often with large numbers of agents (for instance, when routing drivers over highway networks, or data packets over the Internet). While traditionally these fields have used a top down approach, by directly controlling the behavior of each agent in the system, attention has recently turned to an indirect approach: allowing the agents to function independently, while providing incentives that lead them to behave in the desired way. Instead of the traditional assumption of equilibrium behavior, researchers opt increasingly for the evolutionary paradigm, and consider the dynamics of behavior in populations of agents employing simple, myopic decision rules.

The lectures offer a menu whose main course is based on deterministic and stochastic dynamics describing the evolution of frequencies of behavioral types, and whose side dishes consist of examples drawn from disciplines as diverse as microbiology, genetics, animal behavior, evolutionary psychology, route planning, e-auctions, common resources management, or micro-economics.

An introductory part of the course is devoted to a brief sketch of the origins of the field, and in particular to the examples that motivated evolutionary biologists to introduce a population dynamical viewpoint into game theory. This leads to some of the main concepts: evolutionary stability, replicator dynamics, invasion fitness, etc. Much of it can be explained by means of simple examples such as the Rock-Paper-Scissors game. It came as a surprise when childish games of that sort, intended only for the clarification of concepts, were found to actually lurk behind important classes of real-life social and biological interactions. The Ultimatum Game, the Prisoner's Dilemma, or the Stag-hunt Game have been used in hundreds of economic experiments, leading to fascinating insights into the role of fairness norms, moral emotions, unconscious motivations, and cultural differences. Behavioral economics promoted the design of efficient mechanisms for broadband auctions or globalized e-commerce, but also led to hot debates on the economic roles of punishment, inequity aversion, beliefs in supernatural agents, or concerns for reputation.

The transmission of successful strategies by genetic and cultural means results in a rich variety of stochastic processes and, in the limit of very large populations, deterministic adjustment dynamics including differential inclusions and reaction-diffusion equations. Some economists view these types of dynamics as basic tools for so-called equilibrium refinement and equilibrium selection concepts. (Indeed, most games have so many equilibria that it is hard to select the "right one"). However, evolutionary games have also permitted the move away from the equilibrium-centered viewpoint. Today, we understand that it is often premature to assume that behavior converges to an equilibrium. In particular, an evolutionarily stable strategy need not be reachable. Limit phenomena such as periodic or heteroclinic cycles, or chaotic attractors, may be considered, perhaps not as "solutions of the game", but as predictions of play. On the other hand, large classes of games leading to global convergence are presently much better understood.

The team for this AMS course consists of **Ross Cressman**, Wilfried Laurier University; **Josef Hofbauer**, University of Vienna; **Sabin Lessard**, Université de Montréal; **Bill Sandholm**, University of Wisconsin, **Karl Sigmund**, University of Vienna; and **Sylvain Sorin**, Université Pierre et Marie Curie, Paris. These speakers have substantially contributed to the field. They will provide a thoroughly up-to-date introduction to evolutionary games for mathematicians interested in the bottom-up analysis of social behavior.

Relevant Literature

CRESSMAN, R., *Evolutionary Dynamics and Extensive Form Games*, MIT Press, Cambridge, MA, 2003.

HOFBAUER, J. and SIGMUND, K., Evolutionary game dynamics, *Bull. AMS* **40** (2003), 479–519.

LESSARD, S. and LADRET, V., The probability of fixation of a single mutant in an exchangeable selection model, *Journal of Math Biology* **54** (2007), 721–744.

SANDHOLM, W. H., *Population Games and Evolutionary Dynamics*, Harvard, MIT Press, 2010.

SIGMUND, K., *The Calculus of Selfishness*, Princeton University Press, 2010.

SORIN, S.; VIOSSAT, Y.; and HOFBAUER, J.: Time average replicator and best reply dynamics, *Math. Operations Research* **34** (2009), 263–269

Computational Topology

Afra Zomorodian, Dartmouth College, organizer

Introduction

The area of computational topology developed in response to topological impediments emerging from within geometric problems, such as reconstructing watertight surfaces in computer graphics. Topological problems, however, arise naturally in many areas of inquiry. In robotics, for instance, we need to capture the connectivity of the configuration space of a robot in order to plan optimal trajectories. In computational structural biology, optimal trajectories within the conformation space of a protein define its folding path. More recently, topological data analysis has emerged as a new paradigm for robust analysis of noisy, high-dimensional, heterogeneous, sampled data.

Like topology, computational topology is a large and diverse area. The aim of this short course is to introduce the audience to recent theoretical as well as practical developments of this field, starting with a theoretical grounding in algebraic topology and ending with analysis of real world data using fast software. Topics covered in the course may include:

1. Review of algebraic topology invariants, such as homotopy, homology, and the Euler characteristic, with an emphasis on algorithms and computation.

2. Theory for robust computation of features of spaces, such as persistent homology, multidimensional persistence

3. Data Structures for representing the underlying topology of sampled data, such as the witness complex.

4. Algorithms for computing robust invariants of spaces efficiently, such the persistence algorithm.

5. Software for analyzing sampled data, such as JPlex, mapper, and eucharis.

6. Applications of computational topology to real world data, such as in computer vision, biophysics, and sensor networks.

Lectures

We have the following confirmed speakers with preliminary titles and abstracts for their talks.

Topological Data Analysis

Gunnar Carlsson, Stanford University

Carlsson will talk about the general philosophy of topological data analysis, that one needs methods which are in some way robust to changes in metrics and to noise. He will describe various aspects of ordinary topology, specifically homology, diagrams, and mapping, and how they play out in the data analytics/statistical world. Carlsson will demonstrate software such as JPlex, mapper, and zigzags on real world data, such as image processing, protein folding, gene expression, and possibly climate data.

Planning with Uncertainty

Michael Erdmann, Carnegie Mellon University

Erdmann uses methods from combinatorial topology to create uncertainty-tolerant strategies for accomplishing robotic tasks. A key theorem shows that such a task has a guaranteed solution if and only if a certain simplicial complex associated with the task is homotopic to a sphere of a certain dimension. This special result leads to a general graph controllability theorem characterizing the ability of a system to achieve any goal despite control uncertainty, again in terms of the existence of a certain sphere. These theorems lead to algorithms, all of which have been implemented.

Optimal Generators

Jeff Erickson, University of Illinois at Urbana-Champaign

Many applications of computational topology arise from geometric problems, such as topological simplification of three-dimensional surface models in computer graphics. For these applications, we require geometric descriptions of topological features, based on various geometric measures, such as shortest homology cycles. Erickson will discuss recent results from computational geometry for computing such descriptions, including recent results on homology flows and cohomology cuts of surface-embedded graphs.

Euler Calculus and Data over Networks

Robert Ghrist, University of Pennsylvania

Ghrist will talk about Euler calculus: using sheaves and the Euler characteristic measure to aggregate data over networks. He will demonstrate and give a tutorial on eucharis, software for integration, and integral transforms over networks.

Cubical Homology and Dynamical Systems

Marian Mrozek, Jagiellonian University (Poland)

Mrozek discusses reduction algorithms for computing cubical homology, including classical free reductions as well as shaving, reductions via acyclic subspace, and coreductions, among other techniques. These techniques have been implemented in CHomP, a cubical homology software developed by Mrozek and colleagues. Mrozek will then describe applying homological invariants toward understanding chaotic dynamical systems.

Persistence: Theory & Practice

Afra Zomorodian, Dartmouth College

Zomorodian will introduce persistence, a notion for identifying features of data robustly. He will then discuss various computational theories of persistence for different classes of data, such as static and parameterized data. In each case, he will describe the theoretical structure, algorithms for computation of invariants, their implementation, and application toward real world examples, such as in biophysics and computer vision.

Schedule

It is planned that each speaker will give a ninety-minute talk. Currently, there is one software session for examining three software programs described by the first three speakers (possibly, persistence, mapper, and CHomP.) The idea is to have some interaction with software on the first day, so there is time for discussion on the second day. The panel discussion currently scheduled at the end of the second day may also be turned into a software session.

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See `http://www.ams.org/meetings/`. Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL and in an electronic issue of the *Notices* as noted below for each meeting.

Syracuse, New York

Syracuse University

October 2–3, 2010

Saturday – Sunday

Meeting #1062

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: June 2010
Program first available on AMS website: August 19, 2010
Program issue of electronic *Notices*: October
Issue of *Abstracts*: Volume 31, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Alan Frieze, Carnegie-Mellon University, *Hamilton cycles in random graphs*.

Yan Guo, Brown University, *Asymptotic stability in some fluid problems*.

William Minicozzi, Johns Hopkins University, *Generic singularities of mean curvature flow*.

Andrei Zelevinsky, Northeastern University, *Cluster algebras via quivers with potentials*.

Special Sessions

Advances in Theory and Applications of Evolution Equations, **Tokia Diagana**, Howard University, and **Gaston Ní Guerekata**, **Alexander Pankov**, **Xuming Xie**, and **Guoping Zhang**, Morgan State University.

Analysis, Probability and Mathematical Physics on Fractals, **Luke Rogers**, University of Connecticut, **Robert Strichartz**, Cornell University, and **Alexander Teplyaev**, University of Connecticut.

Analytic Combinatorics, **Miklos Bona**, University of Florida, and **Alex Iosevich**, University of Rochester.

Commutative Algebra and Algebraic Geometry, **Anthony Geramita**, Queen's University, **Graham Leuschke** and **Claudia Miller**, Syracuse University, and **Michael Stillman**, Cornell University.

Difference Equations and Applications, **Michael Radin**, Rochester Institute of Technology.

Geometric Analysis and Flows, **William P. Minicozzi II**, Johns Hopkins University, **Xiaodong Cao**, Cornell University, and **Junfang Li**, University of Alabama at Birmingham.

Graphs Embedded in Surfaces, and Their Symmetries, **Jack E. Graver** and **Mark E. Watkins**, Syracuse University.

Harmonic Analysis, **Dmitriy Bilyk**, University of South Carolina, and **Svitlana Mayboroda**, Purdue University.

Lie Algebras and Representation Theory, **David Hemmer**, State University of New York at Buffalo, and **Emilie Wiesner**, Ithaca College.

Mathematical Image Processing, **Lixin Shen** and **Yuesheng Xu**, Syracuse University.

Nonlinear Analysis and Geometry, **Tadeusz Iwaniec**, **Leonid V. Kovalev**, and **Jani Onninen**, Syracuse University.

Quasiconformal Mappings, Riemann Surfaces, and Teichmüller Spaces (in honor of Clifford J. Earle), **Yunping Jiang**, Queens College and The Graduate Center, City University of New York, and **Sudeb Mitra**, Queens College, City University of New York.

Representations of Algebras, **Ed Green**, Virginia Polytechnic Institute, **Mark Kleiner** and **Dan Zacharia**, Syracuse University, and **Andrei Zelevinsky**, Northeastern University.

Several Complex Variables, **Dan F. Coman** and **Evgeny A. Poletsky**, Syracuse University.

Topology and Combinatorics, **Laura Anderson**, SUNY Binghamton, and **Patricia Hersh**, North Carolina State University.

Los Angeles, California

University of California Los Angeles

October 9–10, 2010

Saturday – Sunday

Meeting #1063

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2010
Program first available on AMS website: August 26, 2010
Program issue of electronic *Notices*: October 2010
Issue of *Abstracts*: Volume 31, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Cristopher Moore, University of New Mexico and the Santa Fe Institute, *Phase transitions in NP-complete problems: A challenge for probability, combinatorics, and computer science*.

Stanley Osher, University of California Los Angeles, *New algorithms in image science*.

Terence Tao, University of California Los Angeles, *The cosmic distance ladder* (Einstein Public Lecture in Mathematics).

Melanie Wood, Princeton University, *Moduli spaces for rings and ideals*.

Special Sessions

Algebraic Structures in Knot Theory, **Sam Nelson**, Claremont McKenna College, and **Carmen Caprau**, California State University Fresno.

Applications of Nonlinear PDE, **Susan J. Friedlander** and **Igor Kukavica**, University of Southern California.

Automorphic Forms and Number Theory, **William Duke**, University of California Los Angeles, **Ozlem Imamoglu**, ETH Zurich, and **Kimberly Hopkins**, University of California Los Angeles.

Combinatorics and Probability on Groups, **Jason Fulman** and **Robert Guralnick**, University of Southern California, and **Igor Pak**, University of California Los Angeles.

Continuous and Discrete Dynamical Systems, **Mario Martelli**, Claremont Graduate University, and **Robert Sacker**, University of Southern California.

Extremal and Probabilistic Combinatorics, **Benny Sudakov**, University of California Los Angeles, and **Jacques Verstraete**, University of California San Diego.

Free Probability and Subfactors, **Edward Effros** and **Dimitri Shlyakhtenko**, University of California Los Angeles, and **Dan-Virgil Voiculescu**, University of California Berkeley.

Global Geometric Analysis, **William Wylie**, University of Pennsylvania, **Joseph E. Borzellino**, California State University San Luis Obispo, and **Peter Petersen**, University of California Los Angeles.

Harmonic Analysis, **Christoph Thiele**, University of California Los Angeles, and **Ignacio Uriarte-Tuero** and **Alexander Volberg**, Michigan State University.

Homotopy Theory and K-theory, **Julie Bergner**, University of California Riverside, and **Christian Haesemeyer**, University of California Los Angeles.

Large Cardinals and the Continuum, **Matthew Foreman**, University of California Irvine, **Alekos Kechris**, California Institute of Technology, **Itay Neeman**, University of California Los Angeles, and **Martin Zeman**, University of California Irvine.

Mathematical Models of Random Phenomena, **Mark Burgin**, University of California Los Angeles, and **Alan C. Krinik**, California State Polytechnic University Pomona.

Mathematics of Criminality, **Andrea Bertozzi**, **Martin Short**, and **George Mohler**, University of California Los Angeles.

Metric and Riemannian Methods in Shape Analysis, **Andrea Bertozzi** and **Mario Micheli**, University of California Los Angeles.

Nonlinear Phenomena—Applications of PDEs to Fluid Flows, **Andrea Bertozzi**, **Nebojsa Murisic**, and **David Uminsky**, University of California Los Angeles.

Recent Trends in Probability and Related Fields, **Marek Biskup**, University of California Los Angeles, **Yuval Peres**, Microsoft Research, and **Sebastien Roch**, University of California Los Angeles.

Rigidity in von Neumann Algebras and Ergodic Theory, **Adrian Ioana**, University of California Los Angeles, **Narutaka Ozawa**, Tokyo University, and **Sorin Popa** and **Yehudah Shalom**, University of California Los Angeles.

Topology and Symplectic Geometry, **Robert Brown** and **Ciprian Manolescu**, University of California Los Angeles, and **Stefano Vidussi**, University of California Riverside.

Notre Dame, Indiana

Notre Dame University

November 5–7, 2010

Friday – Sunday

Meeting #1064

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: September 2010
Program first available on AMS website: September 23, 2010
Program issue of electronic *Notices*: November 2010
Issue of *Abstracts*: Volume 31, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Laura DeMarco, University of Illinois at Chicago, *Polynomial dynamics: Critical points and moduli*.

Jordan Ellenberg, University of Wisconsin, *Geometric analytic number theory*.

David Fisher, Indiana University, *Coarse geometry of solvable groups*.

Jared Wunsch, Northwestern University, *Geometry and analysis of diffracted waves*.

Special Sessions

Algebraic Group Actions on Affine Varieties, **Harm Derksen**, University of Michigan, and **Gene Freudenburg**, University of Western Michigan.

Algebraic and Topological Combinatorics, **John Shareshian**, Washington University, and **Bridget Tenner**, DePaul University.

Applications of Stochastic Processes in Cell Biology, **Peter Thomas**, Case Western University.

Arithmetic, Groups and Geometry, **Jordan Ellenberg**, University of Wisconsin, and **Michael Larsen**, Indiana University.

Commutative Algebra and Its Interactions with Algebraic Geometry, **Claudia Polini**, University of Notre Dame, **Alberto Corso**, University of Kentucky, and **Bernd Ulrich**, Purdue University.

Complex Analysis and Dynamical Systems, **Laura DeMarco**, University of Illinois at Chicago, and **Jeffrey Diller**, University of Notre Dame.

Computability and Its Applications, **Peter Cholak**, **Peter Gerdes**, and **Karen Lange**, University of Notre Dame.

Computation, Analysis, Modeling in PDE and their Applications, **Bei Hu** and **Yongtao Zhang**, University of Notre Dame.

Computational Electromagnetics and Acoustics, **David Peter Nicholls**, University of Illinois at Chicago.

Differential Geometry and its Applications, **Jianguo Cao** and **Brian Smyth**, University of Notre Dame.

Geometry and Lie Theory, **John Caine** and **Samuel Evens**, University of Notre Dame.

Graphs and Hypergraphs, **David Galvin**, University of Notre Dame, and **Hemanshu Kaul**, Illinois Institute of Technology.

Groups, Representations, and Characters, **James P. Cossey**, University of Akron, and **Mark Lewis**, Kent State University.

Hilbert Functions in Commutative Algebra and Algebraic Combinatorics, **Fabrizio Zanello**, Michigan Technological University, **Juan Migliore**, University of Notre Dame, and **Uwe Nagel**, University of Kentucky.

Interdisciplinary Session on Deterministic and Stochastic Partial Differential Equations, **Nathan Glatt-Holtz**, Indiana University, and **Vlad Vicol**, University of Southern California.

Mathematical Modeling and Computation with Applications in Biology, **Mark Alber** and **Zhiliang Xu**, University of Notre Dame.

Nonlinear Evolution Equations, **Alex Himonas** and **Gerard Misiolek**, University of Notre Dame.

Number Theory and Physics, **Adrian Clingher**, University of Missouri St. Louis, **Charles Doran**, University of Alberta, **Shabnam N. Kadir**, Wilhelm Leibniz Universitat, and **Rolf Schimmrigk**, Indiana University.

Numerical Algebraic Geometry, **Daniel J. Bates**, Colorado State University, **Jonathan D. Hauenstein**, Texas A&M University, **Andrew J. Sommese**, University of Notre Dame, and **Charles W. Wampler**, General Motors.

Quasigroups, Loops, and Nonassociative Division Algebras, **Clifton E. Ealy**, Western Michigan University, **Stephen Gagola**, University of Arizona, **Julia Knight**, University of Notre Dame, **J. D. Phillips**, Northern Michigan University, and **Petr Vojtechovsky**, University of Denver.

Rigidity, **David Fisher**, Indiana University, and **Ralf Spatzier**, University of Michigan.

Singularities in Algebraic Geometry, **Nero Budur**, University of Notre Dame, and **Lawrence Ein**, University of Illinois at Chicago.

The Geometry of Submanifolds, **Yun Myung Oh**, Andrews University, **Mihaela Vajiac**, Chapman University, and **Ivko Dimitric**, Pennsylvania State University.

Topology, Geometry and Physics, **Ralph Kaufmann**, Purdue University, and **Stephan Stolz**, University of Notre Dame.

Undergraduate Mathematics Education: A Vision for the 21st Century, **Steven Broad**, St. Mary's College, **Nahid Erfan** and **Alex Himonas**, University of Notre Dame, and **Morteza Shafii-Mousavi**, Indiana University South Bend.

Richmond, Virginia

University of Richmond

November 6–7, 2010

Saturday – Sunday

Meeting #1065

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: September 2010
Program first available on AMS website: September 23, 2010
Program issue of electronic *Notices*: November 2010
Issue of *Abstracts*: Volume 31, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Matthew H. Baker, Georgia Institute of Technology, *Preperiodic points and unlikely intersections*.

Michael J. Field, University of Houston, *Symmetry, structure, and stochastic fluctuations associated to some models of neural dynamics*.

Sharon R. Lubkin, North Carolina State University, *Model perspectives on self-organizing tissues*.

Stefan Richter, University of Tennessee, Knoxville, *Boundary behavior and invariant subspaces in spaces of analytic functions*.

Special Sessions

Applications of Non-Archimedean Geometry, **Matthew H. Baker**, Georgia Institute of Technology, and **Xinyi Yuan**, Harvard University.

Codes and Designs, **James A. Davis**, University of Richmond, and **Qing Xiang**, University of Delaware.

Computational and Applied Mathematics, **Ludwig Kohaupt**, Beuth University, and **Mohammad Siddique**, Fayetteville State University.

Convexity and Combinatorics, **Valeriu Soltan** and **James F. Lawrence**, George Mason University.

Differential Equations and Applications to Physics and Biology, **Junping Shi**, College of William and Mary, and **Zhifu Xie**, Virginia State University.

Geometry of Banach Spaces and Connections with Other Areas, **Frank Sanacory**, College at Old Westbury, and **Kevin Beanland**, Virginia Commonwealth University.

History of Mathematics: A Transnational Discourse, **Della Fenster**, University of Richmond, and **Frédéric Brechenmacher**, University of Lille-North of France-Université d'Artois.

Kac-Moody Algebras, Vertex (Operator) Algebras, and Applications, **William J. Cook**, Appalachian State University, and **Kailash C. Misra**, North Carolina State University.

Mathematical Models in Biology and Medicine, **Lester Caudill**, University of Richmond.

Mathematics and the Arts, **Michael J. Field**, University of Houston, **Gary R. Greenfield**, University of Richmond, and **Reza Sarhangi**, Towson University.

Minimum Rank Problems, **Lon H. Mitchell**, Virginia Commonwealth University, and **Sivaram K. Narayan**, Central Michigan University.

Numerical Methods for Solving Partial Differential Equations in Practice, **Kathryn Trapp**, University of Richmond, and **Katie Gurski**, Howard University.

Operator Theory, **Stefan Richter**, University of Tennessee, and **William T. Ross**, University of Richmond.

Statistical Properties of Dynamical Systems, **Michael J. Field** and **Matthew J. Nicol**, University of Houston.

Topics in Graph Theory, **Daniel W. Cranston**, Virginia Commonwealth University, and **Gexin Yu**, College of William & Mary.

Pucón, Chile

December 15–18, 2010

Wednesday – Saturday

Meeting #1066

First Joint International Meeting between the AMS and the Sociedad de Matematica de Chile.
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: August 2010
Program first available on AMS website: Not applicable
Program issue of electronic *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: To be announced

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/internmtgs.html.

AMS Invited Addresses

Ricardo Baeza, Universidad de Talca, Chile, *p-cohomological dimension of fields of characteristic p*.

Igor Dolgachev, University of Michigan, *Cremona groups and their subgroups*.

Andres Navas, Universidad de Santiago de Chile, *Probabilistic, dynamical and topological aspects of orderable groups*.

Rodolfo Rodriguez, Universidad de Concepcion, *Numerical solution of time-domain electromagnetic problems arising from some metallurgical processes*.

Gunther Uhlmann, University of Washington, *Inside-out: Inverse problems.*

S. R. Srinivasa Varadhan, New York University, *Large deviations.*

AMS Special Sessions

Algebra and Model Theory, **Thomas Scanlon**, University of California, Berkeley, **Xavier Vidaux**, Universidad de Concepcion, **Charles Steinhorn**, Vassar College, and **Alf Onshuus**, Universidad de los Andes, Columbia.

Algebraic Modeling of Knotted Objects, **Vaughan F. R. Jones**, University of California, Berkeley, **Jesús Juyumaya**, Universidad de Valparaìso, **Louis H. Kauffman**, University of Illinois at Chicago, and **Sofia Lambropoulou**, National Technical University of Athens.

Applications of Differential and Difference Equations in Biology and Ecology, **J. Robert Buchanan**, Millersville University, **Fernando Córdova**, Universidad Católica de Maule, and **Jorge Velasco Hernandez**, Institute Nacional de Petroleo.

Arithmetic of Quadratic Forms and Integral Lattices, **Maria Ines Icaza**, Universidad de Talca, Chile, **Wai Kiu Chan**, Wesleyan University, and **Ricardo Baeza**, Universidad de Talca, Chile.

Automorphic Forms and Dirichlet Series, **Yves Martin**, Universidad de Chile, Chile, and **Solomon Friedberg**, Boston College.

Complex Algebraic Geometry, **Giancarlo Urzua** and **Eduardo Cattani**, University of Massachusetts.

Foliations and Dynamics, **Andrés Navas**, Universidad de Santiago de Chile, and **Steve Hurder**, University of Illinois at Chicago.

Group Actions: Probability and Dynamics, **Andrés Navas**, Universidad de Santiago de Chile, and **Rostislav Grigorchuk**, University of Texas.

Inverse Problems and PDE Control, **Matias Courdurier**, Pontificia Universidad Católica de Chile, **Axel Osses**, Universidad de Chile, and **Gunther Uhlmann**, University of Washington.

Non-Associative Algebras, **Alicia Labra**, Universidad de Chile, and **Kevin McCrimmon**, University of Virginia.

Probability and Mathematical Physics, **Hui-Hsiung Kuo**, Louisiana State University, and **Rolando Rebolledo**, Pontificia Universidad Católica de Chile.

Representation Theory, **Jorge Soto Andrade**, Universidad de Chile, and **Philip Kutzko**, University of Iowa.

Spectral Theory and Mathematical Physics, **Bruno Nachtergaele**, University of California, Davis, and **Rafael Tiedra**, Pontificia Universidad Católica de Chile.

New Orleans, Louisiana

New Orleans Marriott and Sheraton New Orleans Hotel

January 6–9, 2011

Thursday – Sunday

Meeting #1067

Joint Mathematics Meetings, including the 117th Annual Meeting of the AMS, 94th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Steven H. Weintraub

Announcement issue of *Notices*: October 2010

Program first available on AMS website: November 1, 2010

Program issue of electronic *Notices*: January 2011

Issue of *Abstracts*: Volume 32, Issue 1

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: September 22, 2010

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/national.html.

Joint Invited Addresses

Robert J. Lang, Robert J. Lang Origami, *From flapping birds to space telescopes: The mathematics of origami* (AMS-MAA-SIAM Gerald and Judith Porter Public Lecture).

Kannan Soundararajan, Stanford University, *To be announced* (AMS-MAA Invited Address).

Chuu-Lian Terng, University of California Irvine, *Title to be announced* (AMS-MAA Invited Address).

Joint Prize Session

Prize Session and Reception: In order to showcase the achievements of the recipients of various prizes, the AMS and MAA are cosponsoring this event at 4:25 p.m. on Friday. A cash bar reception will immediately follow. All participants are invited to attend. The AMS, MAA, and SIAM will award the Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student. The AMS will announce the winners of the Bôcher Memorial Prize, Frank Nelson Cole Prize in Number Theory, Levi L. Conant Prize, Joseph L. Doob Prize, Leonard Eisenbud Prize for Mathematics and Physics, Ruth Lyttle Satter Prize in Mathematics, and Leroy P. Steele Prizes. The MAA will award the Beckenbach Book Prize, Chauvenet

Prize, Euler Book Prize, Yueh-Gin Gung and Dr. Charles Y. Hu Award for Distinguished Service to Mathematics, Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching of Mathematics, David P. Robbins Prize, and Certificates of Meritorious Service. The AWM will present the Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman and the Louise Hay Award for Contributions to Mathematics Education.

This session will also be the venue for the announcement of the Joint Policy Board for Mathematics Communication Award.

117th Meeting of the AMS

AMS Invited Addresses

Denis Auroux, University of California Berkeley, *Title to be announced*.

Andrea L. Bertozzi, University of California Los Angeles, *Title to be announced*.

Alexander Lubotzky, The Hebrew University of Jerusalem, *Expander graphs in pure and applied mathematics* (AMS Colloquium Lectures).

George Papanicolaou, Stanford University, *Title to be announced* (AMS Josiah Willard Gibbs Lecture).

Scott Sheffield, Massachusetts Institute of Technology, *Title to be announced*.

Tatiana Toro, University of Washington, *Title to be announced*.

Akshay Venkatesh, Stanford University, *Title to be announced*.

AMS Special Sessions

Some sessions are cosponsored with other organizations. These are noted within the parenthesis at the end of each listing, where applicable.

Analysis of Reaction-Diffusion Models (Code: SS 31A), **Junping Shi**, College of William and Mary, and **Xuefeng Wang**, Tulane University.

Analytic and Geometric Methods in Representation Theory (Code: SS 38A), **Leticia Barchini**, Oklahoma State University, and **Hongyu He**, Louisiana State University.

Applications of Stochastic Processes in Neuroscience (Code: SS 21A), **Peter Thomas**, Case Western Reserve University, **Kreso Josic**, University of Houston, and **Carson C. Chow**, Institutes of Health (AMS-SIAM).

Applied Optimization and Douglas-Rachford Splitting Methods for Convex Programming (Code: SS 15A), **Ram U. Verma**, Seminole State College of Florida.

Asymptotic Methods in Analysis with Applications (Code: SS 10A), **Diego Dominici**, State University of New York at New Paltz, and **Peter A. McCoy**, U.S. Naval Academy.

Birational Geometry and Moduli Spaces (Mathematics Research Communities session) (Code: SS 1A), **Kevin Tucker**, University of Utah, **Dawei Chen**, University of Illinois at Chicago, **Amanda Knecht**, University of Michigan, and **David Swinarski**, University of Georgia.

Boundary Control and Moving Interface in Coupled Systems of Partial Differential Equations (Code: SS 53A), **Lorena Bociu**, University of Nebraska-Lincoln, and **Jean-Paul Zolesio**, CNRS-INLN and INRIA, Sophia Antipolis, France.

Centers for Teaching/Education/Outreach in Departments of Mathematics (Code: SS 14A), **Michael E. Mays**, West Virginia University (AMS-MAA).

Combinatorial Algebraic Geometry (Code: SS 42A), **Frank Sottile**, Texas A&M University, and **Alexander T. Yong**, University of Illinois, Urbana-Champaign.

Commutative Algebra (Mathematics Research Communities session) (Code: SS 3A), **Christine Berkesch**, Stockholm University, **Bhargav Bhatt**, University of Michigan, Ann Arbor, **Jason McCullough**, University of California, Riverside, and **Javid Validashti**, University of Kansas.

Completely Integrable Systems, Random Matrices, and the Bispectral Problem (Code: SS 28A), **Bojko Bakalov**, North Carolina State University, **Michael Gekhtman**, University of Notre Dame, **Plamen Iliev**, Georgia Institute of Technology, and **Milen T. Yakimov**, Louisiana State University.

Computational Algebraic and Analytic Geometry for Low-Dimensional Varieties (Code: SS 47A), **Mika K. Seppala**, Florida State University, **Tanush Shaskas**, Oakland University, and **Emil Volcheck**, National Security Agency.

Continued Fractions (Code: SS 40A), **James G. McLaughlin**, West Chester University, and **Nancy J. Wyshinski**, Trinity College.

Control and Inverse Problems for Partial Differential Equations (Code: SS 33A), **Ana-Maria Croicu** and **Michele L. Joyner**, Kennesaw State University (AMS-SIAM).

Difference Equations and Applications (Code: SS 6A), **Michael A. Radin**, Rochester Institute of Technology.

Dirac Operators (Code: SS 61A), **Craig A. Nolder**, Florida State University, and **John Ryan**, University of Arkansas.

Expander Graphs in Pure and Applied Mathematics (Code: SS 66A), **Alireza Salehi Golsefidy**, Princeton University, and **Alexander Lubotzky**, Hebrew University of Jerusalem.

Formal Mathematics for Mathematicians: Developing Large Repositories of Advanced Mathematics (Code: SS 12A), **Krystyna M. Kuperberg**, Auburn University, and **Andrzej Trybulec**, **Artur Kornilowicz**, and **Adam Naumowicz**, University of Bialystok.

Geometric Group Theory (Code: SS 46A), **Joshua B. Barnard**, University of South Alabama, and **Pallavi Dani**, Louisiana State University.

Global Dynamics of Discrete Dynamical Systems in the Plane with Applications (Code: SS 56A), **M. R. S. Kulenovic** and **Orlando Merino**, University of Rhode Island.

Groups, Geometry, and Applications (Code: SS 7A), **Delaram Kahrobaei**, City University of New York.

Harmonic Analysis and Partial Differential Equations (Code: SS 65A), **Svitlana Mayboroda**, Purdue University, and **Tatiana Toro**, University of Washington.

History of Mathematics (Code: SS 37A), **Sloan E. Despeaux**, Western Carolina University, **Craig G. Fraser**, University of Toronto, and **Deborah Kent**, Hillsdale College (AMS-MAA).

Hopf Algebras and Their Representations (Code: SS 4A), **M. Susan Montgomery**, University of Southern California, **Siu-Hung Ng**, Iowa State University, and **Sarah J. Witherspoon**, Texas A&M University (AMS-AWM).

Integral Geometry: Analysis and Applications (Code: SS 20A), **Gaik Ambartsoumian**, University of Texas, Arlington, **Gestur Olafsson**, Louisiana State University, **Eric Todd Quinto**, Tufts University, and **Boris S. Rubin**, Louisiana State University.

Interactions of Inverse Problems, Signal Processing, and Imaging (Code: SS 54A), **Zuhair Nashed**, University of Central Florida.

Knot Theory (Code: SS 63A), **Tim D. Cochran** and **Shelley Harvey**, Rice University.

Knots, Links, 3-Manifolds, and Physics (Code: SS 44A), **Robert Kusner**, University of Massachusetts, Amherst, and **Rafal Komendarczyk**, Tulane University.

Lie Algebras, Algebraic Groups, and Related Topics (Code: SS 23A), **Audrey L. Malagon** and **Julie C. Beier**, Mercer University, and **Daniel K. Nakano**, University of Georgia.

Local Commutative Algebra (Code: SS 5A), **Paul C. Roberts** and **Anurag K. Singh**, University of Utah, and **Sandra M. Spiroff**, University of Mississippi.

Logic and Analysis (Code: SS 36A), **Jeremy Avigad**, Carnegie Mellon University, **Ulrich W. Kohlenbach**, Technische Universität Darmstadt, and **Henry Towsner**, University of California Los Angeles (AMS-ASL).

Mathematical Modeling in Environmental Economics (Code: SS 49A), **Natali Hritonenko**, Prairie View A&M University, and **Yuri Yatsenko**, Houston Baptist University.

Mathematical Techniques in Musical Analysis (Code: SS 19A), **Robert W. Peck**, Louisiana State University, and **Thomas M. Fiore**, University of Michigan at Dearborn.

Mathematics Related to Feynman Diagrams (Code: SS 25A), **Victor H. Moll**, Tulane University, and **Olivier Espinosa**, Universidad Santa Maria, Valparaiso.

Mathematics and Education Reform (Code: SS 39A), **William H. Barker**, Bowdoin College, **William G. McCallum**, University of Arizona, and **Bonnie S. Saunders**, University of Illinois at Chicago (AMS-MAA-MER).

Mathematics of Computation: Algebra and Number Theory (Code: SS 11A), **Gregor Kemper**, Technische Universität München, **Michael J. Mossinghoff**, Davidson College, and **Igor E. Shparlinski**, Macquarie University (AMS-SIAM).

Mathematics of Computation: Differential Equations, Linear Algebra, and Applications (Code: SS 52A), **Susanne C. Brenner**, Louisiana State University, and **Chi-Wang Shu**, Brown University (AMS-SIAM).

(The) Mathematics of Modeling Multiscale Heterogeneous Media (Code: SS 51A), **Robert P. Lipton** and **Tadele A. Mengesha**, Louisiana State University.

Measures of Entanglement of Macromolecules and Their Applications (Code: SS 57A), **Isabel K. Darcy**, University of Iowa, **Kenneth C. Millett**, University of California, Santa Barbara, **Eric J. Rawdon**, University of St. Thomas, and **Mariel Vazquez**, San Francisco State University.

Model Theory of Fields and Applications (Mathematics Research Communities session) (Code: SS 2A), **Benjamin A. Hutz**, CUNY Graduate Center, **Jana Marikova**, Western Illinois University, **Jerome Poineau**, University of Strasbourg, and **Yimu Yin**, University of Pittsburgh.

Multivariable Operator Theory (Code: SS 13A), **Ronald G. Douglas**, Texas A&M University, and **Gelu F. Popescu**, University of Texas at San Antonio.

New Topics in Graph Theory (Code: SS 9A), **Ralucca Gera**, Naval Postgraduate School, and **Eunjeong Yi**, Texas A&M University at Galveston.

New Trends in Theory and Applications of Evolution Equations (Code: SS 34A), **Guoping Zhang** and **Gaston N'Guerekata**, Morgan State University, **Wen-Xie Ma**, University of South Florida, and **Yi Li**, University of Iowa.

Noncommutative Harmonic Analysis and Dynamic Systems (Code: SS 41A), **Tao Mei**, University of Illinois, Urbana-Champaign, and **Alan D. Wiggins**, University of Michigan at Dearborn.

Nonlinear Evolution Equations, Analysis, and Geometry (Code: SS 43A), **Ralph Saxton**, University of New Orleans, and **Feride Tiglay**, Ecole Polytechnique Federale de Lausanne.

Nonlinear Waves and Integrable Systems (Code: SS 55A), **Gino Biondini**, State University of New York at Buffalo, and **Barbara Prinari**, University of Colorado at Colorado Springs (AMS-SIAM).

Quadratic Forms in Algebra and Geometry (Code: SS 16A), **Jorge F. Morales**, Louisiana State University, and **Anne Queguiner-Mathieu**, Université de Paris 13.

Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs (Code: SS 22A), **Darren A. Narayan**, **Bernard Brooks**, and **Jobby Jacob**, Rochester Institute of Technology; and **Jacqueline A. Jensen**, Sam Houston State University (AMS-MAA-SIAM).

Self-Organization in Human, Biological, and Artificial Systems (Code: SS 64A), **Andrea L. Bertozzi**, University of California Los Angeles.

Set-Valued Optimization and Variational Problems (Code: SS 62A), **Akhtar A. Khan**, Rochester Institute of Technology, and **Miguel Sama**, Universidad Nacional de Educacion a Distancia, Madrid.

Stochastic Analysis and Mathematical Physics: A Session in Honor of the 80th Birthday of Len Gross (Code: SS 18A), **Bruce K. Driver**, University of California at San Diego, **Maria Gordina**, University of Connecticut, and **Todd Kemp**, Massachusetts Institute of Technology and University of California at San Diego.

Stochastic Analysis and Random Phenomena (Code: SS 29A), **Ambar N. Sengupta** and **P. Sundar**, Louisiana State University.

Stochastic, Fractional, and Hybrid Dynamic Systems with Applications (Code: SS 17A), **A. S. Vatsala**, University of Louisiana at Lafayette, and **G. S. Ladde**, University of South Florida.

Structure Theory for Matroids and Graphs (Code: SS 45A), **Bogdan Oporowski** and **James G. Oxley**, Louisiana State University.

Structured Models in Ecology, Evolution, and Epidemiology: Periodicity, Extinction, and Chaos (Code: SS 50A), **Sophia R.-J. Jang**, **Linda J. S. Allen**, and **Lih-Ing W. Roeger**, Texas Tech University.

Theory and Application of Stochastic Differential Equations and Stochastic Partial Differential Equations (Code: SS 27A), **Armando Arciniega**, University of Texas at San Antonio, **Edward J. Allen**, Texas Tech University, **Sivapragasam Sathananthan**, Tennessee State University, and **Mahmoud Anabtawi**, American University of Sharjah.

Time Scales: Theory and Applications (Code: SS 8A), **Billy Jackson**, University of Northern Colorado, and **Joan Hoffacker**, Clemson University.

Transseries and Ordered Exponential Fields (Code: SS 32A), **Gerald A. Edgar** and **Ovidiu Costin**, The Ohio State University, and **Lou P. van den Dries**, University of Illinois, Urbana-Champaign.

Wavelets, Tilings, and Iterated Function Systems (Code: SS 26A), **Palle E. Jorgensen**, University of Iowa, **David R. Larson**, Texas A&M University, and **Gestur Olafsson**, Louisiana State University.

von Neumann Algebras (Code: SS 48A), **Richard D. Burstein**, Vanderbilt University, and **Remus Nicoara**, University of Tennessee, Knoxville.

Other AMS Sessions

What I Wish I Had Known before Applying for a Job, Thursday, 4:30 p.m.–6:00 p.m. Sponsored by the Committee on the Profession Panel Discussion.

Who Wants to Be a Mathematician—National Contest, organized by **Michael A. Breen**, AMS, and **William T. Butterworth**, DePaul University; Friday, 9:30 a.m.–11:00 a.m. See ten of the nation's best high school students compete for a US$5,000 first prize for themselves and US$5,000 for their school's math department. Semifinals are at 9:30 a.m. and finals at 10:30 a.m. You are invited to come and take part in this educational and fun presentation.

Current Events Bulletin, Friday, 1:00 p.m.–5:00 p.m., organized by **David Eisenbud**, University of California Berkeley. Speakers in this session follow the model of the Bourbaki Seminars in that mathematicians with strong expository skills speak on work not their own. Written versions of the talks will be distributed at the meeting and also be available on line at www.ams.org/ams/current-events-bulletin.html after the conclusion of the meeting.

Proving Hardy Wrong: Math Research with Social Justice Applications, organized by **Eva Curry**, Acadia University; Friday, 1:00 p.m.–2:15 p.m.

Grad School Fair, Saturday, 8:30 a.m.–10:30 a.m. Here is the opportunity for undergrads to meet representatives from mathematical sciences graduate programs from universities all over the country. January is a great time for juniors to learn more, and college seniors may still be able to refine their search. This is your chance for one-stop shopping in the graduate school market. At last year's meeting about 300 students met with representatives from 45 graduate programs. If your school has a graduate program and you are interested in participating, a table will be provided for your posters and printed materials for US$60 (registration for this event must be made by a person already registered for the JMM), and you are welcome to personally speak to interested students. Complimentary coffee will be served. Cosponsored by the AMS and MAA.

Committee on Science Policy Panel Discussion, Saturday, 2:30 p.m.–4:00 p.m.

Congressional Fellowship Session, Saturday, 4:30 p.m.–6:30 p.m.

Committee on Education Panel Discussion, Sunday, 8:30 a.m.–10:00 a.m.

Other AMS Events

Council: Wednesday, 1:30 p.m.

Business Meeting: Sunday, 11:45 a.m. The secretary notes the following resolution of the Council: Each person who attends a business meeting of the Society shall be willing and able to identify himself as a member of the Society. In further explanation, it is noted that each person who is to vote at a meeting is thereby identifying himself as and claiming to be a member of the American Mathematical Society. The Society has a Committee on the Agenda for Business Meetings. The purpose is to make business meetings orderly and effective. The committee does not have legal or administrative power. It is intended that the committee consider what may be called "quasipolitical" motions. The committee has several possible courses of action on a proposed motion, including but not restricted to:

(a) doing nothing,

(b) conferring with supporters and opponents to arrive at a mutually accepted amended version to be circulated in advance of the meeting,

(c) recommending and planning a format for debate to suggest to a business meeting,

(d) recommending referral to a committee, and

(e) recommending debate followed by referral to a committee.

There is no mechanism that requires automatic submission of a motion to the committee. However, if a motion has not been submitted through the committee, it may be thought reasonable by a business meeting to refer it rather than to act on it without benefit of the advice of the committee.

In order that a motion for this business meeting receive the service offered by the committee in the most effective manner, it should be in the hands of the AMS Secretary by December 9, 2010.

AMS Short Courses

There will be two, two-day Short Courses which will take place on Tuesday and Wednesday, January 4 and 5, before the meeting actually begins. Titles and organizers are *Computational Topology*, organized by **Afra Zomorodian**, Dartmouth University, and *Evolutionary Game Dynamics*, organized by **Karl Sigmund**, University of Vienna. There are separate registration fees to participate in these courses. See the complete article beginning on page 1185 of this issue or at www.ams.org/meetings/national/jmm/2125_amssc.html.

Department Chairs Workshop

This annual one-day workshop for chairs and leaders of departments of mathematical sciences will be held a day before the start of the Joint Meetings on Wednesday, January 5, 8:00 a.m.–6:30 p.m. The workshop format is intended to stimulate discussion among attending chairs and workshop leaders. Sharing ideas and experiences with peers provides a form of department chair therapy, creating an environment that enables attending chairs to address departmental matters from new perspectives.

Past workshop sessions have focused on a range of issues facing departments today, including personnel issues (staff and faculty), long-range planning, hiring, promotion and tenure, budget management, assessments, outreach, stewardship, junior faculty development, communication, and departmental leadership.

There is a separate registration fee of US$100 to participate. To register, visit `http://www.ams.org/profession/leaders/ChairsWorkshop2011.RSVPForm.pdf`. For further information please contact the AMS Washington Office at 202-588-1100 or `amsdc@ams.org`.

94th Meeting of the MAA

MAA Invited Addresses

Robert M. Bell, AT&T, *Lessons from the Netflix Prize*, 10:00 a.m. on Sunday.

David M. Bressoud, Macalester College, *Issues of the transition to college mathematics* (MAA Retiring Presidential Address), 9:00 a.m. on Saturday.

Yuval Peres, Microsoft Research, *Laplacian growth and the mystery of the abelian sandpile: A visual tour*, 2:15 p.m. on Thursday.

Edward R. Scheinerman, Johns Hopkins University, *On the intersection of graphs and geometry*, 3:20 p.m. on Thursday.

Katherine Socha, Saint Mary's College of Maryland, *Sea battles, Benjamin Franklin's oil lamp, and jellybellies*, 9:00 a.m. on Friday.

Melanie Matchett Wood, Stanford University, *Binary quadratic forms: From Gauss to algebraic geometry*, 2:15 p.m. on Saturday.

Presentations by Teaching Award Recipients

Saturday, 3:30 p.m.–5:00 p.m., organized by MAA Secretary **Barbara J. Faires**, Westminster College, and moderated by MAA President, **David M. Bressoud**, Macalester College. Winners of the Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching will give presentations on the secrets of their success.

MAA Invited Paper Sessions

The Beauty and Power of Number Theory, organized by **Thomas Koshy**, Framingham State College, and **Shannon Lockard**, Bridgewater State College, Friday, 9:00 a.m.–11:55 a.m. This session focuses on delightful results from number theory (and combinatorics), which exude the beauty and power of number theory.

Fish Tales: Stories from Mathematical Fluid Dynamics, organized by **Katherine Socha**, St. Mary's College of Maryland, Saturday, 9:00 a.m.–11:00 a.m. Speakers will present a range of examples from fluid mechanics, all motivated by real fluid motion or phenomena.

On the Intersection of Graphs and Geometry, organized by **Edward Scheinerman**, Johns Hopkins University, Sunday, 9:00 a.m.–10:50 a.m. and 1:00 p.m.–3:20 p.m.

Laplacian Growth: Visual Mathematics, organized by **Yuval Peres**, Microsoft Research; **Lionel Levine**, Massachusetts Institute of Technology; and **Alexander Holroyd**, Microsoft Research, Thursday, 3:30 p.m.–6:20 p.m.

The Rebirth of Special Functions, organized by **Tewodros Amdeberhan** and **Victor Moll**, Tulane University, Thursday, 9:00 a.m.–11:50 a.m. The topic of special functions was at the center of mathematics in the 19th century. The session will introduce the audience to six different areas in which this topic is making a comeback in the 21st century.

Topics in Hopf Algebras, organized by **Serban Raianu**, California State University, Dominguez Hills, and **Davida Fischman**, California State University, San Bernardino, Friday, 1:00 p.m–4:15 p.m. Hopf algebras were discovered in the early 1940s, were established as a separate field in the late 1960s, and drew a lot of interest in the early 1990's, when quantum groups (which are examples of noncommutative and noncommutative Hopf algebras) began playing a central role in mathematics and physics. One of the most striking aspects of Hopf algebras is their ubiquity. They appear in virtually all branches of mathematics: topology, algebraic geometry, operator theory, probability theory, number theory, representation theory, Lie theory, and combinatorics, to list just a few. With so many fine locations, there is little wonder that Hopf algebras continue to be a very active field, regardless of the fluctuations in the mathematical real estate market during the past seventy years.

MAA Minicourses

Minicourses are open only to persons who register for the Joint Meetings and pay the Joint Meetings registration fee in addition to the appropriate minicourse fee. The MAA reserves the right to cancel any minicourse that is undersubscribed. Participants in minicourses #12 and #13 are required to bring their own laptop computer equipped with appropriate software. Instructions on how to download any data files needed for those courses will be provided by the organizers. All minicourses will be held in the Ile de France rooms of the JW Marriott New Orleans Hotel. The enrollment in each minicourse is limited to 50; the cost of a minicourse is US$75.

Minicourse #1: *Special relativity through a linear algebraic lens*, organized by **John de Pillis**, University of California Riverside. Part 1: Friday, 1:00 p.m.–3:00 p.m.; Part 2: Sunday, 1:00 p.m.–3:00 p.m. Do all moving clocks run slow? Does a moving ruler actually shrink in the direction of motion? Anyone familiar with the basics of matrix theory has all the tools necessary to explore the ideas underlying the mysteries and paradoxes of special relativity. As an example consider how we pass from "reality" to a mathematical model. We see a real observer on a train platform at point x and time t. This defines the mathematical ordered pair (x, t) which, it turns out, is invested with a full vector space structure. This is our link between observed reality and the mathematical model. In this minicourse we will investigate how this mathematical structure along with the standard tools of matrix theory resolve several well-known paradoxes of special relativity.

Minicourse #2: *Getting mathematics majors to think outside the book: Course activities that promote exploration, discovery, conjecture, and proof*, organized by **Suzanne Dorée**, Augsburg College; **Jill Dietz**, St. Olaf College; and **Brian Hopkins**, St. Peter's College. Part 1: Thursday, 2:15 p.m.–4:15 p.m.; Part 2: Saturday, 2:15 p.m.–4:15 p.m. Mathematics majors should explore, make and test conjectures, and prove mathematics of their own creation. Discovery-based activities designed to develop these skills can enliven any mathematics course, deepen student understanding, and help students make the sometimes difficult transition from book-based learners to independent investigators, especially in undergraduate research projects. In this minicourse we will work on sample activities from the undergraduate curriculum including discrete mathematics and other courses, discuss attributes of successful activities in any course, present curricular models incrementally building these skills throughout the major, and help participants plan how to incorporate these ideas in their own courses and program.

Minicourse #3: *Geometry and algebra in mathematical music theory*, organized by **Thomas M. Fiore**, University of Michigan-Dearborn; **Dmitri Tymoczko**, Department of Music, Princeton University; and **Robert Peck**, School of Music, Louisiana State University. Part 1: Friday, 8:00 a.m.–10:00 a.m. Part 2: Sunday, 9:00 a.m.–11:00 a.m. Mathematical music theory is a treasure trove of ideas and examples, especially for instructors looking to enhance their abstract algebra and topology courses. We will present two current areas, transformational theory and musical orbifolds, and provide mathematicians with musical examples that can be easily incorporated into math courses. We will discuss the structure of the neo-Riemannian group, how it transforms chords, its geometric depictions, and recent results on commuting groups. We will also describe how orbifolds provide a natural mathematical framework for modeling a range of musical problems. In these spaces points represent individual musical objects, such as chords, while line segments represent transitions between objects—called "voice leadings" by music theorists. Main topics are the construction and interpretation of relevant geometries, along with their analytical and theoretical applications. Successful REU projects will also be discussed briefly.

Minicourse #4: *Getting students involved in undergraduate research*, organized by **Aparna Higgins**, University of Dayton, and **Joseph Gallian**, University of Minnesota-Duluth. Part 1: Thursday, 9:00 a.m.–11:00 a.m.; Part 2: Saturday, 9:00 a.m.–11:00 a.m. This course will cover many aspects of facilitating research by undergraduates, such as getting students involved in research, finding appropriate problems, deciding how much help to provide, and presenting and publishing the results. Similarities and differences between research conducted during summer programs and research that can be conducted during the academic year will be discussed. Although the examples used will be primarily in the area of discrete mathematics, the strategies discussed can be applied to any area of mathematics.

Minicourse #5: *A Game Theory path to quantitative literacy*, organized by **David Housman**, Goshen College, and **Richard Gillman**, Valparaiso University. Part 1. Friday, 10:30 a.m.–12:30 p.m.; Part 2: Sunday, 1:00 p.m.–3:00 p.m. Game Theory, defined in the broadest sense, can be used to model many real-world scenarios of decision-making in situations involving conflict and cooperation. Further, mastering the basic concepts and tools of Game Theory require only an understanding of basic algebra, probability, and formal reasoning. These two features of Game Theory make it an ideal path to developing habits of quantitative literacy among our students. This audience-participation minicourse develops some of the material used by the presenters in their general education courses on Game Theory and encourages participants to develop their own, similar, courses.

Minicourse #6: *Green linear optimization*, organized by **Glenn Hurlbert**, Arizona State University. Part 1: Friday, 9:00 a.m.–11:00 a.m.; Part 2: Sunday, 9:00 a.m.–11:00 a.m. No, not environmental, just inexperienced. How does it work? What is it good for? What are its big theorems? Can I teach it? Turns out, most experts place the Simplex algorithm among the top ten algorithms of the 20th century, due to its nearly unrivalled impact on the last 50 years of business, engineering, economics, and mathematics. While it is regularly taught to undergraduates in those other disciplines, it is a mystery why it is virtually missing from mathematics departments. Needing little more than the first few weeks of linear algebra, students can experience connections with geometry, probability, combinatorics, algorithms, computing, game theory, economics, graph theory, and modeling. Whether you'd like to offer a course in your department, make connections with your own research, or just satisfy your curiosity, come see what all the fuss is about. This will be a very hands-on experience, with games, puzzles, and experiments motivating main results and techniques. A laptop is not necessary, but if you want to bring yours, you can download WebSim from my homepage to use (`http://mingus.la.asu.edu~hurlbert/`), and even run Maple if you like.

Minicourse #7: *The mathematics of Islam and its use in the teaching of mathematics*, organized by **Victor J. Katz**, University of the District of Columbia. Part 1: Thursday, 9:00 a.m.–11:00 a.m.; Part 2: Saturday, 9:00 a.m.–11:00 a.m. In the current world situation, it is critical that American students be exposed to some of the culture of Islam. Thus, this minicourse introduces college teachers to the mathematics of Islam and develops some ideas on using Islamic mathematical ideas in the teaching of mathematics. The course will consider mathematical ideas taken from arithmetic, algebra, geometry, and trigonometry. Participants will read from some of the original sources and discuss the ideas and their implications. In particular, we will consider how some of the examples of Islamic mathematics can be used in modern courses in high school and college.

Minicourse #8: *The ubiquitous Catalan numbers and their applications*, organized by **Thomas Koshy**, Framingham State College. Part 1: Thursday, 9:00 a.m.–11:00 a.m.; Part 2: Saturday, 9:00 a.m.–11:00 a.m. Catalan numbers are both fascinating and ubiquitous. They pop up in quite unexpected places, such as triangulations of convex polygons, correctly parenthesized algebraic expressions, rooted trees, binary trees, full binary trees, trivalent binary trees, latticewalking, Bertrand's ballot problem, abstract algebra, linear algebra, chess, and the World Series, to name a few. Beginning with a brief history of Catalan numbers, this minicourse presents numerous examples from different areas. We will develop a number of combinatorial formulas for computing them, investigate their parity and their primality-link to Mersenne numbers, and present the various ways they can be extracted from Pascal's triangle and several Pascal-like triangles. We will investigate both Lobb's generalization of Catalan's Parenthesization Problem and tribinomial coefficients, and show how Catalan numbers can be extracted from tribinomial coefficients.

Minicourse #9: *Learning discrete mathematics via historical projects*, organized by **Jerry Lodder**, **Guram Bezhanishvili**, and **David Pengelley**, New Mexico State University; and **Janet Barnett**, Colorado State University, Pueblo. Part 1: Thursday, 2:15 p.m.–4:15 p.m.; Part 2: Saturday, 2:15 p.m.–4:15 p.m. This minicourse is aimed at introducing curricular modules in discrete mathematics, combinatorics, logic, abstract algebra, and computer science based entirely on primary historical source material, developed by an interdisciplinary team of mathematics and computer science faculty at New Mexico State University and Colorado State University at Pueblo. In the first session we plan to discuss the pedagogy behind our approach, give a brief outline of the projects we have developed, and provide snapshots and initial hands-on participant work with four chosen projects. In the second session we will discuss the four projects in detail, including group discussions and more hands-on activity. The projects we have developed so far as well as our philosophy in teaching with historical sources can be found on our homepage: `http://www.cs.nmsu.edu/historical-projects/`

Minicourse #10: *Teaching introductory statistics*, organized by **Michael Posner**, Villanova University, and **Carolyn Cuff**, Westminster College. Part 1: Friday, 1:00 p.m.–3:00 p.m.; Part 2: Sunday, 3:30 p.m.–5:30 p.m. This minicourse, intended for instructors new to teaching statistics, exposes participants to the big ideas of statistics and the ASA-endorsed Guidelines for Assessment and Instruction in Statistics Education report. It considers ways to engage students in statistical literacy and thinking, and contrast conceptual and procedural understanding in the first statistics course. Participants will engage in many of the classic activities that all statistics instructors should know. Internet sources of real data, activities, and best practices articles will be examined. Participants will find out how they can continue to answer the three questions by becoming involved in statistics education related conferences, newsletters, and groups.

Minicourse #11: *Using video case studies in teaching a proof-based gateway course to the mathematics major*, organized by **James Sandefur**, Georgetown University; **Connie Campbell**, Millsaps College; and **Kay Somers**, Moravian College. Part 1: Thursday, 2:15 p.m.–4:15 p.m.; Part 2: Saturday, 2:15 p.m.–4:15 p.m. Many colleges and universities have a gateway course to help mathematics students make the transition to more theoretical courses, with a goal of helping students learn how to understand and construct proofs. The organizers have been videotaping students writing proofs for problems used in gateway courses, and have been using these videos to expand their understanding of students' difficulties and to learn what support helps the students. They have also been using these videos to help students learn to reflect on their own approaches to writing proofs. In this minicourse we will view some of these videos and discuss strategies implied by them, as well as help faculty learn how they might use these videos in their own transition course.

Minicourse #12: *Concepts, data and models: College algebra for the real world*, organized by **Sheldon P. Gordon**, Farmingdale State College, and **Florence S. Gordon**, New York Institute of Technology. Part 1: Friday, 9:00 a.m.–11:00 a.m.; Part 2: Sunday, 9:00 a.m.–11:00 a.m. Almost all students taking college algebra do so to fulfill requirements for other disciplines. The current mathematical needs of our partner disciplines, especially for lab science and data-dependent social science courses are very different from courses that prepare students for calculus. Students need a focus on conceptual understanding, data and statistical analysis, and realistic problem-solving via mathematical modeling to prepare for the mathematical applications they will encounter in those courses. Families of functions and data are the two primary motivating themes around which this approach is centered. A significant amount of statistical reasoning and methods is integrated in natural ways as applications of college algebra topics. All participants are expected to bring a laptop computer to the minicourse.

Minicourse #13: *Creating demonstrations and guided explorations for multivariable calculus using* CalcPlot3D, organized by **Paul Seeburger**, Monroe Community College. Part 1: Friday, 1:00 p.m.–3:00 p.m.; Part 2: Sunday, 1:00 p.m.–3:00 p.m. It is often difficult for students to develop an accurate and intuitive understanding of the geometric relationships of calculus from static diagrams alone. This course explores a collection of freely available Java applets designed to help students make these connections. Our primary focus will be visualizing multivariable calculus using *CalcPlot3D*, a versatile new applet developed by the presenter through NSF-DUE-0736968. Participants will also learn how to customize this applet to create demonstrations and guided exploration activities for student use. Images created in this applet can be pasted into participants' documents. See `http://web.monroecc.edu/calcNSF/`. Some basic HTML experience is helpful. All participants are expected to bring a laptop computer to the minicourse.

MAA Contributed Papers

The MAA Committee on Contributed Paper Sessions solicits contributed papers pertinent to the sessions listed below. Contributed Paper Session organizers generally limit presentations to fifteen minutes. Each session room is equipped with a computer projector, an overhead projector, and a screen. Please note that the dates and times scheduled for these sessions remain tentative. Full descriptions of these sessions may be found at `www.maa.org/meetings/jmm.html or see` the June/July issue of the *Notices*, p. 804.

Alternative Approaches to Traditional Introductory Statistics Courses, **Brian Gill**, Seattle Pacific University; **Nancy Boynton**, SUNY Fredonia; and **Michael Posner**, Villanova University; Sunday afternoon. This session is sponsored by the SIGMAA STAT-ED. Presenters will be considered for the Dex Whittinghill Award for Best Contributed Paper.

Cool Calculus: Lessons Learned Through Innovative and Effective Supplemental Projects, Activities, and Strategies for Teaching Calculus, **Jessica Deshler**, West Virginia University; Friday morning.

Cryptology for Undergraduates, **Robert Edward Lewand**, Goucher College, and **Chris Christensen**, Northern Kentucky University; Thursday afternoon.

Developmental Mathematics Education: Helping Under-Prepared Students Transition to College-Level Mathematics, **Kimberly Presser** and **J. Winston Crawley**, Shippensburg University; Saturday afternoon.

Effective Teaching of Upper Level Mathematics to Secondary Education Mathematics Majors, **Joyati Debnath**, Winona State University; Sunday morning.

Fostering, Supporting and Propagating Math Circles for Students and Teachers, **Tatiana Shubin**, San Jose State University; **Elgin Johnston**, Iowa State University; and **James Tanton**, St. Mark's Institute of Mathematics; Saturday morning. Sponsored by SIGMAA MCST.

Getting Students Involved in Writing Proofs, **Aliza Steurer**, Dominican University; **Jennifer Franko-Vasquez**, University of Scranton; and **Rachel Schwell**, Central Connecticut State University; Thursday afternoon.

Harnessing Mobile Communication Devices and Online Communication Tools for Mathematics Education, **Michael B. Scott**, California State University Monterey Bay, and **Jason Aubrey**, University of Missouri; Thursday morning. This session is sponsored by the Committee on Technologies in Mathematics Education (CTiME) and WEB SIGMAA.

Humanistic Mathematics, **Gizem Karaali**, Pomona College; **Mark Huber**, Claremont McKenna College, and **Dagan Karp**, Harvey Mudd College; Saturday afternoon. This session is sponsored by the *Journal of Humanistic Mathematics*.

Influences of the Calculus Reform Movement on the Teaching of Mathematics, **Steve Benson**, Lesley University; **Marilyn Carlson**, Arizona State University; **Ellen Kirkman**, Wake Forest University; and **Joe Yanik**, Emporia State University; Sunday morning.

Innovations in Service-Learning at All Levels, **Karl-Dieter Crisman**, Gordon College; **Rachelle Ankney**, North Park University; and **Robert Perlis**, Louisiana State University; Thursday afternoon.

Innovative and Effective Ways to Teach Linear Algebra, **David Strong**, Pepperdine University; **Gil Strang**, Massachusetts Institute of Technology; and **David Lay**, University of Maryland; Friday morning.

Journals and Portfolios: Tools in Learning Mathematics?, **Sarah L. Mabrouk**, Framingham State College, Friday afternoon.

The Mathematical Foundations for the Quantitative Disciplines, **Yajun Yang**, Farmingdale State College of SUNY; **Laurette Foster**, Prairie View A&M University; **Ray Collings**, Georgia Perimeter College; and **K. L. D. Gunawardena**, University of Wisconsin Oshkosh; Sunday afternoon. The session is cosponsored by CRAFTY and the MAA Committee on Two-Year Colleges.

Mathematics Experiences in Business, Industry, and Government, **Carla D. Martin**, James Madison University; **Phil Gustafson**, Mesa State College; and **Michael Monticino**, University of North Texas; Saturday morning. Sponsored by the BIG SIGMAA.

The Mathematics of Games and Puzzles, **Laura Taalman**, James Madison University, and **Robin Blankenship**, Morehead State University; Thursday afternoon

The Mathematics of Sustainability, **Elton Graves**, Rose-Hulman Institute of Technology, and **Peter Otto**, Willamette University; Friday afternoon.

Modeling in the ODE Driver's Seat, **Kurt Bryan**, Rose-Hulman Institute of Technology, and **Brian Winkel**, U.S. Military Academy; Friday morning.

New and Continuing Connections between Math and the Arts, **Douglas E. Norton**, Villanova University; Saturday morning. Sponsored by SIGMAA ARTS.

Philosophy of Mathematics in Teaching and Learning, **Dan Sloughter**, Furman University, and **Martin Flashman**, Humboldt State University; Saturday afternoon. Sponsored by the POM SIGMAA.

The Scholarship of Teaching and Learning in Collegiate Mathematics, **Jackie Dewar**, Loyola Marymount University; **Tom Banchoff**, Brown University; **Pam Crawford**, Jacksonville University; and **Edwin Herman** and **Nathan Wodarz**, University of Wisconsin-Stevens Point; Thursday morning.

Treasures from the Past: Using Primary Sources in the Classroom, **Amy Shell-Gellasch**, Beloit College; **Danny Otero**, Xavier University; and **David Pengelley**, New Mexico State University; Friday afternoon. Sponsored by the HOM SIGMAA.

Trends in Undergraduate Mathematical Biology Education, **Timothy D. Comar**, Benedictine University; **Raina Robeva**, Sweet Briar College; and **Mike Martin**, Johnson County Community College; Sunday morning. This session is sponsored by the BIO SIGMAA.

Using Program Assessment to Improve Student Learning, **Bonnie Gold**, Monmouth University; **William A. Marion**, Valparaiso University; and **Jay Malmstrom**, Oklahoma City Community College; Sunday afternoon.

Wavelets in Undergraduate Education, Organizers: **Caroline Haddad**, SUNY Geneseo; **Catherine Beneteau**, University of South Florida; **David Ruch**, Metropolitan

State College of Denver; and **Patrick Van Fleet,** University of St. Thomas; Thursday morning.

General Contributed Paper Session, **Kristen Meyer**, Wisconsin Lutheran College, and **Thomas Hagedorn,** The College of New Jersey; Thursday, Friday, Saturday, and Sunday mornings and afternoons. Papers may be presented on any mathematical topics. Papers that fit into one of the other sessions should be sent to that session, not to the general session.

Submission Procedures for MAA Contributed Paper Abstracts

Abstracts must be submitted electronically at `http://www.ams.org/cgi-bin/abstracts/abstract.pl`. Simply select the New Orleans meeting, fill in the number of authors, and then follow the step-by-step instructions. The deadline for abstracts is Tuesday, **September 22, 2010**.

Participants may submit at most two abstracts for MAA contributed paper sessions at any one meeting. If your paper cannot be accommodated in the session in which it is submitted, it will automatically be considered for the general session. Speakers in the general session are limited to one talk.

The organizer(s) of your session will automatically receive a copy of the abstract, so it is not necessary for you to send it directly to the organizer. All accepted abstracts are published in a book that is available to registered participants at the meeting. Questions concerning the submission of abstracts should be addressed to `abs-coord@ams.org`.

MAA Panels, Posters, and Other Sessions

National Science Foundation Programs Supporting Learning and Teaching in the Mathematical Sciences, organizers/panelists are **Lee Zia**, NSF DUE; **Hank Warchall**, NSF DMS; **Dennis Davenport**, NSF DUE; **Stephanie Fitchett**, NSF DUE; Thursday, 9:00 a.m.–10:20 a.m. A number of NSF divisions offer a variety of grant programs that support innovations in learning and teaching in the mathematical sciences. These programs will be discussed along with examples of successful projects. Anticipated budget highlights and other new initiatives for the next fiscal year will also be presented.

For MAA Student Chapter Advisors: Dynamic Answers to Your Questions, organized by **Jacqueline Jensen**, Sam Houston State University; **Robert W. Vallin**, Slippery Rock University, and **Joyati Debnath**, Winona State University; Thursday, 9:00 a.m.–10:20 a.m. We all want the best for our student chapters: An excited and enthused group of involved students, a resource to find meetings for students to attend, a place to exchange ideas for events, and an understanding of what the MAA can do for your group. Panelists **Bob Anastasio**, MAA; **Kay Somers**, Moravian College; and **Robert Vallin**, Slippery Rock University, will answer questions that have come up already involving the new changes in student memberships, the MAA's Math Club in a Box website, and Math Horizons subscriptions. The panel will also take on any and all questions you have about making your student chapter the best possible. Sponsored by the MAA Committee on Undergraduate Student Activities and Chapters.

Mathematical Outreach Programs for Underrepresented Populations Poster Session, organized by **Betsy Yanik**, Emporia State University; Thursday, 9:00 a.m.–11:00 a.m This session is designed to highlight special programs which have been developed to encourage students from underrepresented populations to maintain an interest in and commitment to succeeding in mathematics. These programs might include such activities as after school clubs, weekend activities, one-day conferences, mentoring opportunities, summer camps, etc. In particular, recipients of Tensor and Summa grants will find this an ideal venue in which to share the progress of their funded projects. We encourage everyone involved with offering outreach activities to consider submitting an abstract to the session organizer, Betsy Yanik, `eyanik@emporia.edu`. Sponsored by the Women and Mathematics Network (a subcommittee on the MAA Committee on the Participation of Women).

Reporting Progress: A Minisymposium of Projects from the NSF Course, Curriculum, and Laboratory Improvement Program, organized by **Dennis Davenport**, **Stephanie Fitchett**, and **Lee Zia**, NSF DUE; Thursday, 2:15 p.m.–3:35 p.m. In this session selected projects from the NSF Division of Undergraduate Education's Course, Curriculum, and Laboratory Improvement Program will provide project updates and present major outcomes. A moderated discussion of common development and implementation issues will follow.

How to Interview for a Job in the Mathematical Sciences, organized by **David Manderscheid**, University of Nebraska-Lincoln.; Thursday, 2:15 p.m.–3:35 p.m. This session is aimed at Ph.D. students and at recent graduates. Panelists **Michael Axtell**, College of St. Thomas; **Allen Butler**, Daniel H. Wagner Associates, Inc.; **James Freeman**, Cornell College; **David Manderscheid**; and **Sarah Ann Stewart**, Belmont University, will give an overview of the employment process with ample opportunity for participants to ask questions. The emphasis will be on the portion of the employment process from interviewing through accepting an offer. Questions that will be addressed include: How do employers conduct interviews? How can you best prepare for these interviews? How do employers choose to whom they will make offers? How do you negotiate once you have an offer? How do you choose among competing offers? Sponsored by the MAA Committee on Graduate Students and The Young Mathematicians Network.

Transition from High School to College: Should There Be an Alternate to Calculus?, organized by **Gail Burrill**, Michigan State University; Thursday, 3:50 p.m.–5:10 p.m. Are we losing potential STEM students because they are reluctant to take calculus as a first course in mathematics or because they have already taken calculus? Panelists **Danny Kaplan**, Macalester College; **Gregory D. Foley**, Ohio University; **Thomas R. Butts**, University of Texas at Dallas; **Al Cuoco**, Education Development Center; **Michael Shaughnessy**, Portland State University, NCTM president; and **Gail Burrill**, will discuss issues related to students who slip under the STEM recruitment radar because no one ever told them math had alternatives to calculus or that they might consider STEM careers. Panelists will offer some possible alternatives including linear algebra, dynamic systems, and advanced quantitative reasoning, and open the floor for input from the audience related to the questions: 1) Should alternative paths be created and why? 2) If so, what mathematical territory seems most promising for such paths? And 3) What is the potential impact of the Common Core Standards on high school graduates, mathematical knowledge and are the current entry-level courses for potential STEM majors the best ones for all students with this knowledge? Sponsored by the MAA/NCTM Mutual Concerns Committee.

Young Mathematicians Network/Project NExT Poster Session, organized by **Michael Axtell**, University of St. Thomas, and **Kim Roth**, Juniata College; Thursday, 4:00 p.m.–6:00 p.m. This poster session is intended to highlight the research activities, both mathematical and pedagogical, of recent or future PhDs in mathematics and related fields. The organizers seek to provide an open venue for people who are near completion, or have finished their graduate studies in the last five years to present their work and make connections with other same-stage professionals, in much the same spirit as the YMN and Project NExT. The poster size will be 48" by 36" (it is best to have the posters 36" high). Posters and materials for posting pages on the posters will be provided on site. We expect to accept about forty posters from different areas within the mathematical sciences.

Current Issues in Actuarial Science Education, organized by **Robert Buck**, Slippery Rock University; **Bettye Anne Case**, Florida State University; **Kevin Charlwood**, Washburn University; and **Steve Paris**, Florida State University; Thursday, 5:00 p.m.–7:00 p.m. A diverse group of working actuaries, publishers, and actuarial educators bring new information from professional society committees, specialized publications initiatives, and academic department experience. The pace of change is faster than in most academic areas, and the session helps faculty adjust as quickly as possible not only to educate their students generally, but give the students good professional information and to determine curriculum change that may be necessary. Panelists include **Steve Paris**, Florida State University; **Bettye Anne Case**, Florida State University; and **Robert Buck**, Slippery Rock University.

There will also be a discussion about organizing an MAA Special Interest Group on Actuarial Education. Sponsored by the Actuarial Educators, Society of Actuaries, Casualty Actuarial Society, and ACTEX Publications.

Career Options for Undergraduate Mathematics Majors, organized by **Ralucca Gera**, Naval Postgraduate School, and **Tom Wakefield**, Youngstown State University; Friday, 9:00 a.m.–10:20 a.m. There are a vast amount of options available for students in today's global market. A degree in mathematics continues to be a desirable asset, yet a common question for students to ask is "what options are available for someone with a math degree?" This panel showcases several options for career paths for students with an undergraduate degree in mathematics. Panelists **Emily Kessler**, Society of Actuaries; **Erin E. Corman**, National Security Agency; **Lee Seitelman**, University of Connecticut; **David Manderscheid**, University of Nebraska-Lincoln; and **Fred Kluempen**, Educational Testing Service, will speak on their own experiences of finding a job and answer questions from the audience. Sponsored by the MAA and the Young Mathematicians Network.

MAA Session for Chairs: The New MAA Curriculum Guide—What Should It Be?, organized by **Daniel Maki**, Indiana University, and **Catherine M. Murphy**, Purdue University Calumet; Friday, 9:00 a.m.–10:20 a.m. The current Curriculum Guide appeared in 2004. CUPM is soliciting suggestions for the next guide. This is your opportunity as chairs of mathematics departments to influence the content and structure of the guide so it will be useful for you as you review and possibly change curricula to meet the needs of tomorrow's students. Panelists **Carol Schumacher**, Kenyon College, and **James Sellers**, Pennsylvania State University, two CUPM members, will lead this session. You will learn about some major themes that are under consideration, and have the opportunity to participate in discussions of what should be kept, what needs to be improved, what is missing and should be added. Some specific questions to think about are: (1) Does your department use the 2004 Curriculum Guide in such areas as curriculum planning, outcomes assessment, self-study, and evaluation? (2) Is there some aspect of the Curriculum Guide you find especially useful? If so, what? Is there some way in which it might be improved so as to be more helpful? (3) Is there something you really hope is considered for inclusion in the new guide that wasn't in the previous guide? For reference the current guide is at `www.maa.org/cupm/curr_guide.html`.

Professional Science Masters Degrees in the Mathematical Sciences Poster Session, organized by **David Manderscheid**, University of Nebraska-Lincoln; Friday, 10:00 a.m.–noon. Professional Science Masters (PSM) Degree programs are a fast growing segment of academe. PSM programs provide students training in an area of science and also business with an eye toward employment in government or industry. The MAA has appointed a task force to identify the MAA niche in PSM programs. The purpose of this poster session is for existing programs to provide information about their programs and their success. It is anticipated that both undergraduate students interested in possibly enrolling in a PSM program and faculty interested in possibly starting a PSM program will attend. Sponsored by the MAA Committee on Graduate Students.

Proposal Writing Workshop for Grant Applications to the NSF Division of Undergraduate Education, presented by **Dennis Davenport**, **Stephanie Fitchett**, and **Lee L. Zia**, Division of Undergraduate Education, National Science Foundation; Friday, 10:35 a.m.–11:55 a.m. The presenters will describe the general NSF grant proposal process and consider particular details relevant to programs in the Division of Undergraduate Education. This interactive session will feature a mock panel review using a series of short excerpts from sample proposals.

Writing the History of the MAA's First 100 Years, organized by **Victor J. Katz**, University of the District of Columbia, and **Janet Beery**, University of Redlands; Friday, 10:35 a.m.–11:55 a.m. The centennial of the MAA will occur in 2015. In preparation for that event, the MAA plans to record various aspects of its history, to appear either in electronic or in hardcopy form as articles or books. Two of the panelists, **Mary Gray**, American University, and **Warren Page**, New York City College of Technology, CUNY, have already written articles on the history of women and journals in the MAA, respectively, while a third, **David Zitarelli**, Temple University, has written the history of his section. They will discuss their procedures for preparing those histories. The fourth panelist, **Carol Mead**, Archives of American Mathematics, is the archivist in charge of the major collection of MAA records and will help prospective researchers learn what is available and how to access it. We hope that those attending this panel session will be motivated to do their own research, either at the section or national level, to help us complete the history of the MAA. Sponsored by the Centennial History Subcommittee of the MAA Centennial Committee.

Assessment of Learning in an Age of Technology, organized by **Michael B. Scott**, California State University Monterey Bay, and **Jason Aubrey**, University of Missouri; Friday, 1:00 p.m.–1:20 p.m. Mathematics educators often use a variety of technologies to enhance student learning. For example, technology can provide opportunity for students to investigate many examples of a particular topic more easily or enhance visualization of a difficult concept. As technology becomes more integrated into the learning experiences of students, one should expect that technology would become more integrated into assessment practices. Moreover, as teaching mathematics using technology evolves, it is natural to ask whether the mathematics being assessed also changes. This session is designed to provide practical strategies and best practices for assessment of learning when teaching with technology. Panelists **Andrew G. Bennett**, Kansas State University; **Gavin LaRose**, University of Michigan; and **Alison Marble Ahlgren**, University of Illinois at Urbana-Champaign, will describe their experiences integrating assessment of mathematical proficiency with technology other than paper and pencil. Sponsored by the Committee on Technologies in Mathematics Education (CTiME) and WEB SIGMAA.

Good Intentions Are Necessary but Not Sufficient: Steps Toward Best Practices in Mentoring Underrepresented Students, organized by **James H. Curry**, University of Colorado; Friday, 1:00 p.m.–3:00 p.m. Do you have an idea for a program that will bring underrepresented students into mathematics? Are you interested in developing a proposal for an NSF Division of Mathematical Sciences workforce program, such as Mentoring through Critical Transition Points (MCTP), Research Experiences for Undergraduates (REU), Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences (UBM), or another project under the unsolicited workforce proposal format? This panel discussion will be led by NSF-supported principal investigators who developed programs having strong mentoring components and who are experienced in working with undergraduate, graduate, and postdoctoral scholars. Panelists **Carlos Castillo-Chavez**, Arizona State University; **A. G. (Loek) Helminck**, North Carolina State University; **Rhonda Hughes**, Bryn Mawr College; **Philip Kutzko**, The University of Iowa; and **M. Helena Noronha**, California State University, Northridge, will discuss project design issues, both successes and failures, they encountered when developing mentoring and other program support structures for underrepresented students. Representatives from the NSF DMS workforce program will be in attendance.

Report from the International Conference on Teaching Statistics: A World View of Statistics Education, organized by **John McKenzie**, Babson College, and **Michael A. Posner**, Villanova University; Friday, 1:00 p.m.–2:20 p.m. Panelists **Rob Carver**, Stonehill College; **Katherine Halvorsen**, Smith College; **John McKenzie**; **Milo Schield**, Augsburg College; and **Gail Burrill**, Michigan State University, will discuss the current state of statistical education around the world. Each of the panelists is actively involved in statistics education and recently attended the International Conference on Teaching Statistics in Slovenia. They will formally address a number of questions concerning statistical education at all levels (primary and secondary schools, colleges and universities, the workplace). Each will identify differences in statistical instruction among countries and provide reasons for such differences. The most appropriate type of statistics—statistical literacy, applied statistics, and mathematical statistics for different countries—will be discussed. Each panelist will explain what other countries can learn from the way statistics is taught in the United States and what the United States can learn from other countries. The numerous advantages of attending an international conference will also be presented. At the end of session there will be ample time for audience participation. Sponsored by the SIGMAA Stat Ed and the ASA/MAA Joint Committee on Undergraduate Statistics.

Projects Supported by the NSF Division of Undergraduate Education Poster Session, organized by **Jon W. Scott**, Montgomery Community College; Friday, 2:00 p.m.–4:00 p.m. This session will feature principal investigators (PIs) presenting progress and outcomes from various NSF funded projects in the Division of Undergraduate Education. The poster session format will permit ample opportunity for attendees to engage in small group discussions with the PIs and to network with each other. Information about presenters and their projects will appear in the program.

Mathematical Culture and Mathematical Life, organized by **Reuben Hersh** and **Vera John-Steiner**, University of New Mexico; Friday, 2:00 p.m.–4:00 p.m. The emotional, social, and political sides of mathematical life are vitally important yet seldom discussed publicly. How do people survive the stresses of mathematical life? What does it mean, personally, to be a “mathematician” nowadays? In what ways are our personalities and problems “the same” as everybody else’s, and in what ways are they very different? How is mathematical life different from, and how is it similar to other lives in “academia”? How are our mathematical lives affected by our gender or our ethnicity? Panelists include **Lenore Blum**, Carnegie-Mellon University; **Philip J. Davis**, Brown University; **Nathaniel**

Dean, Texas State University San Marcos; **Reuben Hersh**; and Gizem **Karaali**, Pomona College.

Creating/Improving the Biomathematics/Biostatistics Course, organized by **Michael A. Posner**, Villanova University; **Raina Robeva**, Sweet Briar College; and **Holly Gaff**, Old Dominion University; Friday, 2:35 p.m.–3:55 p.m. With the growing demand for quantitatively skilled biologists, the creation of new and update of previously established biomathematics, biostatistics, or bioinformatics courses is a popular topic and necessary discussion. The recommendations of the Bio 2010 report have proposed important modifications to these curricula. The faculty on this panel, including **Pam Ryan**, Truman University; **Fred Adler**, University of Utah; **Laurie Heyer**, Davidson College; and **Deborah Nolan**, University of California, Berkeley, have all been involved on their campuses in shaping these courses. They will address questions like: What does this course look like? What topics are covered? What are the best practices? Who are the target audiences? What are the challenges of creating, marketing, getting such a course approved? What are the future directions of these courses? Ample time will be left for participant discussion. Sponsored by SIGMAA BIO, SIGMAA Stat Ed, and the ASA/MAA Joint Committee on Undergraduate Statistics.

Calculus Reform: 25 Years Later, organized by **Steve Benson**, Lesley University; **Joe Yanik**, Emporia State University; **Marilyn Carlson**, Arizona State University; and **Ellen Kirkman**, Wake Forest University; Friday, 2:35 p.m.–3:55 p.m. Twenty-five years ago, the Tulane Conference "kicked off" a nationwide discussion about the teaching of calculus that led to a dramatic, sometimes contentious, re-evaluation of the ways in which calculus was taught, a discussion that continues to this day. Our panelists, **Steve Benson**; **Tom Dick**, Oregon State University; **Deborah Hughes Hallett**, University of Arizona; **Judy Holdener**, Kenyon College; and **Paul Zorn**, St. Olaf College, an eclectic combination of "Tulane" participants, curriculum developers and adapters, and observers of, and participants in, the calculus reform movement, will look back on the last 25 years and share their personal reflections, providing important historical perspective and insight for those who might wish to make similar contributions to the teaching and learning of mathematics (calculus and otherwise). Rather than to promote or (re)debate the issues, or bring back the artificial "us vs. them" distinctions, we wish to look back on the last 25 years and use these lessons to inform the next 25 years (and beyond) of mathematics teaching. Sponsored by the MAA Committee on the Teaching of Undergraduate Mathematics.

Mathematicians and Teachers: Professional Development and Outreach Groups, organized by **James King**, University of Washington and **Gail Burrill**, Michigan State University; Friday, 2:35 p.m.–3:55 p.m. The Institute for Advanced Study's Park City Mathematics Institute (PCMI) is committed to networking mathematicians and teachers. This commitment has resulted in the creation of Professional Development and Outreach (PDO) Groups, organized by mathematicians for local secondary teachers. These programs include weeklong conferences, Mathematics at the Jersey Shore workshops, math days for high school students, and lesson-designing sessions with teachers and preservice students. Panelists **Darryl Yong**, Harvey Mudd University; **Brian Hopkins**, St. Peters College; **James King**; **Harvey Keynes**, University of Minnesota; and **Brynja Kohler**, Utah State University, will describe how their groups are organized, the impact on the teachers in their groups, and issues that emerge in making their PDO groups valuable and continuing learning experiences for the teachers. They will engage the audience in discussing the larger networking picture for mathematicians and teachers and offer suggestions for those interested in starting their own PDO group.

The Benefits of Hosting a Regional Undergraduate Mathematics Conference, organized by **Doug Faires**, Youngstown State University, Saturday, 9:00 a.m.–10:20 a.m. There are currently more than 40 conferences in the United States that receive funding to host conferences under the Regional Undergraduate Mathematics Conferences (RUMC) grant DMS-0846477. The intent of the grant is to have a sufficient number of these conferences so that every U.S. student can attend a mathematics conference without extensive travel or outlay of funds. Many regions in the country now offer this opportunity, either through this program, the MAA sections, or independently run conferences. However there are still regions with large student populations that have not taken advantage of this opportunity. The panel will include the grant PI and four other faculty members. All have directed conferences with funds awarded by the grant. Two of the panelists will be directors of multiple conferences who can tell how the conference has progressed from year to year. The remaining two will be relatively new to the program and give their impressions about what to consider when first designing and hosting a conference. Panelists **Doug Faires**; **Kendra Kilpatrick**, Pepperdine University; **Laura Taalman**, James Madison University; and **Nathan Gibson**, Oregon State University, will give advice for those interested in becoming part of the program, and describe the benefits that undergraduate conferences provide to both students and the faculty involved in the program

Utilizing NSF ADVANCE to Promote the Success of Women Faculty in Mathematics, organized by **Jenna Carpenter**, Louisiana Tech University; Saturday, 9:00 a.m.–10:20 a.m. This panel features four funded NSF ADVANCE Programs and their impact on promoting the success of women faculty in mathematics. Panelists **Judith Silver**, Marshall University; **Brooke Shipley**, University of Illinois at Chicago; **Brenda Johnson**, Union College; and Jenna Carpenter, are PIs/co-PIs on an existing NSF ADVANCE Project. Small, medium, and large institutions are represented, as well as both larger institutional transformation and smaller adaptation and implementation projects. The goals of this session are to 1) increase awareness of NSF ADVANCE in the mathematics community at large; 2) educate mathematics departments about key issues impacting the success of women faculty; and 3) disseminate effective strategies to address these issues and promote faculty success. Topics to be addressed include isolation, high service and teaching loads, climate issues, faculty hiring, dual career issues, networking, university policies, mentoring, professional development, and promotion of research. Each panelist will highlight key aspects of their program, followed by a general question-and-answer session. Materials about ADVANCE and participating projects will be available, as well.

Preparation and Recruitment of Future Mathematics Graduate Students, organized by **Amy Cohen**, Rutgers University; Saturday, 1:00 p.m.–2:20 p.m. A U.S. mathematics major typically studies mathematics about half-time for two-and-a-half years after calculus. A mathematics student outside the U.S. typically studies mathematics full-time for three to five years after calculus before applying to a U.S. doctoral program. Graduate admissions committees often find it easier to see differences in prior achievement than to discern differences in potential for future achievement. Panelists **John Meakin**, University of Nebraska-Lincoln; **Aloyisius (Loek) Helminck**, North Carolina State University; **David M. Bressoud**, Macalester College; and **Ruth Haas**, Smith College, will stimulate discussion of what is needed, what is already being done, and what more can be done to increase the number, diversity, and success of undergraduate mathematics students in the U.S. going on to graduate study. Speakers will have experience with graduate programs in pure and applied mathematics, with undergraduate programs, and with transition programs. Sponsored by the MAA Committee on the Undergraduate Program in Mathematics.

Teaching Statistics Online, organized by **Brian Gill**, Seattle Pacific University; Saturday, 1:00 p.m.–2:20 p.m. Recent years have seen a rapid expansion of the number of courses taught online, and current budget pressures are leading more institutions to consider expanding their online course offerings. However, effective instruction online requires a very substantial time commitment from faculty, and involves much more than simply taking the materials from a traditional classroom course and making them available online. Panelists **Michelle Everson**, University of Minnesota; **Patricia Humphrey**, Georgia Southern University; **Michael Miner**, American Public University; and **Sue Schou**, Idaho State University, bring together statistics instructors and education researchers with experience teaching online and hybrid courses to share advice and resources for teaching statistics online. The American Statistical Association's Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report strongly emphasizes the importance of fostering active learning in the "classroom"; panelists will address strategies for implementing this guideline in an online learning environment. Sponsored by SIGMAA Stat Ed.

The Role of Mentoring in Undergraduate Mathematics: Promising Recruitment and Retention Strategies, organized by **William Velez**, University of Arizona; **Sylvia Bozeman**, Spelman College; and **Ken Millett**, University of California-Santa Barbara; Saturday, 2:35 p.m.–3:55 p.m. Without question, the United States can boast of the best system of higher education in the world. But that does not mean that this system is perfect. It has failed to meet our nation's requirements for graduates trained in the STEM disciplines, a fact that is witnessed by our need to import large numbers of scientists and engineers. Tremendous mathematical talent exists in our population. The challenge to mathematicians is to engage that population in mathematical studies and to nurture their continued mathematical development. Many minority organizations and minority mathematicians have accepted this challenge, with the end result of increasing minority participation in mathematics-based fields. It is clear that programs aimed at minority populations will work with all students. Panelists **Sylvia Bozeman**; **Michelle Craddock**, U.S. Military Academy; **Rebecca Garcia**, Sam Houston State University; and **William Velez** will highlight some of the most successful efforts that have served to increase minority participation. Sponsored by MAA Committee on Minority Participation, Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), and National Association of Mathematicians (NAM).

Inquiry-Proof Instructional Techniques, organized by **Tom Roby**, University of Connecticut; **Dev Sinha**, University of Oregon; **Glenn Stevens**, Boston University; and **Ravi Vakil**, Stanford University; Saturday, 2:35 p.m.–3:55 p.m. There is a wealth of refined teaching techniques which emphasize mathematical inquiry, but relatively little awareness of them even among practitioners with similar philosophies but different methods. This situation lies in contrast with the physical sciences, where scientific inquiry including Web demonstrations and lab experiences is becoming ingrained in the core of the undergraduate curriculum. We bring together panelists, including **Keith Conrad**, University of Connecticut; **Ken Ono**, University of Wisconsin; **David Pengelley**, New Mexico State University; **Margaret Robinson**, Mount Holyoke College; **Brad Shelton**, University of Oregon; and **Michael Starbird**, University of Texas, who have incorporated inquiry in their undergraduate classes in different ways, including experience-first methods, the discovery method, computer-based experimentation, worksheets, and working from historical texts. We will compare these techniques with standard lecture format and with each other, addressing what students retain, when such techniques are useful, and how they fit into the curriculum as a whole. By highlighting these approaches together we hope audience members reflect on which aspects of these approaches might help improve their own teaching, rather than focusing on what they like or do not like about a particular method.

Derivative vs. Integral: The Final Slapdown, organized by **Colin Adams** and **Thomas Garrity**, Williams College; Saturday, 6:00 p.m.–7:00 p.m. Ever since Newton and Leibniz, the derivative and the integral have been locked in mortal combat, doing whatever it takes to try to prove which is the better, and in the process tearing equations asunder and leaving broken and shattered math symbols in their wake. Tonight we determine once and for all who will be crowned the victor, derivative or integral. And mathematics can then revert once again to the bucolic Garden of Eden, where students frolic with equations in peace and harmony.

Publishing Mathematics on the Web, organized by **Thomas E. Leathrum**, Jacksonville State University; Sunday, 9:00 a.m.–10:20 a.m. Emerging technologies, such as browser support for MathML, are changing the ways authors will be expected to present mathematical material in online documents. As academic journals move toward online formats, and as libraries and archives digitize existing content, online presentation will become essential to the profession. Many useful tools have become available recently, including visual editors and simplified embedded mark-up. These tools raise a host of new issues, though, such as how modern online search engines can find math content. Panelists **Robert Miner**, Design Science; **Thomas E. Leathrum**; and **David Ruddy**, Project Euclid/Cornell University, will provide a discussion of available and emerging tools, such as legacy format conversion, authoring tools for current standards including dynamic Web pages, and future standards for presenting mathematics in online documents. The panel will be moderated by **Lawrence Moore**, Duke University. Sponsored by the MAA Committee on Technology in Math Education (CTiME)

Maximize your Career Potential!, organized by **Rachel Esselstein**, California State University Monterey Bay, and **David Manderscheid**, University of Nebraska-Lincoln; Sunday, 9:00 a.m.–10:20 a.m. The past few years have been some of the hardest for finding and keeping employment. What can you do to make yourself a stronger job candidate? Speakers **Geir Helleloid**, Acuitus Inc., and **Aba Mbrika**, Bowdoin College, will focus on advice for current graduate students and postdocs who are at least one year away from applying for jobs. We will discuss what you can do NOW to strengthen your application. Our panelists will address topics such as what you can do in the classes you are teaching and in your research to help you stand out amongst the crowd. We will also discuss internship opportunities that can open new doors and provide valuable work experience. If you are planning on applying for a job in the next few years, you won't want to miss this panel! Sponsored by the MAA Committee on Graduate Students and the Young Mathematicians Network.

Special Interest Groups of the MAA (SIGMAAs)

SIGMAAs are Special Interest Groups of the MAA. SIGMAAs will be hosting a number of activities, sessions, and guest lectures. There are currently twelve such focus groups in the MAA offering members opportunities to interact, not only at meetings, but throughout the year, via newsletters and email-based communications. For more information visit `http://www.maa.org/sigmaa/`.

SIGMAA Officers Meeting, Friday, 10:30 a.m.–noon, chaired by **Amy Shell-Gellasch**, Beloit College.

Mathematics and the Arts: SIGMAA ARTS

New and Continuing Connections between Math and the Arts, Saturday morning (see MAA Contributed Paper Sessions).

Business Meeting, Saturday, January 8, 6:00–7:00 p.m.

Mathematicians in Business, Industry and Government: BIG SIGMAA

Mathematics Experiences in Business, Industry and Government, Saturday morning (See MAA Contributed Paper Sessions.)

Guest Lecture, Saturday, 5:00 p.m.–6:00 p.m, **Tony DeRose**, Pixar Animation Studios, *How mathematics is changing Hollywood*.

Reception, Saturday, 6:15 p.m.–7:30 p.m.

Mathematical and Computational Biology: BIO SIGMAA

Trends in Undergraduate Mathematical Biology Education, Sunday morning (see MAA Contributed Paper Sessions).

Creating/Improving the Biomathematics/Biostatistics Course, Friday afternoon (see MAA Panels).

Business Meeting, Friday, 6:00 p.m.–7:00 p.m.

Guest Lecture, Friday, 7:00 p.m.–8:00 p.m., speaker and title to be announced.

Environmental Mathematics: SIGMAA EM

Paper Session: *Modeling the Oil Spill Disaster and Its Consequences*, Saturday, 1:00 p.m.–4:20 p.m.

The Oil Volcano: Truth and Consequences, a dramatic presentation on Saturday, 6:00–7:00 p.m.

Bus Trip, Sunday morning, exact time to be determined. We will visit the coastal areas with Dr. Paul Kemp of the National Audubon Society. His chief responsibility is working on coastal habitat for birds and other wildlife.

History of Mathematics: HOM SIGMAA

Treasures from the Past: Using Primary Sources in the Classroom, Friday afternoon (see MAA Contributed Paper Sessions).

Reception and Business Meeting, Thursday, 5:30 p.m.–6:30 p.m.

Guest Lecture, Thursday, 6:30 p.m.–7:30 p.m., speaker and title to be announced.

Math Circles for Students and Teachers: SIGMAA MCST

Fostering, Supporting, and Propagating Math Circles for Students and Teachers, Saturday morning (see MAA Contributed Paper Sessions).

Math Circles Demonstration, Sunday, 9:00 a.m.–11:00 a.m. Our mathematical circles are modeled after those in Eastern Europe and are as successful here as they were there. Circles bring mathematicians into direct contact with middle and high school students to work, through the give and take of conversation, on problems that require deep thinking and creative exploration. Circles also provide a social context for these students who enjoy studying mathematics. James Tanton will demonstrate a real math circle in action—with real students!

Philosophy of Mathematics: POM SIGMAA

Philosophy of Mathematics in Teaching and Learning, Saturday afternoon. (See MAA Contributed Paper Sessions.)

Business Meeting, Saturday, 6:00 p.m.–6:30 p.m.

Guest Lecture, Saturday, 6:30 p.m.–7:30 p.m., by **Keith Devlin**, Stanford University, *title to be announced*.

Quantitative Literacy: SIGMAA QL

The Role of QL in the High School Mathematics Curriculum, Friday morning and afternoon (see AMS Special Sessions).

Business Meeting, Thursday, 5:30 p.m.–6:00 p.m.

Reception and Discussion Panel: Mathematics and Democracy Ten Years Later, Thursday, 6:00 p.m.–7:00 p.m.

Research in Undergraduate Mathematics Education: SIGMAA RUME

Research on the Teaching and Learning of Undergraduate Mathematics, **Sean Larsen**, Portland State University; **Natasha Speer**, University of Maine; and **Stacy Brown**, Pitzer College; Friday morning and afternoon.

Business Meeting, Friday, 5:45 p.m.–6:30 p.m.

Statistics Education: SIGMAA STAT-ED

Alternative Approaches to Traditional Introductory Statistics Courses, Sunday afternoon (see MAA Contributed Paper Sessions).

Report from the International Conference on Teaching Statistics: A World View of Statistics Education, Friday afternoon (see MAA Panels).

Creating/Improving the Biomathematics/Biostatistics Course, Friday afternoon (see MAA panels).

Teaching Statistics Online, Saturday afternoon (see MAA panels).

Business Meeting and Reception, Friday, January 7, 5:45 p.m.–7:15 p.m.

Teaching Advanced High School Mathematics: SIGMAA TAHSM

Business Meeting, Thursday, 6:00 p.m.–7:00 p.m.

Mathematics Instruction Using the Web: WEB SIGMAA

Harnessing Mobile Communication Devices and Online Communication Tools for Mathematics Education, Thursday morning (see MAA Contributed Paper Sessions).

Assessment of Learning in an Age of Technology, Friday afternoon (see MAA Panels).

Business Meeting and Open Discussion, Saturday, 4:30 p.m.–6:00 p.m. A discussion providing WEB SIGMAA members with an opportunity to share their interests in teaching and learning mathematics online and the direction of future WEB SIGMAA activities.

MAA Sessions for Students

Grad School Fair, Saturday, 8:30 a.m.–10:30 a.m. Here is the opportunity for undergrads to meet representatives from mathematical sciences graduate programs from universities all over the country. January is a great time for juniors to learn more, and college seniors may still be able to refine their search. This is your chance for one-stop shopping in the graduate school market. At last year's meeting about 300 students met with representatives from 45 graduate programs. If your school has a graduate program and you are interested in participating, a table will be provided for your posters and printed materials for US$60 (registration for this event must be made by a person already registered for the JMM), and you are welcome to personally speak to interested students. Complimentary coffee will be served. Cosponsored by the AMS and MAA.

Graduate School: Choosing One, Getting In, Staying In, organized by **Aaron Luttman**, Clarkson University, and **Kristi Meyer**, Wisconsin Lutheran College; Friday, 10:35 a.m.–11:55 a.m. With so many graduate school choices and so much information available online, how do you decide on a list of schools to apply to? How can you strengthen your application so you will be accepted into a program? How do you choose which school to attend? And once you've started a program, how do you successfully navigate grad school and complete your degree? Panelists **Jessie Lenarz**, Concordia College; **Richard McGehee**, University of Minnesota; and **Jennifer McNulty**, University of Montana, will discuss these and other important issues for those students who are considering a graduate degree or thinking about switching graduate programs. Sponsored by the Young Mathematicians Network and the MAA Committee on Graduate Students.

This Could be YOUR Graduate Research!, organized by **Ralucca Gera**, Naval Postgraduate School, and **Aaron Luttman**, Clarkson University; Friday, 1:00 p.m.–2:20 p.m. Are you interested in graduate school but don't know what kind of research you want to do? Ever feel like you don't really even know what kind of research is being done by mathematicians? This session, including speakers **Timothy Chartier**, Davidson College; **Steven Horton**, U.S. Military Academy; and **Keri Kornelson**, University of Oklahoma, is designed to introduce you to current research in the mathematical sciences. The presenters come from new and developing fields like network science and dynamical systems, as well as classical research areas such as analysis and algebra. Each talk is aimed specifically at introducing undergraduate students to active fields of research. Come and find out about cutting-edge mathematical problems: These could become your graduate research! Sponsored by the MAA and the Young Mathematicians Network.

MAA Lecture for Students, Saturday, 1:00 p.m.–1:50 p.m., will be given by **Steve Abbott**, Middlebury College, on *Turning theorems into plays*.

Undergraduate Student Poster Session, Saturday, 4:00 p.m.–5:30 p.m., organized by **Joyati Debnath**, Winona State University. The session is reserved to undergraduates and first-year graduate students submitting posters on work done while undergraduates. Abstracts are accepted on a first-come basis. Space is limited and students are encouraged to apply early. Beginning September 1, 2010, students can submit abstracts online at `www.maa.org/students/undergrad/poster10.htm`. Examples of poster topics include a new result, a different proof of a known theorem, an innovative solution of a Putnam problem, a new mathematical model, or method of solution of an applied problem. Purely expository posters cannot be accepted. Prizes will be awarded to the top-rated posters with money provided by the AMS, MAA, AWM, CUR, PME, and by the Moore Foundation. Trifold, self-standing 48" by 36" tabletop posterboards will be provided. Additional material or equipment is the responsibility of the presenters. Questions regarding this session should be directed to Joyati Debnath at jdebnath@winona.edu. The deadline for proposals is **November 9, 2010**. Cosponsored by the MAA-CUPM Subcommittee on Undergraduate Research and the MAA Committee on Undergraduate Student Activities and Chapters (CUSAC).

Some more advanced students might be interested in the session on **How to Interview for a Job in the Mathematical Sciences**, Thursday at 2:15 p.m.; **Career Options for Undergraduate Mathematics Majors**, Friday, 9:00 a.m.; **Maximize your Career Potential!**, Sunday at 9:00 a.m.; see the full descriptions in the "MAA Panels…" section.

Also see the "Social Events" section for the open hours of the **Student Hospitality Center**, **Reception for Undergraduates**, and **Reception for Graduate Students and First-Time Participants**.

MAA Short Course

This two-day Short Course on *What is a Matroid? Theory and Applications, from the Ground Up* is organized by **Nancy Ann Neudauer**, Pacific University, and will take place on Tuesday and Wednesday, January 4 and 5, before the annual meeting begins. Gian-Carlo Rota said that "Anyone who has worked with matroids has come away with the conviction that matroids are one of the richest and most useful ideas of our day."

Hassler Whitney introduced the theory of matroids in 1935 and developed a striking number of their basic properties as well as different ways to formulate the notion of a matroid. As more and more connections between matroid theory and other fields have been discovered in the ensuing decades, it has been realized that the concept of a matroid is one of the most fundamental and powerful in mathematics. Examples of matroids arise from networks, matrices, configurations of points, arrangements of hyperplanes, and geometric lattices; matroids play an essential role in combinatorial optimization.

We all know some matroids, but not always by name. In mathematics, notions of independence akin to linear independence arise in various contexts; matroids surface naturally in these situations. We provide a brief, accessible introduction so that those interested in matroids have a place to start. We look at connections between seemingly unrelated mathematical objects, and show how matroids have unified and simplified diverse areas.

Speakers and the titles of their talks include *Matroids you have known*, **Nancy Ann Neudauer**; *Cryptomorphisms and optimization*, **Jenny McNulty**, University of Montana; *Matroid representations*, **Gary Gordon**, Lafayette College; *Matroid operations*, **Dillon Mayhew**, Victoria University of Wellington; *Transversal matroids*, *Joseph Bonin*, The George Washington University; *Oriented matroids*, **Winfried Hochstättler**, Fern Universität, Hagen, Germany; *Research in matroids*, **James Oxley**, Louisiana State University; and *Concluding Session: Tying it together*.

See the full announcement at www.ams.org/meetings/national/jmm/2125_maasc.html. There are separate registration fees to participate in this Short Course. See the fee schedule on the registration form at the back of this issue or visit www.ams.org/amsmtgs/2125_reg.html.

Other MAA Events

Board of Governors,Wednesday, 9:00 a.m.–5:00 p.m.

Section Officers, chaired by Rick Gillman, Valparaiso University; Thursday, 2:30 p.m.–5:00 p.m.

Business Meeting, Sunday, 11:10 a.m.–11:40 a.m., chaired by MAA President **David M. Bressoud**, Macalester College.

Department Liaisons Meeting, Thursday, 9:30 a.m.–11:30 a.m.

Joint PME and MAA Student Chapter Advisors' Meeting, day and time to be determined.

Minority Chairs Meeting, day and time to be determined.

See the listings for various receptions in the "Social Events" section.

MAA Ancillary Workshop

Teaching Introductory Statistics following GAISE and the Common Core, presented by **Robert Gould**, UCLA, Wednesday, 9:00 a.m. to 5:00 p.m. The Guidelines for Assessment and Instruction in Statistics Education (GAISE) were developed by members of the American Statistical Association (which endorses the Guidelines) to assist instructors of Introductory Statistics. The GAISE were integrated to some extent in the Common Core State Standards for Mathematics. The emphasis of the Guidelines on data analysis provides some challenges to mathematics instructors, particularly those relatively new to teaching statistics. In this workshop, we will examine strategically chosen data sets to demonstrate how to use technology to teach fundamental concepts as well as analyze data (Recommendations 2, 3, and 5), and explore the relationship between the GAISE recommendation to emphasize statistical literacy and statistical thinking with the more mathematically minded goals of the Core Curriculum Standards.

This workshop will be held on Wednesday, January 5, the day before the Joint Mathematics Meetings actually begin. There is no cost to participate. For more information and to apply, see www.causeweb.org/workshop.

Activities of Other Organizations

This section includes scientific sessions. Several organizations or special groups are having receptions or other social events. Please see the "Social Events" section of this announcement for details.

Association for Symbolic Logic (ASL)

This two-day program on Saturday and Sunday will include sessions of contributed papers as well as Invited Addresses by **Samson Abramsky**, University of Oxford; **Andreas Blass**, University of Michigan; **Larry Moss**, Indiana University; **Alf Onshuus**, University of Los Andes; **Patrick Speissegger**; McMaster University; **Juris Stephrans,** Your University (CA); and **Monica VanDieren**, Robert Morris University.

See also the session cosponsored by the ASL on *Logic and Analysis* on Friday in the "AMS Special Sessions" listings.

Association for Women in Mathematics (AWM)

In 2011 the Association for Women in Mathematics will celebrate its 40th anniversary. In honor of this special event, AWM plans to hold several activities in addition to its customary ones at the JMM. We hope you will join us during these celebrations.

Thirty-second Annual Emmy Noether Lecture, Friday, 10:05 a.m., will be given by **M. Susan Montgomery**, University of Southern California, *Title to be announced.*

A luncheon will be given in honor of the lecturer on Friday; see the "Social Events" section for details.

Also see the Special Session on *Hopf Algebras and Their Representations* jointly sponsored by the AWM in the "AMS Special Session" listings.

AWM Business Meeting, Thursday, 2:15 p.m.–2:45 p.m.

Schafer Minisymposium, organized by **Sami Assaf**, Massachusetts Institute of Technology, and **Patricia Hersh**, North Carolina State University, Thursday, 2:45 p.m.–6:15 p.m. The minisymposium will feature a retrospective on the contributions of Alice T. Schafer and on the founding of the AWM. It will be followed by five research talks by former Schafer Prize winners. Just before the minisymposium begins, the AWM will recognize the honorees for the Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman. Note that formal prizewinner announcements are made at the Joint Prize Session on Friday afternoon.

Hay Minisymposium, organized by **Cathy Kessel**, Education Consultant, and **W. James Lewis**, University of Nebraska-Lincoln; Friday, 8:00 a.m.–11:00 a.m. This session brings together a group of distinguished mathematics education researchers and mathematicians involved in teacher education to discuss the education of teachers in light of the Common Core Standards Initiative of the National Governors' Association and the Council of Chief State School officers,

Michler and Mentoring Minisymposium, organized by **Georgia Benkart**, University of Wisconsin-Madison, and **J. Matthew Douglass**, University of North Texas, Saturday, 1:00 p.m.–5:30 p.m. This session will highlight the research of AWM Michler Prize winners, and then be followed by a panel discussion to address the critical junctures in research careers in mathematics and on ways to establish, sustain, and expand research, teaching, and service credentials for tenure and promotion.

Workshop, Sunday, 8:00 a.m.–4:00 p.m. With funding from the Office of Naval Research and the National Security Agency, AWM will conduct its workshop for women graduate students and women who have received the Ph.D. within the last five years. Twenty women mathematicians are selected in advance of this workshop to present their research: graduate students will present posters, and recent Ph.D.s will give 20-minute talks. At 1:00 p.m. there is a panel discussion on *Starting a Career in Mathematics*, moderated by **Susan Williams**, University of South Alabama, with panelists **Sarah Frick**, Furman University; **Pierre Gremaud**, SAMSI and North Carolina State University; **T. Christine Stevens**, Saint Louis University, and **Tad White**, National Security Agency. All mathematicians (female and male) are invited to attend the entire program. Departments are encouraged to help graduate students and recent Ph.D.s who do not receive funding to obtain some institutional support to attend the workshop and other meeting sessions. Updated information about the workshop is available at `www.awm-math.org/workshops.html`. AWM seeks volunteers to lead discussion groups and act as mentors for workshop participants. If you are interested, please contact the AWM office; inquiries regarding future workshops may be made to the office at `awm@awm-math.edu`.

Reception, Thursday, 9:30 p.m.–11:00 p.m. See the listing in the "Social Events" section of this announcement.

National Association of Mathematicians (NAM)

Granville-Brown-Haynes Session of Presentations by Recent Doctoral Recipients in the Mathematical Sciences, Saturday, 1:00 p.m.–3:30 p.m.

Cox-Talbot Address, to be given Saturday after the banquet by **Robert Bozeman**, Morehouse College, *Title to be announced*.

Panel Discussion, Sunday, 9:00 a.m.–9:50 a.m., *NAM honors the life of Dr. David Harold Blackwell*.

Business Meeting, Sunday, 10:00 a.m.–10:50 a.m.

Claytor-Woodard Lecture: Sunday, 1:00 p.m., will be given by **Edray Herbert Goins**, Purdue University, *Title to be announced*.

See details about the banquet on Saturday in the "Social Events" section.

National Science Foundation (NSF)

The NSF will be represented at a booth in the exhibit area. NSF staff members will be available to provide counsel and information on NSF programs of interest to mathematicians. The booth is open the same days and hours as the exhibits. Times that staff will be available will be posted at the booth.

Pi Mu Epsilon (PME)

Council Meeting, Saturday, 8:00 a.m.–11:00 a.m.

Rocky Mountain Mathematics Consortium (RMMC)

Board of Directors Meeting, Saturday, 2:15 p.m.–4:10 p.m.

Society for Industrial and Applied Mathematics (SIAM)

This program consists of an Invited Address at 11:10 a.m. on Friday by **William Cook**, Georgia Institute of Technology, *title to be announced*, and a series of Minisymposia scheduled Thursday through Sunday on *Applications of Difference and Differential Equations in Ecology and Epidemiology*, **Zhilan Feng**, Purdue University, and **Yun Kang**, Arizona State University, Thursday morning and afternoon; *Combinatorial Optimization*, **David Hartvigsen**, University of Notre Dame, and **Donald Wagne**r, Office of Naval Research, Friday morning and afternoon; *Education*, **Peter Turner,** Clarkson University, Saturday morning;

Frontiers in Geomathematics, **Willi Freeden**, University of Kaiserslawtern, **Zuhair Nashed**, University of Central Florida, **Volker Michel**, Universität Siegen, and **Thomas Soner**, Technical University of Braunschweig, Germany, Saturday afternoon; *Vistas in Applied Mathematics*, **Maria-Carme Calderer**, University of Minnesota, **Zuhair Nashed**, University of Central Florida, Sunday morning; and *Graph Theory*, **Michael Ferrara**, University of Colorado, Denver, and **Stephen Hartke**, University of Nebraska-Lincoln.

Young Mathematicians Network (YMN)

Open Forum, Friday, 7:30 p.m.–8:30 p.m., organized by **Sarah Ann Stewart**, Belmont University, and **Joshua D. Laison**, Willamette University. All meeting attendees, including undergraduates and graduate students, are invited to discuss topics and issues affecting young mathematicians.

Also see details about other sessions cosponsored by the YMN under these headings: **MAA Panels, Posters, and Other Sessions**: **Project NExT-YMN Poster Session**, Thursday at 4:00 p.m.; **How to Interview**…, Thursday at 2:15 p.m.; **Career Options for Students**…, Friday at 9:00 a.m. and **MAA Sessions for Students: Graduate School: Choosing One**… Friday at 10:35 a.m.; **This could be YOUR Graduate Research**…, Friday at 1:00 p.m.).

Others

Mathematical Art Exhibition, organized by **Robert Fathauer**, Tessellations Company, **Nathaniel A. Friedman**, ISAMA and SUNY Albany, **Anne Burns**, Long Island University, C. W. Post University, **Reza Sarhangi**, Towson University, and **Nathan Selikoff**, Digital Awakening Studios. A popular feature at the last Joint Mathematics Meetings, this exhibition provides a break in your day. On display are works in various media by artists who are inspired by mathematics and by mathematicians who use visual art to express their findings. Fractals, symmetry, and tiling are some of the ideas at play here. Don't miss this unique opportunity for a different perspective on mathematics. The exhibition will be open during the regular exhibit hours.

The Mathematical Sciences in 2025, organized by **Mark L. Green**, University of California Los Angeles, and **Scott Weidman**, National Academy of Sciences; Saturday, 4:30 p.m.-5:20 p.m.

A study commissioned by the National Science Foundation and conducted by the National Academies under the auspices of the Board on Mathematical Sciences and Their Applications has begun that we hope will develop a strategic view that is useful to the NSF and other federal agencies; to chairs, deans, and academic administrators; to the mathematics and statistics communities; to the science and engineering community more broadly; and to the leadership of business, industry, government laboratories, and federal mission agencies.

This study will be a strategic examination of the mathematical sciences and how they can best position themselves to grow and contribute through 2025. It will cover three aspects of the mathematical sciences enterprise: discovery, connections, community. Here, "discovery" refers to basic research at the frontiers of knowledge in mathematics and statistics. "Connections" refers to exploiting research opportunities at boundaries of the mathematical sciences to promote the progress of science, to enhance national security, and to strengthen economic competitiveness. "Community" refers to cultivating a community of researchers, students, and professionals of sufficient breadth, depth, and diversity to sustain the nation's mathematical sciences enterprise in the twenty-first century. Please come to hear more about our goals and to be part of a dialog with the mathematical community.

Summer Program for Women in Mathematics (SPWM) Reunion, Friday 1:00 p.m.–4:00 p.m., organized by **Murli M. Gupta**, George Washington University. SPWM participants will describe their experiences from past programs. See `http://www.gwu.edu/~spwm` for more information.

Social Events

All events listed are open to all registered participants. It is strongly recommended that for any event requiring a ticket, tickets should be purchased through advance registration. Only a very limited number of tickets, if any, will be available for sale on site. If you must cancel your participation in a ticketed event, you may request a 50% refund by returning your ticket(s) to the Mathematics Meetings Service Bureau (MMSB) **by December 27.** After that date no refunds can be made. Special meals are available at banquets upon advance request, but this must be indicated on the Advance Registration/Housing Form. Special meals may be subject to additional fees.

AMS Banquet: As a fitting culmination to the meetings, the AMS banquet provides an excellent opportunity to socialize with fellow participants in a relaxed atmosphere. The participant who has been a member of the Society for the greatest number of years will be recognized and will receive a special award. The banquet will be held on Sunday, with dinner served at 7:30 p.m. Tickets are US$53 including tax and gratuity. The banquet will be preceded by a reception at 6:30 p.m.

Association of Christians in the Mathematical Sciences (ACMS) Reception and Banquet, Friday, 6:00 p.m.–8:30 p.m. This annual dinner at 6:30 p.m. is preceded by a reception at 6:00 p.m. and will be followed by an after-dinner talk by **Maria Zack**. Tickets must be ordered by **November 30**; see `www.acmsonline.org` for details and cost.

Association of Lesbian, Gay, Bisexual, and Transgendered Mathematicians Reception, Friday, 6:00 p.m.–8:00 p.m. All are welcome to attend this open reception cosponsored by NOGLSTP. Come and meet some old friends and allies, and make new friends, too!

AWM Reception: There is an open reception on Thursday at 9:30 p.m. after the AMS Gibbs Lecture. This has been a popular, well-attended event in the past.

AWM Luncheon to honor Noether Lecturer, M. Susan Montgomery, on Friday. Those interested may email `awm@awm-math.org`; a sign-up sheet for those interested will also be located at the AWM table in the exhibit area and also at the AWM Business Meeting on Thursday afternoon.

AWM 40th Anniversary Banquet and Jazz, Friday, 7:00 p.m.–10:00 p.m. Come celebrate the 40th anniversary of the AWM with your friends and colleagues with a few invited toasts followed by some of New Orleans' finest jazz. Tickets are US$60, including tax and gratuity.

Budapest Semesters in Mathematics Annual Alumni Reunion, Saturday, 6:00 p.m.–8:00 p.m. All alumni, family, and spouses are invited.

Claremont Colleges Alumni Reception, Friday, 7:00 p.m.–9:00 p.m. All math faculty, alumni, students, and friends are invited. H'ors d'oeuvres and drinks will be served, and special guests are welcome! Please send your RSVP to `alumni@hmc.edu`.

Reception for Graduate Students and First-Time Participants, Thursday, 5:30 p.m.–6:30 p.m. The AMS and the MAA cosponsor this social hour. Graduate students and first-timers are especially encouraged to come and meet some old-timers to pick up a few tips on how to survive the environment of a large meeting. Refreshments will be served.

Knitting Circle, Friday, 8:15 p.m.–9:45 p.m. Bring a project (knitting/crochet/tatting/beading/etc.) and chat with other mathematical crafters!

MAA–Project NExT Reception, Saturday, 8:30 p.m.–10:30 p.m., organized by **Judith Covington**, Louisiana State University Shreveport; **Joseph A. Gallian**, University of Minnesota-Duluth; **Aparna W. Higgins**, University of Dayton; and P. Gavin LaRose All Project NExT Fellows, consultants, and other friends of Project NExT are invited.

MAA Two-Year College Reception, Thursday, 5:45 p.m.–7:00 p.m., is open to all meeting participants, particularly two-year faculty members. This is a great opportunity to meet old friends and make some new ones. There will be hot and cold refreshments and a cash bar. Sponsored by Pearson Education.

***Mathematical Reviews* Reception**, Friday, 6:00 p.m.–7:00 p.m. All friends of *Mathematical Reviews* (*MR*) are invited to join reviewers and *MR* editors and staff (past and present) for a reception in honor of all the efforts that go into the creation and publication of the *Mathematical Reviews* database. Refreshments will be served.

Mathematical Institutes Open House, Wednesday, 5:30 p.m.–8:00 p.m. Participants are warmly invited to attend this open house cosponsored by several North American mathematical institutes. Come find out about the latest activities and programs at each of the institutes that may be suited to your own research interests.

MER Banquet: The Mathematicians and Education Reform (MER) Forum welcomes all mathematicians who are interested in precollege, undergraduate, and/or graduate educational reform to attend the MER banquet on Friday evening. This is an opportunity to make or renew contacts with other mathematicians who are involved in education projects and to engage in lively conversation about educational issues. The after-dinner discussion is an open forum for participants to voice their impressions, observations, and analyses of the current education scene. There will be a cash bar beginning at 6:30 p.m. Dinner will be served at 7:30 p.m. Tickets are US$55 each, including tax and gratuity.

NAM Banquet, Saturday, 6:00 p.m.–8:40 p.m. The National Association of Mathematicians will host a banquet on Friday evening. A cash bar reception will be held at 6:00 p.m., and dinner will be served at 6:30 p.m. Tickets are US$53 each, including tax and gratuity. The Cox-Talbot Invited Address will be given after the dinner.

NSA Women in Mathematics Society Networking Session, Thursday, 6:00 p.m.–8:00 p.m. All participants are welcome to this annual event. Please stop by the NSA booth in the exhibit hall for the exact location.

New Mexico State University Mathematics Association Reception, Friday, 5:30 p.m.–7:00 p.m. Alumni, faculty, and friends of the New Mexico State University Department of Mathematical Sciences are cordially invited to this reception.

Pennsylvania State University Mathematics Alumni Reception, Thursday, 6:00 p.m.–8:00 p.m. Please join us for h'ors d'oeuvres and beverages, and mingle with math alumni, faculty, and College of Science representatives.

Student Hospitality Center, Thursday–Saturday, 9:00 a.m.–5:00 p.m., and Sunday, 9:00 a.m.–3:00 p.m., organized by **Richard** and **Araceli Neal**, American Society for the Communication of Mathematics.

Reception for Undergraduates, Thursday, 4:00 p.m.–5:00 p.m.

Worship Service, Sunday, 7:00 a.m.–8:00 a.m. Begin the final day of the joint meetings by attending a nondenominational service provided by members of the Association of Christians in the Mathematical Sciences.

Other Events of Interest

AMS Information Booth: All meetings participants are invited to visit the AMS Information Booth during the meetings. A special gift will be available for participants, compliments of the AMS. AMS staff will be at the booth to answer questions about AMS programs and membership.

Book Sales and Exhibits: All participants are encouraged to visit the book, education media, and software exhibits from 12:15 p.m.–5:30 p.m. on Wednesday, 9:30 a.m.–5:30 p.m. on Thursday and Friday, and 9:00 a.m.–noon on Saturday. Books published by the AMS and MAA will be sold at discounted prices somewhat below the cost for the same books purchased by mail. These discounts will be available only to registered participants wearing the official meetings badge. Participants visiting the exhibits are required to display their meetings badge in order to enter the exhibit area.

The AMS and the MAA cordially invite all registered participants to enjoy complimentary tea and coffee while perusing the associations' booths.

Mathematical Sciences Employment Center: Those wishing to participate in the Mathematical Sciences Employment Center should read carefully the important article about the center beginning on page 1182 in this issue of *Notices* or at `www.eims.ams.org`. Employers should pay the appropriate fees; there are no fees for applicants to participate, except that all Employment Center participants must also register for the Joint Mathematics

Meetings (JMM). Official meeting badges are required to enter the Employment Center.

Networking Opportunities: There are many opportunities to meet new friends and greet old acquaintances in addition to the vast array of scientific sessions offered at these meetings. These opportunities are listed on the newcomers page at `www.ams.org/amsmtgs/2125_newcomers.html`. Newcomers may want to investigate the many receptions listed in the "Social Events" section, the Student Hospitality Center, and the Employment Center. On site, a Networking Center featuring casual seating and lists of registered participants sorted by school and math subject classification will be available for your perusal. This is a great place to relax between sessions and forge new friendships.

Registering in Advance and Obtaining Hotel Accommodations

The AMS and MAA make every effort to keep participant expenses at meetings and registration fees for meetings as low as possible. We work hard to negotiate the best hotel rates and to make the best use of your registration dollars to keep the meetings affordable for you. The AMS and the MAA encourage all participants to register for the meeting. When you pay the registration fee, you are helping to support a wide range of activities associated with planning, organizing, and running a major meeting of this size.

How to Register in Advance: The importance of advance registration cannot be overemphasized. Advance registration fees are considerably lower than the fees that will be charged for registration at the meetings. Participants registering by **November 19** may receive their badges, programs, and tickets (where applicable) in advance by mail approximately three weeks before the meetings. Those who do not want their materials mailed should check the box on the form. Because of delays that occur in U.S. mail to Canada, advance registrants from Canada must pick up their materials at the meetings. Because of delays that occur in U.S. mail to overseas, materials are never mailed overseas. There will be a special Registration Assistance Desk at the Joint Meetings to assist individuals who either did not receive this mailing or who have a problem with their registration. Please note that a US$5 replacement fee will be charged for programs and badges that are mailed but not taken to New Orleans. Acknowledgments of registrations will be sent by email to the email addresses given on the Advance Registration/Housing Form. If you do not wish your registration acknowledged by email, please mark the appropriate box on the form.

Internet Advance Registration: This service is available for advance registration and hotel reservations at `jointmathematicsmeetings.org/2125_reg.html`. VISA, MasterCard, Discover, and American Express are the only methods of payment which are accepted for Internet advance registration, and charges to credit cards will be made in U.S. funds. All Internet advance registrants will receive acknowledgment of payment upon submission of this form.

Cancellation Policy: Those who cancel their advance registration for the meetings, minicourses, or short courses by **December 31** will receive a 50% refund of fees paid. Those who cancel their banquet tickets by December 27 will receive a 50% refund of monies paid. No refunds will be issued after these dates.

Joint Mathematics Meetings Registration Fees

	by Dec. 22	at meeting
Member of AMS, ASL, CMS, MAA, SIAM	US$224	US$294
Emeritus Member of AMS, MAA; Unemployed; High School Teacher; Developing Countries Special Rate; Librarian	49	59
Graduate Student Member of AMS, MAA	49	59
Graduate Student Nonmember	76	86
Undergraduate Student	42	52
High School Student	5	10
Temporarily Employed	181	210
Nonmember	349	453
One-Day Member of AMS, ASL, CMS, MAA, SIAM	N/A	160
One-Day Nonmember	N/A	250
Nonmathematician Guest	15	15
MAA Minicourses	75	75*
*if space is available		
Grad Student Fair (table/posterboard/electricity)	US$60	N/A
AMS Short Course		
Member of AMS or MAA	US$100	US$140
Nonmember	134	170
Student/Unemployed/Emeritus	48	69
MAA Short Course		
MAA or AMS Member	US$150	US$160
Nonmember	200	210
Student/Unemployed/Emeritus	75	85

Full-Time Students: Those currently working toward a degree or diploma. Students are asked to determine whether their status can be described as graduate (working toward a degree beyond the bachelor's), undergraduate (working toward a bachelor's degree), or high school (working toward a high school diploma) and to mark the Advance Registration/Housing Form accordingly.

Graduate Student: Those currently working toward a degree or diploma. Students are asked to determine whether their current status can be described as graduate (working toward a degree beyond the bachelor's), undergraduate (working towards a bachelor's degree), or high school (working toward a high school diploma). The member status refers to any graduate student who is a member of the AMS or MAA. These students should check with their department administrator to check their membership status.

Emeritus: Any person who has been a member of the AMS or MAA for twenty years or more and who retired because of age or long-term disability from his or her latest position.

Librarian: Any librarian who is not a professional mathematician.

Unemployed: Any person currently unemployed, actively seeking employment, and not a student. It is not intended to include any person who has voluntarily resigned or retired from his or her latest position.

Developing Country Participant: Any person employed in developing countries where salary levels are radically noncommensurate with those in the U.S.

Temporarily Employed: Any person currently employed but who will become unemployed by June 1, 2011, and who is actively seeking employment.

Nonmathematician Guest: Any family member or friend who is not a mathematician and who is accompanied by a participant in the meetings. These official guests will receive a badge and may attend all sessions and the exhibits.

Participants Who Are Not Members of the AMS or MAA and register for the meetings as a nonmember will receive mailings after the meetings are over with a special membership offer.

Advance registration and on-site registration fees only partially cover the expenses of holding meetings. All mathematicians who wish to attend sessions are expected to register and should be prepared to show their badges if so requested. Badges are required to enter the exhibit area, to obtain discounts at the AMS and MAA Book Sales, and to cash a check with the Joint Meetings cashier.

Advance registration forms accompanied by insufficient payment will be returned, thereby delaying the processing of any housing request, or a US$5 charge will be assessed if an invoice must be prepared to collect the delinquent amount. Overpayments of less than US$5 will not be refunded.

For each invalid check or credit card transaction that results in an insufficient payment for registration or housing, a US$5 charge will be assessed. Participants should check with their tax preparers for applicable deductions for education expenses as they pertain to these meetings.

If you wish to be included in a **list of individuals sorted by mathematical interest**, please provide the one mathematics subject classification number of your major area of interest on the Advance Registration/Housing Form. (A list of these numbers is available by sending an empty email message to `abs-submit@ams.org`; include the number 1067 as the subject of the message.) Copies of this list will be available for your perusal in the Networking Center.

If you do not wish to be included in any mailing list used for promotional purposes, please indicate this in the appropriate box on the Advance Registration/Housing Form.

Advance Registration Deadlines

There are three separate advance registration deadlines, each with its own advantages and benefits.

EARLY meetings advance registration (room drawing)	**November 5**
ORDINARY meetings advance registration (hotel reservations, materials mailed)	**November 19**
FINAL meetings advance registration (advance registration, short courses, Employment Center, minicourses, banquets)	**December 15**

Early Advance Registration: Those who register by the early deadline of **November 5** will be included in a random drawing to select winners of complimentary hotel rooms in New Orleans. Multiple occupancy is permissible. The location of rooms to be used in this drawing will be based on the number of complimentary rooms available in the various hotels. Therefore, the free room may not necessarily be in the winner's first-choice hotel. The winners will be notified by mail prior to **December 24**. So register early!

Ordinary Advance Registration: Those who register after **November 5** and by the ordinary deadline of **November 19** may use the housing services offered by the MMSB but are not eligible for the room drawing. You may also elect to receive your badge and program by mail in advance of the meetings.

Final Advance Registration: Those who register after **November 19** and by the final deadline of **December 15** must pick up their badges, programs, and any tickets for social events at the meetings. Unfortunately, it is sometimes not possible to provide final advance registrants with housing, so registrants are strongly urged to make their hotel reservations by **November 19**. Please note that the **December 15** deadline is firm; any forms received after that date will be returned and full refunds issued. To pick up your materials, please come to the Meetings Registration Desk located on the second floor of the New Orleans Marriott.

Special Assistance

We strive to take the appropriate steps required to ensure that no individual with a disability is excluded, denied services, segregated, or otherwise treated differently. Please tell us what you require to help make your participation more enjoyable and meaningful. If you require special assistance, auxiliary aids or other reasonable accommodations to fully participate in this event, please check off the appropriate box on the Registration/Housing Form or email the MMSB at `mmsb@ams.org`. All requests for special accommodations under the Americans with Disabilities Act of 1990 (ADA) must be made allowing enough time for evaluation and appropriate action by the JMM. Any information regarding your disability will remain confidential.

Hotel Reservations

The AMS and MAA contract only with facilities who are working toward being in compliance with the public accommodations requirements of ADA. Participants requiring hotel reservations should read the instructions on the following hotel pages. Participants who did not reserve a room during advance registration and would like to obtain a room at one of the hotels listed on the following pages should call the hotels directly after **December 17**. However, the MMSB can no longer guarantee availability of rooms or special convention rates after that date.

Participants should be aware that most hotels are starting to charge a penalty fee to guests for departure changes made before or after guests have checked into their rooms. These hotels are indicated on the hotel page at `jointmathematicsmeetings.org/2125_hotelpage.html`. Participants should also inquire about this at check-in and make their final plans accordingly.

Participants should also be aware that it is general hotel practice in most cities to hold a nonguaranteed reservation until 6:00 p.m. only. When one guarantees a reservation by paying a deposit or submitting a credit card number as a guarantee in advance, however, the hotel will usually honor this reservation until checkout time the following day. If the individual holding the reservation has not checked in by that time, the room is then released for sale, and the hotel retains the deposit or applies a room charge to the credit card number submitted equivalent to a one-night stay.

If you hold a guaranteed reservation at a hotel but are informed upon arrival that there is no room for you, there are certain things you can request the hotel do. First, they should provide for a room at another hotel in town for that evening at no charge. (You already paid for the first night when you made your deposit.) Second, they should pay for taxi fares to the other hotel that evening and back to the hotel the following morning, assuming a room is available. Third, they should pay for one telephone call so that you can notify people of where you are staying. The hotel should make every effort to find a room for you in their hotel the following day and, if successful, pay your taxi fares to and from the second hotel so that you can pick up your baggage and bring it to the first hotel. Not all hotels in all cities follow this practice, so your request for these services may bring mixed results or none at all. If you did not receive satisfactory service in this regard, please inform the Housing Coordinator for the meeting.

Importance of Staying in the Official Meetings Hotels: Your patronage of the official Meetings hotels enables the JMM to secure the meeting space at a greatly reduced cost which helps to keep the cost of the meeting and your registration fees down.

Room Drawing: Win FREE room nights at our official hotels as listed on the hotel pages. Multiple winners! Participants who register and reserve a room at any of the listed meetings hotels by **November 5**, will automatically be included in a random drawing to select a winner of free room nights in that hotel. The number of drawings to be made will be based on the number of complimentary room nights available in the various hotels. Multiple occupancy is permissible. The winners will be drawn at random from the hotel reservation lists and notified by email or phone prior to December 24.

Miscellaneous Information

Audio-Visual Equipment: Standard equipment in all session rooms is one overhead projector and screen. Invited 50-minute speakers are automatically provided with two overhead projectors and a laptop projector; AMS Special Sessions and Contributed Papers, and MAA Invited and Contributed Paper Sessions, are provided with the standard equipment and a laptop projector. Blackboards are not available, nor are Internet hookups in session rooms. Any request for additional equipment should be sent to `meet@ams.org` and received by November 1.

Equipment requests made at the meetings most likely will not be granted because of budgetary restrictions. Unfortunately no audio-visual equipment can be provided for committee meetings or other meetings or gatherings not on the scientific program.

Childcare: The American Mathematical Society and the Mathematical Association of America will again offer childcare services for the Joint Mathematics Meetings to registered participants.

The childcare will be offered through KiddieCorp Children's Program. KiddieCorp is an organization that has been providing high-quality programs for children of all ages at meetings throughout the United States and Canada since 1986. Read all about them at `www.kiddiecorp.com/`.

The childcare services provided at the JMM are for children ages 6 months through 12 years old. Space per day will be limited and is on a space available basis. The dates and times for the program are January 6–9, 2011, 8:00 a.m.–5:00 p.m. each day. It will be located at the Sheraton New Orleans. If you would like to know how many children will be in the same age group as your child's, please call KiddieCorp. Parents are encouraged to bring snacks and beverages for their children but items such as juice boxes, Cheerios, and crackers will be provided. KiddieCorp can arrange meals for children at cost plus 15% or parents can be responsible for meals for their children. Parents who have questions about specific programs that will be offered or special requests, rules, or needs for their children must call KiddieCorp ahead of time.

Registration starts on **September 1**. The registration fee is US$30 per family (nonrefundable). Additional cost will be US$10 per hour per child or US$8 per hour per child for graduate students. These reduced child care rates are made possible to the meetings participant by the American Mathematical Society and the Mathematical Association of America, who heavily subsidize the cost of this service, thus keeping this program affordable for families. Parents must be registered for the JMM to participate. Full payment is due at the time of registration with KiddieCorp. Deadline for registering is **December 9, 2010**.

If parents do not pick up their children at the time scheduled or by the end of the day (no later than 5:00 p.m.), they will be charged a late fee of US$5 per child for every 15 minutes thereafter.

Cancellations must be made to KiddieCorp prior to December 9, 2010, for a full refund. Cancellations made after that date will be subject to a 50% cancellation fee. Once the program has begun, no refunds will be issued.

To register, go to `https://www.kiddiecorp.com/jmmkids.htm` or call KiddieCorp at 858-455-1718 to request a form.

Email Services: Limited email access for all Joint Meetings participants will be available in an email center located near the JMM Registration Desk. The hours of operation will be published in the program. Participants should be aware that **complimentary Internet access** will be available in the public areas of the New Orleans Marriott Hotel.

Information Distribution: Tables are set up in the exhibit area for dissemination of general information of possible interest to the members and for the dissemination of information of a mathematical nature not promoting a product or program for sale. Information must be approved by the director of meetings prior to being placed on these tables.

If a person or group wishes to display information of a mathematical nature promoting a product or program for sale, they may do so in the exhibit area at the Joint Books, Journals, and Promotional Materials exhibit for a fee of US$50 (posters are slightly higher) per item. Please contact the exhibits manager, MMSB, P.O. Box 6887, Providence, RI 02940, or by email at `cpd@ams.org` for further details.

The administration of these tables is in the hands of the AMS-MAA Joint Meetings Committee, as are all arrangements for Joint Mathematics Meetings.

Local Information: For information about the city see `www.neworleanscvb.com/jointmath`.

Petition Table: At the request of the AMS Committee on Human Rights of Mathematicians, a table will be made available in the exhibit area at which petitions on behalf of named individual mathematicians suffering from human rights violations may be displayed and signed by meetings participants acting in their individual capacities. For details contact the director of meetings in the Providence office at 401-455-4145 or by email at `pop@ams.org`.

Signs of moderate size may be displayed at the table but must not represent that the case of the individual in question is backed by the Committee on Human Rights unless it has, in fact, so voted. Volunteers may be present at the table to provide information on individual cases, but notice must be sent at least seven days in advance of the meetings to the director of meetings in the Providence office. Since space is limited, it may also be necessary to limit the number of volunteers present at the table at any one time. The Committee on Human Rights may delegate a person to be present at the table at any or all times, taking precedence over other volunteers.

Any material that is not a petition (e.g., advertisements, résumés) will be removed by the staff. At the end of the exhibits on Sunday, any material on the table will be discarded, so individuals placing petitions on the table should be sure to remove them prior to the close of exhibits.

Telephone Messages: The most convenient method for leaving a message is to do so with the participant's hotel. Another method would be to leave a message at the meetings registration desk from January 6 through 9 during the hours that the desk is open. These messages will be posted on the Mathematics Meetings Message Board; however, staff at the desk will try to locate a participant in the event of a bona fide emergency. The telephone number will be published in the program and daily newsletter.

Travel/Transportation

New Orleans is on Central Standard Time. Louis Armstrong New Orleans International Airport (MSY) in Kenner, Louisiana, is located approximately 15 miles north of the French Quarter in New Orleans and is served by all major airlines.

Airline

The official airline for the meeting is United Airlines. Book your flight for the meeting with United or United Express and receive special pricing on scheduled service to New Orleans on applicable carriers. Book your airline reservation with United by calling the toll free reservation line (800-521-4041), going to `united.com`, or going through through your preferred travel professional. **Please be sure to reference the Meeting ID / Tour Code 586XQ**. Reservation agents are available Monday thru Friday from 8:00 a.m. to 10:00 p.m. (ET) at 800-521-4041. **The specialized meeting reservations center will be closed on all major holidays.**

Special pricing includes:

• 5% off published fares—a percentage discount off published fares for qualifying travel in or between the domestic 48 States, Hawaii, and Canada when the tickets are purchased subject to all restrictions and rules applicable to the fare purchased and issued in the United States; see below for other discounts available with over 30 days advance ticketing.

DOMESTIC–US 48 states, Hawaii, & Canada	
Booking Class Discount Account Code All Classes (F,J,A,C,D,Y-L)	5%
Over 30 Days Advance Ticketing	
A,Q,V,W	7%;
M,E,U,H,F,J,C,D,Y,B	10%

• 5% percent discount off `united.com` bookings. Not applicable for discounts off Internet only fares. Applicable for U.S./Canadian locations only.

Additional benefits are:

• Mileage Plus® miles—Each Mileage Plus member will receive full credit to their account for all their miles flown when attending this meeting.

• Special discounts on car rentals with Hertz—Hertz will offer, to participants of the Joint Mathematics Meetings, discounts of up to 20% off the applicable rental rates when reservations are made in conjunction with United Airlines air reservations. To make reservations with Hertz and take advantage of this discount, call 888-444-1074 or to go `www.Hertz.com`. Please make sure you reference Hertz Discount number **CV 02R30006**. See other rental car options below.

Advance Check-In

Available seven days a week, Advance Check-In luggage delivery services will transfer your luggage from the Airport to your hotel. Enjoy New Orleans while leaving behind the worry of carrying around your luggage. For

How to Obtain Hotel Accommodations – 2011 Joint Mathematics Meetings

General

Participants must register in advance in order to obtain hotel accommodations through the Mathematics Meetings Service Bureau (MMSB). Special rates have been negotiated exclusively for this meeting at the following hotels: New Orleans Marriott, Sheraton New Orleans, JW Marriott New Orleans, and Astor Crowne Plaza New Orleans. Reservations must be made through the MMSB to receive these rates. These hotels can ONLY accept reservations directly after **December 17**, at which time rooms and rates will be based on availability. Higher rates will be applied to any rooms reserved directly with these hotels before **December 17.**

To reserve a room, please complete the housing section of the Advanced Registration/Housing (ARH) Form (via paper or the web) by **November 19.** All reservations must be guaranteed by either credit card or deposit by check in the total amount of first night stay. If you use the online form, a credit card number will be required for guarantee. If you use the paper form, a credit card number or check may be given for guarantee. For your security, credit card numbers will not be accepted by postal mail, e-mail, or fax. If you wish to guarantee your room by credit card and are submitting a paper form, the MMSB will call you at the number provided. The online form is located at www.ams.org/meetreg?meetnum=2125. The paper form is located at the back of this announcement. Participants interested in suites should contact the MMSB at mmsb@ams.org or 1-800-321-4267 ext. 4137 or 4144 for further information. **Sorry, reservations cannot be taken over the phone.**

Confirmations

All hotels will be sending out e-mail confirmations if an e-mail address is provided. Please contact the MMSB after **December 17** if you did not receive a confirmation number.

ADA Accessibility

We strive to take the appropriate steps required to ensure that no individual with a disability is excluded, denied services, segregated or otherwise treated differently. Please tell us what you require to help make your participation more enjoyable and meaningful. If you require special assistance, auxiliary aids or other reasonable accommodations to fully participate in this event, please check off the appropriate box on the Registration/Housing Form or e-mail the MMSB at mmsb@ams.org. All requests for special accommodations under the Americans with Disabilities Act of 1990 (ADA) must be made allowing enough time for evaluation and appropriate action by the AMS and MAA. Any information regarding your disability will remain confidential.

Deadlines

- Complimentary Room Drawing: **November 5**
- Reservations through MMSB: **November 19**
- Changes/Cancellations through MMSB: **December 6**

Complimentary Room Drawing

Anyone who reserves a room through the MMSB by **November 5** is eligible for a drawing to receive complimentary room nights during the meeting. See *How to Register in Advance* for details.

Looking for a Roommate?

For your convenience, a search board has been set up at `http://boards2go.com/boards/board.cgi?user=webgoddess1` to help you find a roommate. Good Luck!

Environmental Policies

The majority of the hotels have successful "green" programs in place. Since 2004 Marriott has been awarded more ENERGY STAR labels than any other hotel company. In addition, the Sheraton has numerous guest reward programs in place, such as *"Green Guest Linen and Terry Program"*.

Rates

- Subject to a 13% tax/TID tax plus an additional occupancy charge of US$3
- Only certified students or unemployed mathematicians qualify for student rates.
- See the Advanced Registration/Housing (ARH) Form for a detailed breakdown of rates for each hotel.

Cancellation Policies

- All four hotels: 72 hours prior to arrival, to avoid penalties

Guarantee Requirements

- One night deposit by check, or
- Credit cards (online only): Visa, MC, AMEX, Diners, and Discover. If you reserve a room by paper form, the MMSB will contact you at the phone number provided. For your security, we do not accept credit card numbers by postal mail, e-mail or fax.

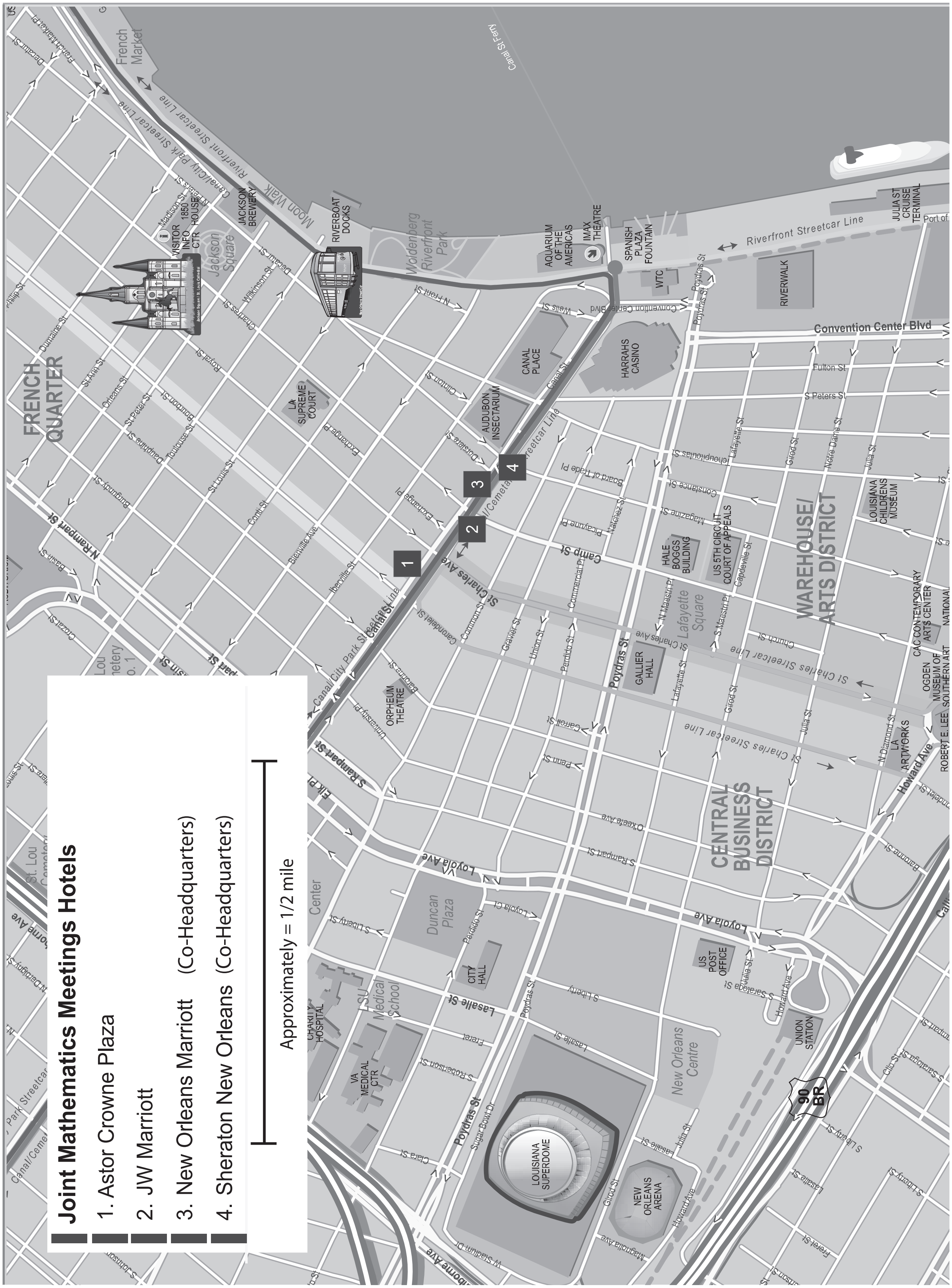
Check-in/Check-out

Check-in at each hotel is 3:00 p.m. Check-out at each hotel is noon.

Internet Access/Wireless

- **Marriott New Orleans:** Complimentary wireless in the lobby and public areas; wired ONLY in guest rooms for a daily rate of US$14.95
- **Sheraton New Orleans:** Complimentary wireless in the lobby and public areas to hotel guests ONLY; wired ONLY in the guest rooms for a daily rate of US$14.95
- **JW Marriott New Orleans:** Complimentary wireless in the lobby and public areas to hotel guests ONLY; wired ONLY in the guest rooms for a daily rate of US$14.95
- **Astor Crowne Plaza New Orleans:** Complimentary wireless in the lobby and public areas; wired ONLY in guest rooms for a daily rate of US$9.95

New Orleans Marriott (Co Headquarters)	Sheraton New Orleans (Co Headquarters)	JW Marriott New Orleans (~1 block from Marriott and Sheraton)	Astor Crowne Plaza New Orleans (~1.5 blocks from Marriott and Sheraton)
555 Canal Street New Orleans, LA 70130 504-581-1000 Single US$158, Double: US$168 Student Single/Double: US$120	500 Canal Street New Orleans, LA 70130 504-525-2500 Main House: Single: US$158, Double: US$178 Club House: Single: US$189, Double: US$199 Student Single/Double US$120 (Main House Only)	614 Canal Street New Orleans, LA 70130 504-525-6500 Single: US$148, Double: US$158	739 Canal Street New Orleans, LA 70130 504-962-0500 Single/Double: US$119 Student Single/Double: US$109
Smoke-free hotel. Restaurants: 5 Fifty 5, 55 Fahrenheit, and Starbucks; Fitness center; Outdoor pool; Spa services; Business center; Full amenities in guest rooms; Safety deposit boxes at front desk; Windows do not open in any rooms, including suites; Children under 15 free in room with an adult; Cribs available upon request at no charge; No pets allowed except service animals; Valet parking only US$33.60 + tax per day; one vehicle allowed per room with limited height restrictions. See the travel section of this announcement for other parking options. **Confirmations sent by e-mail only.**	Smoke-free hotel. Restaurants: Pelican Bar, Roux Bistro, and Starbucks; Fitness center; Outdoor pool; Spa services; Business center; Full amenities in guest rooms; In-room safe; Windows do not open in any rooms, including suites; Children under 18 free in room with an adult; Cribs available upon request at no charge; Pets allowed (under 80 pounds only); Valet parking only for US$22.95 + tax per day (due to height restrictions, oversized vehicles cannot be valet parked). See the travel section of this announcement for other parking options. **Confirmations sent by e-mail only.**	Smoke-free hotel. Restaurants: Shula's America's Steak House, Shula's Lounge (bar), and Lobby Lounge (bar); Spa services; Business center; Full amenities in guest rooms; Safety deposit boxes available at front desk; Windows do not open in any rooms, including suites; Children under 16 free in room with an adult; Cribs available upon request at no charge; Valet parking only for registered guests for US$32.00 + tax per day with limited height restrictions. See the travel section of this announcement for other parking options. **Confirmations sent by e-mail only.**	Smoke-free hotel. Restaurant: Dickie Brennan's Bourbon House Restaurant & Seafood; Fitness center; Spa services; Business center; Full amenities in guest rooms; Safety deposit boxes available at front desk; Windows do not open in any rooms, including suites; Children under 17 free in room with an adult; Cribs available upon request at no charge; Valet parking for registered hotel guests for US$32.00 + tax per day with limited height restrictions. See the travel section of this announcement for other parking options. **Confirmations sent by e-mail only.**


Joint Mathematics Meetings Hotels
1. Astor Crowne Plaza
2. JW Marriott
3. New Orleans Marriott (Co-Headquarters)
4. Sheraton New Orleans (Co-Headquarters)
Approximately = 1/2 mile
FRENCH QUARTER
CENTRAL BUSINESS DISTRICT
WAREHOUSE/ ARTS DISTRICT
Jackson Square
Woldenberg Riverfront Park
Lafayette Square
Duncan Plaza
LOUISIANA SUPERDOME
NEW ORLEANS ARENA
New Orleans Centre
HARRAHS CASINO
CANAL PLACE
RIVERWALK
AQUARIUM OF THE AMERICAS
IMAX THEATRE
SPANISH PLAZA FOUNTAIN
UNION STATION
CITY HALL
US POST OFFICE
Riverfront Streetcar Line
St Charles Streetcar Line
Canal/City Park Streetcar Line
Canal St
Poydras St
Loyola Ave
Convention Center Blvd

more information go to www.advancecheckin.com or call toll-free at 877-467-8898. Agents are available on the lower airport level next to Belt #1 in the baggage claim area 8:00 a.m.–midnight. The charge is US$25.00 for up to three pieces of luggage. Additional bags can be included for US$5.00 each. There may be additional charges for overweight bags. Hotel pick-up requests must be made online.

Traveling from the Airport

To depart the New Orleans airport, head to the lower level baggage claim area, unless you are planning to take the city bus which departs from upper level entrance #7.

SPECIAL!! Motion Transportation LLC: Motion Transportation LLC is offering Joint Mathematics Meetings participants a special offer of US$30 per person round trip, and US$15 per person one way from the Louis Armstrong New Orleans International Airport. Reservations can be made by going to their website, www.motiontransportation.com, or by calling 504-390-3567 and mentioning group code **JMM-2011**. To reserve online, proceed as follows:

- Go to www.motiontransportation.com
- Click on "JMM" button
- Fill in information that is requested and if necessary reference **"JMM-2011"**
- Once page is complete, hit the submit button.
- You will receive a confirmation page.
- Other information: For arrival, participants with reservations will be met by a greeter (holding a sign with "JMM") in the baggage claim area. For departure, participants will need to make arrangements to be picked up two hours prior to their plane departures.
- If questions, call 504-390-3567.

Airport Shuttle: Airport Shuttle, (866-596-2699, 504-522-3500, www.airportshuttleneworleans.com) is the official ground transportation provider for the Louis Armstrong New Orleans International Airport. Shuttle service is available from the airport to the hotels for US$20/per person, one-way, and US$38/per person, round-trip. The first three bags per passenger are free. Travelers must provide their own child car seats or booster seats. Advance reservations are required 48 hours prior to travel for all ADA accessible transfers. Please call well enough in advance for the specially-equipped shuttle to be reserved.

Ticket desks are located on the lower level in the baggage claim area. After you have retrieved your luggage, proceed to the Airport Shuttle Ticket Desk, across from baggage claim areas 3, 6, and 12. The desk is staffed from 8:00 p.m. to 11:00 p.m. After 11:00 p.m. you can purchase a one-way cash ticket from any driver on the loading dock outside of baggage claim area 6, and the driver will provide you with a receipt, if needed. Service is available on a continuous basis with vans departing approximately every 30 minutes. Airport Shuttle vans are white with yellow lettering with "Airport Shuttle" and the phone number 522-3500 on the side. Return trips are best reserved at least 24 hours prior to your flight.

Taxicabs: A cab ride to the Central Business District or the French Quarter costs approximately US$33 for one or two persons and US$14 (per passenger) for three or more passengers. Pickup is on the lower level, outside the baggage claim area. There may be an additional charge for extra baggage.

Bus/Public Transit: The Airport-Downtown Express E-2 Bus picks up outside airport Entrance #7 near the Delta counter on the upper (second) level. In the median, look for the sign and bench. Take the E-2 Bus to Carrollton at Tulane. At Carrollton and Tulane, on the corner by the Burger King, transfer to the #39 Tulane Bus. The #39 will take you to Canal Street at Saratoga. Walk to the middle of Canal Street and wait for the #47-48 Canal Streetcar going toward the river. The Marriott, the Sheraton, the JW Marriott, and the Astor Crowne Plaza are all on Canal Street. There is a streetcar stop about every other block on Canal Street near the French Quarter; get off at Canal and Bourbon Street for the Astor Crowne Plaza, Canal and Chartres for the JW Marriott and at either Canal at Chartres or Canal and Decatur for the New Orleans Marriott and the Sheraton New Orleans. For further information and schedules: E-2 Bus: www.jeffersontransit.org. New Orleans city bus routes: go to www.norta.com, call 504-248-3900 or send email to rideline@norta.com . The current fare for the Airport-Downtown Express (E-2) is US$2. The fareboxes will accept US$1, US$5, US$10, US$20 dollar bills and all U.S. coins, and will provide change in the form of a value card that can be used for future fares. The New Orleans city bus fares are currently US$1.25; senior citizens with valid ID, US$0.40, transfers are 25 cents.

Driving directions to the hotels: Go east on Jerome S. Glazer Airport Access Road toward Airport Access Road (Jerome S. Glazer Airport Access Road turns into Airport Access Road). Take the ramp onto I-10 E. At exit 234 take the left lane toward Poydras Street/Superdome. Stay straight to go onto Poydras Street. Take a left on Camp Street, and continue to Canal Street. To go to the Sheraton, take a right on Canal, the hotel is straight ahead on your right. To go to the New Orleans Marriott, take a right on Canal Street; get into the left-hand lane and make a small U-turn. You will be in front of the Marriott. Continue a few blocks past the Marriott to get to the Astor Crowne Plaza at Canal and Bourbon Street. To go to the JW Marriott, after you take a left on Camp Street, go three blocks to Common Street, and turn left again. The motor lobby entrance is located on the right at 611 Common Street between Camp Street and St. Charles Avenue.

Car Rental

The car rental agencies are located on the lower level of the airport. **Avis** is the official car rental company for the Joint Mathematics Meetings in New Orleans. All rates include unlimited free mileage. Rates do not include any state or local surcharges, tax, optional overages, or gas refueling charges. Renters must meet Avis's age, driver, and credit requirements. For the best available rate and to make a reservation, please call Avis at 800-331-1600 or go online at http://www.avis.com. Please use the Avis Discount Number **J098887**.

Parking Information

Valet parking only with some height restrictions is available at the New Orleans Marriott, Sheraton New Orleans, JW Marriott, and the Astor Crowne Plaza. Please see the hotel page for details. Some other options for parking are:

• **Premium Parking Service**, Iberville Garage, 716 Iberville Street, New Orleans, LA 70130, 504-522-5975, www.premiumparkingservice.com/index2.shtml. Cost: 0–2 hours—US$9; 2–3 hours—US$11; 3–10 hours—US$13; 10–24 hours—US$20. Price includes valet service and 24-hour access. See website for details.

• **Central Parking System**, 365 Canal Street, New Orleans, LA, (504) 525-7275, www.parking.com. 365 Canal is a flat lot and there is a kiosk where you can purchase parking. Cost: 3 hours—US$15; 12 hours—US$25. See website for details.

Please go to http://www.neworleansonline.com/tools/transportation/gettingaround/parking.html for general information about parking in downtown New Orleans.

Public Transportation around New Orleans

Information on public transportation in New Orleans is at www.norta.com (see above for phone and email contact information); check this site for the latest bus and streetcar schedules, maps, and fares. New Orleans has three historic streetcar routes: the St. Charles Avenue Line, the Canal Street Line, and the Riverfront Line.

The St. Charles Line (Rt. 12) runs down St. Charles from Canal Street to Claiborne Avenue, going past Tulane and Loyola Universities, the Garden District, and Audubon Park. Canal Street has two lines. Rt. 47 Canal-Cemeteries travels the length of Canal Street, starting at the river and ending at City Park Avenue near Greenwood Cemetery. Rt. 48 Canal-City Park/Museum starts at the riverfront, travels up Canal Street, and ends near the entrance of the New Orleans Museum of Art. The Riverfront Line (Rt. 2) runs along the Mississippi River starting at the French Market; it stops at the riverfront on Canal Street near the Aquarium, and ends near the New Orleans Convention Center.

For the best value, consider VisiTour Passes offering unlimited rides. A one-day pass is US$5 and can be purchased on a bus or streetcar. Three- and five-day passes are also available.

Weather

New Orleans has a subtropical climate with pleasant year-round temperatures. In January, average temperatures range from a low of 43 degrees to a high of 63 degrees. For up-to-the minute weather information, consult your favorite weather site or check http://www.wunderground.com/US/LA/New_Orleans.html?bannertypeclick=big2.

Statesboro, Georgia

Georgia Southern University

March 12–13, 2011

Saturday – Sunday

Meeting #1068

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: January 2011
Program first available on AMS website: January 27, 2011
Program issue of electronic *Notices*: March 2011
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: November 23, 2010
For abstracts: January 20, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Jason A. Behrstock, Lehman College (CUNY), *Title to be announced*.

Gordana Matic, University of Georgia, *Title to be announced*.

Jeremy T. Tyson, University of Illinois at Urbana-Champaign, *Title to be announced*.

Brett D. Wick, Georgia Institute of Technology, *Title to be announced*.

Special Sessions

Advances in Biomedical Mathematics (Code: SS 4A), **Yangbo Ye**, University of Iowa, and **Jiehua Zhu**, Georgia Southern University.

Algebraic and Geometric Combinatorics (Code: SS 13A), **Drew Armstrong**, University of Miami, and **Benjamin Braun**, University of Kentucky.

Applied Combinatorics (Code: SS 2A), **Hua Wang**, Georgia Southern University, **Miklos Bona**, University of Florida, and **Laszlo Szekely**, University of South Carolina.

Categorical Topology (Code: SS 9A), **Frederic Mynard**, Georgia Southern University, and **Gavin Seal**, EPFL, Lausanne.

Control Systems and Signal Processing (Code: SS 14A), **Zhiqiang Gao**, Cleveland State University, **Frank Goforth**, Georgia Southern University, **Thomas Yang**, Embry-Riddle Aeronautical University, and **Yan Wu**, Georgia Southern University.

Fractals and Tilings (Code: SS 3A), **Ka-Sing Lau**, The Chinese University of Hong Kong, **Sze-Man Ngai**, Georgia Southern University, and **Yang Wang**, Michigan State University.

Geometric Group Theory (Code: SS 7A), **Xiangdong Xie**, Georgia Southern University, **Jason A. Behrstock**, Lehman College, CUNY, and **Denis Osin**, Vanderbilt University.

Geometric Mapping Theory in Euclidean and Non-Euclidean Spaces (Code: SS 11A), **Jeremy Tyson**, University of Illinois at Urbana-Champaign, **David A. Herron**, University of Cincinnati, and **Xiagdong Xie**, Georgia Southern University.

Harmonic Analysis and Applications (Code: SS 5A), **Dmitriy Bilyk**, University of South Carolina, **Laura De Carli**, Florida International University, **Alex Stokolos**, Georgia Southern University, and **Brett Wick**, Georgia Institute of Technology.

Harmonic Analysis and Partial Differential Equations (Code: SS 1A), **Paul A. Hagelstein**, Baylor University, **Alexander Stokolos**, Georgia Southern University, **Xiaoyi Zhang**, IAS Princeton and University of Iowa, and **Shijun Zheng**, Georgia Southern University.

Homological Methods in Commutative Algebra (Code: SS 6A), **Alina C. Iacob**, Georgia Southern University, and **Adela N. Vraciu**, University of South Carolina.

Matrix Theory and Numerical Linear Algebra (Code: SS 8A), **Richard S. Varga**, Kent State University, and **Xiezhang Li**, Georgia Southern University.

Sparse Data Representations and Applications (Code: SS 10A), **Alexander Petukhov** and **Alex Stokolos**, Georgia Southern University, **Ahmed Zayed**, DePaul University, and **Inna Kozlov**, Holon Institute of Technology, Department of Computer Science.

Symplectic and Poisson Geometry (Code: SS 12A), **Yi Lin**, Georgia Southern University, **Alvaro Pelayo**, Washington University, St. Louis, and **Francois Ziegler**, Georgia Southern University.

Iowa City, Iowa

University of Iowa

March 18–20, 2011

Friday – Sunday

Meeting #1069

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: January 2011
Program first available on AMS website: February 5, 2011
Program issue of electronic *Notices*: March 2011
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: November 30, 2010
For abstracts: January 25, 2011

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Mihai Ciucu, Indiana University, *Title to be announced.*

David Damanik, Rice University, *Title to be announced.*

Kevin Ford, University of Illinois Urbana-Champaign, *Title to be announced.*

Chiu-Chu Liu, Columbia University, *Title to be announced.*

Special Sessions

Algebraic K-Theory and Homotopy Theory (Code: SS 8A), **Teena Gerhardt**, Michigan State University, and **Daniel Ramras**, New Mexico State University.

Analytic Number Theory (Code: SS 5A), **Yangbo Ye**, University of Iowa.

Commutative Ring Theory (Code: SS 6A), **Daniel D. Anderson**, University of Iowa, and **David F. Anderson**, University of Tennessee Knoxville.

Geometric Commutative Algebra and Applications (Code: SS 7A), **David Anderson**, University of Washington, and **Julianna Tymoczko**, University of Iowa.

Global and P-adic Representation Theory (Code: SS 3A), **Muthukrishnan Krishnamurthy**, **Philip Kutzco**, and **Yangbo Ye**, University of Iowa.

Modelling, Analysis and Simulation in Contact Mechanics (Code: SS 1A), **Weimin Han**, University of Iowa, and **Mircea Sofonea**, University of Perpignan.

Recent Developments in Nonlinear Evolution Equations (Code: SS 4A), **Yinbin Deng**, Central China Normal University, **Yong Yu** and **Yi Li**, University of Iowa, and **Shuangjie Peng**, Central China Normal University.

Representations of Algebras (Code: SS 2A), **Frauke Bleher**, University of Iowa, and **Calin Chindris**, University of Missouri.

Worcester, Massachusetts

College of the Holy Cross

April 9–10, 2011

Saturday – Sunday

Meeting #1070

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: February 2011
Program first available on AMS website: March 10, 2011
Program issue of electronic *Notices*: April 2011
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 21, 2010
For abstracts: February 15, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Vitaly Bergelson, Ohio State University, *Title to be announced.*

Kenneth M. Golden, University of Utah, *Title to be announced.*

Walter D. Neumann, Columbia University, *Title to be announced.*

Natasa Sesum, University of Pennsylvania, *Title to be announced.*

Special Sessions

Complex Analysis and Banach Algebras (Code: SS 1A), **John T. Anderson**, College of the Holy Cross, and **Alexander J. Izzo**, Bowling Green State University.

Las Vegas, Nevada

University of Nevada

April 30 – May 1, 2011

Saturday – Sunday

Meeting #1071

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: February 2011
Program first available on AMS website: March 17, 2011
Program issue of electronic *Notices*: April 2011
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 30, 2010
For consideration of contributed papers in Special Sessions: January 1, 2011
For abstracts: March 8, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Elizabeth Allman, University of Alaska, *Title to be announced.*

Danny Calegari, California Institute of Technology, *Title to be announced.*

Hector Ceniceros, Stanford University, *Title to be announced.*

Tai-Ping Liu, Stanford University, *Title to be announced.*

Special Sessions

Advances in Modeling, Numerical Analysis and Computations of Fluid Flow Problems (Code: SS 2A), **Monika Neda**, University of Nevada Las Vegas.

Extremal Combinatorics (Code: SS 6A), **Jozsef Balogh**, University of California San Diego, and **Ryan Martin**, Iowa State University.

Geometric PDEs (Code: SS 1A), **Matthew Gursky**, Notre Dame University, and **Emmanuel Hebey**, Université de Cergy-Pontoise.

Multilevel Mesh Adaptation and Beyond: Computational Methods for Solving Complex Systems (Code: SS 4A), **Pengtao Sun**, University of Nevada Las Vegas, and **Long Chen**, University of California Irvine.

Partial Differential Equations Modeling Fluids (Code: SS 5A), **Quansen Jiu**, Capital Normal University, Beijing, China, and **Jiahong Wu**, Oklahoma State University.

Recent Advances in Finite Element Methods (Code: SS 3A), **Jichun Li**, University of Nevada Las Vegas.

Ithaca, New York

Cornell University

September 10–11, 2011

Saturday – Sunday

Meeting #1072

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: June 2011
Program first available on AMS website: July 28, 2011
Program issue of electronic *Notices*: September 2011
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 10, 2011
For consideration of contributed papers in Special Sessions: May 24, 2011
For abstracts: July 19, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Mladen Bestvina, University of Utah, *Title to be announced.*

Nigel Higson, Pennsylvania State University, *Title to be announced.*

Gang Tian, Princeton University, *Title to be announced.*

Winston-Salem, North Carolina

Wake Forest University

September 24–25, 2011

Saturday – Sunday

Meeting #1073

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: June 2011
Program first available on AMS website: August 11, 2011
Program issue of electronic *Notices*: September 2011
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 24, 2011
For consideration of contributed papers in Special Sessions: June 7, 2011
For abstracts: August 2, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Benjamin B. Brubaker, Massachusetts Institute of Technology, *Title to be announced*.

Shelly Harvey, Rice University, *Title to be announced*.

Allen Knutson, Cornell University, *Title to be announced*.

Seth M. Sullivant, North Carolina State University, *Title to be announced*.

Lincoln, Nebraska

University of Nebraska-Lincoln

October 14–16, 2011

Friday – Sunday

Meeting #1074

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: August 2011
Program first available on AMS website: September 1, 2011
Program issue of electronic *Notices*: October 2011
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 14, 2011
For consideration of contributed papers in Special Sessions: June 28, 2011
For abstracts: August 23, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Lewis Bowen, Texas A&M University, *Title to be announced*.

Emmanuel Candes, Stanford University, *Title to be announced* (Erdős Memorial Lecture).

Alina Cojocaru, University of Illinois at Chicago, *Title to be announced*.

Michael Zieve, University of Michigan, *Title to be announced*.

Salt Lake City, Utah

University of Utah

October 22–23, 2011

Saturday – Sunday

Meeting #1075

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2011
Program first available on AMS website: September 8, 2011
Program issue of electronic *Notices*: October 2011
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 22, 2011
For consideration of contributed papers in Special Sessions: July 5, 2011
For abstracts: August 30, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Graeme Milton, University of Utah, *Title to be announced*.

Lei Ni, University of California San Diego, *Title to be announced*.

Igor Pak, University of California Los Angeles, *Title to be announced*.

Monica Visan, University of California Los Angeles, *Title to be announced*.

Port Elizabeth, Republic of South Africa

Nelson Mandela Metropolitan University

November 29 – December 3, 2011
Tuesday – Saturday

Meeting #1076
First Joint International Meeting between the AMS and the South African Mathematical Society.
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Boston, Massachusetts

John B. Hynes Veterans Memorial Convention Center, Boston Marriott Hotel, and Boston Sheraton Hotel

January 4–7, 2012
Wednesday – Saturday
Joint Mathematics Meetings, including the 118th Annual Meeting of the AMS, 95th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2011
Program first available on AMS website: November 1, 2011
Program issue of electronic *Notices*: January 2012
Issue of *Abstracts*: Volume 33, Issue 1

Deadlines
For organizers: April 1, 2011
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Honolulu, Hawaii

University of Hawaii

March 3–4, 2012
Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: March 2012
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: August 3, 2011
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Tampa, Florida

University of South Florida

March 10–11, 2012
Saturday – Sunday
Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: March 2012
Issue of *Abstracts*: To be announced

Deadlines
For organizers: August 10, 2011
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Washington, District of Columbia

George Washington University

March 17–18, 2012
Saturday – Sunday
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: March 2012
Issue of *Abstracts*: To be announced

Deadlines
For organizers: August 17, 2011
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Lawrence, Kansas

University of Kansas

March 30 – April 1, 2012

Friday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *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 Orleans, Louisiana

Tulane University

October 13–14, 2012

Saturday – Sunday
Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 13, 2012
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 9–12, 2013

Wednesday – Saturday
Joint Mathematics Meetings, including the 119th Annual Meeting of the AMS, 96th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2012
Program first available on AMS website: November 1, 2012
Program issue of electronic *Notices*: January 2012
Issue of *Abstracts*: Volume 34, Issue 1

Deadlines

For organizers: April 1, 2012
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Ames, Iowa

Iowa State University

April 27–28, 2013

Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 27, 2012
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Alba Iulia, Romania

June 27–30, 2013

Thursday – Sunday
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Baltimore, Maryland

Baltimore Convention Center, Baltimore Hilton, and Marriott Inner Harbor

January 15–18, 2014

Wednesday – Saturday

Joint Mathematics Meetings, including the 120th Annual Meeting of the AMS, 97th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Matthew Miller
Announcement issue of *Notices*: October 2013
Program first available on AMS website: November 1, 2013
Program issue of electronic *Notices*: January 2013
Issue of *Abstracts*: Volume 35, Issue 1

Deadlines

For organizers: April 1, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Antonio, Texas

Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio

January 10–13, 2015

Saturday – Tuesday

Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: October 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2015
Issue of *Abstracts*: Volume 36, Issue 1

Deadlines

For organizers: April 1, 2014
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Seattle, Washington

Washington State Convention & Trade Center and the Sheraton Seattle Hotel

January 6–9, 2016

Wednesday – Saturday

Joint Mathematics Meetings, including the 122nd Annual Meeting of the AMS, 99th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2015
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2016
Issue of *Abstracts*: Volume 37, Issue 1

Deadlines

For organizers: April 1, 2015
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Atlanta, Georgia

Hyatt Regency Atlanta and Marriott Atlanta Marquis

January 4–7, 2017

Wednesday – Saturday

Joint Mathematics Meetings, including the 123rd Annual Meeting of the AMS, 100th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2016
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2017
Issue of *Abstracts*: Volume 38, Issue 1

Deadlines

For organizers: April 1, 2016
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Program at a Glance

This document provides a thumbnail sketch of all scientific and social events so you can easily see which events may overlap and better plan your time.

Tuesday, January 04

9:00 a.m.–5:00 p.m.	**AMS SHORT COURSE ON EVOLUTIONARY GAME DYNAMICS, PART I**
9:00 a.m.–5:00 p.m.	**AMS SHORT COURSE ON COMPUTATIONAL TOPOLOGY, PART I**
9:00 a.m.–5:00 p.m.	**MAA SHORT COURSE ON WHAT IS A MATROID? THEORY AND APPLICATIONS, FROM THE GROUND UP, PART I**

Wednesday, January 05

8:00 a.m.–6:00 p.m.	**AMS DEPARTMENT CHAIRS WORKSHOP**
9:00 a.m.–5:00 p.m.	**AMS SHORT COURSE ON EVOLUTIONARY GAME DYNAMICS, PART II**
9:00 a.m.–5:00 p.m.	**AMS SHORT COURSE ON COMPUTATIONAL TOPOLOGY, PART II**
9:00 a.m.–5:00 p.m.	**MAA SHORT COURSE ON WHAT IS A MATROID? THEORY AND APPLICATIONS, FROM THE GROUND UP, PART II**
9:00 a.m.–5:00 p.m.	**MAA BOARD OF GOVERNORS**
1:30 p.m.–10:00 p.m.	**AMS COUNCIL**
3:00 p.m.–7:00 p.m.	**JOINT MEETINGS REGISTRATION**, La Galerie Foyer, 2nd Floor, Marriott

Thursday, January 06

7:30 a.m.–4:00 p.m.	**JOINT MEETINGS REGISTRATION**, La Galerie Foyer, 2nd Floor, Marriott
	AMS SPECIAL SESSIONS
8:00 a.m.–10:50 a.m.	*Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, I (AMS-MAA-SIAM)*
8:00 a.m.–10:50 a.m.	*History of Mathematics, I (AMS-MAA)*
8:00 a.m.–10:50 a.m.	*Mathematics of Computation: Differential Equations, Linear Algebra, and Applications, I (AMS-SIAM)*
8:00 a.m.–10:50 a.m.	*Nonlinear Waves and Integrable Systems, I (AMS-SIAM)*
8:00 a.m.–10:50 a.m.	*Quadratic Forms in Algebra and Geometry, I*
8:00 a.m.–10:50 a.m.	*Mathematical Techniques in Musical Analysis, I*
8:00 a.m.–10:50 a.m.	*Integral Geometry: Analysis and Applications, I*
8:00 a.m.–10:50 a.m.	*Theory and Application of Stochastic Differential Equations and Stochastic Partial Differential Equations, I*
8:00 a.m.–10:50 a.m.	*Transseries and Ordered Exponential Fields, I*
8:00 a.m.–10:50 a.m.	*Analytic and Geometric Methods in Representation Theory, I*
8:00 a.m.–10:50 a.m.	*Geometric Group Theory, I*
8:00 a.m.–10:50 a.m.	*Computational Algebraic and Analytic Geometry for Low-Dimensional Varieties, I*

8:00 a.m.–10:50 a.m.	*Mathematical Modeling in Environmental Economics, I*
8:00 a.m.–10:50 a.m.	*Expander Graphs in Pure and Applied Mathematics, I*
	MAA INVITED PAPER SESSION
8:00 a.m.–10:50 a.m.	*The Rebirth of Special Functions*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 a.m.–10:55 a.m.	*Harnessing Mobile Communication Devices and Online Communication Tools for Mathematics Education*
8:00 a.m.–10:55 a.m.	*The Scholarship of Teaching and Learning in Collegiate Mathematics*
8:00 a.m.–10:55 a.m.	*Wavelets In Undergraduate Education*
8:00 a.m.–10:55 a.m.	*General Contributed Paper Session, I*
8:00 a.m.–10:50 a.m.	**SIAM MINISYMPOSIUM ON APPLICATIONS OF DIFFERENCE AND DIFFERENTIAL EQUATIONS IN ECOLOGY AND EPIDEMIOLOGY, I**
8:00 a.m.–7:00 p.m.	**EMPLOYMENT CENTER**
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #4: PART A** *Getting students involved in undergraduate research.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #7: PART A** *The mathematics of Islam and its use in the teaching of mathematics.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE: #8: PART A** *The ubiquitous Catalan numbers and their applications.*
9:00 a.m.–10:20 a.m.	**MAA PANEL DISCUSSION** *For MAA Student Chapter advisors: Dynamic answers to your questions.*
9:00 a.m.–11:00 a.m.	**MAA COMMITTEE ON THE PARTICIPATION OF WOMEN/WOMEN IN MATHEMATICS NETWORK POSTER SESSION** *Mathematical outreach programs for underrepresented populations.*
9:00 a.m.–10:20 a.m.	**MAA PANEL DISCUSSION** *National Science Foundation programs supporting learning and teaching in the mathematical sciences.*
9:30 a.m.–11:00 a.m.	**MAA DEPARTMENT LIAISONS MEETING**
10:05 a.m.–10:55 a.m.	**AMS INVITED ADDRESS** *The symplectic geometry of symmetric products and invariants of 3-manifolds with boundary.* **Denis Auroux**
11:10 a.m.–12:00 p.m.	**AMS-MAA INVITED ADDRESS** *Curves, surfaces, and solitons.* **Chuu-Lian Terng**
1:00 p.m.–2:00 p.m.	**AMS COLLOQUIUM LECTURES: LECTURE I** *Expander graphs in pure and applied mathematics, I.* **Alexander Lubotzky**
2:15 p.m.–3:05 p.m.	**MAA INVITED ADDRESS** *Laplacian growth and the mystery of the abelian sandpile: A visual tour.* **Yuval Peres**
	AMS SPECIAL SESSIONS
2:15 p.m.–6:05 p.m.	*Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, II (AMS-MAA-SIAM)*
2:15 p.m.–6:05 p.m.	*History of Mathematics, II (AMS-MAA)*
2:15 p.m.–6:05 p.m.	*Mathematics of Computation: Differential Equations, Linear Algebra, and Applications, II (AMS-SIAM)*
2:15 p.m.–6:05 p.m.	*Nonlinear Waves and Integrable Systems, II (AMS-SIAM)*
2:15 p.m.–6:05 p.m.	*Quadratic Forms in Algebra and Geometry, II*
2:15 p.m.–6:05 p.m.	*Mathematical Techniques in Musical Analysis, II*
2:15 p.m.–6:05 p.m.	*Integral Geometry: Analysis and Applications, II*
2:15 p.m.–6:05 p.m.	*Theory and Application of Stochastic Differential Equations and Stochastic Partial Differential Equations, II*
2:15 p.m.–6:05 p.m.	*Transseries and Ordered Exponential Fields, I*
2:15 p.m.–6:05 p.m.	*Analytic and Geometric Methods in Representation Theory, II*
2:15 p.m.–6:05 p.m.	*Geometric Group Theory, II*
2:15 p.m.–6:05 p.m.	*Computational Algebraic and Analytic Geometry for Low-Dimensional Varieties, II*
2:15 p.m.–6:05 p.m.	*Mathematical Modeling in Environmental Economics, II*
2:15 p.m.–6:05 p.m.	*Interactions of Inverse Problems, Signal Processing, and Imaging, I*

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #11: PART A** *Using video case studies in teaching a proof-based gateway course to the mathematics major.*

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #2: PART A** *Getting mathematics majors to think outside the book: Course activities that promote exploration, discovery, conjecture, and proof.*

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #9: PART A** *Learning discrete mathematics via historical projects.*

MAA CONTRIBUTED PAPER SESSIONS

2:15 p.m.–6:00 p.m. *Cryptology for Undergraduates*

2:15 p.m.–6:00 p.m. *The Mathematics of Games and Puzzles*

2:15 p.m.–6:00 p.m. *Getting Students Involved in Writing Proofs*

2:15 p.m.–6:00 p.m. *Innovations in Service-Learning at All Levels*

2:15 p.m.–6:00 p.m. *General Contributed Paper Session, II*

2:15 p.m.–5:15 p.m. **SIAM MINISYMPOSIUM ON APPLICATIONS OF DIFFERENCE AND DIFFERENTIAL EQUATIONS IN ECOLOGY AND EPIDEMIOLOGY, II**

2:15 p.m.–3:35 p.m. **MAA COMMITTEE ON GRADUATE STUDENTS/YOUNG MATHEMATICIANS NETWORK PANEL DISCUSSION** *How to interview for a job in the mathematical sciences.*

2:15 p.m.–3:35 p.m. **MAA PANEL DISCUSSION** *Reporting progress: A minisymposium of projects from the NSF Course, Curriculum, and Laboratory Improvement Program.*

2:15 p.m.–2:45 p.m. **AWM BUSINESS MEETING**

2:30 p.m.–5:00 p.m. **MAA SECTION OFFICERS**

2:45 p.m.–6:15 p.m. **AWM SCHAFER MINISYMPOSIUM**

3:20 p.m.–4:10 p.m. **MAA INVITED ADDRESS** *On the intersection of graphs and geometry.* **Edward R. Scheinerman**

MAA INVITED PAPER SESSIONS

3:30 p.m.–6:20 p.m. *Laplacian Growth: Visual Mathematics*

3:50 p.m.–5:10 p.m. **MAA-NCTM MUTUAL CONCERNS COMMITTEE PANEL DISCUSSION** *Transition from high school to college: Should there be an alternate to calculus?*

4:00 p.m.–6:00 p.m. **MAA PROJECT NEXT—YOUNG MATHEMATICIANS' NETWORK POSTER SESSION**

4:30 p.m.–6:00 p.m. **AMS COMMITTEE ON THE PROFESSION PANEL DISCUSSION** *What I wish I had known before applying for a job.*

5:00 p.m.–7:00 p.m. **MAA PANEL DISCUSSION** *Current issues in actuarial science education.*

5:30 p.m.–6:30 p.m. **SIGMAA ON THE HISTORY OF MATHEMATICS RECEPTION AND BUSINESS MEETING**

5:30 p.m.–6:00 p.m. **SIGMAA ON QUANTITATIVE LITERACY BUSINESS MEETING**

5:30 p.m.–8:00 p.m. **MATHEMATICAL INSTITUTES OPEN HOUSE**

6:00 p.m.–7:00 p.m. **SIGMAA ON QUANTITATIVE LITERACY RECEPTION AND PANEL DISCUSSION** *Mathematics and democracy ten years later.*

6:00 p.m.–7:00 p.m. **SIGMAA ON TEACHING ADVANCED HIGH SCHOOL MATHEMATICS BUSINESS MEETING**

6:00 p.m.–8:00 p.m. **PENNSYLVANIA STATE UNIVERSITY MATHEMATICS RECEPTION FOR ALUMNI AND FRIENDS**

6:30 p.m.–7:30 p.m. **SIGMAA ON THE HISTORY OF MATHEMATICS GUEST LECTURE**

8:30 p.m.–9:30 p.m. **AMS JOSIAH WILLARD GIBBS LECTURE** *Title to be announced.* **George Papanicolaou**

9:30 p.m.–11:00 p.m. **AWM RECEPTION**

Friday, January 07

7:30 a.m.–4:00 p.m. **JOINT MEETINGS REGISTRATION**, La Galerie Foyer, 2nd Floor, Marriott

AMS SPECIAL SESSIONS

8:00 a.m.–11:50 a.m. *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, III (AMS-MAA-SIAM)*

8:00 a.m.–11:50 a.m.	*Mathematics and Education Reform, I (AMS-MAA-MER)*
8:00 a.m.–11:50 a.m.	*History of Mathematics, III (AMS-MAA)*
8:00 a.m.–11:50 a.m.	*Mathematics of Computation: Algebra and Number Theory, I (AMS-SIAM)*
8:00 a.m.–11:50 a.m.	*Logic and Analysis, I (AMS-ASL)*
8:00 a.m.–11:50 a.m.	*Birational Geometry and Moduli Spaces (Mathematics Research Communities session), I*
8:00 a.m.–11:50 a.m.	*Wavelets, Tilings, and Iterated Function Systems, I*
8:00 a.m.–11:50 a.m.	*Stochastic Analysis and Random Phenomena, I*
8:00 a.m.–11:50 a.m.	*Model Theory of Fields and Applications (Mathematics Research Communities session), I*
8:00 a.m.–11:50 a.m.	*Commutative Algebra (Mathematics Research Communities session), I*
8:00 a.m.–11:50 a.m.	*Structured Models in Ecology, Evolution, and Epidemiology: Periodicity, Extinction, and Chaos, I*
8:00 a.m.–11:50 a.m.	*Boundary Control and Moving Interface in Coupled Systems of Partial Differential Equations, I*
8:00 a.m.–11:50 a.m.	*Expander Graphs in Pure and Applied Mathematics, II*
8:00 a.m.–11:50 a.m.	*Groups, Geometry, and Applications, I*
8:00 a.m.–10:00 a.m.	**MAA MINICOURSE #3: PART A** *Geometry and algebra in mathematical music theory.*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 a.m.–12:00 p.m.	*Cool Calculus: Lessons Learned Through Innovative and Effective Supplemental Projects, Activities, and Strategies for Teaching Calculus*
8:00 a.m.–12:00 p.m.	*Innovative and Effective Ways to Teach Linear Algebra*
8:00 a.m.–12:00 p.m.	*Modeling in the ODE Driver's Seat*
8:00 a.m.–12:00 p.m.	*General Contributed Paper Session, III*
8:00 a.m.–10:50 a.m.	**SIAM MINISYMPOSIUM ON COMBINATORIAL OPTIMIZATION, I**
8:00 a.m.–11:00 a.m.	**AWM HAY MINISYMPOSIUM**
8:00 a.m.–10:55 a.m.	**SIGMAA RUME SESSION ON RESEARCH ON THE TEACHING AND LEARNING OF UNDERGRADUATE MATHEMATICS, I**
8:00 a.m.–7:00 p.m.	**EMPLOYMENT CENTER**
9:00 a.m.–9:50 a.m.	**MAA INVITED ADDRESS** *Sea battles, Benjamin Franklin's oil lamp, and jellybellies.* **Katherine Socha**
	MAA INVITED PAPER SESSION
9:00 a.m.–11:55 a.m.	*The Beauty and Power of Number Theory*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #12: PART A** *Concepts, data, and models: College algebra for the real world.*
9:00 a.m.–11:00 p.m.	**MAA MINICOURSE #6: PART A** *Green linear optimization.*
9:00 a.m.–10:20 a.m.	**MAA-YOUNG MATHEMATICIANS' NETWORK PANEL DISCUSSION** *Career options for undergraduate mathematics majors.*
9:00 a.m.–10:20 a.m.	**MAA SESSION FOR CHAIRS** *The new MAA Curriculum Guide: What should it be?*
9:30 a.m.–11:00 a.m.	**AMS SPECIAL PRESENTATION** *Who wants to be a mathematician—National contest.*
9:30 a.m.–5:30 p.m.	**EXHIBITS AND BOOK SALES**
10:00 a.m.–12:00 p.m.	**MAA COMMITTEE ON GRADUATE STUDENTS POSTER SESSION**
10:05 a.m.–10:55 a.m.	**AWM EMMY NOETHER LECTURE** *Title to be announced.* **M. Susan Montgomery**
10:30 a.m.–12:30 p.m.	**MAA MINICOURSE: #5: PART A** *A Game Theory path to quantitative literacy.*
10:30 a.m.–12:00 p.m.	**SIGMAA OFFICERS MEETING**
10:35 a.m.–11:55 a.m.	**MAA PANEL DISCUSSION** *Writing the history of the MAA's first 100 years.*
10:35 a.m.–11:55 a.m.	**MAA COMMITTEE ON GRADUATE STUDENTS/YOUNG MATHEMATICIANS' NETWORK PANEL DISCUSSION** *Graduate school: Choosing one, getting in, staying in.*
10:35 a.m.–11:55 a.m.	**MAA PANEL DISCUSSION** *Proposal writing workshop for grant applications to the NSF Division of Undergraduate Education.*
11:10 a.m.–12:00 p.m.	**SIAM INVITED ADDRESS** *Title to be announced.* **William Cook**
1:00 p.m.–2:00 p.m.	**AMS COLLOQUIUM LECTURES: LECTURE II** *Expander graphs in pure and applied mathematics, II.* **Alexander Lubotzky**

AMS SPECIAL SESSIONS

1:00 p.m.–3:50 p.m. *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, IV (AMS-MAA-SIAM)*

1:00 p.m.–3:50 p.m. *Mathematics and Education Reform, II (AMS-MAA-MER)*

1:00 p.m.–3:50 p.m. *History of Mathematics, IV (AMS-MAA)*

1:00 p.m.–3:50 p.m. *Mathematics of Computation: Algebra and Number Theory, II (AMS-SIAM)*

1:00 p.m.–3:50 p.m. *Logic and Analysis, II (AMS-ASL)*

1:00 p.m.–3:50 p.m. *Birational Geometry and Moduli Spaces (Mathematics Research Communities session), II*

1:00 p.m.–3:50 p.m. *Lie Algebras, Algebraic Groups, and Related Topics, I*

1:00 p.m.–3:50 p.m. *Wavelets, Tilings, and Iterated Function Systems, II*

1:00 p.m.–3:50 p.m. *Stochastic Analysis and Random Phenomena, II*

1:00 p.m.–3:50 p.m. *Model Theory of Fields and Applications (Mathematics Research Communities session), II*

1:00 p.m.–3:50 p.m. *Commutative Algebra (Mathematics Research Communities session), II*

1:00 p.m.–3:50 p.m. *Knots, Links, 3-Manifolds, and Physics, I*

1:00 p.m.–3:50 p.m. *Structured Models in Ecology, Evolution, and Epidemiology: Periodicity, Extinction, and Chaos, II*

1:00 p.m.–3:50 p.m. *Interactions of Inverse Problems, Signal Processing, and Imaging, II*

MAA INVITED PAPER SESSION

1:00 p.m.–4:15 p.m. *Topics in Hopf Algebras*

1:00 p.m.–3:00 p.m. **MAA MINICOURSE #10: PART A** *Teaching introductory statistics (for instructors new to teaching intro stats).*

1:00 p.m.–3:00 p.m. **MAA MINICOURSE #13: PART A** *Creating demonstrations and guided explorations for multivariable calculus using CalcPlot3D.*

1:00 p.m.–3:00 p.m. **MAA MINICOURSE #1: PART A** *Special relativity through a linear algebraic lens.*

MAA CONTRIBUTED PAPER SESSIONS

1:00 p.m.–4:15 p.m. *Journals and Portfolios: Tools in Learning Mathematics?*

1:00 p.m.–4:15 p.m. *Treasures from the Past: Using Primary Sources in the Classroom*

1:00 p.m.–4:15 p.m. *The Mathematics of Sustainability*

1:00 p.m.–4:15 p.m. *General Contributed Paper Session, IV*

1:00 p.m.–4:00 p.m. **SIAM MINISYMPOSIUM ON COMBINATORIAL OPTIMIZATION, II**

1:00 p.m.–4:00 p.m. **SIGMAA RUME SESSION ON RESEARCH ON THE TEACHING AND LEARNING OF UNDERGRADUATE MATHEMATICS, II**

1:00 p.m.–2:15 p.m. **AMS PANEL DISCUSSION** *Proving Hardy wrong: Math research with social justice applications.*

1:00 p.m.–3:00 p.m. **MAA PANEL DICUSSION** *Good intentions are necessary but not sufficient: Steps toward best practices in mentoring underrepresented students.*

1:00 p.m.–2:20 p.m. **MAA PANEL DISCUSSION** *This could be YOUR graduate research!*

1:00 p.m.–2:20 p.m. **SIGMAA ON STATISTICS EDUCATION/ASA-MAA JOINT COMMITTEE ON UNDERGRADUATE STATISTICS PANEL DISCUSSION** *Report from the International Conference on Teaching Statistics: A world view of statistics education.*

1:00 p.m.–2:20 p.m. **MAA COMMITTEE ON TECHNOLOGIES IN MATHEMATICS AND EDUCATION/WEB SIGMAA PANEL DISCUSSION** *Assessment of learning in an age of technology.*

1:00 p.m.–4:00 p.m. **SUMMER PROGRAM FOR WOMEN IN MATHEMATICS (SPWM) REUNION**

2:00 p.m.–4:00 p.m. **MAA POSTER SESSION ON PROJECTS SUPPORTED BY THE NSF DIVISION OF UNDERGRADUATE EDUCATION**

2:00 p.m.–4:00 p.m. **MAA PANEL DISCUSSION** *Mathematical culture and mathematical life.*

2:15 p.m.–3:05 p.m. **AMS INVITED ADDRESS** *Self-organization in human, biological, and artificial systems.*
Andrea L. Bertozzi

2:35 p.m.–3:55 p.m. **MAA COMMITTEE ON THE TEACHING OF UNDERGRADUATE MATHEMATICS PANEL DISCUSSION** *Calculus reform: 25 years later.*

2:35 p.m.–3:55 p.m. **MAA PANEL DISCUSSION** *Mathematicians and teachers: Professional development and outreach groups.*

2:35 p.m.–3:55 p.m.	**SIGMAA ON MATHEMATICAL AND COMPUTATIONAL BIOLOGY-SIGMAA ON STATISTICS EDUCATION-ASA/MAA JOINT COMMITTEE ON UNDERGRADUATE STATISTICS PANEL DISCUSSION** *Creating/improving the biomathematics/biostatistics course.*
3:20 p.m.–4:10 p.m.	**AMS INVITED ADDRESS** *Title to be announced.* **Tatiana Toro**
5:30 p.m.–7:00 p.m.	**HAWKES LEARNING SYSTEMS PRESENTATION**
5:30 p.m.–7:00 p.m.	**NEW MEXICO STATE UNIVERSITY RECEPTION**
5:45 p.m.–6:30 p.m.	**SIGMAA ON RESEARCH IN UNDERGRADUATE MATHEMATICS EDUCATION BUSINESS MEETING**
5:45 p.m.–7:15 p.m.	**SIGMAA STATISTICS EDUCATION BUSINESS MEETING AND RECEPTION**
5:45 p.m.–7:15 p.m.	**UNIVERSITY OF KANSAS MATH ALUMNI AND FRIENDS RECEPTION**
6:00 p.m.–7:00 p.m.	**SIGMAA ON MATHEMATICAL AND COMPUTATIONAL BIOLOGY BUSINESS MEETING**
6:00 p.m.–8:00 p.m.	**NSA'S WOMEN IN MATHEMATICS SOCIETY NETWORKING SESSION**
6:00 p.m.–10:00 p.m.	**ASSOCIATION OF CHRISTIANS IN THE MATHEMATICAL SCIENCES BANQUET**
6:00 p.m.–8:00 p.m.	**ASSOCIATION OF LESBIAN, GAY, BISEXUAL, AND TRANSGENDERED MATHEMATICIANS RECEPTION**
6:30 p.m.–9:30 p.m.	**MER BANQUET**
7:00 p.m.–8:00 p.m.	**SIGMAA ON MATHEMATICAL AND COMPUTATIONAL BIOLOGY GUEST LECTURE**
7:00 p.m.–11:00 p.m.	**AWM 40TH ANNIVERSARY BANQUET AND JAZZ**
7:00 p.m.–9:00 p.m.	**CLAREMONT COLLEGES ALUMNI RECEPTION**
7:30 p.m.–8:30 p.m.	**YOUNG MATHEMATICIANS' NETWORK OPEN FORUM** *All meeting participants, including undergraduates and graduate students, are welcome to discuss topics and issues affecting young mathematicians.*
8:15 p.m.–9:45 p.m.	**KNITTING CIRCLE** *Bring a project (knitting/crochet/tatting/beading/etc.) and chat with other crafters.*

Saturday, January 08

7:30 a.m.–4:00 p.m.	**JOINT MEETINGS REGISTRATION**, La Galerie Foyer, 2nd Floor, Marriott
	AMS SPECIAL SESSIONS
8:00 a.m.–10:50 a.m.	*Mathematics of Computation: Algebra and Number Theory, III (AMS-SIAM)*
8:00 a.m.–10:50 a.m.	*Hopf Algebras and Their Representations, I (AMS-AWM)*
8:00 a.m.–10:50 a.m.	*Formal Mathematics for Mathematicians: Developing Large Repositories of Advanced Mathematics, I*
8:00 a.m.–10:50 a.m.	*Multivariable Operator Theory, I*
8:00 a.m.–10:50 a.m.	*Stochastic Analysis and Mathematical Physics: A Session in Honor of the 80th Birthday of Len Gross, I*
8:00 a.m.–10:50 a.m.	*Mathematics Related to Feynman Diagrams, I*
8:00 a.m.–10:50 a.m.	*Completely Integrable Systems, Random Matrices, and the Bispectral Problem, I*
8:00 a.m.–10:50 a.m.	*Nonlinear Evolution Equations, Analysis, and Geometry, I*
8:00 a.m.–10:50 a.m.	*Knots, Links, 3-Manifolds, and Physics, II*
8:00 a.m.–10:50 a.m.	*Boundary Control and Moving Interface in Coupled Systems of Partial Differential Equations, II*
8:00 a.m.–10:50 a.m.	*Self-Organization in Human, Biological, and Artificial Systems, I*
8:00 a.m.–10:50 a.m.	*Harmonic Analysis and Partial Differential Equations, I*
8:00 a.m.–10:50 a.m.	*Groups, Geometry, and Applications, II*
8:00 a.m.–10:50 a.m.	*New Topics in Graph Theory, I*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 a.m.–10:55 a.m.	*New and Continuing Connections between Math and the Arts*
8:00 a.m.–10:55 a.m.	*Mathematics Experiences in Business, Industry, and Government*
8:00 a.m.–10:55 a.m.	*Fostering, Supporting, and Propagating Math Circles for Students and Teachers*

8:00 a.m.–10:55 a.m. *General Contributed Paper Session, V*

8:00 a.m.–11:00 a.m. **SIAM MINISYMPOSIUM ON EDUCATION**

8:00 a.m.–5:00 p.m. **ASL INVITED ADDRESSES AND CONTRIBUTED PAPER SESSIONS**

8:00 a.m.–11:00 a.m. **PME COUNCIL MEETING**

8:00 a.m.–7:00 p.m. **EMPLOYMENT CENTER**

8:30 a.m.–10:30 a.m. **AMS-MAA GRADUATE STUDENT FAIR** *Undergrads! Take this opportunity to meet representatives from mathematical science graduate programs.*

9:00 a.m.–9:50 a.m. **MAA RETIRING PRESIDENTIAL ADDRESS** *Issues of the transition to college mathematics.* **David M. Bressoud**

MAA INVITED PAPER SESSION

9:00 a.m.–11:00 a.m. *Fish Tales: Stories from Mathematical Fluid Dynamics*

9:00 a.m.–11:00 a.m. **MAA MINICOURSE #4: PART B** *Getting students involved in undergraduate research.*

9:00 a.m.–11:00 a.m. **MAA MINICOURSE #7: PART B** *The mathematics of Islam and its use in the teaching of mathematics.*

9:00 a.m.–11:00 a.m. **MAA MINICOURSE: #8: PART B** *The ubiquitous Catalan numbers and their applications.*

9:00 a.m.–10:20 a.m. **MAA PANEL DISCUSSION** *Utilizing NSF ADVANCE to promote the success of women faculty in mathematics.*

9:00 a.m.–10:20 a.m. **MAA COMMITTEE ON GRADUATE STUDENTS—YOUNG MATHEMATICIANS' NETWORK PANEL DISCUSSION** *Maximize your career potential!*

9:00 a.m.–10:20 a.m. **MAA PANEL DISCUSSION** *The benefits of hosting a regional undergraduate mathematics conference*

9:30 a.m.–5:30 p.m. **EXHIBITS AND BOOK SALES**

10:05 a.m.–10:55 a.m. **AMS INVITED ADDRESS** *Title to be announced.* **Akshay Venkatesh**

11:10 a.m.–12:00 p.m. **AMS-MAA INVITED ADDRESS** *To be announced.* **Kannan Soundararajan**

1:00 p.m.–1:50 p.m. **MAA LECTURE FOR STUDENTS** *Turning theorems into plays.* **Steve Abbott**

1:00 p.m.–5:00 p.m. **AMS CURRENT EVENTS BULLETIN**

AMS SPECIAL SESSIONS

1:00 p.m.–5:50 p.m. *Hopf Algebras and Their Representations, II (AMS-AWM)*
1:00 p.m.–5:50 p.m. *Stochastic Analysis and Mathematical Physics: A Session in Honor of the 80th Birthday of Len Gross, II*
1:00 p.m.–5:50 p.m. *Lie Algebras, Algebraic Groups, and Related Topics, II*
1:00 p.m.–5:50 p.m. *Completely Integrable Systems, Random Matrices, and the Bispectral Problem, II*
1:00 p.m.–5:50 p.m. *New Trends in Theory and Applications of Evolution Equations*
1:00 p.m.–5:50 p.m. *von Neumann Algebras*
1:00 p.m.–5:50 p.m. *Local Commutative Algebra*
1:00 p.m.–5:50 p.m. *Dirac Operators*
1:00 p.m.–5:50 p.m. *Set-Valued Optimization and Variational Problems*
1:00 p.m.–5:50 p.m. *Knot Theory, I*
1:00 p.m.–5:50 p.m. *Self-Organization in Human, Biological, and Artificial Systems, II*
1:00 p.m.–5:50 p.m. *Harmonic Analysis and Partial Differential Equations, II*
1:00 p.m.–5:50 p.m. *Difference Equations and Applications*
1:00 p.m.–5:50 p.m. *New Topics in Graph Theory, II*

MAA CONTRIBUTED PAPER SESSIONS

1:00 p.m.–6:00 p.m. *Developmental Mathematics Education: Helping Under-Prepared Students Transition to College-Level Mathematics*
1:00 p.m.–6:00 p.m. *Humanistic Mathematics*
1:00 p.m.–6:00 p.m. *Philosophy of Mathematics in Teaching and Learning*
1:00 p.m.–6:00 p.m. *General Contributed Paper Session, VI*

1:00 p.m.–6:00 p.m. **SIAM MINISYMPOSIUM ON FRONTIERS IN GEOMATHEMATICS**

1:00 p.m.–3:30 p.m. **NAM GRANVILLE-BROWN-HAYNES SESSION OF PRESENTATIONS BY RECENT DOCTORAL RECIPIENTS IN THE MATHEMATICAL SCIENCES**

1:00 p.m.–5:30 p.m. **AWM MICHLER AND MENTORING MINISYMPOSIUM**

1:00 p.m.–4:20 p.m. **SIGMAA ON ENVIRONMENTAL MATHEMATICS SESSION ON MODELING THE OIL SPILL DISASTER AND ITS CONSEQUNCES**

1:00 p.m.–2:20 p.m. **MAA COMMITTEE ON THE UNDERGRADUATE PROGRAM IN MATHEMATICS PANEL DISCUSSION** *Preparation and recruitment of future mathematics graduate students.*

1:00 p.m.–2:20 p.m. **SIGMAA ON STATISTICS EDUCATION PANEL DISCUSSION** *Teaching statistics online.*

1:10 p.m.–2:00 p.m. **AMS INVITED ADDRESS** *Title to be announced.* **Scott Sheffield**

2:15 p.m.–3:05 p.m. **MAA INVITED ADDRESS** *Binary quadratic forms: From Gauss to algebraic geometry.* **Melanie Matchett Wood**

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #11: PART B** *Using video case studies in teaching a proof-based gateway course to the mathematics major.*

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #2: PART B** *Getting mathematics majors to think outside the book: Course activities that promote exploration, discovery, conjecture, and proof.*

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #9: PART B** *Learning discrete mathematics via historical projects.*

2:30 p.m.–4:00 p.m. **AMS COMMITTEE ON SCIENCE POLICY PANEL DISCUSSION** *Title to be announced.*

2:35 p.m.–3:55 p.m. **MAA PANEL DISCUSSION** *Inquiry-proof instructional techniques.*

2:35 p.m.–3:55 p.m. **MAA COMMITTEE ON MINORITY PARTICIPATION—SOCIETY FOR THE ADVANCEMENT OF CHICANOS AND NATIVE AMERICANSN SCIENCE—NATIONAL ASSOCIATION OF MATHEMATICIANS** *The role of mentoring in undergraduate mathematics: Promising recruitment and retention strategies.*

3:20 p.m.–4:40 p.m. **MAA PRESENTATIONS BY TEACHING AWARD RECIPIENTS**

4:30 p.m.–5:20 p.m. **MATHEMATICAL SCIENCES IN 2025—A DISCUSSION**

4:30 p.m.–6:30 p.m. **AMS CONGRESSIONAL FELLOWSHIP SESSION**

4:30 p.m.–6:00 p.m. **SIGMAA ON MATHEMATICS INSTRUCTION USING THE WEB BUSINESS MEETING AND OPEN DISCUSSION** *Come share your interests in teaching and learning mathematics online and discuss the direction of future WEB SIGMAA activities.*

5:00 p.m.–6:00 p.m. **SIGMAA ON MATHEMATICIANS IN BUSINESS, INDUSTRY, AND GOVERNMENT GUEST LECTURE**

6:00 p.m.–7:00 p.m. **MAA DRAMATIC PRESENTATION** *Derivative vs. Integral: The final showdown*

6:00 p.m.–6:30 p.m. **SIGMAA ON THE PHILOSOPHY OF MATHEMATICS BUSINESS MEETING**

6:00 p.m.–7:00 p.m. **SIGMAA ON MATHEMATICS AND THE ARTS BUSINESS MEETING**

6:00 p.m.–7:00 p.m. **SIGMAA ON ENVIRONMENTAL MATHEMATICS DRAMATIC PRESENTATION** *The Oil Volcano: Truth and Consequences.*

6:00 p.m.–8:00 p.m. **BUDAPEST SEMESTERS IN MATHEMATICS REUNION**

6:00 p.m.–9:30 p.m. **NAM RECEPTION AND BANQUET**

6:15 p.m.–7:30 p.m. **SIGMAA ON MATHEMATICIANS IN BUSINESS, INDUSTRY, AND GOVERNMENT RECEPTION**

6:30 p.m.–7:30 p.m. **SIGMAA ON THE PHILOSOPHY OF MATHEMATICS GUEST LECTURE**

7:30 p.m.–8:15 p.m. **NAM COX-TALBOT ADDRESS** *Title to be announced.* **Robert Bozeman**

8:30 p.m.–10:30 p.m. **MAA/PROJECT NEXT RECEPTION** *All Project NExT Fellows, consultants, and other friends of Project NExT are invited.*

Sunday, January 09

7:00 a.m.–7:50 a.m. **ASSOCIATION FOR CHRISTIANS IN THE MATHEMATICAL SCIENCES WORSHIP SERVICE**

7:30 a.m.–2:00 p.m. **JOINT MEETINGS REGISTRATION**, La Galerie Foyer, 2nd Floor, Marriott

	AMS SPECIAL SESSIONS
8:00 a.m.–10:50 a.m.	*Applications of Stochastic Processes in Neuroscience, I (AMS-SIAM)*
8:00 a.m.–10:50 a.m.	*Control and Inverse Problems for Partial Differential Equations, I (AMS-SIAM)*
8:00 a.m.–10:50 a.m.	*Asymptotic Methods in Analysis with Applications, I*
8:00 a.m.–10:50 a.m.	*Formal Mathematics for Mathematicians: Developing Large Repositories of Advanced Mathematics, II*
8:00 a.m.–10:50 a.m.	*Multivariable Operator Theory, II*
8:00 a.m.–10:50 a.m.	*Mathematics Related to Feynman Diagrams, II*
8:00 a.m.–10:50 a.m.	*Analysis of Reaction-Diffusion Models, I*
8:00 a.m.–10:50 a.m.	*Continued Fractions, I*
8:00 a.m.–10:50 a.m.	*Noncommutative Harmonic Analysis and Dynamic Systems, I*
8:00 a.m.–10:50 a.m.	*Combinatorial Algebraic Geometry, I*
8:00 a.m.–10:50 a.m.	*Nonlinear Evolution Equations, Analysis, and Geometry, II*
8:00 a.m.–10:50 a.m.	*Structure Theory for Matroids and Graphs, I*
8:00 a.m.–10:50 a.m.	*Knot Theory, II*
8:00 a.m.–10:50 a.m.	*Time Scales: Theory and Applications, I*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 a.m.–10:55 a.m.	*Trends in Undergraduate Mathematical Biology Education*
8:00 a.m.–10:55 a.m.	*Effective Teaching of Upper Level Mathematics to Secondary Education Mathematics Majors*
8:00 a.m.–10:55 a.m.	*Influences of the Calculus Reform Movement on the Teaching of Mathematics*
8:00 a.m.–10:55 a.m.	*General Contributed Paper Session, VII*
8:00 a.m.–11:00 a.m.	**SIAM MINISYMPOSIUM ON VISTAS IN APPLIED MATHEMATICS**
8:00 a.m.–4:00 p.m.	**AWM WORKSHOP** *This session has several parts that will be listed separately by time in this program. All presentations are open to all JMM participants.*
8:00 a.m.–5:00 p.m.	**ASL INVITED ADDRESSES AND CONTRIBUTED PAPER SESSIONS**
8:30 a.m.–10:30 a.m.	**AWM WORKSHOP: RESEARCH PRESENTATIONS BY RECENT PH.D.S, I**
8:30 a.m.–10:00 a.m.	**AMS COMMITTEE ON EDUCATION PANEL DISCUSSION** *Title to be announced.*
8:50 a.m.–9:50 a.m.	**AMS COLLOQUIUM LECTURES: LECTURE III** *Expander graphs in pure and applied mathematics, III.* **Alexander Lubotzky**
	MAA INVITED PAPER SESSION
9:00 a.m.–10:50 a.m.	*The Intersection of Graphs and Geometry, I*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #12: PART B** *Concepts, data, and models: College algebra for the real world.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #3: PART B** *Geometry and algebra in mathematical music theory.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #6: PART B** *Green linear optimization.*
9:00 a.m.–10:20 a.m.	**MAA COMMITTEE ON TECHNOLOGY IN MATH EDUCATION PANEL DISCUSSION** *Publishing mathematics on the Web.*
9:00 a.m.–11:00 a.m.	**SIGMAA ON MATH CIRCLES FOR STUDENTS AND TEACHERS SPECIAL PRESENTATION** *Math Circles demonstration.*
9:00 a.m.–9:50 a.m.	**NAM PANEL DISCUSSION** *Title to be announced.*
9:00 a.m.–12:00 p.m.	**EXHIBITS AND BOOK SALES**
9:00 a.m.–12:00 p.m.	**EMPLOYMENT CENTER**
10:00 a.m.–10:50 a.m.	**NAM BUSINESS MEETING**
10:05 a.m.–10:55 a.m.	**MAA INVITED ADDRESS** *Lessons from the Netflix Prize.* **Robert M. Bell**
10:30 a.m.–11:00 a.m.	**AWM WORKSHOP: POSTER SESSION WITH PRESENTATIONS FROM WOMEN GRADUATE STUDENTS**
11:10 a.m.–11:40 a.m.	**MAA BUSINESS MEETING**
11:45 a.m.–12:15 p.m.	**AMS BUSINESS MEETING**
1:00 p.m.–1:50 p.m.	**NAM CLAYTOR-WOODARD LECTURE** *Speaker and title to be announced*

1:00 p.m.–3:00 p.m.	**MAA MINICOURSE: #1 PART B** *Special relativity through a linear algebraic lens.*
	AMS SPECIAL SESSIONS
1:00 p.m.–5:50 p.m.	*Centers for Teaching/Education/Outreach in Departments of Mathematics (AMS-MAA)*
1:00 p.m.–5:50 p.m.	*Control and Inverse Problems for Partial Differential Equations, II (AMS-SIAM)*
1:00 p.m.–5:50 p.m.	*Asymptotic Methods in Analysis with Applications, II*
1:00 p.m.–5:50 p.m.	*Applied Optimization and Douglas-Rachford Splitting Methods for Convex Programming*
1:00 p.m.–5:50 p.m.	*Stochastic, Fractional, and Hybrid Dynamic Systems with Applications*
1:00 p.m.–5:50 p.m.	*Applications of Stochastic Processes in Neuroscience, II*
1:00 p.m.–5:50 p.m.	*Analysis of Reaction-Diffusion Models, II*
1:00 p.m.–5:50 p.m.	*Continued Fractions, II*
1:00 p.m.–5:50 p.m.	*Noncommutative Harmonic Analysis and Dynamic Systems, II*
1:00 p.m.–5:50 p.m.	*Combinatorial Algebraic Geometry, II*
1:00 p.m.–5:50 p.m.	*Structure Theory for Matroids and Graphs, II*
1:00 p.m.–5:50 p.m.	*The Mathematics of Modeling Multiscale Heterogeneous Media*
1:00 p.m.–5:50 p.m.	*Global Dynamics of Discrete Dynamical Systems in the Plane with Applications*
1:00 p.m.–5:50 p.m.	*Measures of Entanglement of Macromolecules and Their Applications*
1:00 p.m.–5:50 p.m.	*Time Scales: Theory and Applications, II*
	MAA INVITED PAPER SESSION
1:00 p.m.–3:20 p.m.	*The Intersection of Graphs and Geometry, II*
1:00 p.m.–3:00 p.m.	**MAA MINICOURSE #13: PART B** *Creating demonstrations and guided explorations for multivariable calculus using CalcPlot3D.*
1:00 p.m.–3:00 p.m.	**MAA MINICOURSE: #5: PART B** *A Game Theory path to quantitative literacy.*
	MAA CONTRIBUTED PAPER SESSIONS
1:00 p.m.–5:30 p.m.	*Alternative Approaches to Traditional Introductory Statistics Courses*
1:00 p.m.–5:30 p.m.	*Using Program Assessment to Improve Student Learning*
1:00 p.m.–5:30 p.m.	*The Mathematical Foundations for the Quantitative Disciplines*
1:00 p.m.–5:30 p.m.	*General Contributed Paper Session, VIII*
1:00 p.m.–6:00 p.m.	**SIAM MINISYMPOSIUM ON GRAPH THEORY**
1:00 p.m.–2:15 p.m.	**AWM WORKSHOP PANEL DISCUSSION** *Starting a career in mathematics.*
2:30 p.m.–4:30 p.m.	**AWM WORKSHOP: RESEARCH PRESENTATIONS BY RECENT PH.D.S, II**
3:00 p.m.–4:00 p.m.	**AMS-MAA-SIAM GERALD AND JUDITH PORTER PUBLIC LECTURE** *From flapping birds to space telescopes: The mathematics of origami.* **Robert J. Lang**
3:30 p.m.–5:30 p.m.	**MAA MINICOURSE #10: PART B** *Teaching introductory statistics.*
6:30 p.m.–7:30 p.m.	**AMS BANQUET RECEPTION**
7:30 p.m.–10:00 p.m.	**AMS BANQUET**

2011 Joint Mathematics Meetings Advance Registration/Housing Form

Name ____
(please write name as you would like it to appear on your badge)

Mailing Address ____

____

Telephone ______________________ Fax: ______________________

In case of emergency (for you) at the meeting, call: Day # ______________ Evening #: ______________

E-mail Address ____

Acknowledgment of this registration and any hotel reservations will be sent to the e-mail address given here, unless you check this box: *Send by U.S. Mail* ☐

Affiliation for badge ______________________ (company/university) Nonmathematician guest badge name: ______________________ (accompanying registered mathematician; please note charge below)

☐ **I DO NOT want my program and badge to be mailed to me on 12/10/10. (Materials will be mailed to the address listed above unless you check this box.)**

Registration Fees

Membership ✓ all that apply. First row is eligible for JMM member registration fee.

❏ AMS ❏ MAA ❏ ASL ❏ CMS ❏ SIAM
❏ ASA ❏ AWM ❏ NAM ❏ YMN

Joint Meetings	**by Dec 15**	**at mtg**	**Subtotal**
❏ Member AMS, MAA, ASL, CMS, SIAM	US$ 224	US$ 294	
❏ Nonmember	US$ 349	US$ 453	
❏ Graduate Student (Member of AMS or MAA)	US$ 49	US$ 59	
❏ Graduate Student (Nonmember)	US$ 76	US$ 86	
❏ Undergraduate Student	US$ 42	US$ 52	
❏ High School Student	US$ 5	US$ 10	
❏ Unemployed	US$ 49	US$ 59	
❏ Temporarily Employed	US$ 181	US$ 210	
❏ Developing Countries Special Rate	US$ 49	US$ 59	
❏ Emeritus Member of AMS or MAA	US$ 49	US$ 59	
❏ High School Teacher	US$ 49	US$ 59	
❏ Librarian	US$ 49	US$ 59	
❏ Press	US$ 0	US$ 0	
❏ Nonmathematician Guest	US$ 15	US$ 15	
			$________

AMS Short Course 1: *Computational Topology (1/4–1/5)*

❏ Member of AMS or MAA	US$ 100	US$ 140	
❏ Nonmember	US$ 134	US$ 170	
❏ Student, Unemployed, Emeritus	US$ 48	US$ 69	
			$________

AMS Short Course 2: *Evolutionary Game Dynamics (1/4–1/5)*

❏ Member of AMS or MAA	US$ 100	US$ 140	
❏ Nonmember	US$ 134	US$ 170	
❏ Student, Unemployed, Emeritus	US$ 48	US$ 69	
			$________

MAA Short Course: *What is a Matroid? Theory and Applications from the ground up. (1/4–1/5)*

❏ Member of MAA or AMS	US$ 150	US$ 160	
❏ Nonmember	US$ 200	US$ 210	
❏ Student, Unemployed, Emeritus	US$ 75	US$ 85	
			$________

MAA Minicourses (see listing in text)

I would like to attend: ❏ One Minicourse ❏ Two Minicourses
Please enroll me in MAA Minicourse(s) #_____ and/or #_____
In order of preference, my alternatives are: #_____ and/or #_____
Price: US$75 for each minicourse.
(For more than 2 minicourses call or email the MMSB.) $________

Graduate Program Fair

❏ Graduate Program Table US$ 60 N/A $________

Employment Center *Please go to http://www.ams.org/emp-reg to register. For further information contact Steve Ferrucci at emp-info@ams.org.*

Events with Tickets

❏ Graduate Student/First Time Attendee Reception (1/6) (no charge)
MER Banquet (1/7) US$ 55 #___Chicken #___Veg #___Kosher
AWM Banquet (1/7) US$ 60 #___Chicken #___Salmon #___Veg #___Kosher
NAM Banquet (1/8) US$ 53 #___Chicken #___Veg #___Kosher
AMS Banquet (1/9) US$ 53 #___Chicken #___Fish #___Veg #___Kosher
(Additional fees may apply for Kosher meals.)

$________

Total for Registrations and Events $________

Payment

Registration & Event Total (total from column on left) $ __________
Hotel Deposit (only if paying by check) $ __________

Total Amount To Be Paid **$** __________

(Note: A US$5 processing fee will be charged for each returned check or invalid credit card. Debit cards are not accepted.)

Method of Payment

❏ **Check**. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates. For all check payments, please keep a copy of this form for your records.

❏ **Credit Card**. All major credit cards accepted. For your security, we do not accept credit card numbers by postal mail, e-mail or fax. If the MMSB receives your registration form by fax or postal mail, we will contact you at the phone number provided on this form. For questions, contact the MMSB at mmsb@ams.org.

Signature: ______________________________________

❏ **Purchase Order** #__________________ (please enclose copy)

Other Information

Mathematical Reviews field of interest # ____________

How did you hear about this meeting? Check one: ❏ Colleague(s) ❏ *Notices* ❏ *Focus* ❏ Internet

❏ This is my first Joint Mathematics Meetings.
❏ I am a mathematics department chair.
❏ For planning purposes for the MAA Two-year College Reception, please check if you are a faculty member at a two-year college.
❏ I would like to receive promotions for future JMM meetings.
❏ Please do not include my name on any promotional mailing lists.
❏ Please ✓ this box if you have a disability requiring special services.

Mailing Address/Contact:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887 **Fax**: 401-455-4004
Telephone: 401-455-4143 or 1-800-321-4267 x4143; **E-mail:** mmsb@ams.org

Deadlines *Please register by the following dates for:*

To be eligible for the complimentary room drawing:	**Nov. 5, 2010**
For housing reservations, badges/programs mailed:	**Nov. 19, 2010**
For housing changes/cancellations through MMSB:	**Dec. 6, 2009**
For advance registration for the Joint Meetings, short courses, minicourses,and tickets:	**Dec. 15, 2009**
For 50% refund on banquets, cancel by:	**Dec. 27, 2010***
For 50% refund on advance registration, minicourses & short courses, cancel by:	**Dec. 31, 2010***

***no refunds after this date**

Registration for the Joint Meetings is not required for the short courses but it is required for the minicourses & Employment Center.

2011 Joint Mathematics Meetings Hotel Reservations – New Orleans, LA

Please see the hotel page in the announcement or web for detailed information on each hotel. To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc., in the column on the left and by circling the requested room type and rate. If the rate or the hotel requested is no longer available, you will be assigned a room at a ranked or unranked hotel at a comparable rate. Please call the MMSB for details on suite configurations, sizes, availability, etc. Suite reservations can only be made through the MMSB to receive the convention rate. Reservations at the following hotels must be made through the MMSB to receive the convention rates listed. Reservations made directly with the hotels before December 17 will be changed to a higher rate. All rates are subject to a 13% sales/TID tax, plus an additional occupany tax of US$3. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

❏ Deposit enclosed (see front of form)

❏ Hold with my credit card. **For your security, we do not accept credit card numbers by postal mail, e-mail or fax.** If the MMSB receives your registration form by postal mail or fax, we will contact you at the phone number provided on the reverse of this form.

Date and Time of Arrival ______________ **Date and Time of Departure** ______________

Name of Other Room Occupant ______________ **Arrival Date** ________ **Departure Date** ________ **Child (give age(s)** ____

Name of Other Room Occupant ______________ **Arrival Date** ________ **Departure Date** ________ **Child (give age(s)** ____

Order of choice	Hotel	Single	Double 1 bed	Double 2 beds	Triple 2 beds	Triple 2 beds w/cot	Triple - king or queen w/cot	Quad 2 beds	Quad 2 beds w/cot	Suites Starting rates
	New Orleans Marriott (Co-headquarters)									
	Regular Rate	US$ 158	US$ 168	US$ 168	US$ 188	N/A	US$ 188	US$ 208	N/A	US$ 325
	Student Rate	US$ 120	US$ 120	US$ 120	US$ 140	N/A	US$ 140	US$ 160	N/A	N/A
	Sheraton New Orleans (Co-headquarters)									
	Regular Rate	US$ 158	US$ 178	US$ 178	US$ 203	N/A	US$ 228	US$ 228	N/A	US$ 299
	Club Level	US$ 189	US$ 199	US$ 199	US$ 219	N/A	US$ 244	US$ 239	N/A	N/A
	Student Rate	US$ 120	US$ 120	US$ 120	US$ 140	N/A	US$ 165	US$ 160	N/A	N/A
	JW Marriott New Orleans									
	Regular Rate	US$ 148	US$ 158	US$ 158	US$ 178	N/A	US$ 178	US$ 195	N/A	US$ 850
	Astor Crowne Plaza New Orleans									
	Regular Rate	US$ 119	US$ 119	US$ 119	US$ 139	N/A	US$ 159	US$ 159	N/A	US$ 269
	Student Rate	US$ 109	US$ 109	US$ 109	US$ 129	N/A	US$ 149	US$ 149	N/A	N/A

Special Housing Requests:.

❏ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are:______________

____

❏ Other requests: ______________

❏ I am a member of a hotel frequent-travel club and would like to receive appropriate credit.
The hotel chain and card number are:______________

E-mail confirmations (no paper) will be sent by all hotels if an e-mail address is provided.

If you are not making a reservation, please check off one of the following:

❏ I plan to make a reservation at a later date.

❏ I will be making my own reservations at a hotel not listed. Name of hotel:______________

❏ I live in the area or will be staying privately with family or friends.

❏ I plan to share a room with______________ , who is making the reservations.

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: Michel L. Lapidus, Department of Mathematics, University of California, Surge Bldg., Riverside, CA 92521-0135; e-mail: `lapidus@math.ucr.edu`; telephone: 951-827-5910.

Central Section: Georgia Benkart, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388; e-mail: `benkart@math.wisc.edu`; telephone: 608-263-4283.

Eastern Section: Steven H. Weintraub, Department of Mathematics, Lehigh University, Bethlehem, PA 18105-3174; e-mail: `steve.weintraub@lehigh.edu`; telephone: 610-758-3717.

Southeastern Section: Matthew Miller, Department of Mathematics, University of South Carolina, Columbia, SC 29208-0001, e-mail: `miller@math.sc.edu`; telephone: 803-777-3690.

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 can be found at** `www.ams.org/meetings/`.

Meetings:

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 92 in the January 2010 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset in LaTeX. Visit `http://www.ams.org/cgi-bin/abstracts/abstract.pl`. Questions about abstracts may be sent to `abs-info@ams.org`. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

0002-9920(20101)57:9;1-4