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About the cover: Seattle Speakers (see page 55)
This self-contained text takes both an analytical/theoretical approach and a visual/intuitive approach to the local and global properties of curves and surfaces. This edition includes more exercises and project ideas, reorganized material on the Gauss–Bonnet theorem, and a new chapter on curves and surfaces in \( \mathbb{R}^n \). New sections cover applications to cartography and problems in spherical and hyperbolic geometry.

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Understanding Many-Particle Systems with Machine Learning

September 12 – December 16, 2016 | Los Angeles

Organizers: Álán Aspuru-Guzik (Harvard University), Gabor Csányi (University of Cambridge), Mauro Maggioni (Duke University), Stéphane Mallat (École Normale Supérieure), Marina Meila (University of Washington), Klaus-Robert Müller (Technische Universität Berlin), and Alexandre Tkatchenko (Fritz-Haber-Institut der Max-Planck-Gesellschaft).

Scientific Overview

Interactions between many constituent particles (bodies) generally give rise to collective or emergent phenomena in matter. Even when the interactions between the particles are well defined and the governing equations of the system are understood (for example the Coulomb interaction between protons and electrons and the Dirac/Schrödinger equation in quantum mechanics), the collective behavior of the system as a whole does not trivially emerge from these equations. Examples of collective behavior are abundant in nature, manifesting themselves at all scales of matter, ranging from atoms to galaxies. Machine learning methods have been used extensively in a wide variety of fields ranging from, for example, the neurosciences, genetics, multimedia search to drug discovery. Machine learning models can be thought of as universal approximators that learn a (possibly very complex) nonlinear mapping between input data (descriptor) and an output signal (observation).

It is the goal of this IPAM long program to bring together experts in many particle problems in condensed-matter physics, materials, chemistry, and protein folding, together with experts in mathematics and computer science to synergetically address the problem of tackling emergent behavior and understanding the underlying collective variables in many particle systems.

Workshop Schedule

- Understanding Many-Particle Systems with Machine Learning Opening Day: September 12, 2016
- Understanding Many-Particle Systems with Machine Learning Tutorials: September 13-16, 2016
- Workshop IV: Synergies between Machine Learning and Physical Models: December 5-9, 2016
- Culminating Workshop at Lake Arrowhead Conference Center: December 11-16, 2016

Participation

This long program will involve senior and junior researchers from several communities relevant to this program. You may apply for financial support to participate in the entire fourteen-week program, or a portion of it. We prefer participants who stay for the entire program. Applications will be accepted through June 12, 2016, but offers may be made up to one year before the start date. We urge you to apply early. Mathematicians and scientists at all levels who are interested in this area of research are encouraged to apply for funding. Supporting the careers of women and minority researchers is an important component of IPAM’s mission and we welcome their applications. More information and an application is available online.

www.ipam.ucla.edu/mps2016
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Welcome from the New Notices Editor-in-Chief

The Notices of the American Mathematical Society must be interesting and valuable to its wide and diverse readership around the world, including research mathematicians, students, and everyone else interested in mathematics. Our top priority is to present compelling readable articles on the latest advances in mathematics, well-illustrated, and subject to extensive editing and cutting to provide a sharp focus and to avoid the overly technical.

We’re starting this issue with alluring notes from invited speakers at this month’s Joint Mathematics Meetings in Seattle, to entice those attending and to include everyone else in the excitement. We’ve added a new Graduate Student Section, with email interviews by the first graduate student member of the Editorial Board, an enhanced version of the popular “WHAT IS...?” feature, and some excerpts from the AMS Graduate Student Blog.

Our redesigned webpage invites online moderated discussion and commentary, as a first step toward future Web enhancements. Every February and September we’ll have a “Mathematical Moment” for sharing with your friends. Some of the more routine material is being replaced with shorter blurbs and links to fuller information. Our new closing “Back Page” includes a cartoon contest and an original comic strip.

Please send us contributions of all types you think appropriate for Notices. Write about math. Write an article about how to find a job for the Graduate Student Section. Write about how to write a letter of recommendation. Write about women and minorities. Write a Doceamus article about how to bring the latest math into the undergraduate classroom. Write about support for research vs. adjuncts in public institutions. Send in contributions for the Back Page, including math in the news or ads, or funny very short stories from around your department. Whenever possible, include high resolution graphics (with written permissions for the AMS to reproduce them). Above all, be interesting.

Institutions are invited to send illustrated short blurbs on upcoming events of special interest. Other publications are invited to send short blurbs on their articles of special interest to our readers for consideration for simultaneous publication.

Notices is freely available online, and you can have email notification of its posting, which occurs around the middle of the previous month, about when the hard copies are mailed out. The hard copy is a privilege of AMS membership.

Enjoy the issue. Send your comments and suggestions to Frank.Morgan@williams.edu, or better, post them with the new Commentary Feature on our webpage ams.org/notices.
JMM 2016 Lecture Sampler
Kristin Estella Lauter, Karen E. Smith, Panagiota Daskalopoulos, Marta Lewicka and M. Reza Pakzad, Tanya A. Moore, Tatiana Toro, Daniel Alan Spielman, Steve Zelditch, and Alex Eskin

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Some of the Joint Mathematics Meetings invited speakers have kindly provided these introductions to their lectures in order to entice meeting attendants and to include nonattendants in the excitement.

—Frank Morgan

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Prestrained Elasticity: From Shape Formation to Monge-Ampère Anomalies

Imagine an airplane wing manufactured in a hyperbolic universe and imported into our Euclidean space. The incompatibility of the two geometries would be an obstacle for the relative ideal hyperbolic distances in the wing to be realized in the ambient Euclidean space. As a consequence, the wing would take on a deformed shape and be subject to internal stresses, making it not suitable for flying. This scenario, though imaginary, describes an everyday phenomenon known as prestrain in nonlinear elasticity. Here, prestrain refers to an incompatible ideal metric, and, contrary to the above situation, it can play a positive role in nature and in applications.

Figure 1 shows the optimal “relaxations” of a planar film allowed to freely seek a strain-minimizing deformation in space. Although the prescribed strain is radially symmetric, the resulting configurations are not; they exhibit large-scale buckling and multiscale wrinkling, and in fact they still retain residual strain albeit smaller than the original one.

How “good” are these relaxations in general? This problem can be studied through a variational model pertaining to the non-Euclidean version of nonlinear elasticity, which postulates formation of a target Riemannian metric resulting in the morphogenesis of the tissue that attains a configuration closest to being the metric’s isometric immersion. It now turns out that the answer to the above question depends on the scaling of the energy minimizers in terms of the film’s thickness and a posteriori by the emerging isometry constraints on deformations with low regularity.

The study of mappings with weak regularity and the behavior of rough solutions to PDEs arising in geometry or physics has been an important part of analysis for decades. Many physical phenomena modeled by PDEs cannot be described by merely smooth solutions. On the other hand, lack of regularity can lead to nonphysical solutions or even to situations where generically every function is close to a solution. This kind of mathematical behavior goes back to early work by Nash and Kuiper on isometric embeddings, where a Riemannian surface can be $C^1$ isometrically embedded in $\mathbb{R}^3$, while higher smoothness requires higher dimensions.

In practical applications, thin films can be residually strained by a variety of means, such as inhomogeneous growth, plastic deformation, swelling or shrinkage driven by solvent absorption, or opto-thermal stimuli in glass sheets. An interesting application, suggested by Kim et al. [4], creates curvy films by using light technology for the temperature-responsive flat gel sheets that transform into a prescribed curved surface when the in-built metric is activated (see Figure 2).

We hope that the study of thin films will lead to a better understanding of three-dimensional solids and such fundamentals as energy scaling laws, the role of curvature or symmetry breaking. Current disagreements between theory and experiment need also to be resolved.

Incompatible Elasticity and Residual Stresses

Let $\Omega \subset \mathbb{R}^n$ be a simply connected domain, and let $G$ be a smooth Riemannian metric on $\Omega$. It is well known that
when the Riemann curvature tensor $\text{Riem}(G)$ vanishes in $\Omega$, there exists a mapping $u$ (in other words, a deformation) of $\Omega$ into $\mathbb{R}^n$ which is an isometric immersion of $G$:

$$\nabla u(x) \cdot \nabla u(x) = G(x) \quad \forall x \in \Omega.$$  

When the mentioned condition fails (as it fails for a generic choice of $G$), one proceeds by seeking an orientation-preserving deformation $u$ which minimizes the difference between the tensor fields in the right and left hand sides of (1). This difference is measured by the energy functional, called the prestrained (or incompatible) elasticity:

$$E(u) = \int_{\Omega} \text{dist}^2(\nabla u(x) G(x))^{-1/2}, SO(n)) \, dx,$$

defined over the set of admissible deformations $u \in W^{1,2}(\Omega, \mathbb{R}^n)$ with square integrable derivatives of first order. The distance in matrix space $\mathbb{R}^{n \times n}$ is measured in terms of the Hilbert-Schmidt norm $|A|^2 = \text{trace}(A^T A)$. Note that $E(u) = 0$ if and only if $u$ is orientation preserving and satisfies (1). In this case, a change of variable reduces (2) to a standard nonlinear elasticity functional of the type $\int_{\Omega} W(\nabla u) \, dx$, which has been largely studied in the literature.

In the incompatible case when $\text{Riem}(G) \neq 0$, existence of an energy gap phenomenon was shown in [8]. Namely, the equilibrium state of the body $\Omega$ must have a positive energy content, $\inf E > 0$, which we refer to as the residual energy. So far, only partial quantified estimates of this infimum in terms of $\text{Riem}(G)$ have been obtained. To better understand this problem, as well as to explore the relationship between the components of the target metric and the Riemann curvature as the driving force behind respectively the mechanical response and the residual stress, one is led to study models with reduced complexity, e.g., through dimension reduction.

A thin film can be modeled by the Cartesian product $\Omega^h = \omega \times (-\frac{h}{2}, \frac{h}{2})$, with the mid-plate $\omega \subset \mathbb{R}^2$ and small thickness $h \ll 1$. In what follows, we are concerned with analyzing the infimum energy and the structure of minimizers of the energy functional below, now also in relation to the vanishing thickness $h \to 0$:

$$E^h(u^h) = \frac{1}{h} \int_{\Omega^h} \text{dist}^2((\nabla u^h)^{(h)}(G^h)^{-1/2}, SO(3)) \, dx,$$

$$\forall u^h \in W^{1,2}(\Omega^h, \mathbb{R}^3).$$

$\Gamma$-Convergence

A major difficulty in studying the functionals (3) is that the frame invariance of the energy density spoils convexity. Thus, in general, direct methods of calculus of variations cannot be applied, and the minimizing sequences to (3) must be studied through asymptotic analysis, exploiting the small thickness of the domain. Namely, one first hopes to establish compactness properties for approximate minimizers of $E^h$ as $h \to 0$. These, naturally, vary among different ranges of the scaling exponent $\beta$ in $\inf E^h \sim h^\beta$, which is in its turn induced by the prestrain $G^h$. Having found the admissible set of the limiting deformations, one then looks for suitable “dimensionally reduced” energies that would carry the structure of $E^h$. The method of $\Gamma$-convergence is one of the strategies available for this purpose in the variational toolbox.

In the present set-up for thin films, proving $\Gamma$-convergence of $h^{-\beta}E^h$ consists of deriving two inequalities. The first inequality establishes a lower bound: $I_{\beta}(u) \leq \liminf_{h \to 0} h^{-\beta}E^h(u^h)$ for any sequence $u^h$ converging to a mapping $u$. The second inequality shows that the previous bound is optimal in the sense that for any given admissible $u$, we have $I_{\beta}(u) = \limsup_{h \to 0} h^{-\beta}E^h(u^h)$ for a particular recovery sequence $u^h$ converging to $u$.

The main feature of this definition, which in fact justifies its applicability, is that the limits of any converging sequence of minimizers of $E^h$ coincide with the minimizers of $I_{\beta}$. Again, the results vary and depend on the chosen scaling $\beta$; in general, larger energies admit larger deformations, while smaller energies (induced by $G^h$ with small Riemann curvatures in terms of $h$) admit only more restrictive deformations that need to preserve certain stringent curvature constraints.

Curvature-Driven Energy-Scaling Quantization

We start by a short excursion in the context of compatible prestrains satisfying $\text{Riem}(G) = 0$. In this case, a change of variable brings the energy (3) to the standard nonlinear elasticity functional defined on deformations $u^h$ of a tubular neighborhood $S^h$ of a surface $S \subset \mathbb{R}^3$, with trivial prestrain $G = I_{d_s}$. When $S = \omega \subset \mathbb{R}^2$, the quantitative geometric rigidity estimate established in [3] leads to the rigorous study of the dimensionally reduced thin models in low-energy scalings. For more general geometries, a conjecture has been put forward [9] concerning an infinite hierarchy of limiting thin shell models, each valid in its respective energy-scaling regime induced by the scaling of the applied body forces. In each case, the $\Gamma$-limit of $h^{-\beta}E^h$ consisted of a computable combination of bending and stretching.
In certain situations, the geometry of $S$ allows for the matching of lower-order infinitesimal isometries to higher-order ones, whereas the corresponding theories collapse to one and the same theory, valid under the lower-order infinitesimal isometry constraint. The conjecture and this “collapse phenomenon” is so far consistent with all the rigorously established analytical results.

The picture in the prestrained elasticity scenario, where $\text{Riem}(G) \not\equiv 0$, is richer in as much as it does not generate one sequential hierarchy but rather a network of limiting models, differentiated by the scaling of the components of the curvatures of $G^h$ when $h \to 0$.

When $G^h = G$ is independent of thickness parameter, an energy gap phenomenon can be observed [1]. Namely, the only possible scaling after the nonzero energy drops below $h^2$ is that of order $h^3$. In the first case, the $\Gamma$-limit of $h^{-2}E^h$ consists of a curvature functional defined over the $W^{2,2}$ isometric immersions of the two-dimensional manifold $(\omega, G_{2x2})$ into $\mathbb{R}^3$. In the second case, the three Riemann curvatures $R_{1123}, R_{1213}$, and $R_{1232}$ of $G$ vanish identically. The $\Gamma$-limit of $h^{-3}E^h$ is then given in terms of stretching, i.e. the change of metric, and bending that is the induced change of the second fundamental form with respect to the unique isometric immersion that gives the zero energy in the prior $\Gamma$-limit, plus a new term that quantifies exactly the remaining three possibly nonzero Riemann curvatures.

The Monge-Ampère Constrained Energy

The Monge-Ampère equation:

$$\det \nabla^2 \nu = f \quad \text{in} \ \omega \subset \mathbb{R}^2$$

can be seen as a “small slope” variant of the isometric immersion equations, and it naturally arises in the thin limit residual theories of the model (3). Indeed, for the incompatibility tensor of the form $G^h = \text{Id}_3 + 2h^2S$ where $0 < \gamma < 2$, the $\Gamma$-limit $I$ of $h^{-\gamma}E^h$ is effectively defined [7], [6] on the deformations of regularity $W^{2,2}$ for which the pull-back of the Euclidean metric coincides with the prestrain $G^h$ at the first order of expansion of their Gauss curvatures. This condition is precisely equivalent to (4) with $f = -\text{curl}^2 \text{curl} S_{2x2}$, whereas we have $I(\nu) = \int_\omega |\nabla^2 \nu|^2$.

For future purposes, let us note that the above discussion motivates the following weak form of the two-dimensional Monge-Ampère equation (4):

$$\det \nabla^2 \nu := -\frac{1}{2} \text{curl}^2 \text{curl}(\nabla \nu \otimes \nabla \nu) = f.$$  

The Monge-Ampère constrained variational problem $I$ is the source of a wide range of questions: from the technical obstacles in deriving the model as a $\Gamma$-limit to the study of regularity and multiplicity of minimizers or critical points, of which many remain open. Along these lines, we recently demonstrated the surprising existence of a class of anomalous solutions to (5). The rest of this article is dedicated to this line of inquiry.

Convex Integration for the Monge-Ampère Equation

When $f$ is nonnegative, any $\nu \in W^{2,2}(\omega)$ satisfying (4) must actually be $C_1$ and convex. Once the convexity is established, the path opens up for applying the standard results in the theory of nonlinear PDEs to obtain better interior regularity of $\nu$ depending on the given regularity of $f$. For the “flat case” $f \equiv 0$, any such $\nu$ must be developable: it is $C_1$, and for every point $x \in \omega$ there exists either a neighborhood of $x$ or a segment passing through it and joining $\partial \omega$ at both its ends, on which $\nabla \nu$ is constant.

The same assertions of convexity/developability are true [10] for solutions $\nu \in C^{1,\alpha}(\omega)$ of (5) with $\frac{2}{3} < \alpha < 1$. Let us point out that a crucial step in proving results for the weak Hölder regular solutions is a commutator estimate that yields a degree formula for the Hölder continuous mapping $\nabla \nu$. Such commutator estimates were used for the Euler equations by Constantin, E, and Titi and for the isometric immersion problem by Conti, Delellis, and Szekelyhidi. This relationship is not surprising in view of the presence of a quadratic term in the equations in all three cases.

The parallels with the isometric immersions and Euler’s equations do not stop here. In both cases, the known rigidity statements are contrasted with existence of anomalous flexible solutions in lower regular regimes. It is perhaps surprising that similar statements on existence of anomalous solutions to the Monge-Ampère equation (4) have been missing in the literature. Indeed, the reformulation (5) leads to the following counterintuitive result [10]. Fixing an exponent $\alpha < \frac{1}{2}$ and the right-hand side $f \in L^{7/6}(\omega)$, the set of $C^{1,\alpha}(\bar{\omega})$ solutions to (5) is dense in $C^{0,1/3}(\bar{\omega})$.

The critical value of Hölder’s exponent at the threshold of rigidity and flexibility is not yet clear; it has been conjectured to be $\frac{1}{2}$ or $\frac{2}{3}$, relying on various intuitions. Here and also in the case of isometries, the Nash-Kuiper iteration method cannot yield anomalous solutions with regularity better than $C^{1,1/3}$, but on the other hand, there seems to be little indication of how to prove the rigidity for the regimes $\frac{1}{3} \leq \alpha \leq \frac{2}{3}$. This situation is, again, parallel with the recent results in the context of fluid dynamics (see Delellis and Szekelyhidi [2] and the references therein), where the famous Onsager’s conjecture puts the Hölder regularity threshold for the energy conservation of the weak solutions to the Euler equations at exactly $C^{0,1/3}$.

Conclusion

In this article, we motivated how the prestrain metric problem can be formulated for three-dimensional elastic bodies and showed how it leads to problems in geometry and analysis. In particular, rigidity properties of the weak solutions to geometric PDEs come to the forefront, including the discovery of the anomalous solutions to the Monge-Ampère equation. The investigation of the dimensionally reduced models can also shed light on the
precise role which is played by the curvature tensor in the stress distribution within a three-dimensional body and can eventually lead to a better understanding of the shape formation phenomena through growth, plasticity, etc. Coming back to the energy (3), a direct consequence of the existence of the anomalous $C^{1,\alpha}$ solutions in the regime $\alpha < 1/7$, is that for all given $G^h = \text{Id}_3 + 2h^2S$ one has: $\inf E^h \ll h^{1/2}$. This could be improved to: $\inf E^h \ll h$, if the anomalous regime was extended to $\alpha < 1/3$. Finally, scaling regimes between $h^2$ and $h^{1/2}$, and the corresponding behaviour of thin prestrained films, are not yet well understood. Other largely unexplored related topics include homogenization, symmetry and symmetry breaking, inverse prestrain analysis (useful, e.g., in tumor detection) and randomly generated prestrain. These avenues of research connect between theory of elasticity, differential geometry, analysis, and PDEs. We also hope that a thorough theoretical understanding of the phenomena discussed in this article could help in engineering sheets or bodies with finely controlled shapes, dynamics, structural resistance to loads, and elastic properties such as rigidity and flexibility.

References

Daniel Alan Spielman

Graphs, Vectors, and Matrices

Algebraic Graph Theory

Graphs are the quintessential objects of study in discrete mathematics. They are usually described as a set of vertices, $V$, that are connected by a set of edges, $E$, each of which is a pair of vertices. Graphs encode connections and are one of the most commonly used representations of data. While we first learn to prove theorems about graphs through local arguments and combinatorial manipulations, much of what I want to know about a graph is revealed through the more continuous approach of algebraic graph theory.

We define the Laplacian quadratic form of a weighted, undirected graph with positive edge weights $w_{a,b}$ to be the function from $x \in \mathbb{R}^V$ to real numbers given by

$$\phi_G(x) \overset{\text{def}}{=} \sum_{(a,b) \in E} w_{a,b} (x(a) - x(b))^2.$$ 

So, the coefficient of $x(a)x(b)$ in $\phi_G(x)$ is $-w_{a,b}$ if $(a, b)$ is an edge and zero otherwise. The coefficient of $x(a)^2$ is the weighted degree of vertex $a$: $\sum_{(a,b) \in E} w_{a,b}$. The Laplacian matrix of $G$, denoted $L_G$, is the symmetric matrix such that

$$\phi_G(x) = x^T L_G x.$$ 

To build intuition for why the eigenvalues and eigenvectors of $L_G$ should reveal combinatorial properties of $G$, in my talk I’ll present Hall’s spectral graph drawing algorithm [Hal70]. When we introduce graphs to students, we often do so through pictures. We draw the vertices as little circles and the edges as lines or curves connecting the circles representing their endpoints. While we obtain the same graph wherever we put the circles, some drawings reveal the structure of the graph much better than others. For example, consider the two drawings in Figure 1. They both represent the same graph, but the second reveals its structure much better than the first. As suggested by Hall, it was drawn by using two eigenvectors of the Laplacian matrix of the graph to determine the coordinates of the vertices.

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Sparsification

Sparsification is the approximation of a graph by a graph with fewer edges. We say that a graph $G$ is an $\epsilon$-approximation of a graph $H$ with the same vertex set if for all $x \in \mathbb{R}^V$,

\begin{equation}
(1 + \epsilon) \phi_G(x) \geq \phi_H(x) \geq (1 + \epsilon)^{-1} \phi_G(x).
\end{equation}

We may express this condition in a linear algebraic manner by introducing the notation $A \gg B$ to indicate that $x^T A x \geq x^T B x$ for all vectors $x$. For symmetric matrices $A$ and $B$, this is equivalent to saying that $A - B$ has no negative eigenvalues. With this notation, (1) becomes

\begin{equation}
(1 + \epsilon) L_G \gg L_H \gg (1 + \epsilon)^{-1} L_G.
\end{equation}

For small $\epsilon$ this is a very strong condition. Among other things, it implies that $L_G$ and $L_H$ have approximately the same eigenvalues.

Every graph may be approximated by a sparse graph, where the number of edges in the sparse graph depends on the quality of the approximation. The strongest result of this form that we presently know comes from the following theorem of [BSS12].

**Theorem 1.** For every graph $G$ on $n$ vertices and every $\epsilon > 0$, there is a graph $H$ having at most $\lceil n/\epsilon^2 \rceil$ edges so that

\begin{equation}
(1 + \epsilon)^2 L_G \gg L_H \gg (1 + \epsilon)^{-2} L_G.
\end{equation}

The proof of this theorem is purely linear-algebraic and relies on the association of vectors with the edges of a graph. We define the **vector associated with edge** $(a,b)$ to be the vector

\[ u_{a,b} \overset{\text{def}}{=} e_a - e_b, \]

where $e$ is the elementary unit vector in direction $a$. That is, $u_{a,b}$ has a 1 in position $a$, a $-1$ in position $b$, and is zero everywhere else. For a vector $x \in \mathbb{R}^V$,

\[ x(a) - x(b) = u_{a,b}^T x, \]

and thus

\[ (x(a) - x(b))^2 = (u_{a,b}^T x)^2 = x^T (u_{a,b} u_{a,b}^T) x. \]

So, we can write $L_G$ as

\[ \sum_{(a,b) \in E} w_{a,b} u_{a,b} u_{a,b}^T. \]

In [BSS12] we derive Theorem 1 as a consequence of the following theorem about collections of vectors.

**Theorem 2.** Let $u_1, \ldots, u_m$ be vectors in $\mathbb{R}^n$, and let $\epsilon > 0$. Then, there exists a subset $S \subseteq \{1, \ldots, m\}$ of size at most $\lceil n/\epsilon^2 \rceil$ and real numbers $s_i > 0$ so that for

\[ A = \sum_{i=1}^m u_i u_i^T \quad \text{and} \quad B = \sum_{i \in S} s_i u_i u_i^T, \]

\[ (1 + \epsilon)^2 A \gg B \gg (1 - \epsilon)^2 A. \]

Even the problem of sparsifying the complete graph is interesting. Recall that the complete graph on $n$ vertices is the graph with every possible edge. Sparse approximations of the complete graph are expander graphs (see [HLW06]), and they have proved incredibly useful in computer science and combinatorics. The best sparse approximations of the complete graphs are the Ramanujan graphs constructed by Margulis (1988) and Lubotzky, Phillips, and Sarnak (1988).

**Weaver’s Conjecture and the Kadison-Singer Problem**

The Kadison-Singer problem [KS59], which comes from the study of $C^*$ algebras and quantum physics, has been shown to be related to problems in many branches of mathematics (see [CFTW06]). We [MSS13] solve this problem by proving a conjecture in discrepancy theory that Weaver (2004), using results of Akemann and Anderson (1991), proved would give a positive solution to the Kadison-Singer problem.

Weaver’s conjecture concerns a collection of complex vectors, $u_1, \ldots, u_m$, such that

\[ \sum_{i=1}^m u_i u_i^* = I. \]

For most purposes, it suffices to consider the outer products of real vectors with their transposes. Collections of vectors that satisfy (2) are said to be in “isotropic position” and are also called a “Parseval frame”. The sum in this expression is also known as a “decomposition of the identity”. For example, the vectors in an orthonormal basis are in isotropic position, as are the set of vectors associated with the edges of a complete graph. The vectors in Figure 2 are in isotropic position.

\[ \sum_{(a,b) \in E} w_{a,b} u_{a,b} u_{a,b}^T. \]

In [BSS12] we derive Theorem 1 as a consequence of the following theorem about collections of vectors.
We would like to know conditions under which a set of vectors in isotropic position is guaranteed to contain a subset whose sum of outer products approximates half the identity. The most obvious obstacle to this happening is if one of the vectors, $u_i$, has large norm. For example, if $u_i$ has norm 1, then the sum will have an eigenvalue of 1 if $i \in S$ and an eigenvalue of 0 if $i \notin S$. Weaver conjectured that vectors of large norm are the only obstacle.

**Conjecture 1.** There are positive constants $\alpha$ and $\epsilon$ so that for every collection of vectors $u_1, \ldots, u_m$ in isotropic position such that $\|u_i\|^2 \leq \alpha$ for all $i$, there exists a subset $S \subseteq \{1, \ldots, m\}$ so that $$(1 - \epsilon)I \geq \sum_{i \in S} u_i u_i^* \geq \epsilon I.$$ 

This conjecture has a provocative resemblance to Theorem 2. Using some ideas from the proof of that theorem, along with the theory of real stable polynomials and an elementary but new proof technique that we call the *method of interlacing families of polynomials*, we [MSS15] prove a strong version of this conjecture.

**Theorem 3.** For every constant $\alpha > 0$ and every collection of vectors $u_1, \ldots, u_m$ in isotropic position such that $\|u_i\|^2 \leq \alpha$ for all $i$, there exists a subset $S \subseteq \{1, \ldots, m\}$ so that $$(1/2 + \beta)I \geq \sum_{i \in S} u_i u_i^* \geq (1/2 - \beta)I,$$ where $\beta = \sqrt{2\alpha} + \alpha$.

**Editor’s Note:** Daniel Spielman’s use of the discrete Laplacian is complemented by Steve Zelditch’s use of the continuous Laplacian; see page 15.

**References**


*Karen E. Smith*

**Noether’s Legacy: Rings in Geometry**

I am deeply honored to lecture in the name of my mathematical idol, Emmy Noether.

Emmy Noether is responsible for the modern definition of commutative rings and their homomorphisms. Her 1921 paper “Idealtheorie in Ringbereichen” laid out the foundations of modern algebra and continues to impact mathematics well beyond algebra nearly a century later.

Then as now, rings of functions provide natural examples of abstract rings, an example as relevant today as it was in Noether’s time. Even in high school, we add and multiply real-valued functions of the real line, quickly absorbing the basic properties (such as distributivity of multiplication over addition) that make up the axioms of Noether’s definition.

This is especially true in algebraic geometry, where geometric objects called varieties turn out to be more or less equivalent to the rings of polynomial functions on them. Some relatively concrete questions about a variety $V$ include the following: Is $V$ smooth? How can we tell if it is smooth?

Even if $V$ is not smooth, how damaging are its singularities? Can we perhaps ignore them for some computations or purposes? Can we measure the singularities precisely? All these questions can be answered

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She did not realize that one could have a career as a mathematician until college, when her freshman calculus teacher, Charles Fefferman, suggested it. After teaching high school for a year, she discovered that schools will pay for you to get a PhD. In 2001 she won the Ruth Lyttle Satter Prize for her work in commutative algebra. She is especially proud of her record of mentoring, already with sixteen completed PhD students.

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by studying the algebraic features of rings of functions on $V$.

Precisely, an affine algebraic variety $V$ is the common zero set, in $\mathbb{C}^n$, of a (possibly infinite) collection of polynomials. Its \textit{coordinate ring}, denoted $\mathcal{C}[V]$, is the $\mathbb{C}$-algebra of complex valued functions on $V$ generated by the (restrictions to $V$ of the) coordinate functionals $z_1, \ldots, z_n$. Noether’s famous \textit{First Isomorphism Theorem} gives a concrete presentation of the coordinate ring. Indeed, the natural restriction mapping

$$\mathcal{C}[z_1, \ldots, z_n] \rightarrow \mathcal{C}[V]$$

sending each polynomial to its restriction to $V$ is easily seen to be a surjective ring homomorphism. So the First Isomorphism Theorem implies that

$$\mathcal{C}[V] \cong \frac{\mathcal{C}[z_1, \ldots, z_n]}{\text{kernel } \rho},$$

where the kernel of the restriction map, of course, consists of the polynomials vanishing at every point of $V$. So, for example, the coordinate ring of the cone in $\mathbb{C}^3$ defined by $x^2 + y^2 = z^2$ is the ring $\mathcal{C}[x, y, z]/(x^2 + y^2 - z^2)$.

The points of an affine algebraic variety $V$ are in one-one correspondence with the maximal ideals of its coordinate ring $\mathcal{C}[V]$; this is the content of Hilbert’s Nullstellensatz, or \textit{zero set theorem}. Indeed, all the algebrao-geometric features of the variety— for example, its dimension, its subvarieties, its singular set— have algebraic characterizations in the coordinate ring. This idea was greatly expanded by Grothendieck, who taught us to view every commutative ring, no matter how abstract, as the ring of functions on some corresponding space.

In my Noether lecture, I will explain one surprisingly effective method for understanding varieties with ring theory: reduction to prime characteristic. In the case of the cone, the idea is to go beyond the coordinate ring $\mathcal{C}[x, y, z]/(x^2 + y^2 - z^2)$ and study instead the family of “reductions modulo $p$”:

$$\mathbb{F}_p[x, y, z]/(x^2 + y^2 - z^2),$$

as $\mathbb{F}_p$ ranges through all the fields of $p$ elements, $p$ prime.

Why would one do so? Why would one throw away the tools of analysis, such as integration and differentiation, and instead look at algebras over finite fields? What do we gain?

The point is that the ring $\mathbb{F}_p[x, y, z]/(x^2 + y^2 - z^2)$ has characteristic $p$. A commutative ring $R$ of prime characteristic $p$ has the property that the $p$th power map

$$R \rightarrow R \text{ sending } f \mapsto f^p$$

is a ring homomorphism. This homomorphism, called the Frobenius map, turns out to be a tremendous tool. In particular, it sheds light on the singularities of algebraic varieties in many ways.

Already half a century ago, Ernst Kunz characterized smoothness of complex varieties using Frobenius: smoothness turns out to be equivalent to a simple algebraic property called flatness of Frobenius in the corresponding family of modulo $p$ reductions. More recent theorems characterize the so-called rational singularities of complex varieties, again, as a property of the modulo $p$ reductions defined using Frobenius. This technique has found many applications throughout mathematics, including, for example, to cluster algebras in combinatorics.

In another direction, numerical invariants for measuring the “badness” of complex singularities have been defined with Frobenius. Starting with a complex variety defined by a single polynomial $f$ with integer coefficients, for example, the so-called $F$-pure threshold of $f$ is a different rational number for each choice of $p$; interestingly, as $p$ grows to infinity, these $F$-pure thresholds converge to (the reciprocal of) a well-known invariant of complex singularities called the analytic index of singularities, defined by integration.

My hope is that my audience will glimpse the beauty of this blooming field of “Frobenius techniques” in commutative algebra and grasp a small part of our collective mathematical indebtedness to Emmy Noether’s profound contribution to algebra.

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\(\text{Figure 1. Desingularizing the cone.}\)

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\(\text{Figure 2. The real points of four different varieties in } \mathbb{C}^3, \text{ each defined by one polynomial.}\)
Steve Zelditch

Geodesics and Global Harmonic Analysis

Harmonic analysis originates with the exponential functions $\phi_k(x) = e^{i2\pi k(x,x)}$ of Fourier analysis on $\mathbb{R}^n$ (with $k \in \mathbb{R}^n$) or on the torus $\mathbb{T}^n = \mathbb{R}^n / \mathbb{Z}^n$ (with $k \in \mathbb{Z}^n$). The idea is to express any function (or distribution) as a linear combination of the exponentials,

$$f(x) \sim \sum_{k \in \mathbb{Z}^n} a_k e^{i2\pi k(x,x)},$$

and to relate properties of $f$ to the dual properties of the Fourier coefficients $a_k$. As eigenfunctions of the Laplacian $\Delta = \sum_{j=1}^n \frac{\partial^2}{\partial x_j^2}$ on $\mathbb{R}^n$, the exponentials $e^{i2\pi k(x,x)}$ form a (generalized) orthonormal basis of eigenfunctions of $L^2$.

In the case of the flat torus, the exponentials (i) have uniformly bounded $L^\infty$-norms, $|e^{i2\pi k(x,x)}| \leq 1$, (ii) have the ‘WKB form’ of $a(x) e^{i\phi(x)}$ where the amplitude $a = 1$ and $\phi(x) = (x, \frac{k}{\pi})$.

These properties reflect the flatness of the Euclidean metric and are rarely found on other Riemannian manifolds $(M,g)$ where $g = \{g_{ij}\}$ is the metric tensor. The main theme of this article is that eigenfunctions of the Laplacian $\Delta_g$ of the metric in general reflect the geometry of geodesics. Henceforth we drop $g$ from the notation for a Riemannian manifold $M$, but it should be kept in mind that eigenfunctions and geodesics depend on the metric $g$.

A round 2-sphere provides an opposite extreme where certain eigenfunctions are ‘as large as possible’. The zonal (rotationally invariant) spherical harmonics $Y^j_\ell(x)$ of eigenvalues $\ell(\ell + 1)$ have the possible largest $L^\infty$ norm of size $\sqrt{\ell}$. There is a universal estimate

$$||\phi_\ell||_{L^\infty} \leq C_g \frac{\sqrt{\ell}}{\ell^{\frac{n-1}{2}}}, \quad (||\phi_\ell||_{L^2} = 1, n = \text{dim}(M),$$

where $C_g$ depend only on $g$ and not on the eigenvalue $\lambda$.

[Schw]

An illustration of “global harmonic analysis” is the following recent result of the author with C. D. Sogge (building on prior results of Y. Safarov, the authors, and J. Toth).

\textbf{Theorem 1.} Let $M$ be a real-analytic Riemannian surface. If $M$ possesses a sequence of $\Delta_g$-eigenfunctions $\phi_\lambda$ achieving the bound (2) for some $C_g > 0$, then $M = S^2$ (topologically) and must possess a “pole”, i.e., a point such that every geodesic leaving $p$ is a closed geodesic of period $2\pi$.

Examples of surfaces with poles are surfaces of revolution, the poles being the obvious poles (fixed points of the $S^1$ action). Every point of the round $S^2$ is a pole. On the other hand, every geodesic leaving one of the four umbilic points $p$ of a tri-axial ellipsoid is a “self-focal” point, but none are poles (every geodesic $\gamma(t)$ leaving $p$ returns to $p$ at time $2\pi$, but $\gamma'(0) \neq \gamma'(2\pi)$ in general).

Theorem 1 is a corollary of a general result valid in all dimensions, but as yet the existence of a “pole” is proved only in dimension 2.

We intend Theorem 1 as an illustration of a result of global harmonic analysis. The existence of closed geodesics through $p$ cannot be proved using small time behavior of waves and geodesics or by nonwave methods. Analogous problems may be posed for $L^p$ norms with $p < \infty$. For instance, it is known that certain eigenfunctions on the round $S^2$ known as the highest weight spherical harmonics $Y^j_\ell$ are Gaussian beams which “blow up” on the equatorial geodesic but have Gaussian decay in the normal directions. They achieve the maximum possible $L^p$ norms on $S^2$ for $p \leq 6$; the analogue of (2) for other $L^p$ norms is due to C. D. Sogge (see [Sog]). It is natural to conjecture that a surface can have a sequence of eigenfunctions achieving the maximal $L^p$ bound with $p < 6$ only if it has a stable elliptic closed geodesic, somewhat like the equator, and if the eigenfunctions are something like Gaussian beams concentrating on that closed geodesic. This is a very good open problem in the field.

On any complete Riemannian manifold, geodesics depend on curvature and so do eigenfunctions of the Laplacian, but the key link is through the wave equation and dynamics of the long-time global geodesic flow. The title of this article, “Global harmonic analysis”, is
meant to indicate how global properties of the geodesic flow are related to the asymptotics of eigenfunctions. Experts will recognize that the relations are between classical and quantum mechanics in the semiclassical or high-frequency limit. The author has not seen a proof of (2) using the standard elliptic estimates of geometric analysis; it is a good illustration of the power of wave equation methods.

Let us compare how local and global harmonic analysts approach a problem on eigenfunctions. The local harmonic analyst works with the partial differential equation

\[ \Delta \phi(x) = -\lambda^2 \phi(x), \quad x \in B \subset M, \]

locally in a ball B. When \( \lambda = 0 \), the equation says that \( \phi \) is harmonic. Even when \( \lambda > 0 \), a local harmonic analyst sees this as constraining just how far the eigenfunction is from being a harmonic function. Dilating a “small ball” \( B(p, \sqrt{\lambda}) \) by the factor \( \lambda \) stretches out the eigenfunction to a nearly harmonic one and allows one to use the tools of local harmonic analysis (such as mean value inequalities). By comparison, the global harmonic analyst works with the “wave equation”

\[ e^{it\sqrt{-\Delta}} \phi = e^{i\lambda \phi}, \]

which is only valid if (3) holds globally on \( M \). The “propagator” \( e^{it\sqrt{-\Delta}} \) or solution operator of the wave equation propagates singularities along geodesics. The global harmonic analyst doesn’t want to suppress oscillations in \( \phi \) by stretching them out, but rather exploits the ever more rapid oscillations as \( \lambda \to \infty \). Ultimately, this leads to relations between asymptotics of eigenfunctions as \( \lambda \to \infty \) and the long-time behavior of geodesics, e.g., whether they are periodic (as on round spheres) or wind around uniformly in the unit cotisphere bundle (as for negatively curved manifolds).

Another rich area for global harmonic analysis is the asymptotic behavior of nodal sets of eigenfunctions. To contrast again local versus global properties of eigenfunctions, it is a classical local result that there exists a zero of \( \phi \) in every ball \( B(p, \frac{c_\lambda}{\lambda}) \subset M \); i.e., the nodal set \( N_{\phi_\lambda} = \{ x : \phi_\lambda(x) = 0 \} \) is \( \frac{1}{\lambda} \)-dense. The proof uses only that \( \Delta \phi_\lambda = -\lambda^2 \phi_\lambda \) in a ball \( B(p, \lambda^2) \) and not globally on \( (M, g) \), and in this sense is a model of local harmonic analysis of eigenfunctions. Putting together local arguments, Donnelly-Fefferman (1987) proved that for real-analytic \( (M, g) \), the hypersurface measure \( H^{n-1}(N_{\phi_\lambda}) \) of the nodal sets satisfies the bounds

\[ c_1 \lambda \leq H^{n-1}(N_{\phi_\lambda}) \leq C_2 \lambda, \]

for some \( c_1, C_2 > 0 \). The inequality was earlier conjectured by S. T. Yau for general \( C^\infty \) metrics, but that remains a very open problem.

A further well-known nodal problem is to count the number of nodal domains. A nodal domain is a connected component of \( M \setminus N_{\phi_\lambda} \). The nodal domains partition \( M \) into disjoint open sets:

\[ M \setminus N_{\phi_\lambda} = \bigcup_{j=1}^{\mu(\phi)} \Omega_j, \]

When \( 0 \) is a regular value of \( \phi_\lambda \), the level sets are smooth curves. When \( 0 \) is a singular value, the nodal set is a singular (self-intersecting) curve. The question is: how many connected components does the nodal set have? The classical Courant bound is that the number \( N(\phi_j) \) of the jth eigenfunction in an orthonormal basis is bounded by \( j \); in general, \( N(\phi_\lambda) \) is bounded by \( N(\lambda) \) (the number of eigenvalues \( \leq \lambda \)). It is known that there is no nontrivial lower bound for \( N(\phi_\lambda) \) that holds for every sequence of eigenfunctions on every \( (M, g) \); for example, it was shown by H. Lewy that there exist \( (M, g) \) and sequences of \( \phi_j, \lambda_j \to \infty \) with only two or three nodal domains. An obvious question is whether any \( (M, g) \) possesses at least one sequence of eigenfunctions for which \( N(\phi_\lambda) \to \infty \) as \( \lambda \to \infty \). It was pointed out by T. Hoffman-Ostenhof that this is (apparently) an open problem. At first, it seems obviously true: on \( S^2 \), for instance, such a sequence exists for the standard metric (e.g., the zonal harmonics). Connect any metric \( g \) on \( S^2 \) by an analytic path \( g_t \) of metrics with \( t \in [0, 1] \) and “analytically continue” the eigenfunctions \( \phi_j(t) \) along the path (this is possible). Then show that that number of nodal domains does not change for a “generic” path. Unfortunately, this outline overlooks the fact that for a generic path of metrics and the associated paths of eigenfunctions \( \phi_j(t) \), two nodal domains will collide (i.e.,
intersect) at some times $t_k$ at a singular point of $\phi_j(t_k)$, and two nodal domains can merge into one. By the time $t = 1$, the $\lambda_j$ nodal domains may have merged into just a fixed number of domains independent of $\lambda_j$. Although such a conspiratorial situation seems unlikely, there is no proof that it does not occur for any path $g$, between the standard metric and another given metric. In fact, it is a challenge to prove the existence of any reasonably large class of metrics which possess a sequence $\phi_{j_k}$ of eigenfunctions for which $N(\phi_{j_k}) \to \infty$. The following result with Jumehyuk Jung gives a reasonably large class.

**Theorem 2.** Let $(X, g)$ be a surface with curvature $k \leq 0$ and with concave boundary. Then for any orthonormal eigenbasis $\{\phi_j\}$ of Dirichlet (or Neumann) eigenfunctions, one can find a density 1 subset $A$ of $\mathbb{N}$ such that

$$\lim_{j \to \infty} N(\phi_j) = \infty.$$ 

A density one subset $A \subset \mathbb{N}$ is one for which $\frac{1}{N} \# \{j \in A : j \leq N\} \to 1$, $N \to \infty$. An example of a nonpositively curved surface with concave boundary is a Sinai-Lorentz billiard in which one removes a small disc $C$ from $X$.

The proof is based on proving that there are “many” zeros and critical points of eigenfunctions of Neumann eigenfunctions (or of normal derivatives of Dirichlet eigenfunctions) along the boundary $\partial M$. That is, the proof very much depends on the existence (and concavity) of a boundary. The results were inspired by one of Ghosh-Resnikov-Sarnak for Hecke eigenfunctions.

Let us outline the proof in the Neumann case. The geodesic billiard flow of $M$ is ergodic under the assumption that the curvature is $\leq 0$ and the boundary is concave. Hence the eigenfunctions are “quantum ergodic”. Without going into the details, ergodicity of eigenfunctions means that they oscillate a lot and in all directions as $\lambda_j \to \infty$. We then restrict the eigenfunctions to the boundary $\partial M$. The main point is to prove that the Neumann eigenfunctions $\phi_j$ have a growing number of zeros on $\partial M$ as $\lambda_j \to \infty$. In fact, this is true for any curve on $M$, not just the boundary.

The last step is a topological argument (based on the Euler inequality for embedded graphs in surfaces). Suppose that a Neumann eigenfunction vanishes at $N$ points and that the genus of $M$ is $h$. Each nodal line emanating from the boundary must return to the boundary at some other point. In general, the curve together with the boundary might not bound a domain. But an Euler inequality for graphs in $M$ shows that there must exist at least $\frac{1}{2} N - C_h$ nodal domains formed this way, where $C_h = h + h_M$ where $h_M$ is the number of components of $\partial M$.

In conclusion, the global results use long-time dynamical properties of the geodesic flow, such as its ergodicity (or, at the opposite extreme, its integrability or periodicity) to prove results about eigenfunctions and waves that are often invisible to the more traditional local harmonic analysis in small balls.

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**References**


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**Alex Eskin**

**The SL(2, $\mathbb{R}$) Action on Moduli Space**

Alex Eskin, Compton Distinguished Service Professor at the University of Chicago, will talk about ergodic theory with applications to billiards (just the math; won’t help you win, but applies on any polygonal table, convex or not). *His recent breakthrough work with Mirzakhani and Mohammadi on SL(2, $\mathbb{R}$) actions on moduli space has as an application this new result by Lelièvre, Monteil, and Weiss: If the angles are rational multiples of $\pi$, from every point on the table you can shoot the cue ball to all but finitely many other points.*

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**Editor’s Note:** See the related “WHAT IS …an Ergodic Transformation?” on page 26.

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Kristin Estella Lauter

Homomorphic Encryption for Private Genomic Computation

The capacity to sequence the human genome has opened up a treasure chest of possibilities for understanding human disease, searching for cures, and providing personalized medicine. But it also raises both important privacy challenges and questions about how to securely store and handle genomic data for computation. Just as data on individual preferences and behavior is a valuable economic commodity in the present, human genomic data has been called the “currency of the future.” Protecting access to it is crucial.

Mathematics provides important infrastructure and tools for solving a host of problems in genomic computation. Mathematical modeling and machine learning algorithms help scientists learn from data to do predictive analysis, and pattern matching is used for sequence alignment. The mathematics of cryptography has recently provided an important new tool for protecting privacy in genomic computation: homomorphic encryption.

Homomorphic encryption keeps genetic data private but still allows another party to do computations on it. Consider a patient or a consumer who has his or her genome sequenced and stores the result locally on a personal computer or device. To obtain a private prediction—such as the likelihood of having a disease associated with a known genotype—from a Cloud service, the client first encrypts the genomic data homomorphically, then sends the encrypted data to the Cloud for processing without sending the decryption key. The Cloud computes on the encrypted data and returns an encrypted result to the client. The client then decrypts the result locally.

Here’s an analogous classroom-related example: A professor stores her students’ encrypted grades in the Cloud and keeps the decryption key, which may be shared with the university administration, for example. The Cloud service can compute an encrypted version of the mean and standard deviation of the final exam or other statistical functions of students’ grades without knowing the grades. The encrypted results can be decrypted by anyone who has the decryption key.

Construction of a homomorphic encryption scheme that allows computation of any circuit was an open problem for several decades until Craig Gentry provided

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length, along with the inner product of the two vectors obscured by some Gaussian noise, $e$ (error). (Sample: $(a, as + e)$.) These problems are believed to be hard due to security reductions, proved by Regev and coauthors Lubashevsky and Peikert, to other known problems on lattices, such as certain approximate versions of the Shortest Vector Problem (SVP), which has been studied for decades.

The vectors in the above description are thought of as elements of a lattice, but they can also be viewed as coefficients of a polynomial in a polynomial ring, and this is the point of view in the Ring Learning With Errors setting. For cryptosystems based on RLWE, the polynomial ring which we use in practice is the ring of integers in a cyclotomic number field, presented as

$$Z[\zeta_m] = Z[X]/\Phi_m(X).$$

In fact, the question of the hardness of the RLWE problem in general number rings raises many interesting new questions in number theory which we are only beginning to investigate.

Cryptographic systems based on number theoretic constructions provide a surprising potential solution for ensuring privacy in outsourced genomic computation. This is a beautiful example of several apparently unrelated branches of science intersecting to provide coherent solutions to human problems.

References and links to articles in the popular press can be found on my webpage: research.microsoft.com/en-us/people/klauter/default.aspx

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**Tanya A. Moore**

**Why Mathematicians and Statisticians Are Needed to Create Lasting Social Impact**

Tanya Moore, Presidio Graduate School, is cofounder of the Infinite Possibilities Conference, a national biennial conference designed to support, promote, and empower underrepresented minority women in mathematics and statistics. She has been featured in *Black Enterprise* and *O, The Oprah Magazine*. Her talk will highlight the obvious and not-so-obvious ways mathematicians and statisticians are today’s change agents.

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Panagiota Daskalopoulos

Ancient Solutions to Parabolic Equations

Some of the most important problems in geometric partial differential equations are related to the understanding of singularities. Focusing in on a singularity, a certain "blow-up" procedure yields special solutions defined for all time $-\infty < t \leq T$, for some $T \leq +\infty$. We refer to such solutions as eternal if $T = +\infty$ and ancient if $T < +\infty$. The classification of such solutions, when possible, often sheds new insight into singularity analysis.

Common examples of singularities are solitons, which maintain their shape as time advances. Shrinking solitons are often examples of ancient solutions, while steady solitons are examples of eternal solutions. One often sees other ancient or eternal solutions which come from the gluing of solitons. The main question is whether these special solutions and the solitons are the only nontrivial ancient or eternal solutions of the flow.

We will focus on an area of active research: ancient solutions to geometric flows, such as the Ricci flow, the Mean Curvature flow, or the Yamabe flow.

Under the Ricci flow, the metric of an $n$-dimensional Riemannian manifold $M$ shrinks by its Ricci curvature, a natural intrinsic curvature of the manifold. The Ricci flow was introduced by R. Hamilton in his seminal 1981 paper and developed by him in a series of subsequent breakthrough works leading to G. Perelman’s 2002 seminal works on the resolution of the Poincaré Conjecture.

In 2012, in joint work with R. Hamilton and N. Sesum, we proved that there are just two types of ancient solutions on a compact surface ($n = 2$). The simplest type is a round sphere contracting to a point. The second type, due to J. R. King and P. Rosenau, is two cigars glued together, as in Figure 1, the so-called sausage model of quantum field theory.

The proof relies on both analytical and geometric tools, such as a priori estimates, monotonicity of nonstandard Lyapunov functionals, geometric blow-up arguments, geometric estimates on isoperimetric ratios, and the application of the maximum principle on a rather complex quantity which vanishes on the King-Rosenau solutions.

A similar conjecture holds for 3-dimensional compact manifolds under a noncollapsing condition: that the only ancient non-collapsed solutions to the Ricci flow are contracting spheres and analogues of the King-Rosenau solutions due to G. Perelman. The noncollapsing condition is necessary due to the existence of other collapsed examples discovered by V. A. Fateev and related to quantum field theory.

One of the remarkable features of the 2-dimensional Ricci flow is its conformal invariance, because in 2D it coincides with the Yamabe flow, in which the metric shrinks in a given conformal class by a rate proportional to its scalar curvature. The Yamabe flow was introduced by Hamilton in 1989 as a parabolic approach to the resolution of the so-called Yamabe problem, solved by S. Brendle in 2005–2007.

It turns out that for the Yamabe flow there are more types of ancient solutions. In a recent work with M. del Pino and Sesum, we constructed ancient solutions of the Yamabe flow on, for example, the 3-dimensional sphere as moving towers of 2-spheres joined by thin necks, as in Figure 2.

The appearance of the towers of bubbles shows that the classification of ancient solutions to the compact Yamabe flow on $S^n$ poses a rather difficult task. On the other hand, it gives a new way for constructing special solutions. It shows how one may glue two or more ancient solutions of a parabolic equation to construct a new ancient solution of the same equation. More recently, in joint work with del Pino, J. King, and Sesum, we have constructed a four-parameter of ancient solutions which converge, as $t \to -\infty$, to two self-similar solutions moving in opposite directions. The picture that one has is very similar to that in Figure 1, where the cigar solution is replaced by a one-parameter family of self-similar solutions (solitons) which may be viewed as traveling waves in cylindrical coordinates. Our solutions are not given in closed form, except for one (the analogue of the sausage model in the Ricci flow), which was previously discovered by King.

One of the best-known extrinsic geometric flows is the Mean Curvature flow, in which a hypersurface in $\mathbb{R}^{n+1}$...
moves in the normal direction at a rate proportional to the mean curvature. Since this flow is known for its many exotic examples of singularities, one expects to have many ancient solutions. The simplest ancient solution is a contracting sphere. One hopes to provide a classification of ancient solutions by imposing natural geometric conditions, such as convexity or noncollapsedness. The latter condition is necessary due to “pancake”-type solutions, which collapse as $t \to -\infty$.

For the case $n = 1$ of the *curve-shortening flow* in the plane, S. Angenent found interesting compact noncollapsing solutions: two “Grim Reapers” that approach each other from opposite ends of the plane, so named because of the way they sweep away all other possibilities as they come together. In joint work with Hamilton and Sesum, we proved that there are no other convex ancient solutions.

It is unknown how much of this generalizes to higher dimensions. B. White has found noncollapsing convex and compact ancient solutions. In joint work with Angenent and Sesum we have made some partial progress toward proving that these are the only ones by providing the detailed asymptotic analysis of rotational symmetric solutions as $t \to -\infty$.

The results above are only a small step forward towards understanding ancient solutions to parabolic equations. All the existing classification results are based on knowing all the candidates as either being solitons or given in closed form. The next big step forward would be to classify other ancient solutions, including the examples mentioned above. In that respect the classification of all ancient noncollapsed and compact solutions to the mean curvature flow would be the first result in this direction.

For more information come to our talk and see our recent papers at [arXiv.org](http://arxiv.org) and references therein.

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**Tatiana Toro**

**Analysis on Nonsmooth Domains**

Tatiana Toro, Robert R. and Elaine F. Phelps Professor in Mathematics at the University of Washington in Seattle, will deliver the NAM Claytor-Woodard Lecture this year. Toro is a mathematician working at the interface of geometric measure theory, harmonic analysis, and partial differential equations. The cross-pollination between these three areas has been one of the pillars of her research. Her work focuses on understanding mathematical questions that arise in environments where the known data is very rough. The main premise of her work is that objects that at first glance appear to be very irregular do in fact exhibit quantifiable regular characteristics when viewed through the right lens.

In her lecture Toro will focus on the deep interplay between the geometry of a domain and the boundary regularity of solutions to elliptic partial differential equations. This will allow her to illustrate the way in which ideas and tools from geometric measure theory, harmonic analysis, and partial differential equations come together to produce interesting and surprising results. It will also provide a concrete example of an instance in which the right magnifying glass reveals a precise structure that would have otherwise remained invisible.

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Interview with Ian Agol

Ian Agol, Professor of Mathematics at the University of California, Berkeley, proved the virtual Haken Conjecture in 2012. This interview was conducted by email by Alexander Diaz-Lopez.

Diaz-Lopez. When did you know you wanted to be a mathematician?

Agol. I was interested in physics and math entering Caltech, and I had mapped out the courses I would need to take in order to take string theory as a senior. However, I did poorly in an advanced physics class as a sophomore. Hence I decided to become a mathematics major. I also preferred the rigor of mathematics over the approximations and heuristics of physics.

Diaz-Lopez. Who encouraged or inspired you?

Agol. I had excellent mathematics teachers all throughout my education, but my geometry teacher Spreck Rosecrans my first year in high school inspired me by giving me extra problems to work on.

Diaz-Lopez. Who encouraged or inspired you?

Agol. I had excellent mathematics teachers all throughout my education, but my geometry teacher Spreck Rosecrans my first year in high school inspired me by giving me extra problems to work on.

Diaz-Lopez. How would you describe your research to a graduate student?

Agol. I study 3-dimensional manifolds, with an emphasis on manifolds admitting hyperbolic metrics. I was interested in knot theory as a first-year graduate student, but drifted towards 3-manifold theory when I learned that Thurston’s geometrization theorem allowed a complete and practical classification of knots. As my career has progressed, I have delved into deeper subjects in mathematics, including Riemannian geometry and geometric group theory, in order to solve questions in 3-manifold topology. Most of the revolutions in the subject have come from other fields (dynamics, partial differential equations, mathematical physics, algebraic geometry, symplectic geometry, number theory), which is exciting because it requires one to continuously learn new mathematics, giving one new perspectives on the topic.

Diaz-Lopez. What theorem are you most proud of and what was the most important idea that led to this breakthrough?

Agol. A few years ago, work I did resolved the virtual Haken conjecture. This work relied on expertise of my collaborators Daniel Groves and Jason Manning, as well as on the much deeper work of Dani Wise and his collaborators (especially Haglund, Hsu, and Sageev) and the work of Kahn and Markovic. One remarkable thing about this topic is the way that it married quite disparate techniques and relied on results from dynamics and deep ideas in geometric group theory initiated by Gromov. Anyway, even though the question was regarding a problem in 3-manifold topology, the method of resolution (whose strategy was formulated by Wise) went into a broader category of word-hyperbolic groups and high-dimensional cube complexes. Nevertheless, some of my key contributions to the problem were to extend the intuition I had developed regarding hyperbolic 3-manifolds to the broader categories required to solve the problem, such as hyperbolic Dehn filling (in the joint work with Groves and Manning), geometrically finite Kleinian groups, and hierarchies for Haken 3-manifolds. Moreover, it seems that the broader category was necessary to solve the problem, since one could carry out certain inductive arguments, which would not have been possible considering only the category of hyperbolic 3-manifolds. So I would say that the most important idea in the proof was to port 3-manifold techniques and the intuition developed regarding them over to geometric group theory, although I should make it clear that I wasn’t the first to develop these generalizations, but was building on the work of many others.

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Editor’s Note: Since this interview, Agol has won the three million dollar Breakthrough Prize in Mathematics.

“I suggest spending part of your time thinking about very hard problems”
Diaz-Lopez. What advice do you have for graduate students?
Agol. I suggest spending part of your time thinking about very hard problems (sure, even the Riemann hypothesis). It might not seem like it, but in graduate school you have much more time than you will as a postdoc or professor (if that’s your career goal), and you can afford to waste some time on difficult problems (if you don’t mind the life of a graduate student). You might even solve it! As a graduate student, I spent some time thinking about the Poincaré conjecture and questions related to the virtual Haken conjecture, as well as the linearity of braid groups. I also thought about a problem about energy of links posed by my advisor, which I didn’t solve, as well as many other problems that seemed more accessible at the time. Eventually I found a do-able problem and wrote a thesis. Even though it was frustrating to get nowhere on the harder problems, the time I spent turned out to be extremely valuable in my career, because when progress was made by others, I could immediately appreciate the difficulty of what was done. Moreover, the problems I listed above have now all been solved by me or others. The problem on energy of links that I originally thought was simpler than the other problems turned out to be solved historically last (using the remarkable insights of Marques and Neves).

Diaz-Lopez. All mathematicians feel discouraged occasionally. How do you deal with discouragement?
Agol. Yes, one thing about math research is that, unless you are not challenging yourself enough, you spend most of your time not solving problems, which can be frustrating. Having collaborators can be quite helpful, partly to vent your emotions. But also verbal discussion of mathematics puts you in a different frame of mind. Together with the useful comments of a mathematician who may have a different knowledge base, this can help outline the difficulties and sometimes lead to new avenues to pursue.

Diaz-Lopez. You have won several honors and awards. Which one has been the most meaningful and why?
Agol. The Senior Berwick Prize. Although I couldn’t make it to the UK for the award presentation, it is meaningful because it was a prize for a paper in the Journal of Topology regarding Thurston’s virtual fibering conjecture. The Journal of Topology came into existence after the editorial board of Topology resigned because they didn’t approve of the publishing practices of Elsevier, and they established the new Journal of Topology to replace it, published by the London Mathematical Society. This was risky, because it takes time for a new journal to build a reputation. I admired the board’s action, and thus to support the journal, I decided to submit the paper, rather than submit it to a more-established journal. Thus, I was pleased to receive some recognition for the paper, which certainly justified publishing there. Now I am on the editorial board!

Diaz-Lopez. If you were not a mathematician, what would you be?
Agol. I have an identical twin brother Eric who is an astrophysicist, so I could certainly see myself as a physicist, but only of the theoretical sort - I did terribly in lab classes.

Diaz-Lopez. If you could ask a question to one famous mathematician, who would it be and what would you ask?
Agol. Let’s imagine we could resurrect Poincaré and explain to him the resolution of his conjecture (however long that might take). Then I would ask him what he thought of the solution, and whether he was surprised that it took so long to discover.

Diaz-Lopez. If you could recommend one lecture (book, paper, article, etc.) to graduate students, what would it be?
Agol. I’m fond of the paper “Shapes of polyhedra and triangulations of the sphere” by William Thurston. It’s not his most difficult result, but it’s insightful, and it makes it unnecessary to read the Deligne-Mostow papers, which I find quite difficult.

Image courtesy of Ian Agol.


See also “Getting Into Shapes: From Hyperbolic Geometry to Cube Complexes and Back”, by Erica Klarreich, Quanta, October 2, 2012.

Alexander Diaz-Lopez is a PhD student at the University of Notre Dame. Diaz-Lopez is the first graduate student member of the Notices Editorial Board.
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WHAT IS... an Ergodic Transformation?

Cesar E. Silva

The theory of ergodic transformations developed from considerations in statistical mechanics involving the distribution of orbits in phase space. Now ergodic systems arise in many areas of mathematics, and ergodic methods have contributed to the solution of problems in several fields.

We start with a concrete example, paraphrasing a question of Gelfand. Are there infinitely many powers of 6 that start with a 9? In the first 18 powers of 6 (see Table 1) there is no initial 9. Indeed, in the first 175 powers of 6 (see Table 2) there is no initial 9. The first one does not appear until

$$6^{176} = 900782763852462026451029188204752173096220152128337050337806145052753525662789031588822572244113988772749324097608129063079175520256.$$ 

We know that $6^n$ starts with a 9 if and only if

$$9 \times 10^k \leq 6^n < 10 \times 10^k,$$

for some $k$. Taking logs of both sides yields the condition

$$\log 9 \leq n \log 6 - k < \log 10,$$

for some $k$.

Let $T$ denote translation by $\log 6$ modulo 1

$$T(x) = x + \log 6 \pmod 1,$$

and let $T^n$ denote the composition of $T$ with itself $n$ times. So $6^n$ starts with a 9 if and only if

$$T^n(0) \in [\log 9, 1).$$

Thus the frequency of powers of 6 that start with a 9, if it exists, is given by

$$\lim_{n \to \infty} \frac{1}{n} \sum_{i=0}^{n-1} \mathbb{1}_{[\log 9, 1)} \circ T^i(0),$$

where $\mathbb{1}_A$ is the indicator function of a set $A$. Figure 1 shows the first 100 points in the orbit of 0, and we see that they miss $[\log 9, 1)$.

<table>
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<th>Digit</th>
<th>$n \leq 175$</th>
<th>$n \leq 175 \cdot 10^3$</th>
<th>Benford</th>
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<td>1</td>
<td>38.67</td>
<td>30.10</td>
<td>30.10</td>
</tr>
<tr>
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<td>19.33</td>
<td>17.60</td>
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<tr>
<td>3</td>
<td>16.00</td>
<td>12.50</td>
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<td>9.69</td>
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<td>6.67</td>
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<td>5.11</td>
<td>5.12</td>
</tr>
<tr>
<td>9</td>
<td>0.00</td>
<td>4.58</td>
<td>4.58</td>
</tr>
</tbody>
</table>

Table 1. $6^n$ for $n = 1, \ldots, 18$.

Table 2. Frequencies of the first digit of $6^n$ for $n \leq 175$, $n \leq 175 \cdot 10^3$, and Benford’s law.

We have just defined a dynamical system consisting of a set of states $X = [0, 1)$ (the phase space of the system), and a transformation $T$ defined on $X$ that one can easily verify preserves Lebesgue measure $\mu$; $\mu(T^{-1}(A)) = \mu(A)$ for all measurable sets $A$. If we had a set $A$ such that $x \in A$ if and only if $T(x) \in A$ (i.e., an invariant set), then we could restrict the dynamics of $T$ to $A$. For example, if 0 were in $A$ and $[\log 9, 1)$ in $A^c$, then the limit in (1) would be 0.

A transformation $T$ is ergodic if every measurable invariant set or its complement has measure 0. When a transformation $T$ is ergodic, by the ergodic theorem, for

where the logarithm is base 10. This means that $n \log 6$ is in some translation of the interval $[\log 9, \log 10)$, or equivalently

$$n \log 6 \mod 1 \in [\log 9, \log 10).$$

Cesar Silva is the Hagey Family Professor of Mathematics at Williams College. He studied at Pontificia Universidad Católica del Perú, and at the University of Rochester with Dorothy Maharam, who introduced him to Kakutani and Oxtoby, his two other mathematical influences, and to his wife Margaret, Oxtoby’s daughter. He has run the Falmouth Road Race, a good 50 percent slower than their two daughters. His email address is csilva@williams.edu.

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all integrable functions $f$ and for all $x$ outside a set of measure zero,

$$(2) \quad \lim_{n \to \infty} \frac{1}{n} \sum_{i=0}^{n-1} f \circ T^i(x) = \int f \, d\mu.$$ 

By taking $f$ to be $\mathbb{1}_{([\log 9, 1])}$, we get the desired density for initial 9s if we know that (2) holds for $x = 0$, which it does for this transformation. The proof begins by showing that, since $\log 6$ is irrational, for all $x$ the orbit $\{T^n(x) : n \in \mathbb{N}\}$ is dense (Kronecker’s theorem).

Thus 9s appear as first digits in powers of 6 with frequency $\mu([\log 9, 1]) = \log(10/9) \approx 4.58\%$. It also follows, for example, that 1 appears as first digit in powers of 6 with frequency $\log(2) \approx 30.10\%$. These are the frequencies predicted by Benford’s law for appearances of 9 and 1 as first digit in many mathematical and real-world contexts.

When $X$ is a compact space and $T$ is continuous on $X$, the system $(X, T)$ is uniquely ergodic if there is only one probability measure $\mu$ for which $T$ is measure-preserving. Uniquely ergodic is stronger than ergodic, because if a transformation is not ergodic, using a nontrivial invariant set and its complement, it is easy to come up with other measures for which $T$ is still measure-preserving. When $T$ is uniquely ergodic, then (2) holds for all continuous functions $f$ for all points $x$. We say that every orbit of $x$ is equidistributed in $[0, 1)$.

There are ergodic transformations that are not uniquely ergodic. The flips of a coin where the probability of heads is $p$ ($0 < p < 1$) and tails is $1 - p$ can be modeled by a set $\Sigma$ consisting of all infinite sequences of 0s and 1s (where we write 0 for heads and 1 for tails). The passage of time is represented by the transformation $\sigma$, which shifts each sequence $x$ in $\Sigma$ to its left. There is a natural product measure $\mu_p$ on $\Sigma$ that comes from assigning the probabilities $(p, 1-p)$ to $\{0, 1\}$. The shift is measure-preserving and ergodic for each measure $\mu_p$. Similarly, one defines a shift that models the tosses of a possibly biased $n$-sided die. Ornstein in 1970 (see [1]) classified completely these Bernoulli shifts by their entropy, a rate at which nearby points typically move away from each other.

There is another interesting and remarkable construction of a measure-preserving system arising from considering a number-theoretic question. Szemerédi in 1975 answered a conjecture of Erdős and Turán by showing that a set of integers of positive upper density (for example, the even numbers have density $1/2$) contains arithmetic progressions of arbitrary length. In 1977, Furstenberg showed how to associate to each set of positive upper density a measure-preserving system so that the set contains an arithmetic progression of length $k$ precisely when the measure-preserving system is $k$-multiply recurrent. He then proved all finite measure-preserving systems are $k$-multiply recurrent for all $k$ (see [1]).

There are other celebrated results where an equidistribution property has been shown. A transformation $T$ on $X$ gives an action of the group $\mathbb{Z}$ on $X$, where the action of $n \in \mathbb{Z}$ on $x \in X$ is $n \cdot x = T^n x$. In the 1990s Ratner proved that, for the action of unipotent matrices on finite-volume quotients of Lie groups, the orbit of every point is equidistributed in its closure, which is a nice manifold.

We conclude with a topic that appears in A. Eskin’s invited address (see page 17). Recently Eskin, Mirzakhani, and Mohammadi proved a series of remarkable theorems that can be thought of as analogues of Ratner’s results in the case of actions of the group of $2 \times 2$ real matrices with determinant 1 on the moduli space of translation surfaces (see [2]). Translation surfaces were introduced to study billiard flows. Among the many recent applications of their breakthrough results, one by Lelièvre, Monteil, and Weiss states that for billiards on polygons with angles that are rational multiples of $\pi$, from every point $x$ there are billiard trajectories to all but finitely many other points.

**Further Reading**


On Our Path toward a More Diverse Mathematical Community
By Alexander Diaz-Lopez, University of Notre Dame

As informed by the AMS Report on the 2012–2013 New Doctoral Recipients, only 6 percent of mathematics PhD degrees conferred to US citizens in 2013 were given to Hispanics, African-Americans, American-Indians and Native Hawaiian. Women accounted for 27 percent. … As graduate students, what can we do to help improve and promote diversity in mathematics?

1. First and foremost, you have to do well in your program.

2. Go to conferences, seminars, colloquia, etc. …

3. Find a mentor, in fact find several mentors. A mentor could be a professor from your undergraduate institution, a professor from your current institution, a former adviser of yours or simply someone you met at a conference/seminar and kept in touch with. These mentors will advise you throughout your career, write letters for you (recommendation letters are usually very important!), and inform you of opportunities you may otherwise not be looking for. The SACNAS, USTARS, and Blackwell-Tapia conferences are great for such purposes (and so are many others). If you decide to organize programs/workshops/conferences (especially targeted towards improving underrepresentation in mathematics), these mentors will be your main source of help and advice.

4. Get involved locally. Most universities have several student organizations. Join any (or all) math organizations. Also look for organizations representing minority students. These organizations often run seminars, conferences and events in which topics regarding diversity...
in mathematics are discussed. Also, often hearing other success stories from some of your peers will motivate you.

It is important to understand that as a graduate student your main purpose is to do well and obtain your PhD. However, you can start creating connections and getting the necessary experience to then be successful at your efforts towards a more diverse mathematical community.

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**Culture Analytics at IPAM**

The digital footprints that people leave behind when they access the Internet or social media offer a treasure trove of cultural information. IPAM's upcoming program on Culture Analytics will explore the mathematical opportunities and challenges that have emerged as a result. Scholars in the social sciences and humanities as well as mathematics, engineering, and computer science are invited to participate in workshops at IPAM March 7–June 10, 2016. For more information, go to [ipam.ucla.edu/ca2016](http://ipam.ucla.edu/ca2016).

A close-up of the visualization of 50,000 Instagram images shared in Bangkok. Artists: Nadav Hochman, Lev Manovich, Jay Chow. Used with permission.
Write stuff up. Write up background, write down little ideas and bits of progress you make. It’s difficult to imagine that these trivial, inconsequential bits will make it to your dissertation. But recreating a week’s/month’s worth of ideas is way more time-consuming that just writing them down now. Or better yet, TeX it up.

What I would recommend is not being too narrowly focused, but finding a few things that really interest you and develop different skillsets. Make sure you can do some things that are abstract, but also quantitative/programming oriented things, because this shows that you can attack a problem from multiple angles. In my experience, these two sides also serve as nice vacations from each other, which can be important when you start to work hard on research.

A talk can be too short if not enough material is introduced to make it interesting, but in research level talks, the last third of the talk (approximately) is usually very technical and usually only accessible to experts in the field. I will avoid going into details that are not of general interest and I plan to present more ideas than theorems. The most important thing when giving any talk is to know your audience.
Yair Minsky

Some of my earliest memories of Bill Thurston—hands perched over a table in the Fine Hall common room, fingers moving to indicate the Teichmüller space of the $n$-times-punctured sphere—are filled with his sense of visual intuition and conceptual depth. I began working with Bill as an undergraduate more or less by accident. I had the notion that I could contribute more to mathematics at that point by programming computers, and people told me “talk to Thurston. He’s been using computers to draw pictures of fractals.” In the end I did not do a programming project; Bill suggested I work out a naive version of his theorem for critically finite rational maps, using only the Brouwer fixed point theorem. As I struggled with this, I began to be exposed to Bill’s style of doing mathematics, the importance of clear geometric intuition, and the beauty of topology. He did not push me hard or insist that I learn a lot of background, but provided a kind of gentle guidance and encouragement that I found very helpful. I remember feeling somewhat cowed by fellow students who had mastered a lot of mathematical machinery and receiving a very clear signal from Bill that this is not all there is to doing good mathematical work.

After a brief flirtation with computer science graduate school, I came back to mathematics and back to working with Bill in a more systematic way. His unique style of talking about and explaining mathematics affected my whole approach to the subject, for better and worse. Most inspiring was his insistence on understanding everything in as intuitive and immediate a way as possible. A clear mental image of a mathematical construction or proof was worth much more than a formalization or a calculation. When I didn’t understand a proof, Bill would rarely repeat the details. Instead he would often just come up with another proof. This gave a window into a system of interconnected structure.

Bill’s writing had what I came to think of as the “unique correct completion property”. He wrote clearly but sparsely, and upon first (or second) reading it was hard to know how to fill in the details in his arguments. I repeatedly had the experience of thinking for a long time and realizing finally that there was a real missing point or condition that needed to be mentioned. Then, upon reconsulting the text, I would discover that the point had been written in there the whole time.

I volunteered one time in Bill’s course to look up the proof of something; to my detriment I cannot remember what it was. I dutifully studied the proof, understood the sequence of calculations, and reported back to the class, where I began working through them on the board. Bill looked on with a pained expression on his face and eventually said, “I didn’t mean a formula...”

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William P. Thurston died on August 21, 2012, at the age of 65. This is the second part of a two-part obituary; the first appeared in the December 2015 issue of the Notices.

from a vast conceptual landscape and the struggle as a student to obtain a hint of these intuitions. When he talked his eyes would be half-closed and a slight smile would be on his face as he described something that he could see very clearly.

Of course, in the end it was all mathematics, not mysticism, and the insights came down to proofs, clear statements, and sometimes even a rare formula. When I didn’t understand a proof, Bill would rarely repeat the details. Instead he would often just come up with another proof. This gave a window into a system of interconnected structure.

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There was a year that Bill and Dennis Sullivan combined their groups of graduate students in a joint seminar that alternated between Princeton and the CUNY Graduate Center. We learned a lot of mathematics from these seminars and from the conversations that took place around them and on the train rides. Bill’s interaction
with Dennis always gave me the feeling that a vast and deep universe is out there, with structure that they both understood intimately.

Bill's influence continued long past graduate school. The questions he raised and the techniques he introduced have continued to be a central part of the way I do mathematics. I still do not feel I have really understood something or can be confident about a proof until I have been able to scratch out some kind of geometric doodle that encapsulates the argument. Bill cared a lot about mathematical communication and the process of doing mathematics, and I try to keep in mind his insistence that mathematics is not just about theorems but really about patterns and structure.

Lee Mosher

I first encountered Bill Thurston’s name as an undergraduate senior at Michigan State when my mentor, Richie Miller, told me to “go to Princeton and study with Thurston.” So I did, starting in 1979.

Being Bill's student during that time was a heady experience, during which I learned how exciting mathematics could be. A stream of visitors came through who became mentors and colleagues in future years, including David Epstein, Michael Handel, Ulrich Oertel, Daryl Cooper, and many others. Bill's mathematical ideas spread through papers, lecture notes, courses, seminars, discussions, and many other forms of activity. I witnessed and experienced firsthand the benefit of how Bill practices mathematics, as he would later describe in a summary sentence from his essay “On proof and progress in mathematics” [Bull Amer. Math. Soc., (N.S.) 30 (1994), 161–177]: “The measure of our success is whether what we do enables people to understand and think more clearly about mathematics.”

In that first year (as well as subsequent years) I attended Bill's course, which was full of ideas and techniques and theorems and tricks and which imparted more than just mathematics, but a way of thinking about mathematics. I also attended the graduate student seminar, where I learned a fair amount of background from the older students, including David Gabai and Robert Meyerhoff. I had not interacted much at all with Thurston during my first semester when, one day, while wandering down the corridor of the new Fine Hall, Thurston came wandering towards me in the opposite direction, looking at me with a smiling and expectant demeanor. I realized with a slight panic that I ought to say something, so I blurted out some half-formed thoughts about simple closed curves based on things I had learned in the graduate seminar. He took me up to his office and gave me a copy of the book in which his work on this topic, including his magnificent theory of pseudo-Anosov homeomorphisms of surfaces, had been written up by the French seminar led by Fathi, Laudenbach, and Poenaru. Over the years I often found Bill to be similarly generous with his time and his mathematical ideas.

During my Princeton years Thurston and Rachel Findley, his wife at that time, were also gracious and generous with their personal time. Matt Grayson and I hung out a lot with Bill and Rachel and their children, Nathaniel, Dylan, and Emily. During our last two years at Princeton, Matt lived with them, I lived nearby, and Bill, Rachel, Matt, and I formed a kind of food co-op in which we jointly shopped for food, cooked meals at their house, and attempted, with limited success, to keep some semblance of order in the kitchen.

Bill's enthusiasm during the early stages of mathematical discovery was infectious. Once, while sitting in his living room, Bill said to me, “I can do this group with grep,” which was sort of strange to hear at first. But being his student I knew just enough computerese to have an inkling of what he was saying: he was able to compute in that group with the UNIX utility for processing regular expressions using finite deterministic automata. From there, it was exciting to observe the quick unfolding of the theory of automatic groups.

Conversation with Bill could be hard, either because of strange statements that would stop you in your tracks or what would seem to be his lack of attention. Matt Grayson tells a story about the encounter between his father and Thurston at our 1983 Princeton graduation. After talking with Thurston, Mr. Grayson came to Matt and said that the conversation was difficult because Thurston’s attention seemed to wander. Matt advised his father: “He thinks about many things at the same time. Try saying just every other word.” Mr. Grayson came back later and said, “You were right! That worked.”

Bill was also generous with his deep knowledge of mathematics. In the spring of 1995 at MSRI, while Thurston was director, Benson Farb and I were quixotically attempting to prove that a certain class of groups, the solvable Baumslag-Solitar groups, were all quasi-isometric to each other. We had trouble constructing certain quasi-isometries of the hyperbolic plane—when we pushed them this way, they sprung out that way, and so on—and we began to suspect that these quasi-isometries were much more rigid than

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we had at first thought. We explained our troubles to Bill, who told us about a related but somewhat obscure phenomenon long known to complex analysts: a rigidity property for certain conformal maps of the hyperbolic plane, maps closely related to the quasi-isometries we were vainly attempting to construct. That was just the idea that we needed, and our project flipped over instead to developing a rigidity property for those groups.

In our graduate student years Matt Grayson and I would marvel at the mysteriousness of Bill’s ideas, saying to each other, “He’s so weird.” We thought that Bill was obscurely acknowledging this point when, during our third year of graduate school, as part of Bill’s entourage visiting the University of Colorado, a bumper sticker appeared on his blue van with the word “Alien” superimposed over the mountain silhouette familiar from the Colorado license plate. Of course we also figured that it was really just an antichauvinistic response to the popular “Native” bumper sticker of the time.

The marvel of Bill’s ideas continued to his last years. His recent article “Entropy in dimension one” contains a wonderful theorem characterizing the entropies of free group outer automorphisms. He includes an example that continues to boggle my mind of a free group outer automorphism with entropy 3, in sharp contrast to the irrationality of the entropies of surface group outer automorphisms.

The world is a richer place for Bill Thurston having been in it.

**Jeff Weeks**

Bill treated everybody with equal respect. Whether he was talking with the university president or with the janitor, it didn’t matter; he treated all people with kindness. This may or may not have been a direct result of Bill’s Quaker beliefs; it was certainly consistent with them.

During my years as his graduate student, Bill gave me much mathematical advice. Most of it I have forgotten, and much of it I didn’t fully grasp even then. Yet one piece of advice made an impression on me at the time and has stuck with me ever since: “Don’t make arbitrary choices. Do only what you’re forced to do.” In other words, if you’re trying to prove a theorem and you find you need to make an arbitrary choice, then you’re probably looking at things the wrong way. You should resist the temptation to simply make the choice and push on. Instead, you should stop, take a step back, and try to rethink the problem in a way that requires no arbitrary choice. That advice from Bill has served me well countless times over the years, and I’ve passed it on to all students willing to listen. It applies not only for proving theorems but also for designing software: if a particular algorithm requires you to make an arbitrary choice, it’s time to stop, step back, and find a better and more natural algorithm.

Bill’s gift, of course, was his vision, both in the direct sense of seeing geometrical structures that nobody had seen before and in the extended sense of seeing new ways to understand things. While many excellent mathematicians might understand a complicated situation, Bill could look at the same complicated situation and find simplicity. For example, his method for putting hyperbolic structures on knot complements is a straightforward exercise in cut-and-paste topology. When I first saw that method I was struck by its simplicity. My fellow graduate students and I could have discovered it years earlier. We had all the tools we needed, and the method was easy, almost obvious. But we didn’t see it. Bill did.

**Benson Farb**

Being a Thurston student was inspiring and frustrating—often both at once. At our second meeting I told Bill that I had decided to work on understanding fundamental groups of negatively curved manifolds with cusps. In response I was introduced to the famous “Thurston squint”, whereby he looked at you, squinted his eyes, gave you a puzzled look, then gazed into the distance (still with the squint). After two minutes of this he turned to me and said, “Oh, I see, it’s like a froth of bubbles, and the bubbles have a bounded amount of interaction.” Being a diligent graduate student, I dutifully wrote down in my notes: “Froth of bubbles. Bounded interaction.” After our meeting I ran to the library to begin work on the problem. I looked at the notes. Froth? Bubbles? Is that what he said? What does that mean? I was stuck.

Three agonizing years of work later I solved the problem. It’s a lot to explain in detail, but if I were forced to summarize my thesis in five words or less, I’d go with “Froth of bubbles. Bounded interaction.”

A Thurston lecture would typically begin by Bill drawing a genus 4 surface, slowly erasing a hole, adding it back in, futzing with the lines, and generally delaying things while he quickly thought up the lecture he hadn’t prepared. Why did we all still attend? The answer is that once in

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a while we would receive a beautiful insight that was absolutely unavailable via any other source.

Here’s an example. Consider a Tinker Toy set of rigid unit-length rods, bolts, and hinges. Rods can have one end bolted to a table and can be hinged to each other. For any given Tinker Toy $T$, bolted down on a table at one point, we have the space $C(T)$ of all possible configurations of $T$. If $T$ is a single rod, then $C(T)$ is a circle. If one adds a hinged rod on the end of $T$, the resulting configuration space is the torus. What other smooth, compact manifolds can you get with this method? I still remember the communal thrill when Bill explained to us how to obtain all compact, smooth manifolds as a component of some $C(T)$. Further, every smooth map between manifolds can actually be represented via some rods connecting the two associated Tinker Toys.

Thurston completely transformed several areas of mathematics, including 3-manifold theory, foliation theory, geometric group theory, and the theory of rational maps. His papers contain a dizzying array of deep, original, influential ideas. All of this is well known. However, in my opinion Thurston’s influence is underrated; it goes far beyond the (enormous) content of his mathematics. As Bill wrote in his paper “On proof and progress in mathematics” [Bull. Amer. Math. Soc. (N.S.) 30 (1994), 161–177]:

“What mathematicians most wanted and needed from me was to learn my ways of thinking, and not in fact to learn my proof of the geometrization conjecture for Haken manifolds.”

We did learn his ways of thinking—or at least some approximation of them. Bill changed our idea of what it means to "encounter" and "interact with" a mathematical object. The phrase "I understand X" has taken on a whole new meaning. Mathematical symbols and even pictures are not sufficient for true understanding, especially in geometry and topology. We must strive to live somehow inside the objects we study, to experience them as three-dimensional beings. I think that this change is now almost invisible; it has become a structural feature of the way many of us do mathematics.¹ This kind of pervasive influence can be likened to the way that Grothendieck changed the way many people think about mathematics, even on topics Grothendieck himself never touched.

The change in viewpoint described above was taken beyond topology by many of Thurston’s students, who went out and “Thurstonized” a number of other areas of mathematics, changing those areas in a notable way. Oded Schramm’s work is a case in point. Early in his career Schramm solved many of the major open problems about circle packings. This theory gives a way to really understand (in the Thurstonian sense) the Riemann Mapping Theorem as the limit of an iterative process. Schramm then moved on to apply his geometric insight to understand the scaling limit for many two-dimensional lattice models in statistical physics. The Schramm-Loewner evolution gives a geometric, “what it looks like” understanding of these limits.

Bill was probably the best geometric thinker in the history of mathematics. Thus it came as a surprise when I found out that he had no stereoscopic vision, that is, no depth perception. Perhaps the latter was responsible somehow for the former? I once mentioned this theory to Bill. He disagreed with it, claiming that all of his skill arose from his decision, apparently as a first-grader, to “practice visualizing things” every day.

I think that there is a fundamental misunderstanding that many people have about Thurston’s work. In particular, the completeness of the proofs in his later work has sometimes been questioned. Such complaints are not justified. One can point to Thurston’s occasional lack of proper attributions and to some brevity in his mathematical arguments, but, for the most part, he gave complete, albeit concise, proofs. The skepticism seems to stem from the frustration one can feel in not understanding what Bill was trying to communicate and the desire for more detail, only to realize, after understanding things, that the details were there all along.

I had an uneven relationship with Bill. However, like so many other people, my mathematical viewpoint was shaped by his way of thinking. In interacting with other mathematical greats, one gets the feeling that these people are like us but just 100 (OK, 500) times better. In contrast, Thurston was a singular mind. He was an alien. There is no multiplicative factor here; Thurston was simply orthogonal to everyone. Mathematics loses a dimension with his death.

Danny Calegari

I counted Bill as my friend, as well as my mentor, and I have many vivid and happy memories of time I spent with him.

I remember seeing Bill for the first time when I arrived at Berkeley in 1995. At the start of the academic year, all the incoming graduate students were ushered into the colloquium room to meet some of the senior personnel. Bill was there in his capacity as director of MSRI (the Mathematical Sciences Research Institute). He was wearing jeans with big holes at the knees. He made a speech about MSRI, inviting us all to come up the hill and interact with the visitors there. He also encouraged us to pronounce it as “emissary” rather than “misery”. It didn’t work; we all called it “misery” (and still do).

I remember actually taking the bus up the hill (maybe a few months later?) in the vague hope of running into Bill and asking him to be my advisor (people had warned me against this, saying that Bill “wasn’t taking students,” because he was too busy running MSRI). I don’t think I had a very clear plan about how this was going to work out. I walked in and saw Bill chatting with Richard Kenyon about the entropy of dimer tilings and hyperbolic volume. At this point I basically froze, turned around, and walked out again.

¹This reminds me of the story of the old fish who passes by two young fish and says, “Morning, boys. How’s the water?” The two young fish look at each other, and one asks the other, “What the heck is water?”

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I remember Bill running the “very informal foliations seminar” at MSRI with Dave Gabai, Joe Christy, and a few other people. This seminar was not advertised; I basically wandered in off the street into the middle of a three-hour lecture by Bill, explaining his new ideas about universal circles and how they might be used to approach the geometrization conjecture for 3-manifolds with taut foliations. By the time he was done, I had decided I wanted to work on foliations, and I more or less had my thesis problem.

I remember when Bill moved to Davis. This was the only time I ever saw him in his office at Berkeley, when he was cleaning it out. I remember the little photo that used to be on the door—the one that’s on the cover of More Mathematical People [Harcourt Brace Jovanovich, Boston, 1990]—of Bill as a child working at a desk. He saw me watching him carrying his boxes out of his office and looking at the photo and gave a slightly embarrassed smile.

I remember emailing Bill in early 1998 to explain a few of my tentative ideas about foliations, which had been inspired by his slitherings paper. He invited me to come out to visit him at Davis and talk to him in person. Over the next year or so I drove out there perhaps a couple of times per month, struggling up the freeway in my third-hand lemon, with the wind rushing in through the bad seals in the door frame. We would have conversations that lasted for hours, stopping occasionally for lunch and coffee. Bill basically became my “unofficial advisor” (my official advisor, Andrew Casson, was moving to Yale), and perhaps because he did not have many “real” students at Davis at the time, I got a lot of his attention. We spent a lot of time working through the theory of universal circles; I learned a huge amount of mathematics, not only stuff obviously connected to foliations (or even low-dimensional topology) but combinatorics, analysis, group theory, and so on. And yet, Bill listened very carefully to my ideas and always gave them his full attention and consideration. At the time I don’t think I appreciated how rare this attitude is in a senior mathematician towards a graduate student.

I remember when we were trying to work out the details of some construction, Bill got very enthusiastic, and we went to the campus store to buy some enormous sheets of paper and a few sets of colored pencils, bringing them all back to Bill’s office and laying the paper out on the floor. Bill was really excited by this episode; he remarked that he used to do this sort of thing “all the time” when he was at Princeton. I got the impression he hadn’t done it for a while.

I remember working to try to get a project finished in the week before Bill’s daughter was born (we didn’t make it in time). My wife and I were thinking about having kids at the time, and I shyly asked him about the experience. He became very emotional and tender and talked about what it was like to hold a newborn and have them lie in your arms, trusting you completely.

I remember visiting Bill in the winter of 2008. At the time my family and I were on a vegan kick, and I remember discussing veganism and Colin Campbell’s book The China Study with Bill while waiting for the cafeteria people to make us our vegan burritos for lunch. Bill’s wife happened to be very sick that week, and in addition they were moving house, so Bill was very distracted. When I left at the end of my visit, Bill apologized for being distracted with so many other things but hoped that I’d visit again soon. Of course I told him not to apologize, that I’d had a great visit (which was true), and that I hoped I would come again soon when we both had more free time. That was the last time I saw him.

Ian Agol

My first encounter with Thurston was during a graduate student workshop at MSRI. He demonstrated to us how he could count in binary on his fingers and told us how many steps we had taken on the hike to the picnic, which he had counted out using his method while hiking. Later during the workshop, when I expressed my interest to him in finding a solution to the unknotting problem using grid diagrams, he immediately dismissed my approach and took me up to the computer lab to demonstrate the program SnapPea (written by his former student Jeff Weeks and others). This made an impression on me, since his geometric approach clearly gave a more powerful way to study knots than the intrinsic three-dimensional route I was taking (it’s interesting to note, however, that grid diagrams have become an important tool recently in the study of knots and their invariants). Moreover, SnapPea enabled Thurston to take a deep mathematical construction (namely, his proof of the geometrization conjecture for Haken manifolds) and make it into a very concrete output that could be appreciated by nonexperts. I learned later that his approach to mathematics was to start with a simple model where things could be understood very explicitly, and once this model was understood well, it would help him understand the more general case. For example, he told me that he re-proved Andreev’s theorem for Haken reflection groups using the techniques that would generalize to his proof of the geometrization conjecture for Haken manifolds. This principle has guided my own research, where I always ask myself when first considering a problem, “What is the simplest nontrivial special case of a given problem?”

My first meeting with Thurston at Davis was a bit of déja vu: I began to explain a result from my thesis about volumes of Haken hyperbolic 3-manifolds using the Gromov norm, and he immediately began thinking of an alternative approach using the new technology developed by Besson-Courtois-Gallot. Although this approach didn’t work initially, it eventually led to a collaboration several years later when the more powerful techniques of Perelman became available.

I sat in on a graduate seminar run by Thurston each quarter called Experimental Mathematics, where he would ask for questions that interested the students and then would attempt to investigate the problem

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Genevieve Walsh

I want to try to give an impression of what it was like to be Bill Thurston’s student at Davis. When I first arrived at the University of California, Davis, in 1997, Bill was a new professor, teaching Differential Geometry. He was quite famous by this time, and his class was packed. I still have some of my notes from this class. They are filled with pictures of turning the plane minus a point into a cylinder, pictures of a cube folded along its faces, descriptions of the space of all hexagons, with plane fields and Lie brackets and frame bundles, with computations of the fundamental groups of knot complements, with descriptions of “group negative curvature” and quasi-isometries, with laminations and Gabai’s Ubiquity Theorem, and with pictures of what it is like to live in the different geometries. For example, there is a picture of a very skinny person with an arc connecting the head and feet. Next to it is an explanation: “In $\mathbb{H}^2 \times \mathbb{E}$, you look tall and skinny. (Not many fit in vertical circles; a lot fit in horizontal circles.)”

By the end of the year, there were three students left in the class. I was hooked.

I began to work with Bill Thurston, and my notebooks from this period contain many pictures of cusps and bending laminations and computations to figure out what the knot is from a gluing diagram of its complement. I was also lucky to have many like-minded mathematicians in the department to help with clarification. Greg Kuperberg, Ian Agol, Abby Thompson, and Joel Hass were all very useful resources. Still, I was often confused. After our meetings, I would try to write up quickly what had happened so I would not forget what was going on. Here are a few random excerpts: “I’m not sure exactly why we started talking about this, but I asked about bending and he started telling me about complex projective structures....”

“This is kind of a way to ‘see’ the link with the Hopf fibration and the Clifford torus. Figure out how this works.”

“I made a little bit of progress over the weekend, mostly by reading the paper by Hatcher and Thurston, which I still do not totally understand and which Thurston doesn’t want to explain to me.”

“I asked about whether or not quadratic differentials can be identified with the tangent space of Teichmüller space. He said, yes they can, but sometimes it’s better to use the dual. He said to look it up in some book, he might get it mixed up.”

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“In this meeting, we mainly talked about the paper by Cooper and Long, which shows that most Dehn fillings are virtually Haken. I’m writing this up on paper because there were a lot of pictures in this meeting.”

“So I got to tell him that the Schwarzian derivative is \( f''/f' - (3/2)(f''/f')^2 \).”

Apart from trying to understand and picture many different things, and figuring out formulas which he steadfastly refused to put in his papers, I was also supposed to be working on some project. The problem was, I wasn’t completely sure what this was. One day, instead of meeting in his office, he went out and brought us some coffee and some great circle links. Of course, I was thrilled to be out talking math, having coffee, and walking around with a bag full of perfectly round key rings. But I still didn’t know what I was supposed to DO with them. I asked Joel Hass for some mathematical direction one time, to which he replied, “Do whatever it is that Bill tells you to do!” Great circle links did turn out to be beautiful examples of several phenomena, but I didn’t figure that out until later. They are also just plain fascinating, as are so many of his suggestions.

Years later I went to Cornell to give a talk and had the opportunity to meet with Bill Thurston again. He was very ill and seemed tired as we talked in his small house one afternoon by the fire. Bill was wearing a big wool sweater that dwarfed him, and he could barely speak. But Bill asked what I was doing mathematically, and I wanted to talk about it. So I asked him about the space of acute triangulations of the 2-sphere that are combinatorially equivalent to some specific triangulation. In particular, is this space connected? We talked about it, and he turned the problem over in his head, thinking about it from different points of view. He thought it was interesting, and at one point he nodded and said, “I think it probably is.”

Carol Wood

Bigger than life and smarter than I could have imagined, Bill Thurston brought a generation of mathematicians to see things that they might otherwise have missed: mathematical things, of course, but not only. In remembering Bill, I would like to point to things he saw and did at MSRI, resulting in changes in the fabric of the institution.

It has been my privilege over time to meet all the MSRI directors and their teams. Each has put an imprint on MSRI, and each has worked hard and smart, to the benefit of mathematicians and mathematicians. My perspective is that of someone who was a member in 1989–90, a member of Bill’s team in 1996–97, and, subsequently, a program organizer and trustee. Bill was director of MSRI from 1992 to 1997; his deputies were Bob Osserman, Lenore Blum, T. Y. Lam, and, for the final year, me. Bill thought deeply about things. He formulated a vision of the role of MSRI and of himself as director, some of which was articulated in a document called “Possibilities”. I cannot assign individual credit to each event of Bill’s years as director, 1992–97, although anyone involved with MSRI in that era would know that the genius touch for public events was Bob Osserman’s.

Under Bill’s leadership, MSRI’s reach broadened dramatically. Here are some examples:

- **Mathematical Conversations**, in which mathematics teachers and researchers meet as equals, as well as workshops and conferences about mathematics education, such as one on the “calculus wars”.
- Programs for students and young researchers, including introductory workshops and the admission of graduate students to research programs. (In 1989–90 we had to smuggle students into the building!)
- Public events, most famously the Fermat Fest in San Francisco in October 1993, but several other events aimed at bringing mathematically relevant topics to the general public.
- Introduction of the latest forms of technology and communication, including video streaming, Mbone, and Elmo projection. I recall a demonstration of 3D printing in 1997, something only now poised for widespread use.
- Promoting diversity, with the establishment of the Human Resources Advisory Committee, by hosting the first-ever CAARMS (Conference for African-American Researchers in the Mathematical Sciences), by coorganizing the Julia Robinson Conference with the Association for Women in Mathematics.
- Opening sponsorship to departments beyond the eight in the original proposal, so that there were thirty in 1997. (At present there are over ninety sponsors.)

One change, a cosmetic one, was to trade the MSRI nickname “misery”, with its negative connotations, for “emissary”, to indicate the outward-looking institute it

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was to become. Ironically, this new nickname did not take except as the name of the newsletter: some of the old guard persist with “misery”, but most often the four initials are articulated, in the mouthful “em-ess-are-eye”. I admit I never cottoned to either nickname, so I’m happy with the end result.

Most, if not all, of the changes Bill achieved may seem less original or revolutionary today, but they were sea changes in the mathematical culture of the day, all the more so since they took place in an institution devoted to the best of mathematics, and these changes put MSRI well ahead of the curve. Bill’s initiatives were developed in subsequent years under the leadership of David Eisenbud and Robert Bryant, who added their own ideas as well. Today, mathematicians students, educators, departments, and researchers worldwide claim ownership of MSRI. The visionary Bill Thurston had indeed thrown open the doors, and good luck to anyone who tries to pull them shut again!

In 1996–97, Bill’s final year as director of MSRI, I joined the team as deputy director, a job offered to me out of the blue. This was not the first time since we met in the early ’90s that Bill had proposed a role for me that I could barely imagine for myself, but it was the biggest role by far. In conversations with others that spring about the job, I heard complaints, grumbles, even predictions of disaster for MSRI. I trusted Bill’s judgment, buoyed by Alberto Grunbaum’s saying he too thought I could do the job. When I arrived at MSRI, Bill greeted me, as he did all visitors at that time, by displaying his handmade tape model showing the great similarities between human and pig DNA. I witnessed then and many times thereafter his childlike capacity for sheer delight. That was my first hint that this daunting job was also going to be fun.

Bill was the kindest, least pretentious, and most affable person I have ever worked alongside. Moreover, he had assembled a staff remarkably talented and dedicated to the concept of an institute which served its community. My role was straightforward: to make timely decisions so that others could do their jobs. Bill was untidy and Bill was a perfectionist, a combination that sometimes challenged this practical, not-so-visionary deputy. However, during what he might easily have considered his “annus horribilis”, I never heard a complaint from Bill nor an unkind word from him about anyone. (I cannot say the same for me.) Seeing that the MSRI train ran on time was—and still is—a 24-7 job. But I regretted then, and regret all the more with his untimely death, that I didn’t stop more often just to enjoy being around Bill. When I did, it was delightful.

The last time I saw Bill was in Boston at the mathematics meetings in January 2012. He spoke of his plan to visit Berkeley to be near family. He intended to come to MSRI that year for the first time since 1997. I know Robert Bryant shares my regret that fate intervened. Bill’s talks, illustrates very well Bill’s working style: he expressed appreciation to the mathematics community for its acceptance of him and his ideas. In our finest moments, mathematicians are tolerant of each other’s quirks, a fact about which I have always felt proud. No one achieved this acceptance of others more effectively and more widely than Bill Thurston. For his leadership at MSRI, as well as for his mathematics, the mathematics community owes him an enormous debt of gratitude.

**Tan Lei**

I was visiting John Hubbard at Cornell during the winter of 1986. His student Ben Wittner and I were among the first generation of students exploring Thurston’s newly found characterization theorem for rational maps. This powerful theorem gives a necessary and sufficient condition for a flexible object, dynamics on a branched covering, to represent a rigid object, the dynamics of a rational map. It is one of the fundamental theorems in the theory of iterations of rational maps.

Ben and I decided to make a one-day trip to Princeton to meet Bill Thurston in person. That was the first time I met Bill. I was very impressed by his highly animated seminar, scheduled at lunchtime, full of young people eating burgers and drinking cokes while discussing mathematics around him.

Many years later I mentioned this to Bill, and he said that a lunchtime seminar was not a common practice, but they were trying to get a more informal atmosphere to lower people’s defenses so that they could discuss more naturally what they were actually thinking. Bill also expressed that he was spoiled in Princeton, where he was surrounded by a big group of graduate students and junior mathematicians, enabling him to take the role of queen bee. I think that around this time he was supervising several PhD students simultaneously.

Despite his fundamental role in the theory of holomorphic dynamics, Bill Thurston rarely participated in the activities of the community, probably because he was totally absorbed by his other interests (and what interests?). Most of the newcomers in the field did not have the chance to meet him in person.

Luckily for us, Bill renewed his interest in rational dynamics during the last two or three years of his life and started to participate in our conferences. The reason for this comeback was explained in his talk at the Banff conference in honor of John Milnor’s eightieth birthday in February 2011: he was led by his investigation of realizing Perron numbers as various dynamical growth factors. A video record of this talk can be viewed on the conference webpage.

This video, as well as many other video records of Bill’s talks, illustrates very well Bill’s working style: he definitely preferred geometrical visions to formulae, he used computers intensively to do calculations and illustrations for him, and in his descriptions of mathematical objects he often put himself inside, like the moment he was talking about projective space and looking up towards the line at infinity. Later on I experienced many face-to-face and email conversations with him in that style. I must say it wasn’t always easy (actually quite often

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26th of March: pattern. Here is how he described the discovery on the space of such laminations, he recognized a familiar geometric meaning that I never saw before. Later on, Arnaud Chéritat and I wrote a tribute to Thurston (on the French website Images des mathématiques) illustrating his point of view of this theorem.

Here are some of Bill’s own words about his being a geometer:

“I’ve always taken a “lazy” attitude toward calculations. I’ve often ended up spending an inordinate amount of time trying to figure out an easy way to see something, preferably to see it in my head without having to write down a long chain of reasoning. I became convinced early on that it can make a huge difference to find ways to take a step-by-step proof or description and find a way to parallelize it, to see it all together at once—but it often takes a lot of struggle to be able to do that. I think it’s much more common for people to approach long case-by-case and step-by-step proofs and computations as tedious but necessary work, rather than something to figure out a way to avoid. By now, I’ve found lots of “big picture” ways to look at the things I understand, so it’s not as hard.

Another deep conviction of Bill Thurston’s was that all mathematics is connected: The more you make connections, the more you see things as interconnected and the more you expect these connections.

I once witnessed his exceptional connecting skills in action, a truly remarkable experience. In March 2011, Bill was investigating the space of iterated cubic polynomials. Each such polynomial can be combinatorially described by a finite lamination in the unit disc called “a primitive cubic major”; it is either an equilateral triangle inscribed in the circle or a pair of chords that each cuts off a segment of angle-length $2\pi/3$. While trying to visualize the space of such laminations, he recognized a familiar pattern. Here is how he described the discovery on the 26th of March:

“This figure can be embedded in $S^3$, which should somehow connect to the parameter space picture…. This figure is also a spine for the complement of the discriminant locus for cubic polynomials, but I’m not sure how that description fits in.

Having sensed a connection between the new object and the old familiar one, he obviously set off in search of a genuine link. The complement of the discriminant locus consists of polynomials with no multiple roots. However, it is not obvious at all how such a polynomial might appear from a pair of disc chords, but they should be connected somehow. At some moment Bill decided to try the opposite direction: why not try to put oneself in the familiar object and try to reach the new one from there? Why not try first to construct a pair of chords from a cubic polynomial with no multiple roots? This idea put him on the right track. He soon saw that the construction could easily be made, be reversed, and even worked for any degree. Here is what he wrote on April 1:

Take any degree $d$ polynomial $P$ with no multiple zeros, and look at $\log(P)$, thought of as a map from $\mathbb{C}\setminus\{\text{roots}\}$ to an infinite cylinder. For each critical point, draw the two separatrices going upward (i.e., this is the curve through each critical point of $P$ that maps by $P$ to a vertical half-line on the cylinder, a ray in $\mathbb{C}$ pointed opposite the direction to the origin).

Then make the finite lamination in a disk that joins the ending angles of these separatrices. This is a degree-$d$ major set. Conversely, for each major set, there is a contractible family of polynomials whose separatrices end at the corresponding pairs of angles.

To pick a canonical representative of each of these families: look at polynomials whose critical values are on the unit circle. This forms a spine for the complement of the discriminant locus for degree $d$ polynomials.

This is it! A beautiful theorem is born; a surprising bridge is built.

Bill was obviously very proud of this discovery, as we can see by how he presented it one year later.$^3$

It turns out that the set of all “critical” degree $d$ polynomials can be approximately described by collections of arcs of the disk whose endpoints have angle between them of the form $\kappa/d$. It took me a while to realize that the set of all such arcs, along with the limiting cases where some endpoints coincide and there are additional implicit arcs, describe[s] a spine for sets of $d$ disjoint points in $\mathbb{C}$, that is, its fundamental group is the braid group and higher homotopy groups are trivial.

People who had the chance to meet Bill Thurston know that he was a very caring and friendly person. You could feel his respect for others and his keenness to make everybody comfortable. I remember once, over a conference dinner table, he asked us one by one, with a gentle smile and with full attention, “So how did you come to mathematics?” One of us, Pascale Roesch, said that she initially hesitated between psychology and mathematics, and that response provoked a vivid conversation around the table for a long while.

At some point Bill was invited to a brain study about creative people. He got his brain tested, scanned, and modeled. During one of my visits to Cornell, while I was deeply absorbed by some hard thinking, he checked his email and said, out of nowhere, “My brain will arrive tomorrow.” After a long moment of total confusion, I finally realized that he was only talking about the clay model of his brain which was sent to him.

Later on Bill showed off proudly his “brain” to everybody, and I must say it provoked quite a sensation in me, holding in my hands this exceptional “brain”.

Sadly, we have since then lost this brain, leader of thoughts, and the many theorems he was about to prove. But, above all, we have lost a very dear friend. Bill, William Paul Thurston, will always be missed.

---

$^3$Topology Festival, Cornell, May 2012, from Kathryn Lindsey.
Curtis McMullen

Simple Curves
Thurston was a master at finding fresh and novel ways of looking at things.

What could be simpler than a loop on a surface? But in Thurston’s hands, the collection of all simple loops (once completed) became a geometric object in its own right—the space \( \mathbb{P}ML \) of projective measured laminations. It now plays a central role as the boundary of Teichmüller space and stands as one of Thurston’s most widely used inventions/discoveries (anticipated in the work of Nielsen). Yet it emerges from elementary topology as directly as the real numbers emerge from the work of Teichmüller space and stands as one of Thurston’s laminations.

The accompanying figure, taken from his Princeton notes The Geometry and Topology of 3-Manifolds (1979), gives part of the construction of stereographic coordinates on \( \mathbb{P}ML \), showing this space is a sphere (of dimension \( 6g - 7 \) for a surface of genus \( g > 1 \)).

View from Harvard, 1980s
I first heard about Thurston’s work when I was a graduate student at Harvard, 1981–85. He had recently discovered a characterization of the branched covers of \( S^2 \) that arise in the dynamics of rational maps, but no detailed write-up was available. In this exciting atmosphere, Hubbard (who was visiting for a semester) lectured to a small group on the audacious idea of the proof: an iterative scheme on Teichmüller space whose fixed point would give the desired rational map. In those days Thurston’s mimeographed Princeton notes, whose typed pages were covered with drawings that sometimes crossed the text itself, sat on the library reserve shelf next to more forbidding texts that assumed background in schemes, \( L \)-functions, symbols of operators, etc., and were often unencumbered by pictures, intuitions, or even examples. One sometimes heard that Thurston’s notes were full of “great ideas,” with a hint that rigorous arguments were missing and the work might be impounded for mathematical misdemeanor.

Thurston at Princeton
While a professor at Princeton, Thurston served as my NSF postdoctoral supervisor, 1987–90. As I soon realized, Thurston actually had an uncanny ability to turn his insights into transparent logical proofs which integrated, rather than disguised, the underlying geometric intuition.

The audience for Thurston’s course at Princeton included Peter Doyle and me in the front row, a coterie of graduate students, and a back row of visitors from the IAS. During my first year he lectured on his geometrization theorem for Haken 3-manifolds, a tour de force with another iteration on Teichmüller space as its engine: the famous skinning map.

The course began with a discussion of the boundary of the convex hull of the limit set of a Kleinian group: it is a hyperbolic surface bent along a measured lamination. Similar-looking pleated surfaces interpolate between the faces of the convex core, and the area of each surface is controlled by its Euler characteristic. These ideas then flowed into a series of compactness results (approximate Mostow rigidity) which underpin convergence of the skinning iteration: boundedness yields uniform contraction.

When asked a question, Thurston would usually fix his gaze on the middle-distance as if to grasp some private, kinesthetic-geometric model. He almost always worked things out live, on the spot, especially in class. His ideas seemed to come out of nowhere. It was as if Thurston had started off on a different track at an early age and had looked at everything since then with fresh eyes; to fully appreciate his work might require a complete reeducation.

To explain the idea of orbifolds, Thurston once brought two mirrors and a toy Smurf to a kindergarten class. By changing the angle between mirrors, the children could see first three, and then four, and then more copies of the original stuffed figure. He then added a third mirror, making a triangle. The children crowded around and peered into it from above, to see an infinite Smurf universe, with the figures repeating at different angles forever.

On another occasion the course started with a discussion of the “pentagon problem” from the 1986 high school math Olympiad. Numbers \( (x_i)_{i=1}^5 \) are assigned to the vertices of a pentagon, with \( \sum x_i > 0 \). A move consists of picking a vertex with \( x_i < 0 \), changing its sign, and then subtracting the same amount from its two neighbors. Will this process eventually make all the numbers positive? Soon the blackboard was covered with cone manifolds and polygons and butterfly moves. Although he didn’t mention it in class, by the end of the semester Thurston had connected this Olympiad problem to the work of Picard and Deligne–Mostow on hypergeometric functions and rediscovered their constructions of nonarithmetic lattices in \( PU(1, n) \), \( n > 1 \).

Thurston at MSRI
Figure 2 is taken from “The theory of foliations of codimension greater than one” [Comment Math. Helv. 49 (1974), 214–231]. Thurston’s work in this area is an
example of the power of the $h$-principle: by exploiting the flexibility of smooth constructions with sufficient imagination, one can construct a foliation that realizes any given homotopy data. (The same methods can be used for sphere eversion, as illustrated in his movie Outside In.)

While director at MSRI (1992–97), Thurston once lectured on a special case: any manifold with zero Euler characteristic admits a smooth codimension-one foliation. The lecture involved parking garages and ramps running up and down, as well as a preliminary triangulation of the manifold. Bott was in the audience, somewhat dismayed by these hands-on constructions. He asked at the end: Can’t one do this sort of thing using an evolution equation from differential geometry that would gradually deform a field of tangent hyperplanes until it becomes integrable? Thurston’s answer was immediate: The solution to a parabolic equation would be real-analytic, but it is well known (Haefliger) that real-analytic foliations are much harder to construct than smooth ones (e.g., there are none of codimension one on $S^3$).

**Thurston in Banff**

The last illustration (Figure 3) comes from Thurston’s final paper, “Entropy in dimension one” [Princeton Math. Soc., 51, Princeton Univ. Press, 2014, pp. 339–384]; it shows the Galois conjugates in $\mathbb{C}$ of the expansion factors for critically finite quadratic maps of the interval. These expansion factors are simply the values of $\lambda > 1$ such that $x = 0$ has a finite forward orbit under the tent map $x \mapsto \lambda(1 - |x|)$.

This paper, which returns to the work begun by Milnor and Thurston in the 1970s, characterizes the entropies of multimodal maps and free-group automorphisms. The latter, when realized on train tracks, also become one-dimensional dynamical systems, and the essential unity between these two subjects and the mapping-class group of a surface emerges.

Thurston spoke on this work at a conference in Banff in honor of Milnor in 2011. By that time he had been energetically networking, via email and dropbox, with a group of younger mathematicians from around the world, many of whom were present. After Banff, and more than thirty years after his mimeographed notes had arrived, graduate students and postdocs at Harvard were holding a weekly reading group on this new paper by Thurston.

Bill’s radical way of looking at things continues to shape mathematics as much as his deepest theorems.
The Mathematics of Being Human

A new play by Michele Osherow and Manil Suri

What plane figures can be constructed using only a compass and an unmarked straightedge?

What human insights can be constructed using only fourteen lines of iambic pentameter and a rigid rhyme scheme?

What do these two challenges have in common? Quite a bit, it would seem, judging from their parallel phrasing. Both are about searches for universal truths, and both implicitly recognize the way carefully crafted restrictions can serve as a catalyst to creativity and augment the expressive power of the medium.

But of course the two challenges are also very different. To viscerally experience this difference, spend some time meditating on Edna St. Vincent Millay’s sonnet which famously begins:

Euclid alone has looked on Beauty bare.

Just like a proof from the Elements, this poem’s artful beauty is closely tied to the way its strict formal requirements interact with the content. But the lasting durability of Millay’s sonnet also hinges on a degree of ambiguity in what it communicates. (Why a “holy, terrible day”?) With continued reflection, Euclid’s propositions grow sharper and more austere, but it is arguably the opposite quality that distinguishes a great poem from a charming limerick or a work of art from a simple illustration.

Inevitably, everyone who sets off to explore the intersection of science and art finds themselves confronting versions of this tension. Despite being well-traveled territory, this old debate is given a fresh and contemporary analysis in The Mathematics of Being Human, a recent play co-written by Michele Osherow and Manil Suri. The two authors are colleagues at the University of Maryland, Baltimore County (UMBC). Osherow is a professor of English and director of the Judaic Studies program, but she also boasts a strong connection to the theater. This includes extensive experience as a professional actor and dramaturg, as well as ongoing scholarly work on Shakespeare and Renaissance literature. Suri is a mathematician and widely published writer whose novels have garnered enthusiastic praise in the United States, India, and beyond.

The storyline for The Mathematics of Being Human takes its premise and basic scaffolding from the real-life collaboration between Suri and Osherow, who several years ago co-taught an interdisciplinary seminar to an incoming group of UMBC first-year students. The line between fact and fiction in the play is hard to discern, but it is probably best to assume that the storytelling is highly inventive. This mindset is more challenging than it sounds, however, because in performances thus far the two authors have also been cast as the leads, essentially playing freely adapted versions of themselves. In the first scene we encounter two professors—mathematician Mike Pearson (played by Suri) and literature professor Naomi...
are also some fresh surprises. The script includes a tour of Oulipo and an insightful encounter with the Millay sonnet alluded to in the opening paragraph of this review. The play even manages to incorporate Shakespeare through the tragedy of King Lear. King Lear opens with the dilemma of how Lear should divide his kingdom among his three daughters. This simple-sounding division problem is Kessler’s entry point for attempting a bold mathematical reading of the whole play centered around the question of whether only “nothing will come of nothing,” as Lear famously proposes. Playing his role of resident philistine to the hilt, an exasperated Pearson finally takes out his frustrations by assigning the class the “King Lear Problem” of trisecting an angle with only straightedge and compass.

Which brings us around again to the play’s ever-present sense of humor. In bringing their coteaching experience to the stage, the authors made the decision to create a steadily rising sense of animosity between the two professors at the front of the classroom. And make no mistake, these two are not Shakespeare’s Benedict and Beatrice, whose verbal jousting is a smoke screen for some latent affection. With each passing class, Pearson and Kessler become steadily less tolerant of each other, which could be off-putting if it weren’t so entertaining. When Pearson grows animated discussing large supercomputers crunching out millions of digits of pi, Kessler is quick to deconstruct it as the “mathematical performance of masculinity.” When Kessler attempts to explore why mathematicians are often portrayed as insane, Pearson helpfully points out that “we don’t all go mad. At least not until we go ‘interdisciplinary’.”

Another useful way the play helps its audience deal with its ornery antagonists is by adding two good-natured students to the cast (played wonderfully by UMBC undergraduates Savannah Chamberlain and Chaz Atkinson). The two first-years watch with intrigue and amusement as the course they are taking crumbles into chaos, and there is a way in which their generational perspective serves as an effective counterpoint to that of their obstinate instructors. Without giving too much away, the script’s most satisfying theatrical moment comes toward the end of the

The scene is very funny, and so are many to follow. More than anything else it is this mixture of comic self-mockery with an informed authenticity that makes the play succeed. The authenticity is the primary ingredient. Osherow and Suri are accomplished scholars and teachers who brought a full-bodied commitment to constructing their original course—at least that is the impression one gets from watching the play. Many of the usual math-for-poets suspects are here—irrational numbers, pi, the Monty Hall Problem, fractals—but there

Left to right: Chaz Atkinson, Manil Suri, Michele Osherow, and Savannah Chamberlain during a performance on November 4, 2014, at the University of Maryland, Baltimore County (UMBC).
study is to explore the ways it is, or isn’t, different from the avenues our colleagues in the next building have chosen.

The year 2015 was a busy one for the play. A warmly received performance at the winter 2015 Joint Meetings in San Antonio was followed up by performances at the National Museum of Mathematics in March and the Bridges conference of math and art in Baltimore in July. Independent productions (with a new cast) are scheduled for 2016 at the University of Pittsburgh and also in New Delhi. There is a reason why the venues are academic in nature. Witty and lighthearted, *The Mathematics of Being Human* is at its core a heady piece that engages its audience’s minds without making any sustained attempt to engage its hearts. This is not so much a flaw as it is a by-product of the script’s real-life origins. It’s not clear how well the play would hold up as a free-standing piece of theater, but it would certainly be an entertaining addition to any symposium about science and art. The majority of the performances thus far have been for mathematicians, but the script is very much aimed at a general audience. To their credit, the playwrights largely refrain from doing anything too didactic—in terms of the mathematics or the literature—but the allusions to Euclid and Shakespeare and Stoppard and Snow are dense enough that some familiarity with the intellectual terrain is a prerequisite to appreciate the show.

So is this play an argument for or against interdisciplinary teaching? Like a good piece of art, *The Mathematics of Being Human* doesn’t make this obvious or absolute for its viewers. “Was there any advantage to coming at things from such different perspectives?” Kessler asks in the play’s denouement. On this question, at least, the playwrights agree to defer to Shakespeare’s poetry over Euclid’s precision, pointing out that while the search is noble, some answers are destined to forever remain part of “the mystery of things.”

Requests to mount productions of the play are welcomed by the authors and can be addressed to Manil Suri at suri@umbc.edu.
CALL FOR PAPERS

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This report presents a brief statistical profile of recipients of doctoral degrees awarded by departments in the mathematical sciences at universities in the United States during the period July 1, 2014 and June 30, 2015. It is preliminary in the sense that, as of November 1, 2015, not all departments have responded to the survey instrument through which data is collected. A list of the nonresponding departments is presented below.

Data collected to this point shows that 1,696 new PhDs were awarded by the 271 mathematical sciences departments that responded in time for this report. Some attributes of the data are:

- 1,189 Males
- 507 Females
- 1,185 in Mathematics
- 511 in Statistics/Biostatistics
- 780 US citizens
- 916 non-US citizens
- 74% are US employed
- 507 Females
- 916 non-US citizens
- 74% are US employed
- 49% of those employed in the US are US citizens

Based on the data collected so far, it is likely that the final count of PhDs awarded during 2014–2015 will be slightly higher than the number (1,926) reported for 2013–2014.

Once data collection is concluded, a more detailed final report will be published in the August 2016 issue of Notices.

As of press time for this issue of Notices, the following departments had not yet responded to the survey. Every effort will be made to collect responses for inclusion in the New Doctoral Recipients Report. In order to be included in the final report, Doctorates Granted survey forms should be sent no later than March 4, 2016. Departments yet to respond can obtain copies of the Doctorates Granted survey forms by visiting [www.ams.org/annual-survey/surveyforms](http://www.ams.org/annual-survey/surveyforms), emailing ams-survey@ams.org, or calling 1-800-321-4267, ext. 4189.

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University of California, Merced, School of Natural Sciences
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Northwestern University, Statistics
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Oklahoma State University, Statistics
Rutgers School of Public Health, Biostatistics
University of Alabama-Tuscaloosa, Information Systems Statistics & Management Science Department
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Yale University, Statistics
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• communicating with the AMS members and disseminating information related to the mathematical sciences and federal science and education policy

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Applications received by March 28, 2016 will receive full consideration.

The American Mathematical Society is an Affirmative Action/Equal Opportunity Employer
Uffe Haagerup, a world-renowned analyst and leading figure in operator algebras, passed away on July 5, 2015, in a tragic drowning accident near his summer house in Faaborg, Denmark. He spent most of his career as a professor at the University of Southern Denmark (Odense), and during 2010–2014 he was a professor at the University of Copenhagen while holding an Advanced European Research Council (ERC) grant. Uffe was a uniquely gifted mathematician of incredible analytic power and insight, which he generously shared with his many collaborators. His kindness and warm personality were greatly valued by his many friends and colleagues in Denmark and abroad.

Uffe was born December 19, 1949, in the town of Kolding, but grew up in Faaborg, the younger of two brothers. At age ten Uffe started helping the local surveyor and solved difficult trigonometric problems in the process. His problem-solving skills earned him national acclaim when a few years later his proposed development plan for a large summer house area was chosen over the one of a Copenhagen contractor.

In 1968 Uffe enrolled in the physics and mathematics program at the University of Copenhagen. Fascinated with both general relativity and quantum mechanics, he began his graduate studies in physics, but switched to mathematics after being exposed to operator algebras. In 1973, as a master’s student, he solved a key open question related to the recently emerged Tomita-Takesaki theory. This resulted in his first publication, “The standard form of von Neumann algebras”, which has since then been used over and over again. It also led to his first job in 1974, namely, a tenure-track position at the recently opened Department of Mathematics at Odense University, where he later became professor at the age of thirty-one. Except for sabbaticals, he chose to stay in Den-
Uffe Haagerup’s mathematical career is a succession of amazing breakthrough achievements and influential contributions to operator algebras and functional analysis. A highlight is his brilliant solution (Acta Math., 1987) of the challenging Connes bicentralizer problem, also known as the Champagne problem. This settled the uniqueness of the hyperfinite factor of type III, and completed the classification of injective von Neumann factors, a program initiated by Murray and von Neumann in the 1930s and almost brought to completion by the work of Connes in the 1970s.

Uffe’s remarkable paper on an example of a nonnuclear C*-algebra with the metric approximation property (Inventiones Math., 1978) is, in many ways, characteristic of his research. He set out to solve the hard analytic problem of whether the metric and the completely positive approximation properties are the same. In the process of proving that they are not, he discovered a new property of a group, which became known as the Haagerup property and now plays a major role in geometric group theory. It was a key element in the proof of the Novikov conjecture for Gromov hyperbolic groups. The associated approximation property for factors of type II₁ was crucial in the solution by Popa of the long-standing problem of existence of a von Neumann factor nonisomorphic to a matrix algebra over itself and of exhibiting a factor with trivial fundamental group. Uffe also made major contributions to Voiculescu’s free probability theory and to random matrices. In the mid-1990s, in a masterful display of combinatorial power, Uffe showed that the mysterious number \( (5 + \sqrt{13})/2 \) is the smallest index larger than 4 of a subfactor, known as the Haagerup. It is an interesting problem whether there are quantum systems with Haagerup symmetry.

Uffe was a strikingly creative problem solver whose impact was widespread. Topologists will know Haagerup from his paper with Munkholm (Acta Math., 1981), where they resolve Thurston’s conjecture on simplices of maximal volume in hyperbolic spaces using elementary calculus. Uffe’s recent work on factorizable completely positive maps and its impact on quantum information theory is yet another example of how far his influence extended.

Uffe’s many honors during his career include being a plenary speaker at the ICM in Beijing, 2002, and a recipient of the European Latvian Prize from the European Science Foundation in 2012. He was editor-in-chief of Acta Mathematica, 2000–2006.

An analyst is characterized by the ability of having “direct access to the infinite”, and Uffe Haagerup possessed that quality to perfection. He will be deeply missed by the entire mathematical community.
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**January 2016:**


*100 Essential Things You Didn't Know You Didn't Know about Math and the Arts,* by John D. Barrow (W. W. Norton, January 2016). Although his research centers on cosmology and theoretical physics, Barrow has a special love for mathematics and has written several popular books on the subject. He is also director of the Millennium Mathematics Project at the University of Cambridge. His book *The Constants of Nature* (Pantheon, 2003) was reviewed by Brian E. Blank in the November 2003 *Notices*.


The list in each edition of Bookshelf highlights current books that have mathematical themes and are aimed at a broad audience potentially including mathematicians, students, and the general public.

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Applications will be accepted until the post is filled.

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Salary will be highly competitive, commensurate with qualifications and experience. The University offers a comprehensive fringe benefit package, including medical care, plus a contract-end gratuity for an appointment of two years and housing benefits for eligible appointee. Further information about the University and the general terms of service for appointments is available at [https://www2.per.cuhk.edu](https://www2.per.cuhk.edu).

**Application Procedure**

Application forms are obtainable (a) at [https://www2.per.cuhk.edu.JK](https://www2.per.cuhk.edu.JK), or (b) in person/by mail with a stamped, self-addressed envelope from the Personnel Office, The Chinese University of Hong Kong, Shatin, Hong Kong.

Please send the completed application forms and/or full curriculum vitae, together with copies of qualification documents, a publication list and/or abstracts of selected published papers, and names, addresses and fax numbers/e-mail addresses of three referees to whom the applicants’ consent has been given for their providing references (unless otherwise specified), to the Personnel Office by post or by fax to (852) 3942 0947.

Please quote the reference number and mark ‘Application – Confidential’ on cover. The Personal Information Collection Statement will be provided upon request.
Mathematical Moments

Adding a New Wrinkle

Some people actually appreciate wrinkles. Whether in skin, fabrics, or plastic wrap, wrinkles form because materials bend. Geometry and the mathematical subjects used in understanding a wide range of topics are at play, and—in the case of changing shape in flight to improve lift or to get a better handle on a flower's bloom, and so on. Such a simple rule can still lead to amazingly intricate fractal patterns. For some observers the question is, “Is this ever going to end?” but most sports fans want to know, “How is this going to end?” a team of researchers used a mathematical idea to set the odds. For more Information, see John D. Barrow, Carl D. Murow, and Stanley J. Demos, 2009.

Discover that our solar system came principally from astronomy and cosmology but math plays a role, too. The existence of the nine planets was predicted by mathematicians based on Newton’s law of gravitation before anyone even dreamt of an eighth planet. Recently, integral and differential equations along with mathematical models have increasingly raised the accuracy of estimates of the length of Saturn’s day. And applying probability and statistics in the chemical composition of simulations of growing plants early in the solar system’s history have bolstered the impact theory about the Moon’s origin.

Earth’s orbit is almost completely determined by the Sun’s gravity, but our path through space is also affected by the pull of other planets and the Moon. Unfortunately, explicitly solving the equations associated with the gravities of many objects is impossible. So researchers are using numerical approximations and non-linear dynamics to see if the tiny effects of ever-changing gravitational forces will accumulate and eventually alter the solar system’s stability. They’ve determined that there is a very small chance the effects could become extreme in planetary collisions. No need to relocate just yet, though, as this could take billions of years.

Working Within the System

Passing Plates

Geometry and partial differential equations are two of the mathematical subjects used in the study of wrinkling. This includes the behavior of thin films, how flowers bloom, and—in the case of the items pictured—the possibility of objects changing shape in flight to improve lift or to get a better handle on a flower’s bloom, and so on. Such a simple rule can still lead to amazingly intricate fractal patterns. For some observers the question is, “Is this ever going to end?” a team of researchers used a mathematical idea to set the odds. For more Information, see John D. Barrow, Carl D. Murow, and Stanley J. Demos, 2009.

Detecting seismic events—which emerge from the variability within the Earth’s crust—is another way to see if the tiny effects of ever-changing gravitational forces will accumulate. The driving force for earthquakes is the friction between tectonic plates. Although friction between tectonic plates is the ultimate factor in determining earthquakes, the uncertainties in modeling material properties, whether in skin, fabrics, or plastic wrap, wrinkles form because materials bend. Geometry and the mathematical subjects used in understanding a wide range of topics are at play, and—in the case of changing shape in flight to improve lift or to get a better handle on a flower’s bloom, and so on. Such a simple rule can still lead to amazingly intricate fractal patterns. For some observers the question is, “Is this ever going to end?” but most sports fans want to know, “How is this going to end?” a team of researchers used a mathematical idea to set the odds. For more Information, see John D. Barrow, Carl D. Murow, and Stanley J. Demos, 2009.

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Jacob Tsimerman of the University of Toronto has been awarded the 2015 SASTRA Ramanujan Prize, awarded annually for outstanding contributions by young mathematicians to areas influenced by the work of Srinivasa Ramanujan. The age limit for the prize has been set at thirty-two because Ramanujan achieved so much in his brief life of thirty-two years. The prize was awarded in December 2015 at the International Conference on Number Theory at SASTRA University in Kumbakonam (Ramanujan’s hometown), where the prize has been given annually.

The prize citation reads as follows: “Jacob Tsimerman is an extraordinary young mathematician who has made deep and highly original contributions to diverse parts of number theory, and most notably to the famous Andre-Oort conjecture. He is one of the few mathematicians to have complete mastery over two very different areas of mathematics—analytic number theory and algebraic geometry. This has enabled him to achieve significant progress on a number of fundamental problems lying at the interface of the two subjects.

“Much of Tsimerman’s research stems from the spectacular PhD thesis entitled ‘Towards an unconditional proof of the Andre-Oort conjecture and surrounding problems’ that he wrote at Princeton University in 2010 under the direction of Professor Peter Sarnak. The thesis concerns arithmetical questions around the Andre-Oort conjecture and makes substantial progress towards it.

“The Andre-Oort conjecture states that special subsets of Shimura varieties that are obtained as Zariski closures of special points are finite unions of Shimura varieties. Shimura varieties are special algebraic varieties (such as moduli spaces of Abelian varieties) which arise as quotients of suitable complex domains by arithmetic groups. Thus Shimura varieties lie at the heart of arithmetic geometry and automorphic forms. Yves Andre initially stated this conjecture for one-dimensional subvarieties, and subsequently Frans Oort proposed that it should hold more generally. The conjecture lies at the confluence of Diophantine problems and the arithmetic of modular forms. By assuming the Generalized Riemann Hypothesis (GRH), the conjecture was proved in 2006 by Klinger, Ullmo, and Yafaev, but as of 2008 only the very simplest cases had been proved unconditionally. One of the techniques to attack the Andre-Oort conjecture is to obtain suitable bounds for certain Galois orbits of special points. A major achievement of Tsimerman in his thesis was to establish certain unconditional bounds up to dimension 6, and this was published in the Journal of the American Mathematical Society in 2012. This went beyond the work of Ullmo and Yafaev, who had unconditionally established such bounds up to dimension 3.

“Another very important result in his thesis was to answer in the affirmative a question due to Nick Katz and Oort whether there exists an Abelian variety over the set of all algebraic numbers which is not isogenous to the Jacobian of a stable algebraic curve over the algebraic numbers. This fundamental result appeared in the Annals of Mathematics in 2012. Previously Ching-Li Chai and Frans Oort had answered the question assuming the Andre-Oort conjecture, but Tsimerman was able to do so unconditionally.

“About a decade ago, Jonathan Pila had introduced a new method to attack the Andre-Oort conjecture. In
2009 Tsimerman and Pila joined forces and over the next few years established several deep results, one of which was a functional transcendence statement known as Ax-Lindemann for Abelian varieties of all dimensions (Ax-Lindemann is one of the tools to attack the Andre-Oort conjecture). This paper has just been accepted in the Annals of Mathematics. In another major joint paper of Pila-Tsimerman that appeared in Compositio Mathematica in 2013, they establish the Andre-Oort conjecture for certain moduli spaces of Abelian surfaces.

“The most recent advance by Tsimerman is his proof this year of the Andre-Oort conjecture for the moduli spaces of principally polarized Abelian varieties of any dimension $g$, which has been sought for a long time. What was missing was a certain lower bound for Galois orbits of special points in dimensions greater than 6. Tsimerman’s brilliant insight was to use a recently proven weighted average version of a conjecture of Colmez to establish the crucial lower bound, building on deep results of Andreatta, Goren, Howard, and Madapusi-Pera.

“Tsimerman has made major contributions not just to the Andre-Oort conjecture, but to many other fundamental problems. Even as a graduate student at Princeton, Tsimerman collaborated with Manjul Bhargava (recipient of the first SASTRA Ramanujan Prize in 2005) and Arul Shankar to determine the second term in the asymptotic formula for the number of cubic fields with a bounded discriminant. This work appeared in Inventiones Mathematica in 2013. Especially relating to Ramanujan’s mathematics, we note his 2014 paper joint with Ali Altug entitled ‘Metaplectic Ramanujan conjecture over function fields with applications to quadratic forms’ that appeared in the International Mathematical Research Notices (IMRN). Most recently, Tsimerman and Pila have turned their attention to multiplicative relations among singular moduli—a topic dear to Ramanujan.

“Tsimerman has several more first-rate contributions spanning algebraic geometry, number theory, mathematical logic, and analysis. He is an exceptionally broad and creative mathematician. The breadth of his expertise seems unrivaled among number theorists of his age. All indications are that he will continue to contribute at the very highest level and will be a major force in the world of mathematics for the next several decades.”

Jacob Tsimerman was born in Kazan, Russia, on April 26, 1988. He received his PhD in 2011 from Princeton University under Peter Sarnak, supported by an AMS Centennial Fellowship. He held a postdoctoral position at Harvard University. In 2014 he was awarded a Sloan Fellowship and joined the faculty at the University of Toronto.

The members of the 2015 SASTRA Ramanujan Prize Committee were:

- Krishnaswami Alladi, chair, University of Florida
- Henri Darmon, McGill University
- Winnie Li, Pennsylvania State University
- Hugh Montgomery, University of Michigan
- Peter Paule, Johannes Kepler University, Linz
- Michael Rapoport, University of Bonn
- Cameron Stewart, University of Waterloo

The full list of awardees of the SASTRA Ramanujan Prize follows.

- 2005 Manjul Bhargava and Kannan Soundararajan (two full prizes)
- 2006 Terence Tao
- 2007 Ben Green
- 2008 Akshay Venkatesh
- 2009 Kathrin Bringmann
- 2010 Wei Zhang
- 2011 Roman Holowinsky
- 2012 Zhiwei Yun
- 2013 Peter Scholze
- 2014 James Maynard
- 2015 Jacob Tsimerman

—Krishnaswami Alladi University of Florida

Bhatt and Wood Awarded

To help other latecomers, I want to point out that I started out relatively late in math: at least half of my time in college was spent trying to be an engineer (my BS is from the engineering school at Columbia), and, before college, I basically spent all my time playing cricket.

— Bhargav Bhatt

Outside of mathematics, my recent hobbies include reading Supreme Court briefs and opinions and ballroom dancing with my husband. I also love the theater, and in college I studied drama with a particular focus in performing Shakespeare.

— Melanie Matchett Wood

2015 Packard Fellowships

BHRAGAV BHATT of the University of Michigan and MELANIE MATCHETT WOOD of the University of Wisconsin, Madison, have been awarded Packard Fellowships by the David and Lucile Packard Foundation, which provided eighteen early-career scientists in science and engineering flexible funding and the freedom to take risks and explore new frontiers in their fields of study in 2015. Bhatt works in arithmetic geometry, a field that lies at the intersection of algebraic geometry and number theory. Much of his work, according to the prize citation, “draws inspiration from topology (the study of shapes, up to continuous perturbation) to understand the behavior of certain subtle notions in arithmetic geometry.” About Wood’s work, the prize
citation says, in part, “the structure of how numbers like 1, 2, 3,...factor into primes is incredibly complex. It not only underlies the encryption that protects all of our data online, but also contains the oldest unsolved mysteries of mathematics. Wood develops geometric and probabilistic tools that can unlock some of these mysteries.” The two new fellows will receive grants of $875,000 each over five years to pursue their research.

—From a Packard Foundation announcement

Cox Awarded Michell Medal

BARRY COX of the University of Adelaide has been awarded the 2015 J. H. Michell Medal of the Australian Mathematical Society for his “groundbreaking” contributions to the area of nanotechnology. His work involves the geometry of carbon nanotubes that properly incorporate the effect of curvature. The award is given for distinguished research in applied and/or industrial mathematics, with a significant proportion of the research work having been carried out in Australia and/or New Zealand.

—From an ANZIAM announcement

Pi Mu Epsilon Student Paper Presentation Awards

Pi Mu Epsilon (PME), the US honorary mathematics society, makes annual awards to recognize the best papers by undergraduate students presented at a PME student paper session. PME held a session in conjunction with the Mathematical Association of America MathFest held August 5-8, 2015, in Washington, DC. The AMS, the American Statistical Association, and Budapest Semesters in Mathematics for Excellence in Student Exposition or Research sponsor awards to student speakers for excellence in exposition and research. The names, institutions, and paper titles of the award-winning students follow.

ANNA SNYDER, Hope College, “An extension of a theorem of Polya”

MONICA BUSSER, Youngstown State University, “Unique Hamiltonicity and computational algebraic geometry”

WILLIAM O’BROCHTA, Hendrix College, “Rational decision-making models of conflicts in the 1990s”

MADELINE HANSAK, Texas A&M University, “Magnetic spectral decimation on self-similar fractals”

ELLIO GOLIAS, Kent State University, “Geometry to number theory: Minkowski’s theorem”

SARAH HILSMA, Hope College, “Real algebraic level curves and the intersection of lines of positive slope”

ZACK WHILE, Youngstown State University, “The ultimate mind-bender: Futurama’s mind-switching problem”

DOUGLAS KNOWLES, State University of New York at Geneseo, “Finite fun with numerical ranges”

DANIEL GILES, Portland State University, “Convex optimization methods for the smallest intersecting ball problem”

JOHN VASTOLA, University of Central Florida, “On the structure and calculation of a class of infinitely nested radicals”

SAMANTHA PARSONS, Roanoke College, “Interests in conflict: Supporting scientific development and ensuring data security”

SHARAT CHANDRA, University of California, Irvine, “On the morphology of arithmetic sums of Cantor sets”

JACK JENKINS, State University of New York at Geneseo, “There’s a glitch in the matrix!”

A. J. Vogt, Duquesne University, “A mathematical framework for evaluating a cost-effective balance of human trafficking prevention and aid resources”

COLE WATSON, Hope College, “Graph pebbling and Graham’s conjecture”

JACK RYAN, North Central College, “Recognition of textural differences in infrared and ultraviolet images using fractal characteristics”

MEGAN CHAMBERS, Youngstown State University, “An agent-based model of Eleutherodactylus coqui on the Big Island of Hawaii.”

—From a Pi Mu Epsilon announcement

About the Cover

Above the lighted nighttime Seattle skyline float the images of some of this year’s JMM Invited Speakers who contributed to the Notices’ 2016 Joint Mathematics Meetings Lecture Sampler (page 7).

Thanks to Daniel Alan Spielman, Kristin Estella Lauter, Mohammad Reza Pakzad, Tanya A. Moore, Tatiana Toro, Panagiota Daskalopoulos, Karen E. Smith, Steve Zelditch, Alex Eskin, Marta Lewicka, Teresa Levy, Katharine Merow, Bill Casselman, and iStock Photo for contributions to this cover.

—Frank Morgan
Editor-in-Chief
Frank.Morgan@williams.edu
Fan China Exchange Program

- Gives eminent mathematicians from the U.S. and Canada an opportunity to travel to China and interact with fellow researchers in the mathematical sciences community

- Allows Chinese scientists in the early stages of their careers to come to the U.S. and Canada for collaborative opportunities

Applications received before March 15 will be considered for the following academic year.

For more information on the Fan China Exchange Program and application process see [www.ams.org/employment/chinaexchange.html](http://www.ams.org/employment/chinaexchange.html) or contact the AMS Membership and Programs Department by telephone at 800-321-4267, ext. 4113 (U.S. and Canada), or 401-455-4113 (worldwide), or by email at chinacxchange@ams.org
Inside the AMS

Math in Moscow Scholarships Awarded

The AMS has made awards to five mathematics students to attend the Math in Moscow program in the spring of 2016. Following are the names of the undergraduate students and their institutions:

IAN CAVEY, Boise State University
JONATHAN GERHARD, James Madison University
JACOB MAYLE, Colgate University
ELISE McMAHON, Ave Maria University
MAHRUD SAYRAFI, University of California Berkeley.

Each received a cash award of US$9,800.
Math in Moscow is a program of the Independent University of Moscow that offers foreign students (undergraduate or graduate students specializing in mathematics and/or computer science) the opportunity to spend a semester in Moscow studying mathematics. All instruction is given in English. The fifteen-week program is similar to the Research Experiences for Undergraduates programs that are held each summer across the United States.

The AMS awards several scholarships for US students to attend the Math in Moscow program. The scholarships are made possible through a grant from the National Science Foundation. For more information about Math in Moscow, consult [www.mccme.ru/mathinmoscow](http://www.mccme.ru/mathinmoscow) and the article "Bringing Eastern European Mathematical Traditions to North American Students," Notices, November 2003, pages 1250–4.

—Elaine Kehoe

2015 Trjitzinsky Memorial Awards Presented

The AMS has made awards to seven undergraduate students through the Waldemar J. Trjitzinsky Memorial Fund. The fund is made possible by a bequest from the estate of Waldemar J., Barbara G., and Juliette Trjitzinsky. The will of Barbara Trjitzinsky stipulates that the income from the bequest should be used to establish a fund in honor of the memory of her husband to assist needy students in mathematics.

For the 2015 awards, the AMS chose seven geographically dispersed schools to receive one-time awards of US$3,000 each. The mathematics departments at those schools then chose students to receive the funds to assist them in pursuit of careers in mathematics. The schools are selected in a random drawing from the pool of AMS institutional members.

Waldemar J. Trjitzinsky was born in Russia in 1901 and received his doctorate from the University of California, Berkeley, in 1926. He taught at a number of institutions before taking a position at the University of Illinois, Urbana-Champaign, where he remained for the rest of his professional life. He showed particular concern for students of mathematics and in some cases made personal efforts to ensure that financial considerations would not hinder their studies. Trjitzinsky was the author of about sixty mathematics papers, primarily on quasi-analytic functions and partial differential equations. A member of the AMS for forty-six years, he died in 1973.

Following are the names of the selected schools for 2015, the names of the students receiving Trjitzinsky awards, and brief biographical sketches of these students.

**Johns Hopkins University: Kiyon Hahm.** Hahm, who comes from Irvine, California, will graduate from Johns Hopkins University in 2016 with a degree in mathematics and has plans to attend law school. While at Johns Hopkins, she has been on the dean’s list and is actively involved with Phi Mu Sorority. She is also involved with university dance marathons that benefit the Johns Hopkins Children’s Center.

**New Mexico State University: Stephen W. Brazil.** Brazil is a junior majoring in applied mathematics with a minor in computer science. He was raised in a rural ranch/farm/oil field community with little exposure to innovations in science and technology. Despite this, he relished mathematics throughout his high school years. His first proof-based class was a revelation, and he was immediately drawn to the wonderful world of higher mathematics. The logical and analytic approach required of mathematics has influenced other aspects of his life, including his musical training. He currently works as a math tutor at New Mexico State, helping students struggling in their freshman and sophomore courses to improve their understanding of mathematics.
Oregon State University: Josephine A. Sechrist. Sechrist is entering her senior year and is a University Honors College student pursuing a double degree in mathematics and international studies, along with a minor in Spanish and an option in secondary education. She plans to become a high school math and Spanish teacher and perhaps teach English as a second language in Spain or in South America. During the summer of 2015, she studied in Spain, where she gathered materials for her honors thesis. She is an elected senator of the Associated Students of Oregon State University. As a member of Delta Gamma sorority, she serves as director of philanthropy and as a member of the university-wide Pan-Hellenic Council. She also serves as a student ambassador for the College of Science at Oregon State University.

University of Delaware: Alexandra Platt. Platt is a senior mathematics and economics major with a human development and family studies minor. She was born and raised in New Jersey, graduating high school with a 3.9 GPA and three honors. She has a love for mathematics and a dedication to helping others. She has tutored her peers for the past six years and hopes to work as a high school math teacher in low-income areas and attend graduate school.

University of Michigan, Ann Arbor: Kristen M. Amman. Amman is a rising star amongst seniors at the University of Michigan majoring in both pure mathematics and English language and literature. She plans to combine her passions of teaching and learning mathematics in graduate school by contributing to the research of undergraduate mathematics education. In particular, she is interested in how different teaching methods impact students' abilities to conceptualize and create mathematical proofs.

University of Northern Iowa: Emily Wardenburg. Wardenburg is a single mother pursuing a secondary mathematics teaching degree. She grew up in a small, rural Iowa community, began her college education at Kirkwood Community College, and then transferred to the University of Northern Iowa. She wants to become a teacher because she is passionate about making a difference in other peoples’ lives. Currently, she teaches classes at her church and mentors a middle school student. On a daily basis, Emily faces the challenge of balancing her full-time college education with a part-time job while serving as a good role model for her daughter.

University of Tulsa: Sara Catherine Fee. Fee was born to Thomas and Catherine Fee in 1994 in Tulsa, Oklahoma, and is the oldest of four girls. She attended Cascia Hall Preparatory School when her father passed away and then went on to the University of Tulsa to pursue a double major in mathematics and education. Sara is currently a senior looking forward to teaching middle and high school students.

—Elaine Kehoe

Erdős Memorial Lecture

The Erdős Memorial Lecture is an annual invited address named for the prolific mathematician Paul Erdős (1913–1996). The lectures are supported by a fund created by Andrew Beal, a Dallas banker and mathematics enthusiast. The Beal Prize Fund, now US$1,000,000, is being held by the AMS until it is awarded for a correct solution to the Beal Conjecture (see www.math.unt.edu/~mauldin/beal.html). At Mr. Beal’s request, the interest from the fund is used to support the Erdős Memorial Lecture.

RAVI VAKIL of Stanford University will present the 2016 Erdős Memorial Lecture during the 2016 Spring Western Section Meeting at the University of Utah, April 9–10, 2016. The title of his talk will be “Cutting and Pasting in Algebraic Geometry.”

—AMS announcement

From the AMS Public Awareness Office

On Teaching and Learning Mathematics Blog.
Providing mathematicians with high-quality commentary and resources regarding teaching and learning.
Editor-in-chief Benjamin Braun and contributing editors Priscilla Bremser, Art Duval, Elise Lockwood, and Diana White, offer practical “teaching tips,” commentary on current mathematics education research, discussions of social/curricular educational policy, examples of effective programs, and more. blogs.ams.org/matheducation/.

“Mathematically Inspired Images”. See an album of works by Kerry Mitchell on Mathematical Imagery. “I draw from the areas of geometry, fractals, and numerical analysis, and combine them with image processing technology. The resulting images powerfully reflect the beauty of mathematics that is often obscured by dry formulae and analyses.” www.ams.org/mathimagery/.

—Annette Emerson and Mike Breen
AMS Public Awareness Officers
paoffice@ams.org
The creators of MathJobs.Org welcome you to:

MathPrograms.Org

Announcing...

Receive, read, rate, and respond to electronic applications for your mathematical sciences programs, such as undergraduate summer research programs and travel grant competitions.

Customize your settings and control the application form; also set secure access for the admissions committee.

Enter program announcements for public display.

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Service is FREE to applicants. Institutions pay annually for one program or for multiple programs.
Applications are invited for a full-time position as an Associate Editor of Mathematical Reviews/MathSciNet, to commence as early as possible in late spring/early summer 2016. The Mathematical Reviews (MR) division of the American Mathematical Society (AMS) is located in Ann Arbor, Michigan, in a beautiful, historic building close to the campus of the University of Michigan. The editors are employees of the AMS; they also enjoy certain privileges at the university. At present, the AMS employs approximately seventy-eight people at Mathematical Reviews, including sixteen mathematical editors. MR’s mission is to develop and maintain the MR Database, from which MathSciNet is produced.

An Associate Editor is responsible for broad areas of the mathematical sciences. Editors select articles and books for coverage, classify these items, determine the type of coverage, assign selected items for review to reviewers, and edit the reviews on their return.

The successful applicant will have mathematical breadth with an interest in current developments, and will be willing to learn new topics in pure and applied mathematics. In particular, we are looking for an applicant with expertise in algebraic geometry, or related areas of mathematics, such as commutative rings and algebras or group theory. The ability to write well in English is essential. The applicant should normally have several years of relevant academic (or equivalent) experience beyond the Ph.D. Evidence of written scholarship in mathematics is expected. The twelve-month salary will be commensurate with the experience that the applicant brings to the position. Applications (including a curriculum vitae; bibliography; and the names, addresses, phone numbers, and email addresses of at least three references) should be sent to:

Dr. Edward Dunne
Executive Editor
Mathematical Reviews
P. O. Box 8604
Ann Arbor, MI 48107-8604
email: egd@ams.org
Tel: (734) 996-5257
Fax: (734) 996-2916
URL: www.ams.org/mr-database
Blog: blogs.ams.org/beyondreviews

The review of the applications will begin on February 15, 2016 and will continue until the position is filled.

The American Mathematical Society is an Affirmative Action/Equal Opportunity Employer.
AMS-Simons Travel Grants Program

Starting February 1, 2016, the AMS will begin accepting applications for the AMS-Simons Travel Grants program, with support from the Simons Foundation. Each grant provides an early-career mathematician with US$2,000 per year for two years to reimburse travel expenses related to research. Sixty new awards will be made in 2016. Applications will be accepted through www.mathprograms.org. The deadline is March 31, 2016. Applicants must be located in the United States or be US citizens to apply. For complete details of eligibility and application instructions, visit: www.ams.org/programs/travel-grants/AMS-SimonsTG or contact Steven Ferrucci, email: ams-simons@ams.org, telephone: 800-321-4267, ext. 4113.

—AMS announcement

Simons Foundation Collaboration Grants for Mathematicians

The Simons Foundation’s Mathematics and Physical Sciences division invites applications for Collaboration Grants for Mathematicians. The grants provide funding of US$7,000 per year for five years. The application deadline is January 28, 2016. For more information see https://www.simonsfoundation.org/funding/funding-opportunities/mathematics-physical-sciences/collaboration-grants-for-mathematicians/

—From a Simons Foundation announcement

The Paul Bruckman-Fibonacci Prize

Through a donation from George Hisert, a retired lawyer from California, the Fibonacci Association has endowed two prizes of US$1,000 each for mathematicians early in their careers: one for a paper in the Fibonacci Quarterly and one for a paper presented at the International Fibonacci Conference. The prize is named in honor of late Paul S. Bruckman, a long-time contributor to the Fibonacci Quarterly. For more details see www.fq.math.ca/Announcements/bruckmanprize.pdf.

—From a Fibonacci Association announcement

*NSF Major Research Instrumentation Program

The National Science Foundation (NSF) Major Research Instrumentation (MRI) program serves to increase access to shared scientific and engineering instruments for research and research training. Proposals may be submitted only by institutions of higher education or nonprofit organizations. The deadline is January 13, 2016. For more information see www.nsf.gov/funding/pgm_summ.jsp?pims_id=5260.

—From an NSF announcement

EDGE for Women

The EDGE Program (Enhancing Diversity in Graduate Education) aims to strengthen the ability of women students to successfully complete graduate programs in the mathematical sciences. EDGE sponsors a summer session and promotes networking and community. A follow-up mentoring program and support network is established with the participants’ graduate programs. Applicants should be women entering PhD programs in the mathematical sciences. The EDGE 2016 Summer Session will be held at Purdue University from June 6 through July 2. A stipend plus travel, room, and board will be awarded to participants. The deadline to apply is February 29, 2016. For further information, visit www.edgeforwomen.org.

—From an EDGE announcement

*The most up-to-date listing of NSF funding opportunities from the Division of Mathematical Sciences can be found online at: www.nsf.gov/dms and for the Directorate of Education and Human Resources at www.nsf.gov/dir/index.jsp?org=ehr. To receive periodic updates, subscribe to the DMSNEWS listserv by following the directions at www.nsf.gov/mps/dms/about.jsp.
National Academies Research Associateship Programs

The National Academies 2016 Postdoctoral and Senior Research Associateship Programs provide opportunities for PhD, ScD, or MD scientists and engineers to perform research at more than 100 research laboratories throughout the United States and overseas. Most of the laboratories are open to both US and non-US nationals. Full-time associateships will be awarded for research in the fields of mathematics, chemistry, earth and atmospheric sciences, engineering, applied sciences, life sciences, space sciences, and physics. Deadlines are on the first of February, May, August, and November, 2016. For further information and application materials, see the National Academies website at sites.nationalacademies.org/PGA/RAP/PGA_050491.

—From an NRC announcement

PIMS Education Prize

The Pacific Institute for the Mathematical Sciences (PIMS) awards an annual prize to a member of the PIMS community who has enhanced public awareness and appreciation of mathematics communication among groups and organizations concerned with mathematical training at all levels. The deadline for nominations is March 15, 2016. For more information see www.pims.math.ca/pims-glance/prizes-awards.

—From a PIMS announcement

CAIMS/PIMS Early Career Award

The Canadian Applied and Industrial Mathematics Society (CAIMS) and the Pacific Institute for Mathematical Sciences (PIMS) sponsor the Early Career Award in Applied Mathematics to recognize exceptional research in any branch of applied mathematics, interpreted broadly. The nominee’s research should have been conducted primarily in Canada or in affiliation with a Canadian university. The prize is to be awarded every year to a researcher fewer than ten years past the date of PhD at the time of nomination. The award comes with a cash prize of CAD$1,000 and an invitation to deliver a plenary lecture at the CAIMS annual meeting. The deadline for nominations is January 31, 2016. For more information see www.pims.math.ca/pims-glance/prizes-awards.

—From a PIMS announcement

News from IMA

The Institute for Mathematics and its Applications (IMA) is hosting a hot topics workshop May 16–19, 2016, called “Resource Trade-offs: Computation, Communication, and Information.” Large-scale machine learning and data analysis is characterized by a significant consumption of computational and statistical resources, which are often influenced by various constraints such as maintaining data privacy, exhibiting robustness to outliers and noise, and tackling partial access to the data. The workshop’s goal is to bring together experts with diverse backgrounds whose work pertains to these questions and to exchange ideas while identifying new research opportunities. See www.ima.umn.edu/2015-2016/SW5.16-19.16/.

Also IMA will hold a special workshop on “Dynamics and Differential Equations,” dedicated to the memory of Professor George Sell, from June 22–25, 2016. It encompasses several areas of his research, including ordinary differential equations, partial differential equations, infinite-dimensional dynamical systems, and dynamics of nonautonomous evolutionary equations. See www.ima.umn.edu/2015-2016/SW6.22-25.16/.

—From an IMA announcement

Invitation to Summer Research at MSRI

Come spend time at MSRI in the summer! We have room for a modest number of visitors to research singly or in small groups. We can provide offices, library facilities, and bus passes, and especially encourage groups of two to six to apply together. To make visits productive, we require at least a two-week commitment. Possible dates are from June 13 to July 31, 2016. Applications are due by February 1, 2016 and should contain a statement (at most a page) of the proposed research and a two-page CV similar to the NSF biographical sketch (www.nsf.gov/pubs/2003/nsf03041/2.htm) with academic history and lists of up to five relevant publications and up to five further publications. Email p308@msri.org to submit an application.

—From an MSRI announcement
Introducing a NEW
AMS Member Benefit

Early View allows individual AMS members to read peer-reviewed and accepted article manuscripts long before they appear in published form. Articles in Early View will be available until replaced by their final copyedited and proofread versions. Articles will be tagged with a DOI that will carry through to their final versions, making it easy to cite them in your research.

The Early View system will launch with these four journals:

- Journal of the American Mathematical Society
- Mathematics of Computation
- Proceedings of the American Mathematical Society
- Transactions of the American Mathematical Society

Start using AMS Early View today!
This section contains new announcements of worldwide meetings and conferences of interest to 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. New announcements only are published in the print Mathematics Calendar featured in each Notices 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. Asterisks (*) mark those announcements containing revised information.

In general, print announcements of meetings and conferences carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a brief 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 also be noted.

The complete listing of the Mathematics Calendar is available at:

\[ \text{www.ams.org/meetings/calendar/mathcal} \]

All submissions to the Mathematics Calendar should be done online via:

\[ \text{www.ams.org/cgi-bin/mathcal/mathcal-submit.pl} \]

Any questions or difficulties may be directed to mathcal@ams.org.

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January 2016

04 – May 20  **Differential Geometry**  
**Location:** University of Ouargla, Algeria  
My studies in lie algebra and its representation; group theory  
**URL:** www.univ-ouargla-dz/index.php/fr/

11 – 22  **CIMPA-ICTP School on Toric Methods in Geometry, Arithmetic and Dynamics**  
**Location:** Pontificia Universidad Catolica de Chile, Santiago, Chile  
The main purpose of this research school is to motivate and train Latin American students and young researchers in these subjects. The first week consists four courses. The second week consists of two courses and ten survey talks. Please see the website for a list of course titles, speakers, and for further details.  
**URL:** indico.ictp.it/event/7651/

25 – 29  **RTNS 2016 Winter School**  
**Location:** Seville, Spain  
This is the thirteenth Winter School in Dynamical Systems of the DANCE Spanish network. This series of courses aims at training their participants both theoretically and in applications in the field of the nonlinear science; with the aim that theory and applications enforce each other. This will be done in an atmosphere of informal discussion, interchange of ideas and critical discussion of results. Attention will be paid to the numerical and computational issues. As in the previous editions the School will consist of three courses: Alessandra Celletti (Univ. degli Studi di Roma Tor Vergata), Perturbation theory, KAM theorem and celestial mechanics; Ronnie Pavlov (Univ. of Denver), Multidimensional symbolic dynamics; Juan Sánchez Umbría (Univ. Politécnica de Catalunya), Numerical methods for large-scale dissipative dynamical systems.  
**URL:** www.dance-net.org/rtns2016/

29 – 31  **International Conference on the Occasion of Silver Jubilee of the Indian Society of Industrial and Applied Mathematics**  
**Location:** Sharda University, Knowledge Park-3, Greater Noida, U.P.(Delhi NCR), India  
The Idea of establishing the Indian Society of Industrial and Applied Mathematics was mooted during a Symposium on “Differential Equation with Industrial Application” in 1990 at the Department of Mathematics (AMU) in the presence of distinguished Indian Mathematicians besides a couple of eminent foreign mathematicians like Professor Helmut Neunzert, Prof. Martin Brokate and Prof. Rene’ Lozi, Prof. Abul Hasan Siddiqi, chairman of the Department and Director of the Symposium was authorized to take appropriate steps to register the society. A resume of activities is given at society website.  
**URL:** www.siam-india.in  
**URL:** www.sharda.ac.in

February 2016

1 – 5  **Conference on Open Problems in Nonsmooth Dynamics**  
**Location:** Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain  
With so much progress in recent decades, the landscape of nonsmooth and hybrid dynamical systems is changing. This conference will bring together some of the big breakthroughs and exciting new applications. With key speakers, themed contributed sessions, discussion time and posters, we will look at where the field is going next, how recent advances can be exploited, and what
big challenges are emerging from novel technologies. The conference will be open to a wide range of theoretical and applied themes, and provide a forum to discuss common issues. The conference will initiate a three-month Intensive Research Program being held at the CRM, and will help set the agenda for this major international event (Intensive Research Program: Advances in Nonsmooth Dynamics).

**URL:** [www.crm.cat/en/Activities/Curs_2015-2016/Pages/CNonsmooth.aspx](http://www.crm.cat/en/Activities/Curs_2015-2016/Pages/CNonsmooth.aspx)

### 3 – 5 8th Iranian Group Theory Conference

**Location:** University of Tabriz, Tabriz, Iran.

This is the 8th of a series of conferences organized regularly every year by the collaboration of Iranian group theory society. The conference committee cordially invites researchers in the area of group theory to take part in this conference. The registration will be open on October 2015 and detailed information about the venue, accommodation, fees and will be published then in the website of the conference. Iranian group theory conference has started since 2005 with the aim of improving scientific relationships between researchers and students who are interested in group theory. It also aims to exchanging ideas in various areas of group theory.

**URL:** [www.grouptheory.ir/8igtc](http://www.grouptheory.ir/8igtc)

### 8 – 11 Function Theory on Infinite Dimensional Spaces

**Location:** Mathematical Sciences Building, Universidad Complutense de Madrid, Madrid, Spain.

This will be the 14th edition of a series of conferences that have taken place on a biennial basis since 1989. It is organized by the Department of Mathematical Analysis of Complutense University of Madrid. Besides the plenary talks, several parallel sessions of 20-minute talks will be organized. Participants willing to deliver a short talk should send the organizers a tentative title and an abstract. Preference will be given to the following fields: geometry of Banach spaces, nonlinear analysis, differentiability, polynomials and multilinear mappings in Banach spaces, holomorphy, hypercyclicity and dynamical systems, and related topics. Up to now the following mathematicians have shown their interest to participate in the conference: Richard M. Aron, Geraldo Botelho, Daniel Carando, Krzysztof Chris Ciesielski, Aris Daniilidis, Robert Deville, Veronica Dimant, Estibalitz Durand, Alberto Ibort, Sebastián Lajara, Antoine Lemenant, Manuel Maestre and Daniele Puglisi.

**URL:** [www.mat.ucm.es/~confexx/](http://www.mat.ucm.es/~confexx/)

### 19 – 21 15th New Mexico Analysis Seminar

**Location:** University of New Mexico, Albuquerque, New Mexico.

The 15th New Mexico Analysis Seminar will take place February 19-21, 2016 at the University of New Mexico in Albuquerque. This year’s seminar will feature a mini-course from Christopher Sogge (Johns Hopkins University) on “Global Harmonic Analysis and the Concentration of Eigenfunctions”. In addition to the principal lecture series, the conference allocates time for contributed talks by the participants. In the past we have had participants from more than 70 institutions, from 30 different states, and eight different countries, with the bulk of participants coming from the Southwest region. We anticipate to provide some travel and hotel support for participants to help defray costs. Preference will be given to graduate students and recent PhD graduates. More information on the seminar, along with registration information can be found at conference website.

**URL:** [www.math.unm.edu/conferences/15thAnalysis/](http://www.math.unm.edu/conferences/15thAnalysis/)

### 19 – 21 Texas Geometry and Topology Conference

**Location:** Texas Christian University, Fort Worth, TX

The Spring 2016 Texas Geometry and Topology Conference will be held February 19-21, 2016, at Texas Christian University in Fort Worth, Texas. Financial support is available for travel and local expenses, with graduate students and recent Ph.D.s especially encouraged to apply. Preference for financial support will go to those registered by January 22. Confirmed Speakers: Christian Bár (University of Potsdam) Ruth Charney (Brandeis University) David Damanik (Rice University) Jon Hauenstein (University of Notre Dame) Tara Holm (Cornell University) Alejandro Uribe (University of Michigan) Guoliang Yu (Texas A&M University)

**URL:** [faculty.tcu.edu/gfriedman/tgtc2016/](http://faculty.tcu.edu/gfriedman/tgtc2016/)

### 22 – 26 Workshop on Analysis, Geometry and Mathematical Relativity: a celebration of Robert Bartnik's 60th birthday

**Location:** Monash University, Melbourne, Australia.

This workshop is both an event in the Monash Summer Visitor Program and an occasion to celebrate Robert Bartnik’s 60th birthday. In line with Robert’s research interests, the focus will be on topics in analysis, geometry, and mathematical relativity. The workshop is open to anyone with an interest in analysis, geometry or general relativity. There is no registration fee, but all participants must register. Early registration is strongly recommended as the total number of participants is limited by the capacity of the lecture theatre.

**Deadline for registration is December 22, 2015.**

**URL:** [agmr.eventbrite.com.au](http://agmr.eventbrite.com.au)

### 22 – 26 Workshop on Positivity and Valuations

**Location:** Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain

The aim of the workshop is to bring together algebraic geometers working on valuation theory or interested in the use of valuations for the study of projective algebraic varieties; the main focus is going to be the relationship between valuations and positivity properties of line and vector bundles. The event will consist of a limited number of talks (roughly 10-15) by distinguished invited speakers, which will take place during the morning sessions, and whose goal is to stimulate further discussion. The afternoons will be devoted to performing research in working groups on topics in the area of the workshop chosen by the participants at the beginning of the venue.

**URL:** [www.crm.cat/en/Activities/Curs_2015-2016/Pages/PositValuations.aspx](http://www.crm.cat/en/Activities/Curs_2015-2016/Pages/PositValuations.aspx)
March 2016

22 – March 4  **CIMPA-CIMAT-ICTP School on Moduli of Curves**

**Location:** CIMAT, Guanajuato, Mexico  The courses will be in English Algebraic Curves and their Moduli Spaces Higher Dimensional Varieties and their Moduli Spaces Gomestic Invariant Theory and Bridgeland Stability Minimal Model Program/Birational Geometry and Topology of Mg Moduli and Degenerations of Algebraic Curves via Tropical Geometry.

**Registration/Deadline** Registration is now open (deadline: October 25, 2016).

**URL:** www.cimpa-icpam.org/ecoles-de-recherche/ecoles-de-recherche-2016/liste-chronologique-des-ecoles-de/article/moduli-of-curves-736?lang=fr

**April 2016**

25 – 29  **AIM Workshop: Open textbooks in MathBook XML**

**Location:** American Institute of Mathematics, San Jose, California.

This workshop, sponsored by AIM and the NSF, will bring together teams of authors of open source mathematics textbooks, developers of technical tools supporting authoring of these books, and experienced editors providing reviews, advice, and guidance. During the workshop, authors will begin by converting existing book projects from LaTeX to a highly structured format. The textbooks will then easily convert to print, PDF, HTML, EPUB, and Jupyter Notebooks.

**URL:** amath.org/workshops/upcoming/mathbookxml

May 2016

2 – 4  **Workshop "Hilbert's Sixth Problem"**

**Location:** University of Leicester, Leicester, United Kingdom.

Hilbert's 6th problem gives a unique framework for collaborations of multiscale analysis with other fields of the mathematical sciences, from probability, logic and abstract algebra to mathematical physics. The main aims of the workshop are: 1. To facilitate interdisciplinary discussion across key mathematical and physical disciplines involved in solution of Hilbert's sixth problem about the state of the art. 2. To synthetise an integral interdisciplinary point of view on Hilbert's sixth problem and renew the programmatic call in the light of the latest achievements. 3. To provide guidance to early career researchers via an indication of future research directions in Hilbert's sixth problem. 4. To disseminate the modern achievements and renewed programmatic call in a series of review publications.

**URL:** math.le.ac.uk/people/ag153/homepage/HilbertWeb/HilbertWorkshop2016.htm

2 – 6  **Workshop on Function spaces and high-dimensional approximation**

**Location:** Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.

The workshop will promote the modern research connecting Fourier analysis, function spaces, and their links to modern developments in the high-dimensional approximation theory. The purpose of this meeting is to bring together the leading experts, and disseminate the latest progress in research, and in the interaction of these fields. The topics of the workshop include: · Function spaces and Embedding/Duality/Extension theorems · Smoothness of multivariate functions · Fourier transforms inequalities · Weighted inequalities · Hyperbolic cross approximation · Sparse approximation

**URL:** crm.cat/en/Activities/Curs_2015-2016/Pages/Function-Spaces.aspx
08 - 14 **Algebra, Geometry and Topology of Singularities**  
**Location:** Galatasaray University, Istanbul, Turkey  
This is an international workshop intending to give a panorama on Singularity Theory and bring together the specialists and the young researchers on the subject. The talks will be focused on the current results of the different aspects of the Singularities, such as the algebraic, geometric and topological studies.  
**URL:** math.gsu.edu.tr/singularities2016/

9 - 11 **Advanced Course by Jill Pipher**  
**Location:** Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.  
These advanced courses are devoted to different topics in connection with High-dimensional approximation, Harmonic Analysis, and closed areas, such as PDE’s. The courses will focus on the problems which have attracted a lot of attention in the recent years.  

9 - 12 **International Meeting on Applied Mathematics in Errachidia**  
**Location:** Errachidia, Morocco.  
The aim of the International Meeting on Applied Mathematics is to bring researchers and professionals to discuss recent developments in both theoretical and applied mathematics, to create the knowledge exchange platform between mathematicians. The conference is broad-based that covers all branches of engineering sciences, mathematics and interdisciplinary researches.  
**URL:** sites.google.com/site/imamerrachidia2016/home

16 - 20 **ICERM Workshop: Effective and Algorithmic Methods in Hyperbolic Geometry and Free Groups**  
**Location:** ICERM at Brown University, 121 South Main St., Providence, Rhode Island.  
While much work remains, both computation and theory have progressed. Fast algorithms have been developed for running computations in the mapping class group and other finitely generated groups, as well as for recognizing certain types 3-manifolds and knot and link complements up to homeomorphism. These have been supplemented by a new wave of constructive theorems which explicitly relate the algebra of the fundamental group of a hyperbolic 3-manifold to its geometry, and to the geometry of various simplicial complexes, such as the curve complex. This ICERM workshop will focus on such advances, as well as on the development of new algorithms and extension of algorithmic techniques to the study of free groups. The workshop aims to bring together researchers from a broad range of related fields to work towards a more effective and quantitative understanding of 3-manifold topology, geometric group theory, and hyperbolic geometry.  
**URL:** icerm.brown.edu/topical_workshops/tw16-2-hgfg/

19 - 23 **3rd International Conference on Recent Advances in Pure and Applied Mathematics (ICRAPAM 2016)**  
**Location:** La Blanche Resort Hotel, Bodrum, Mugla-Turkey  
This year ICRAPAM is supported by Istanbul Commerce University, Istanbul Medeniyet University and Institute of Mathematics of National Academy of Science of Ukraine. INVITED SPEAKERS - Prof. Jeff Connor, Ohio University, USA  
- Prof. A. M. Samoilenko, Inst. of Math. of NAS, Ukraine  
- Prof. Ghiocel Groza, Tech. Uni. Civil Engineering Bucharest, Romania  
- Prof. Werner Varnhorn, Universitat Kassel, Germany  
- Prof. F. Abdullayev, Mersin Uni., Turkey  
- Prof. Ljubisa D.R. Kocinac, Uni. of Nis, Serbia  
- Prof. Reza Saadat, Iran Uni. of Sci. and Tech., Iran  
**URL:** www.icrapam.org

23 - 25 **Workshop on Software and Applications of Numerical Algebraic Geometry**  
**Location:** University of Notre Dame, Notre Dame, Indiana.  
This workshop will focus on solving systems of polynomial equations using numerical algebraic geometry. It will introduce the participants to algorithms of numerical algebraic geometry so that they can use and develop variations to address their own research problems of interest. Progress related to the redevelopment of Bertini along with an introduction for creating solving modules will also be discussed. Finally, this workshop will bring together researchers from a variety of application fields to discuss successes and current challenges related to solving systems of polynomial equations.  
**URL:** www.nd.edu/~jhauenst/Workshop2016/

23 - 26 **Mixed Integer Programming Workshop (MIP 2016)**  
**Location:** University of Miami, in Coral Gables, FL.  
The 2016 Mixed Integer Programming workshop will be the thirteenth in a series of annual workshops held in North America designed to bring the integer programming community together to discuss very recent developments in the field. The workshop consists of a single track of invited talks and features a poster session that provides an additional opportunity to share and discuss recent research in MIP.  
**URL:** https://sites.google.com/site/mipworkshop2016

23 - June 3 **Advanced School on Geometric Group Theory and Low-Dimensional Topology: Recent Connections and Advances**  
**Location:** ICTP, Trieste, Italy.  
The motivation for this advanced school is to expose students, postdocs and researchers to various key roles that geometric group theory has played in recent advances in low-dimensional topology and geometry. These include (but not limited to) the role of virtually special groups, representations of Kleinian groups in $SL(2,\mathbb{C})$ and generalizations (e.g. Higher Teichmuller Theory), the Mapping
Mathematics Calendar

Class Group and its recent role in low dimensional geometry and topology and group theoretic connections with Heegaard Floer theory through left-orderability.

URL: indico.ictp.it/event/7646/

23 – June 03  Group Theory and P Groups
Location: Ouargla University, Algeria
Group Theory; Group Cohomology.
URL: www.univ-ouargla.dz/index.php/fr/
URL: www.univ-ouargla.dz/index.php/fr/

24–27  Combinatorial and additive number theory (CANT 2016)
Location: CUNY Graduate Center, New York, New York.
This is the fourteenth in a series of annual workshops sponsored by the New York Number Theory Seminar on problems and results in combinatorial and additive number theory and related parts of mathematics. The list of speakers with abstracts of their talks will be posted on the website www.theoryofnumbers.com There are daily sessions on open problems, and graduate students are encouraged to attend. Proceedings of the conference have been published by Springer. Mathematicians who would like to speak at the meeting should submit a title and abstract to: meylvyn.nathanson@lehman.cuny.edu
URL: www.theoryofnumbers.com

27 - 29  15th Panhellenic Conference of Mathematics Analysis
Location: Department of Mathematics and Applied Mathematics, University of Crete, Heraklion, Crete, Greece.
This is the central conference of Mathematical Analysis (in a broad sense) in Greece and takes place every couple of years.
Topics include Harmonic and Complex Analysis, Functional Analysis, Operator Theory, Dynamical Systems, Differential Equations, Numerical Analysis.
Invited Speakers Haim Brezis (to be confirmed), Tony Cárbery, Vassilios Douglas, Nikos Frantzikinakis, Aristides Katavolos, Emmanouil Milakis, Grigoris Paouris.
URL: fourier.math.uoc.gr/pcma2016/

30 – June 4  Advanced Course on Constructive Approximation and Harmonic Analysis
Location: Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
These advanced courses are devoted to different topics in connection with High-dimensional approximation, Harmonic Analysis, and closed areas, such as PDE.s. The courses will focus on the problems which have attracted a lot of attention in the recent years.

30 – June 4  International conference "Complex Analysis and Related Topics"
Location: The Ivan Franko National University of Lviv, Lviv, Ukraine.
The following topics will be presented on the conference: complex analysis of one variable; complex analysis of several variables.
URL: analysis16.mathlviv.org.ua/

June 2016

2 – 4  Representation Theory Conference
Location: Uppsala University, Uppsala, Sweden.
Organizer Volodymyr Mazorchuk.
Invited Speakers Maria Gorelik, Stefan Kolb, Julian Külshammer, Erhard Neher, Alisair Savage, Peng Shan, Sarah Scherotzke, Jan Stovicek.
Contact rt2016@math.uu.se

5 – 10  XII International Conference on Approximation and Optimization in the Caribbean
Location: Havana University, Havana, Cuba. This conference is the twelfth of a series founded in 1987 and previously organized in different countries around the Caribbean area. The goal is to support high level mathematical research and education on Approximation, Optimization and related topics. It includes invited lectures, tutorials, mini-symposia, and contributed talks.
URL: gama.uc3m.es/appopt/

06 – 09  25th International Workshop on Matrices and Statistics (IWMS'2016)
Location: University of Funchal, Madeira (Portugal)
The purpose of the workshop is to bring together researchers sharing an interest in a variety of aspects of statistics and its applications as well as matrix analysis and its applications to statistics, and offer them a possibility to discuss current developments in these subjects. The workshop will bridge the gap among statisticians, computer scientists and mathematicians in understanding each other’s tools. We anticipate that the workshop will stimulate research, in an informal setting, and foster the interaction of researchers in the interface between matrix theory and statistics Some emphasis will be put on related numerical linear algebra issues and numerical solution methods, relevant to problems arising in statistics. The workshop will include invited talks and special sessions devoted to cutting edge research topics.
URL: www.iwms.ipt.pt

6 – 10  Conference on Harmonic Analysis and Approximation Theory (HAAT 2016)
Location: Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
The main goal of the conference HAAT2016, besides presenting the recent developments in Constructive Approximation and Harmonic Analysis, is promoting their integration and research exchange. In particular, the conference promotes the idea of applying the research tools from one research area for problems in the other area. As a consequence, such an integration will possibly result in solving many applied problems in other areas of science.
**6 - 10 Time-Frequency Analysis and Related Topics**  
**Location:** Strobl, Austria  
Topics include function spaces, time-frequency analysis and Gabor analysis, sampling theory and compressed sensing, pseudodifferential operators and Fourier integral operators, numerical harmonic analysis, abstract harmonic analysis, and applications of harmonic analysis. Plenary Speakers: Albrecht Böttcher [TU Chemnitz], Anders Hansen [University of Cambridge], Arieh Iserles [University of Cambridge], Gitta Kutyniok [TU Berlin], Rachel Ward [UT Austin], Maciej Zworski [University of California, Berkeley].  
**URL:** nuhag.eu/strobl16

**12 – 19 54th International Symposium on Functional Equations**  
**Location:** Hotel Aurum, Hajdúszoboszló, Hungary  
**Topics** Functional equations and inequalities, mean values, functional equations on algebraic structures, Hyers-Ulam stability, regularity properties of solutions, conditional functional equations, iteration theory; applications of the above.  
**Organizers** Zsolt Páles, Inst. of Math., Univ. of Debrecen, 4010 Debrecen, Hungary; pales@science.unideb.hu  
**Scientific Committee** J. Aczél (Honorary Chair; Waterloo, ON, Canada), W. Benz (Hamburg, Germany), Z. Daróczy (Debrecen, Hungary), L. Reich (Graz, Austria). Honorary Members: R. Ger (Chair; Katowice, Poland), Zs. Páles (Debrecen, Hungary), M. Sablik (Katowice, Poland), J. Schweiga (Graz, Austria), and A. Sklar (Chicago, Illinois).  
**Information** Participation at these meetings is by invitation only. Those wishing to be invited to this or one of the following meetings should send details of their interest to: Roman Ger, Inst. of Math., Silesian Univ., Bankowa 14, PL-40-007 Katowice, Poland; romanger@us.edu.pl before January 15, 2016.  
**URL:** isfe.up.krakow.pl/54/index.php

**13 – 17 ICERM Workshop: Algorithmic Coding Theory**  
**Location:** ICERM at Brown University, 121 South Main St., Providence, Rhode Island.  
The goal of this workshop is to bring together researchers from several different communities, 2016 - applied math, theoretical computer science, communications and electrical engineering, 2016 - to focus on a few quickly-moving topics in algorithmic coding theory. Topics will include: Polar codes, Codes for interactive communication, Local decoding and coding for distributed storage, Non-malleable codes.  
**URL:** icerm.brown.edu/topical_workshops/tw16-3-act/

**13 – 17 MURPHYS-HSFS-2016**  
**Location:** Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain  
Centre de Recerca Matemàtica, Barcelona, and the Collaborative Research Center 910, Berlin are pleased to announce the joint international multidisciplinary workshop MURPHYS-HSFS-2016. The workshop, devoted to mathematical theory and applications of the multiple scale systems and systems with hysteresis, will take place at the Centre de Recerca Matemàtica, in a beautiful suburb of Barcelona. MURPHYS 2016 (Multi-Rate Processes and Hysteresis) is the 8th workshop that continues a series of biennial conferences focused on multiple scale phenomena, singular perturbations, phase transitions and hysteresis phenomena occurring in mathematical, physical, economical, engineering and information systems.  
**URL:** www.crm.cat/en/Activities/Curs_2015-2016/Pages/MURPHYS.aspx

**13 – 22 Recent Advances in Complex Differential Geometry**  
**Location:** (I.M.T) Toulouse University, Toulouse, France.  
Recent advances in complex differential geometry is a two-week program covering a wide range of topics in both Kähler and non-Kähler geometry and is part of the CIMI thematic trimester Complex Geometry and Beyond. Lectures and seminars will take place at the Institut de Mathématique de Toulouse (Toulouse, France). Week 1, from Monday June 13th 2016 to Friday June 17th 2016 is a a summer school. Week 2, from Friday June 17th 2016 to Wednesday June 22nd 2016 is an international conference. Details are available on the website of the conference.  

**13 – 24 Harmonic Analysis and Elliptic Equations on real Euclidean Spaces and on Rough Sets**  
**Location:** Mathematical Sciences Research Institute, Berkeley, CA.  
The goal of the workshop is to present harmonic analysis techniques in $\mathbb{R}^n$ (the “flat” setting), and then to show how those techniques extend to much rougher settings, with application to the theory of elliptic equations. Thus, the subject matter of the workshop will introduce the students to an active, current research area: the interface between harmonic analysis, elliptic PDE, and geometric measure theory.  
**URL:** www.msri.org/summer_schools/776

**14 – 17 2016 World Conference on Natural Resource Modeling**  
**Location:** Flagstaff, AZ.  
The 2016 International Conference of the Resource Modeling Association will be held June 14 - 17 in Flagstaff, Arizona, U.S.A. “Quantitative Modeling for Managing Natural Resources in an Era of Climate Change” is the theme of this conference. Four keynote speakers will address the use of mathematical models to study biodiversity and the effects of climate change on various ecosystems and offer recommendations for managing them in a sustainable manner. In addition to the keynote presentations there will be contributed paper sessions. Topics that will be considered at the conference are water resource management, economic issues with managing natural resources, fisheries (fresh and salt water), biodiversity, wildlife management, forest management, and protection of ecosystems.  
**URL:** resourcemodeling.org
27 – July 1  **ICERM Workshop: Illustrating Mathematics**  
**Location:** ICERM at Brown University, 121 South Main St., Providence, Rhode Island. 
Research and outreach are normally thought to divide mathematics in two. This separation is, however, completely artificial; it is impossible to "find" a mathematical idea without explaining it. Exploration and exposition are two sides of the same coin. One striking example of this is the epochal work of William Thurston; often his theorems were accompanied by pictures, and computer programs, illustrating the underlying ideas. The goal of this conference is to bring together mathematicians from a range of fields, and practitioners from the digital arts (animation, 3D printing, laser cutting, CNC routing, virtual reality, computer games, etc). The attendees will share their expertise in mathematics and with the procedural tools used to illustrate mathematics. In addition to talks in the traditional style, we plan to hold several workshops to train attendees about a variety of digital media, in particular 3D printing.  
**URL:**  
icerm.brown.edu/topical_workshops/tw16-1-im/  

27 – July 1  **3rd Barcelona Summer School on Stochastic Analysis**  
**Location:** Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain. 
The Barcelona Summer School on Stochastic Analysis is a one-week scientific activity consisting mainly of courses addressed to PhD students and young researchers on current research topics in Stochastic Analysis. Selected participants are also given the opportunity to deliver short talks or to display posters. The courses in 2016 will be the following (a detailed description is given below) on Approximations of Stochastic PDEs, by István Gyöngy (University of Edinburgh, UK) Regularity Structures, by Martin Hairer (University of Warwick, UK).  
**URL:**  

27 – July 1  **2016 EWM-EMS Summer School - Geometric and Physical aspects of Trudinger-Moser type inequalities**  
**Location:** Institut Mittag-Leffler, Djuhrholm, Sweden. 
Starting from the state of art, the school aims at promoting new directions in sharp limiting inequalities of Trudinger-Moser types and applications to problems arising from geometry and physics. Professors Hajer Bahouri, Sun-Yung Alice Chang and Gabriella Tarantello will present three courses focusing on this topic, along with additional talks given by some of the participants, as well as a poster session. These supplementary research activities will complement the main courses and motivate further discussion among participants. Students, post-docs and other young researchers will have the opportunity to get up to date with new research advances, or to enter this fascinating field of research.  
**Deadline For applications** November 30, 2015.  
**URL:**  
sites.google.com/site/2016ewmemssummerschool  

30 – July 1  **AGMP 2016 Algebraic Geometry and Mathematical Physics**  
**Location:** University of Tromso, Tromso, Norway 
The conference is in honor of Arnfinn Laudal on his 80th birthday. The conference will consist of 4 invited lectures: Alain Connes, Collège de France, IHEA Gert-Martin Greuel, University of Keiserslautern Ulf Persson, Chalmers Lê Dũng Tráng, Université de Marseille. Also, there will be contributed presentations. All talks will be plenary. The official language of conference is English. The conference will cover, but is not limited to, the main themes: Algebra, Geometry, dynamical symmetries and conservation laws, mathematical physics and applications. This in particular includes the themes: Deformation theory and quantization, Hom-algebras and n-ary algebraic structures, Hopf algebra, integrable systems and related mathematical structures, geometric and physical aspects. The conference will consists of plenary, invited and contributed papers. Prospective authors are invited to submit their papers on topics included but not limited to applications of differential equations in: Mathematical Physics; Mathematical Finance; Mathematical Biology; Nonlinear waves; Mechanics; Fractional Analysis; Neuroscience. The proceedings will be published in peer reviewed journal.  
**URL:**  
site.uit.no/agmp/  

July 2016  
**Location:** The conference will held in the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, Sofia, Bulgaria 
Third International Conference on New Trends of Differential Equations in Sciences is organized by the Department of Differential Equations and Mathematical Physics at Institute of Mathematics and Informatics, Bulgarian Academy of Sciences (www.math.bas.bg/ntades/). Differential equations have a lot of applications in different scientific fields. This conference will be devoted to such applications. A number of phenomena in nature (physics, chemistry, biology) and in society (economics) result in problems leading to study of linear and nonlinear differential equations. The conference consists of plenary, invited and contributed papers. Prospective authors are invited to submit their papers on topics included but not limited to applications of differential equations in: Mathematical Physics; Mathematical Finance; Mathematical Biology; Nonlinear waves; Mechanics; Fractional Analysis; Neuroscience. The proceedings will be published in peer reviewed journal.  
**URL:**  
www.math.bas.bg/ntades/  

4 – 15  **School on Algebraic, Geometric and Probabilistic Aspect of Dynamical Systems and Control Theory**  
**Location:** ICTP, Trieste, Italy. 
This is a follow-up to two separate schools which were held at ICTP in 2011 and 2013. Both of them in the broad area of Dynamical Systems, the first was essentially a Brazilian-Iranian school and the second a joint ICTP-SISSA-Moscow school. The school will cover some topics in Dynamical Systems and Control Theory from various inter-related perspectives. In particular it will highlight the connections between the study of Dynamical Systems
from an algebraic, a geometrical and a probabilistic (ergodic) point of view.

**URL:** indico.ictp.it/event/7647/

4 – 22 **EAUMP-ICTP School in Number Theory**

**Location:** EAUMP, Kigali, Rwanda.

The proposed school is the next one in a series of schools organized under the East African Universities Mathematics Programme (EAUMP), which started in 2004. This programme has core funding from the International Science Programme (ISP) of the Government of Sweden, and has as one of its aims to improve the pure mathematics Masters and Postgraduate training in the Eastern Africa region. The participating Universities of the EAUMP are University of Dar es Salaam, Tanzania; University of Nairobi, Kenya; University of Zambia; Makerere University, Uganda; University of Rwanda (recently merged from National University of Rwanda and Kigali Institute of Science and Technology), Rwanda.

**URL:** indico.ictp.it/event/7650/

10 – 15 **28th International Biometric Conference**

**Location:** Victoria Conference Centre, Victoria, BC, Canada.

The International Biometric Conference (IBC) is dedicated to recent developments and application of Biometry and Statistics in many different fields of life and environmental sciences. The IBC is held every two years in one of the 34 regions of the International Biometric Society (IBS, www.biometricsociety.org) The IBS has 6,000 members worldwide, and the conference attracts statisticians and students from around the world who are interested in the development and application of statistical and mathematical theory and methods to the biosciences. Numerous opportunities for student prizes and awards. Invited Sessions and Short Courses are confirmed. Call for Contributed Sessions ends January 6, 2016. Early Registration ends April 15, 2016.

**URL:** www.biometricconference.org

10 – 22 **Summer Graduate School: An Introduction to Character Theory and the McKay Conjecture**

**Location:** Mathematical Sciences Research Institute, Berkeley, CA.

Character Theory of Finite Groups provides one of the most powerful tools to study groups. In this course we will give a gentle introduction to basic results in the Character Theory, as well as some of the main conjectures in Group Representation Theory, with particular emphasis on the McKay Conjecture.

**URL:** www.msri.org/summer_schools/767

11 – 15 **The 20th Conference of the International Linear Algebra Society (ILAS)**

**Location:** KU Leuven, Leuven, Belgium.

The 20th ILAS conference takes place in Belgium.

**Plenary speakers** Koenraad Audenaert, Pierre Comon, Paul van Dooren, Bruno Iannazzo, Monique Laurent, Elizabeth Meckes, Pablo A. Parrilo (LAA speaker, supported by Elsevier), Andre Ran, Fernando de Teran (SIAG/LA speaker). The current list of invited minisymposia is Data-Driven Model Reduction by Athanasios C. Antoulas, Matrix Equations by Peter Benner and Beatrice Meini, Matrix Inequalities and Operator Means by Jean-Christophe Bourin and Takeaki Yamazaki, Linear Algebra and Quantum Computation by Chi-Kwong Li, Raymond Sze, and Yiu Tung Poon, Image Restoration and Reconstruction by Marco Donatelli and Jim Nagy, Matrix Methods in Network Analysis by Francesco Tudisco and Dario Fasino, Low-Rank Tensor Approximations by Andre Uschmajew and Bart Vandereycken, Matrix methods for solving systems of multivariable polynomial equations by Bernard Mourrain, Marc Van Barel, and Vanni Noferini.

**URL:** ilas2016.cs.kuleuven.be

11 – 15 **Quantum Algebras, Quantum Integrable Models and Quantum Information**

**Location:** The Sven Lovén Centre for Marine Sciences of the University of Gothenburg, Kristineberg, Sweden.

The conference is a satellite event to the 7th European Congress of Mathematics (ECM) in Berlin. The main purpose of the conference is to stimulate and promote interactions between three major research areas: (quantum) algebra, including (quantum) geometry, (quantum) integrable models and (quantum) information theory. This conference continues the following series of satellite conferences to the European Congresses of Mathematics: Noncommutative Geometry and Representation Theory in Mathematical Physics. Satellite conference to the 4th ECM in Stockholm (2004). Noncommutative Structures in Mathematics and Physics. Satellite conference to the 5th ECM in Amsterdam (2008). 3Quantum: Algebra Geometry Information. Satellite conference to the 6th ECM in Krakow (2012).

**URL:** science.gu.se/qqq2016

11 – 21 **Summer School in Probability**

**Location:** Northwestern University, Evanston, Illinois

The Summer School in Probability, to be held in July 2016, at Northwestern University, will include six introductory mini-courses on various topics within probability, aimed at graduate students and recent PhDs.

**URL:** www.math.northwestern.edu/~auffing/summer.html

12 – 15 **International Conference ON Analysis and Its Applications (ICAA-2016)**

**Location:** Ahi Evran University, Kirsehir/Turkey

Aim and Objectives: The purpose of the conference is to bring together experts and young analysts from all over the world working in analysis and its applications to present their researches, to exchange new ideas, to discuss challenging issues, to foster future collaborations and to interact with each other. Topics to be covered include (but are not limited to): Operator Theory, Fixed Point Theory and its Applications, Applications in Differential Equations and Partial Differential Equations, Inequalities, Algorithms, Set-valued Analysis, Variational Analysis including Variational Inequalities, Optimization and its Applications, Convex Analysis and its Applications, Smooth and non-smooth Analysis, Geometry of Banach Spaces, Fourier Analysis, Modern Methods in
Mathematics Calendar

Summability and Approximation, Sequence Spaces and Matrix Transformations, Measure of Noncompactness.

**URL:**  [www.icaa2016.org/](http://www.icaa2016.org/)

18 – 20  **ICERM Workshop: Stochastic numerical algorithms, multiscale modelling and high-dimensional data analytics**

**Location:**  ICERM at Brown University, 121 South Main St., Providence, Rhode Island.

The workshop will focus on recent advances in the design of rigorous discrete-dynamics based sampling approaches, algorithms development for large-scale data analysis and stochastic dynamical systems, scalable and rigorous numerical methods for stochastic differential equations and sampling from high-dimensional distributions, and exploitation of low-dimensional structures in high-dimensional data and stochastic dynamical systems for model reduction and efficient Monte-Carlo schemes. The meeting will foster the interchange and deployment of the latest methodologies for sampling and approximation.

**URL:**  icerm.brown.edu/topical_workshops/tw16-5-sna/

18 – 22  **International Workshop on Operator Theory and Applications**

**Location:**  Washington University, St. Louis, Missouri.

IWOTA’s primary objective is to bring together researchers in the area of operator theory and related fields, including applications in engineering and mathematical physics (such as differential and integral equations, interpolation theory, system and control theory, signal processing, scattering theory). These meetings provide opportunities for all participants to present their own work in contributed talks, to interact with other researchers from around the globe, and to broaden their knowledge of the field by hearing the invited lectures of eminent mathematicians. IWOTA emphasizes cross-disciplinary interaction between mathematicians, electrical engineers and mathematical physicists.

**URL:**  openscholarship.wustl.edu/iwota2016/

18 – 29  **Electronic Structure Theory**

**Location:**  Lawrence Berkeley National Laboratory, University of California, Berkeley, California.

Ab initio or first principle electronic structure theories, particularly represented by Kohn-Sham density functional theory (KS-DFT), have been developed into workhorse tools with a wide range of scientific applications in chemistry, physics, materials science, biology etc. What is needed are new techniques that greatly extend the applicability and versatility of these approaches. At the core, many of the challenges that need to be addressed are essentially mathematical. The purpose of the workshop is to provide graduate students a self-contained introduction to electronic structure theory, with particular emphasis on frontier topics in aspects of applied analysis and numerical methods.

**URL:**  [www.msri.org/summer_schools/778](http://www.msri.org/summer_schools/778)

25 – August 5  **Summer Graduate School: Chip Firing and Tropical Curves**

**Location:**  Mathematical Sciences Research Institute, Berkeley, California.

Tropical geometry uses a combination of techniques from algebraic geometry, combinatorics, and convex polyhedral geometry to study degenerations of algebraic varieties; the simplest tropical objects are tropical curves, which one can think of as "shadows" of algebraic curves. Linear equivalence of divisors on an abstract tropical curve is determined by a simple but rich combinatorial process called "chip firing", which was discovered independently in the discrete setting by physicists and graph theorists. From a pedagogical point of view, one can view tropical curves as a combinatorial model for the highly analogous but more abstract theory of algebraic curves, but there is in fact much more to the story than this: one can use tropical curves and chip firing to prove theorems in algebraic geometry and number theory. This field is relatively new, so participants will have the opportunity to start from scratch and still get a glimpse of the cutting edge in this active research area.

**URL:**  [www.msri.org/summer_schools/777](http://www.msri.org/summer_schools/777)

August 2016

1 – 5  **ICERM Workshop: Cycles on Moduli Spaces, Geometric Invariant Theory, and Dynamics**

**Location:**  ICERM at Brown University, 121 South Main St., Providence, Rhode Island.

An integral part of the workshop is a series of three mini-courses on the following subjects: Cycles and birational geometry of moduli spaces of curves, Geometric invariant theory, with applications to constructions of moduli spaces, and affine invariant manifolds and invariants in Teichmüller dynamics. The mini-courses will be aimed primarily at non-experts and will benefit graduate students and early career researchers in related areas, who are particularly encouraged to apply to participate in the workshop.

**URL:**  icerm.brown.edu/topical_workshops/tw16-4-ms/

1 – 9  **Alterman Conference on Geometric Algebra and Summer School on Kähler Calculus**

**Location:**  University of Transilvania, Brasov, Romania

This event comprises two parts, a Clifford Algebra (CA) Conference, and a summer school that promotes the Kaehler calculus (KC). This calculus is based on CA of differential forms and generalizes Cartan’s calculus. It has direct application to relativistic quantum mechanics (QM) by replacing Dirac’s equation with one for scalar-valued differential forms. Spinors then emerge as solutions with symmetry, antiparticles surge with the same sign of energy as particles, and operators are concomitants of processes rather than ad hoc creations. We shall deal with applications to mathematical analysis, like the replacing of Hodge’s theorem with actual integration of the differential system that specifies Kaehler’s exterior and interior derivatives (read curl and divergence). We shall also deal with an additional generalization to Clifford valued differential forms. It takes us beyond Dirac type environments into one that seems appropriate for high energy physics and QM foundations.

**URL:**  [cs.unitbv.ro/~acami/index.htm](http://cs.unitbv.ro/~acami/index.htm)
1 - 12 School and Workshop on Homological Methods in Algebra and Geometry  
**Location:** AIMS Ghana, Biriwa, Ghana.  
In collaboration with AIMS Ghana, The Abdus Salam International Centre for Theoretical Physics (ICTP) is organizing a "School and Workshop on Homological Methods in Algebra and Geometry". The school and workshop will be held at AIMS Ghana, from August 1-13. The first week will consist of three minicourses: Khovanov homology and categorification-Brent Everitt (University of York) Noncommutative algebraic geometry-Paul Smith (University of Washington) Geometric representation theory (TBC)-Geordie Williamson (MPI Bonn). The second week will comprise of research talks on these topics.  
**URL:** indico.ictp.it/event/7649/  

1 - 12 CIMPA-ICTP Mathematics Research School on Lattices and Application to Cryptography and Coding Theory  
**Location:** Ho Chi Minh University of Pedagogy, Ho Chi Minh City, Vietnam.  
Lattices play a central role in number theory and its applications. The aim of this school is to introduce participants to the ubiquity of lattices in number theory, algebra, arithmetic algebraic geometry, cryptography and coding theory. The theory of lattices will be developed from its very beginning and the basic notions required for the applications in number theory, algebra, arithmetic algebraic geometry will be provided. Appearances of lattices that we intend to cover include: The natural lattices structures of Mordell-Weil groups and unit groups. Lie algebra root lattices. The lattice basis reduction algorithm "LLL", which as many applications to many areas of mathematics and finally the construction of the famous Leech lattice. On the applied side we plan to cover constructions of good error-correcting codes and of good sphere packings via dense lattices.  
**URL:** indico.ictp.it/event/7665/  

1 - 19 School and Conference on Moduli Spaces, Mirror Symmetry and Enumerative Geometry  
**Location:** ICTP, Trieste, Italy.  
Moduli spaces and enumerative geometry are important classical topics of algebraic geometry. In recent decades they have received important new input from theoretical physics, among others with the advent of mirror symmetry, which made surprising predictions for classical problems of enumerative geometry. Mirror symmetry has since developed further and is a subject of intensive study. Many new powerful concepts, tools and techniques have been developed in recent years, in part in order to understand these predictions. These include moduli spaces of maps and Gromov-Witten invariants, virtual fundamental classes, Donaldson-Thomas and Pandharipande-Thomas invariants, stability conditions on derived categories and their moduli spaces. In this school we will introduce the participants to this important and fascinating subject and its powerful techniques. The topics of the school include Derived categories, Stability conditions on derived categories and applications to birational geometry.  
**URL:** indico.ictp.it/event/7648/  

**September 2016**  
12 - 16 School and Workshop on Geometric Correspondence of Gauge Theories  
**Location:** ICTP, Trieste, Italy.  
The main focus is on recent developments on exact results in supersymmetric quantum field theories and superstrings on curved backgrounds and their impact on enumerative geometry, knot theory and representation theory of infinite dimensional algebras.  
**URL:** indico.ictp.it/event/7645/  

26 - 30 International School on Dynamical Systems in Biology-ISDS 2016  
**Location:** Strathmore University, Nairobi, Kenya.  
ISDS 2016 is the second school of a biennial series of international graduate schools on Mathematical Modelling in Biology and Medicine organized by IMS of Strathmore University. In an intense but informative session, the first school "International School on Mathematical Epidemiology (ISME)" took place from September 1-5, 2015, at the Strathmore University Madaraka Campus.  
**URL:** www.ims.strathmore.edu  

**November 2016**  
11 - 12 First EAI International Conference on Computer Science and Engineering  
**Location:** Batu Feringhi, Penang Island, Malaysia.  
The requirements demands in problem solving have been increasingly in demand in exponential way. The new technologies in computer science and engineering have reduced the dimension of data coverage worldwide. Thus the recent inventions in ICT have inched towards reducing the gaps, and coverage of domains globally. The digging of information in a large data, and the soft-computing techniques have contributed a strength in prediction, analysis, and decision potentials in the niche areas such as Computer Science, Engineering, Management, Social Computing, Green Computing, Aviation, Finance, Telecom etc. Nurturing the research in Engineering and Computing are evident that finding a right pattern in the ocean of data.  
**URL:** compse-conf.org/2016/show/cf-calls  

**July 2017**  
31 - August 04 Recent Trends in Pure and Applied Mathematics  
**Location:** “1 Decembrie 1918” University of Alba Iulia, Romania  
International Conference on Recent Trends in Pure and Applied Mathematics(TREPAM 2017) aims to bring together leading academic scientists, researchers and professionals to exchange and share their experiences and research results in several fields of pure and applied mathematics and their applications in science and technology.  
**URL:** trepam.uab.ro/
August 2017
21 – 21 Introductory Workshop: Phenomena in High Dimensions
Location: Mathematical Sciences Research Institute, Berkeley, California.
This workshop will consist of several short courses related to high dimensional convex geometry, high dimensional probability, and applications in data science. The lectures will be accessible for graduate students.
URL: www.msri.org/workshops/809

April 2018
9 – 13 Representations of Finite and Algebraic Groups
Location: Mathematical Sciences Research Institute, Berkeley, California.
The workshop will bring together key researchers working in various areas of Group Representation Theory to strengthen the interaction and collaboration between them and to make further progress on a number of basic problems and conjectures in the field.
Topics Of the workshop include–Global-local conjectures in the representation theory of finite groups–Representations and cohomology of simple, algebraic and finite groups–Connections to Lie theory and categorification, and Applications to group theory, number theory, algebraic geometry, and combinatorics.
URL: www.msri.org/workshops/820
New from Princeton

**Mathematics and Art**
A Cultural History
Lynn Gamwell
With a foreword by Neil deGrasse Tyson

“Handsome ly illustrated and containing a wealth of information, this book is a must for anyone interested in the relations between science, nature, mathematics, and art. It is destined to become a classic on par with E. H. Gombrich’s landmark work *The Sense of Order*.”
—Eli Maor, author of *e: The Story of a Number*

**L.A. Math**
Romance, Crime, and Mathematics in the City of Angels
James D. Stein

“With L.A. Math, James Stein has written a fun collection of short stories whose mysteries are resolved through classical mathematical conundrums. A unique book that is suitably entertaining both in and out of the classroom.”
—Arthur Benjamin, author of *The Magic of Math*

**Mathematics in Ancient Egypt**
A Contextual History
Annette Imhausen

“Imhausen is one of the leading contemporary researchers in the mathematics of ancient Egypt and her book, which spans the whole of Egyptian mathematics from the early dynastic periods to the Greco-Roman era, will be the quintessential scholarly work in the field.”
—Amy Shell-Gellasch, Montgomery College

**The Best Writing on Mathematics 2015**
Edited by Mircea Pitici

This annual anthology brings together the year’s finest mathematics writing from around the world. Featuring promising new voices alongside some of the foremost names in the field, *The Best Writing on Mathematics 2015* makes available to a wide audience many articles not easily found anywhere else.

**Mathematical Knowledge and the Interplay of Practices**
José Ferreirós

Offering a wealth of philosophical and historical insights, *Mathematical Knowledge and the Interplay of Practices* challenges us to rethink some of our most basic assumptions about mathematics, its objectivity, and its relationship to culture and science.

**Classification of Pseudo-reductive Groups**
Brian Conrad & Gopal Prasad

The results and methods developed in *Classification of Pseudo-reductive Groups* will interest mathematicians and graduate students who work with algebraic groups in number theory and algebraic geometry in positive characteristic.

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Algebra and Algebraic Geometry

**Lie Algebras and Related Topics**

Marina Avitabile, *Università degli Studi di Milano-Bicocca, Italy*, Jörg Feldvoss, *University of South Alabama, Mobile, AL*, and Thomas Weigel, *Università degli Studi di Milano-Bicocca, Italy*, Editors

This volume contains the proceedings of the Workshop on Lie Algebras, in honor of Helmut Strade's 70th birthday, held from May 22–24, 2013, at the Università degli Studi di Milano-Bicocca, Milano, Italy.

Lie algebras are at the core of several areas of mathematics, such as Lie groups, algebraic groups, quantum groups, representation theory, homogeneous spaces, integrable systems, and algebraic topology.

The first part of this volume combines research papers with survey papers by the invited speakers. The second part consists of several collections of problems on modular Lie algebras, their representations, and the conjugacy of their nilpotent elements as well as the Koszulity of (restricted) Lie algebras and Lie properties of group algebras or restricted universal enveloping algebras.


Contemporary Mathematics, Volume 652

**Irreducible Geometric Subgroups of Classical Algebraic Groups**

Timothy C. Burness, *University of Bristol, United Kingdom*, Soumaïa Ghandour, *Lebanese University, Nabatieh, Lebanon*, and Donna M. Testerman, *École Polytechnique Fédérale de Lausanne, Switzerland*

Contents: Introduction; Preliminaries; The C_1, C_3 and C_6 collections; Imprimitive subgroups; Tensor product subgroups, I; Tensor product subgroups, II; Bibliography.

Memoirs of the American Mathematical Society, Volume 239, Number 1130

Notices of the AMS Volume 63, Number 1
Reduced Fusion Systems over 2-Groups of Sectional Rank at Most 4

Bob Oliver, LAGA, Institut Galilée, Université Paris, Villetaneuse, France

Contents: Introduction; Background on fusion systems; Normal dihedral and quaternion subgroups; Essential subgroups in 2-groups of sectional rank at most 4; Fusion systems over 2-groups of type $G_2(q)$; Dihedral and semidihedral wreath products; Fusion systems over extensions of $UT_3(4)$; Appendix A. Background results about groups; Appendix B. Subgroups of 2-groups of sectional rank 4; Appendix C. Some explicit 2-groups of sectional rank 4; Appendix D. Actions on 2-groups of sectional rank at most 4; Bibliography.

Memoirs of the American Mathematical Society, Volume 239, Number 1131


Analysis

Complex Analysis and Dynamical Systems VI

Part 1: PDE, Differential Geometry, Radon Transform

Mark L. Agranovsky, Bar-Ilan University, Ramat-Gan, Israel, Matania Ben-Artzi, Hebrew University of Jerusalem, Israel, Greg Galloway, University of Miami, Coral Gables, FL, Lavi Karp, ORT Braude College, Karmiel, Israel, Dmitry Khavinson, University of South Florida, Tampa, FL, Simeon Reich, Technion-Israel Institute of Technology, Haifa, Israel, Gilbert Weinstein, Ariel University, Israel, and Lawrence Zalcman, Bar-Ilan University, Ramat-Gan, Israel, Editors

This volume contains the proceedings of the Sixth International Conference on Complex Analysis and Dynamical Systems, held from May 19–24, 2013, in Nahariya, Israel, in honor of David Shoikhet’s sixtieth birthday.

The papers in this volume range over a wide variety of topics in Partial Differential Equations, Differential Geometry, and the Radon Transform. Taken together, the articles collected here provide the reader with a panorama of activity in partial differential equations and general relativity, drawn by a number of leading figures in the field. They testify to the continued vitality of the interplay between classical and modern analysis.

The companion volume (Contemporary Mathematics, Volume 667) is devoted to complex analysis, quasiconformal mappings, and complex dynamics.

This item will also be of interest to those working in differential equations.

This book is co-published with Bar-Ilan University (Ramat-Gan, Israel).


Contemporary Mathematics, Volume 653

Differential Equations

Global Carleman Estimates for Degenerate Parabolic Operators with Applications

P. Cannarsa, Università di Roma Tor Vergata, Italy, and P. Martinez and J. Vancostenoble, Institut de Mathématiques, Université Paul Sabatier, Toulouse, France

Contents: Introduction; Part 1. Weakly degenerate operators with Dirichlet boundary conditions: Controllability and inverse source problems: Notation and main results; Global Carleman estimates for weakly degenerate operators; Some Hardy-type inequalities (proof of Lemma 3.18); Asymptotic properties of elements of $H^2(\Omega) \cap H^1_{\text{loc}}(\Omega)$; Proof of the topological lemma 3.21; Outlines of the proof of Theorems 3.23 and 3.26; Step 1: computation of the scalar product on subdomains (proof of Lemmas 7.1 and 7.16); Step 2: a first estimate of the scalar product: proof of Lemmas 7.2, 7.4, 7.18 and 7.19; Step 3: the limits as $\Omega^p \to \Omega$ (proof of Lemmas 7.5 and 7.20); Step 4: partial Carleman estimate (proof of Lemmas 7.6 and 7.21); Step 5: from the partial to the global Carleman estimate (proof of Lemmas 7.9–7.11); Step 6: global Carleman estimate (proof of Lemmas 7.12, 7.14 and 7.15); Proof of observability and controllability results; Application to some inverse source problems: proof of Theorems 2.9 and 2.11; Part 2. Strongly degenerate operators with Neumann boundary conditions: Controllability and inverse source problems: notation and main results; Global Carleman estimates for strongly degenerate operators; Hardy-type inequalities: proof of Lemma 17.10 and applications; Global Carleman estimates in the strongly degenerate case: proof of Theorem 17.7; Proof of Theorem 17.6 (observability inequality); Lack of null controllability when $\alpha > 2$: proof of Proposition 16.5; Explosion of the controllability cost as $\alpha \to 2^-$ in space dimension 1: proof of Proposition 16.7; Part 3. Some open problems: Some open problems; Bibliography; Index.

Memoirs of the American Mathematical Society, Volume 239, Number 1133


Stability of KAM Tori for Nonlinear Schrödinger Equation

Hongzi Cong, Dalian University of Technology, China, Jianjun Liu, Sichuan University, Chengdu, Sichuan, China, and Xiaoping Yuan, Fudan University, Shanghai, China

Contents: Introduction and main results; Some notations and the abstract results; Properties of the Hamiltonian with $p$-tame property; Proof of Theorem 2.9 and Theorem 2.10; Proof of Theorem 2.11; Proof of Theorem 1.1; Appendix: technical lemmas; Bibliography; Index.

Memoirs of the American Mathematical Society, Volume 239, Number 1134


General Interest

What’s Happening in the Mathematical Sciences, Volume 10

Dana Mackenzie and Barry Cipra

What’s Happening in the Mathematical Sciences is a collection of articles highlighting some of the most recent developments in mathematics. These include important achievements in pure mathematics, as well as its fascinating applications.

On the pure mathematics side, “Prime Clusters and Gaps: Out- 나의 연구에 대한 영향을 줄 수 있는 방식이 있다. The Kadison-Singer problem and its applications in signal processing algorithms used to analyze and synthesize signals are described in “The Kadison-Singer Problem: A Fine Balance”. “Quod Erat Demonstrandum” presents two examples of perseverance in mathematicians’ pursuit of truth using, in particular, computers to verify their arguments. And “Following in Sherlock Holmes’ Bike Tracks” shows how an episode in one of Sir Arthur Conan Doyle’s stories about Sherlock Holmes naturally led to very interesting problems and results in the theory of completely integrable systems.

On the applied side, “Climate Past, Present, and Future” shows the importance of mathematics in the study of climate change and global warming phenomena. Mathematical models help researchers to understand the past, present, and future changes of climate, and to analyze their consequences. “The Truth Shall Set Your Fee” talks about algorithms of information exchange in cyberspace. Economists have known for a long time that trust is a cornerstone of commerce, and this becomes even more important nowadays when a lot of transactions, big and small, are done over the Internet. Recent efforts of theoretical computer scientists led to the development of so-called “rational protocols” for information exchange, where the parties in the information exchange process find that lies do not pay off.

Over the last 100 years many professional mathematicians and devoted amateurs contributed to the problem of finding polygons that can tile the plane, e.g., used as floor tiles in large rooms and walls. Despite all of these efforts, the search is not yet complete, as the very recent discovery of a new plane-tiling pentagon shows in “A Pentagonal Search Pays Off”. Mathematics can benefit coaches...
and players in some of the most popular team sports as shown in “The Brave New World of Sports Analytics”. The increased ability to collect and process statistics, big data, or “analytics” has completely changed the world of sports analytics. The use of modern methods of statistical modeling allows coaches and players to create much more detailed game plans as well as create many new ways of measuring a player’s value. Finally, “Origami: Unfolding the Future” talks about the ancient Japanese paper-folding art and origami’s unexpected connections to a variety of areas including mathematics, technology, and education.


What’s Happening in the Mathematical Sciences, Volume 10

Geometry and Topology

On the Singular Set of Harmonic Maps into DM-Complexes
Georgios Daskalopoulos, Brown University, Providence, RI, USA, and Chikako Mese, Johns Hopkins University, Baltimore, MD, USA

Contents: Introduction; Harmonic maps into NPC spaces and DM-complexes; Regular and singular points; Metric estimates near a singular point; Assumptions; The Target variation; Lower order bound; The Domain variation; Order function; The Gap Theorem; Proof of Theorems 1–4; Appendix A. Appendix 1; Appendix B. Appendix 2; Bibliography.

Memoirs of the American Mathematical Society, Volume 239, Number 1129

Knots, Molecules, and the Universe
An Introduction to Topology
Erica Flapan, Pomona College, Claremont, CA

This book is an elementary introduction to geometric topology and its applications to chemistry, molecular biology, and cosmology. It does not assume any mathematical or scientific background, sophistication, or even motivation to study mathematics. It is meant to be fun and engaging while drawing students in to learn about fundamental topological and geometric ideas. Though the book can be read and enjoyed by nonmathematicians, college students, or even eager high school students, it is intended to be used as an undergraduate textbook.

The book is divided into three parts corresponding to the three areas referred to in the title. Part 1 develops techniques that enable two- and three-dimensional creatures to visualize possible shapes for their universe and to use topological and geometric properties to distinguish one such space from another. Part 2 is an introduction to knot theory with an emphasis on invariants. Part 3 presents applications of topology and geometry to molecular symmetries, DNA, and proteins. Each chapter ends with exercises that allow for better understanding of the material.

The style of the book is informal and lively. Though all of the definitions and theorems are explicitly stated, they are given in an intuitive rather than a rigorous form, with several hundreds of figures illustrating the exposition. This allows students to develop intuition about topology and geometry without getting bogged down in technical details.

Contents: Universes: An introduction to the shape of the universe; Visualizing four dimensions; Geometry and topology of different universes; Orientability; Flat manifolds; Connected sums of spaces; Products of spaces; Geometries of surfaces; Knots: Introduction to knot theory; Invariants of knots and links; Knot polynomials; Molecules: Mirror image symmetry from different viewpoints; Techniques to prove topological chirality; The topology and geometry of DNA; The topology of proteins; Index.

On Non-Topological Solutions of the $A_2$ and $B_2$ Chern-Simons System

Weiwei Ao, University of British Columbia, Vancouver, British Columbia, Canada, Chang-Shou Lin, Taida Institute of Mathematics, Taipei, Taiwan, and Juncheng Wei, University of British Columbia, Vancouver, British Columbia, Canada

Contents: Introduction; Proof of Theorem 1.1 in the $A_2$ case; Proof of Theorem 1.1 in the $B_2$ case; Appendix; Bibliography.

Memoirs of the American Mathematical Society, Volume 239, Number 1132


Control and Stabilization of Partial Differential Equations

Kais Ammari, Université de Monastir, Tunisie, Editor

This volume is a result of lectures given at the CIMPA School on Control and Stabilization of PDEs, held from May 9–19, 2011, in Monastir, Tunisia. Different control techniques for linear parabolic equations were presented, and the deduction of the null controllability of such equations from local Carleman inequality was described. Overall, Carleman-type and Hardy-type inequalities for the null controllability of degenerate parabolic equations were discussed.

Current issues in the control of conservation laws, such as the control of classical solutions in singular control limits and the control solutions with shock waves, were also highlighted during this school. Finally, different techniques and methods for the stability of evolution equations with and without delay, applicable to Navier-Stokes equations, were presented.

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: V. Barbu, Stabilization of the Navier-Stokes equation; G. Lebeau, Introduction aux inégalités de Carleman; S. Nicaise, Stabilization of second order evolution equations with unbounded feedback delay.

Séminaires et Congrès, Number 29


The Ohio State University

COLUMBUS, OH

Eminent Scholar

The Department of Mathematics in the College of Arts and Sciences at The Ohio State University seeks applications to fill an Eminent Scholar position in Scientific Computation within the Department of Mathematics.

The ideal candidate will be someone who will be a leader in the research field of Scientific Computation and will be able to carry out interdisciplinary research forging new connections with other departments at The Ohio State University and other institutions. It is expected that this faculty member will be significantly engaged with the graduate and undergraduate programs in the Mathematics Department (e.g., directing PhD, master’s thesis and/or directing undergraduate research). This position is partially funded by Ohio State’s Discovery Themes Initiative, a significant faculty hiring investment in key thematic areas in which the university can build on its culture of academic collaboration to make a global impact.

Qualifications: A doctoral degree in Mathematics is required at the time of application. The ideal candidate will have an excellent research record in the area of Scientific Computation and evidence of strong teaching ability.

Please apply online through [http://www.mathjobs.org](http://www.mathjobs.org).

Complete applications will include a cover letter, curriculum vitae, research statement, teaching statement, a list of publications, and three or more letters of recommendation. Application deadline: 4/30/16.

The Ohio State University is an equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation or gender identity, national origin, disability status, or protected veteran status.
Timely, Informative Alerts

The AMS Bookstore New Releases email alert is the best way to keep current with new developments in your field and learn about forthcoming and recently published titles. These monthly mailings allow you to:

• Access each book’s abstract page on the AMS Bookstore
• Preview chapter samples, Tables of Contents, Indexes, and author supplemental materials
• Learn about Bookstore sales, special discounts, publishing highlights, and more

It’s convenient, it’s free, and you can unsubscribe at any time. Sign up today!

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Classified Advertisements

Positions available, items for sale, services available, and more

ALABAMA

UNIVERSITY OF ALABAMA

2015 Topology Search Advertisement

The Department of Mathematics at The University of Alabama invites applications for a tenure-track Assistant Professor position in the area of Topology beginning on August 16, 2016. We are particularly interested in applicants researching low dimensional topology or knot theory and their connections with gauge theory, Floer theories, or symplectic/contact topology. However, applicants from other areas of topology or related areas in differential geometry may also be considered. The University of Alabama is a Learner Centered institution. The ideal candidate should be committed to providing stellar education to undergraduate and graduate students. In addition, the successful candidate should be interested in supervising undergraduate research opportunities and graduate dissertations. The University is also pushing to improve its research position, and expects the successful candidate to develop a strong research program and to pursue external funding.

Applications should complete the online application at facultyjobs.ua.edu/postings/37692. The application should include a letter of application, a current curriculum vita, a research statement, a teaching statement, and four letters of recommendation (one of which concerns teaching). The recommendation letters should be sent electronically to: math@ua.edu. Candidates must possess a doctoral degree in mathematics or a closely related field by August 16, 2016. Further experience in teaching and research is desirable. Applications will be reviewed on an ongoing basis starting December 12th, and will continue to be accepted until the position is filled. The University of Alabama is an Equal Opportunity/Affirmative Action employer and actively seeks diversity among its employees. Women, Hispanic, African-American and other minority candidates are strongly encouraged to apply. For more information about the department and the university visit our website at math.ua.edu.

000001

CALIFORNIA

UNIVERSITY OF CALIFORNIA,
SANTA BARBARA

Department of Mathematics

Faculty Position
Job #Math14
Tenure-Track Position

The Department of Mathematics invites applications for a Tenure-Track Assistant Professor position in Differential Geometry. Candidate should strengthen and complement the research of the existing group in Geometry; interaction with other research groups is also encouraged. Demonstrated excellence in research and teaching are required. Candidates must possess a PhD by September 2016. Appointments begin July 1, 2016.

To apply for this position(s), applicants must submit a curriculum vitae, statement of research, statement of teaching philosophy & the American Mathematical Society cover sheet (available online at www.ams.org), & arrange for four letters of reference to be sent (at least one of which is directed towards teaching). Materials should be submitted electronically via www.mathjobs.org. Applications received on or before November 1, 2015 will be given full consideration. Questions can be emailed to: recruitment@math.ucsb.edu.

The department is especially interested in candidates who can contribute to the diversity & excellence of the academic community through research, teaching and service. The University of California is an Equal Opportunity/Affirmative Action Employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

000003

UNIVERSITY OF CALIFORNIA
SANTA BARBARA

Department of Mathematics

Senate Lecturer Position
Job #Math15

The Department of Mathematics at the University of California, Santa Barbara seeks applications for a Lecturer with

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 publisher reserves the right to reject any advertising not in keeping with the publication’s standards. Acceptance shall not be construed as approval of the accuracy or the legality of any advertising.

The 2015 rate is $3.50 per word with a minimum two-line headline. 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.


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 US 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 US 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 US and Canada or 401-455-4084 worldwide for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02904; or via fax: 401-331-3842; or send email to classifieds@ams.org. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.
Potential Security of Employment (similar to tenure-track), beginning July 1, 2016.

Qualifications: Candidates must possess a PhD in Mathematics or a closely related field. The successful applicant will be a broadly trained mathematician who is dedicated to undergraduate teaching and pedagogy in the context of a research university.

Duties and Responsibilities: In addition to making significant contributions to lower-division teaching, the Lecturer PSOE will assist with curriculum development, advise undergraduate students and participate in service activities. Specific duties include the development and implementation of new courses and curricula at the undergraduate level and leadership roles in undergraduate activities and advising, in community outreach activities and in improving instructional resources. It is expected that the Lecturer PSOE will be involved in the submission of grants, attend relevant professional meetings, review programs, and mentor visiting and junior faculty. The Lecturer PSOE will interact directly with senior faculty, virtually all of who teach in the lower division on a regular basis.

Further information about Mathematics at UCSB can be found at [www.math.ucsb.edu](http://www.math.ucsb.edu).

To apply for this position, applicants should submit a letter of interest outlining teaching, research, and service interests and accomplishments together with a curriculum vita, and arrange for at least three letters of recommendation to be sent. Materials should be submitted electronically via [www.mathjobs.org](http://www.mathjobs.org). Applications received on or before January 1, 2016 will be given full consideration. For questions or additional information, please email: recruitment@math.ucsb.edu.

The department is especially interested in candidates who can contribute to the diversity & excellence of the academic community through teaching and service. The University of California is an Equal Opportunity/Affirmative Action Employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

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**KANSAS**

UNIVERSITY OF KANSAS
Mathematics Department

The Department of Mathematics at the University of Kansas invites applications for a tenure-track faculty position in PDE-Analysis-Dynamical Systems. Candidates must demonstrate an outstanding record of research and must be strongly committed to excellence in teaching. Requirements for the positions include a PhD or ABD in mathematics or a closely related field is expected by the start date of the appointment (August 18, 2016). For a complete announcement and to apply online, go to [https://employment.ku.edu/academic/46898](https://employment.ku.edu/academic/46898). A complete online application includes: C.V., cover letter, research and teaching statements, and the names and contact information for four references. In addition, at least four recommendation letters (teaching ability must be addressed in at least one letter) should be submitted electronically to [www.mathjobs.org/jobs/jobs/8069](http://www.mathjobs.org/jobs/jobs/8069). Initial review of applications will begin December 1, 2015 and continue as long as needed to identify a qualified pool. EEO Employer, “KU policy on discrimination at [www.policy.ku.edu/IOA/nondiscrimination](http://www.policy.ku.edu/IOA/nondiscrimination).”

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**TEXAS**

BAYLOR UNIVERSITY
Jean and Ralph Storm Endowed Chair in Mathematics

The Department of Mathematics invites applications to fill the Jean and Ralph Storm Chair of Mathematics. The successful candidate, who is expected to be at the full-professor level, will be an excellent mathematician, with national and international recognition for scholarship, demonstrated excellence in teaching at the undergraduate and graduate levels and a history of successful, sustained grantsmanship. This endowed position provides an annual discretionary research fund to the successful candidate. Applications in all areas of mathematics will be considered. Active research areas in the department are in the general areas of algebra, analysis, differential equations, mathematical physics, numerical analysis, computational mathematics, representation theory, and topology. Several faculty in the department are engaged in interdisciplinary research with other departments on campus. Baylor encourages women, minorities, veterans, and individuals with disabilities to apply. Detailed information about the department can be found at [www.baylor.edu/math](http://www.baylor.edu/math).

To ensure full consideration, complete applications must be submitted by 02/15/16. Applications will be reviewed immediately after this date and will be accepted until the position is filled.

We encourage all applicants to submit their materials online at [www.mathjobs.org/jobs](http://www.mathjobs.org/jobs). Candidates should possess an earned doctorate in the appropriate field of study. A complete application includes a cover letter of application (please refer to the job number BQ 34499), at least three letters of recommendation, a current curriculum vitae, original doctoral transcripts, and a statement of support for Baylor’s Christian mission (see [www.baylor.edu/profuturis/](http://www.baylor.edu/profuturis/)), indicating your religious affiliation and a few brief statements about your faith. Alternatively, candidates can arrange for their application materials to be sent directly to Dr. Lance L. Littlejohn, Department of Mathematics, Baylor University, One Bear Place #97328, Waco, TX 76798-7328.

Baylor University is a private Christian university and a nationally ranked research institution, consistently listed with highest honors among The Chronicle of Higher Education’s “Great Colleges to Work For”. Chartered in 1845 by the Republic of Texas through the efforts of Baptist pioneers, Baylor is the oldest continuously operating university in Texas. The university provides a vibrant campus community for over 15,000 students from all 50 states and more than 80 countries. Baylor is a dynamic research institution, consistently listed among the top 200 public research universities in the country by blending interdisciplinary research with an international reputation for educational excellence and a faculty commitment to teaching and scholarship. Baylor is actively recruiting new faculty with a strong commitment to the classroom and an equally strong commitment to discovering new knowledge as we pursue our bold vision, Pro Futuris ([www.baylor.edu/profuturis/](http://www.baylor.edu/profuturis/)).

Baylor University is a private not-for-profit university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity Employer, Baylor is committed to compliance with all applicable anti-discrimination laws, including those regarding age, race, color, sex, national origin, marital status, pregnancy status, military service, genetic information, and disability. As a religious educational institution, Baylor is lawfully permitted to consider an applicant’s religion as a selection criterion.

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**BRAZIL**

FAPEP
Postdoctoral Research Fellowships

The Instituto de Ciências Matemáticas e de Computação, Universidade de São Paulo at São Carlos, São Paulo, Brazil, welcomes applications for 3 post-doctoral positions within the singularity theory group. The positions are supported by the FAPESP grant 2014/00304-2. Applications should be sent by email to Professor Maria Aparecida Soares Ruas (email: maasruas@icmc.usp.br) no later than February 20, 2016 and should include: a covering letter indicating the motivation for applying, a curriculum vitae and short research project.

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**NOTICES OF THE AMS**
As part of the Society’s commitment to the open flow of communication and community engagement, the AMS uses several networking tools to supplement the channels currently in place for members, press and the general public.

We invite you to share AMS website content and set up RSS feeds for website updates and blogs.

www.ams.org/social
Mathematics at the 2016 AAAS Meeting

Washington Marriott, Wardman Park, Washington, DC
February 11–15, 2016

The American Association for the Advancement of Science (AAAS), founded in 1848, is the world’s largest general scientific society and is the publisher of Science. The AAAS is divided into twenty-four disciplinary-based sections, including Section A (Mathematics). The 2016 annual meeting of the AAAS will be held in Washington on February 11–15. The theme of this year’s meeting is “Global Science Engagement,” and this year’s meetings feature sessions that will be of special interest to mathematicians, mathematics educators, and students of mathematics. The AAAS Annual Meeting is organized into symposia, which have three or more speakers and often a discussant who reflects on the talks that are given. Section A is sponsoring three symposia this year, featuring outstanding expository talks by prominent mathematicians and scientists. The three symposia sponsored by Section A this year are:

“Mathematics Making a Difference in Africa”

Applied mathematics is at a promising juncture in the developing world. Developing countries in Africa have recognized the very favorable cost-benefit ratio of mathematics as part of the effort to cope with pressing economic and humanitarian issues, including climate and environmental threats, the spread of disease, and urbanization. Applied mathematics has become a regional priority for research and education, and the last few years have seen the creation of several mathematical research centers in Africa, funded by the World Bank and international organizations and promoted by the Next Einstein Initiative. These innovative centers are now actively engaged in training a cadre of mathematical scientists and partnering with Western institutions of higher education. Speakers in this symposium will discuss recent progress in applied mathematics in Africa, how universities can be effective partners in modeling projects to promote development, and how educational resources and research tools can be shared.

“Mathematics and Music”

Mathematics may be the most abstract of the sciences, and music the most abstract of the arts. Mathematics deals with conceptual and logical truth and appreciates intrinsic beauty. Music can involve a similar appreciation of abstract relationships, though it also evokes mood and emotion through tones and rhythm. Thinkers from Pythagoras to Vincenzo Galilei and Euler have noted the intersections between the disciplines. This symposium considers how mathematics and music overlap: the tuning of chords and how this relates to overtones; the geometry arising from a new framework for the varied array of chord progressions in Western music; and the structural coherence needed to make a piece of music rhetorically viable.

“Massively-Collaborative Global Research in Mathematics and Science”

In recent years, dozens of research projects have emerged that make novel use of computing and communication technologies, dramatically expanding the types of problems that can be considered and leading to breakthroughs in many areas of science. Distributed computing projects can address the design of molecules, improve climate prediction models, analyze astronomical data from radio telescopes, identify prime numbers and elliptic curve factorizations, and develop sustainable water use models, to name a few uses. In addition, contests such as those hosted by InnoCentive
or [Challenge.gov](http://Challenge.gov) call for people to work individually or collectively to solve problems posed by industry or government. These projects use the Internet to collaborate across national boundaries, pulling together diverse expertise and “citizen scientists” to implement extensive computer calculations (e.g., running simulations from high-energy physics or checking mathematical proofs), or to take advantage of “human computing” (e.g., digitizing old texts or studying images from the Hubble Space Telescope by dividing work into micro-tasks or games). This session describes specific projects—protein folding leading to drug development, and the identification of prime numbers with implications for cryptography—accompanied by an overarching discussion of the field of massively-collaborative global research.

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**Effective and Algorithmic Methods in Hyperbolic Geometry and Free Groups**  
May 16-20, 2016  
*Organizing Committee*: Tarik Aougab, Brown University; Jeffrey Brock, Brown University; Mladen Bestvina, University of Utah; Eriko Hironaka, Florida State University; Johanna Mangahas, University at Buffalo, SUNY

**Algorithmic Coding Theory**  
June 13-17, 2016  
*Organizing Committee*: Mary Wootters, Carnegie Mellon University; Atri Rudra, University at Buffalo, SUNY; Hamed Hassani, ETH Zurich

**Illustrating Mathematics**  
June 27-July 1, 2016  
*Organizing Committee*: Kelly Delp, Cornell University; Saul Schleimer, University of Warwick; Henry Segerman, Oklahoma State University; Laura Taalman, James Madison University

**Stochastic Numerical Algorithms, Multiscale Modeling and High-dimensional Data Analytics**  
July 18-22, 2016  
*Organizing Committee*: Mark Girolami, University of Warwick; Susan Holmes, Stanford University; Benedict Leimkuhler, University of Edinburgh; Mauro Maggioni, Duke University

**Cycles on Moduli Spaces, Geometric Invariant Theory, and Dynamics**  
August 1-5, 2016  
*Organizing Committee*: Ana-Maria Castravet, Northeastern University; Dawei Chen, Boston College; Maksym Fedorchuk, Boston College; Anton Zorich, Institut de Mathématiques de Jussieu

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**Ways to participate:**  
- Propose a:  
  - semester program  
  - topical workshop  
  - small group research program  
  - summer undergrad program  
- Apply for a:  
  - semester program or workshop  
  - postdoctoral fellowship  
- Become an:  
  - academic or corporate sponsor

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**About ICERM**: The Institute for Computational and Experimental Research in Mathematics is a National Science Foundation Mathematics Institute at Brown University in Providence, RI. [icerm.brown.edu](http://icerm.brown.edu)
Yau Mathematical Sciences Center
Tsinghua University, Beijing, China

Positions:
Distinguished Professorship; Professorship;
Associate Professorship;
Assistant Professorship (tenure-track).

The YMSC invites applications for the above positions in the full spectrum of mathematical sciences: ranging from pure mathematics, applied PDE, computational mathematics to statistics. The current annual salary range is between 0.15-1.0 million RMB. Salary will be determined by applicants’ qualification. Strong promise/track record in research and teaching are required. Completed applications must be electronically submitted, and must contain curriculum vitae, research statement, teaching statement, selected reprints and/or preprints, three reference letters on academic research and one reference letter on teaching (Reference letters must be hand signed by referees), sent electronically to msc-recruitment@math.tsinghua.edu.cn.

The review process starts in December 2015, and closes by April 30, 2016. Applicants are encouraged to submit their applications before December 31, 2015.

Positions: post-doctorate fellowship

Yau Mathematical Sciences Center (YMSC) will hire a substantial statistics, number of post-doctorate fellows in the full spectrum of mathematical sciences. New and recent PhDs are encouraged for this position.

A typical appointment for post-doctorate fellowship of YMSC is for two-years, renewable for the third years. Salary and compensation package are determined by qualification, accomplishment, and experience. YMSC offers very competitive packages.

Completed applications must contain curriculum vitae, research, statement, teaching statement, selected reprints and/or preprints, three reference letters with referee’s signature, sent electronically to msc-recruitment@math.tsinghua.edu.cn.

The review process starts in December 2015, and closes by April 30, 2016. Applicants are encouraged to submit their applications before December 31, 2015.
General Information Regarding Meetings & Conferences of the AMS

Speakers and Organizers: The Council has decreed that no paper, whether invited or contributed, may be listed in the program of a meeting of the Society unless an abstract of the paper has been received in Providence prior to the deadline.

Special Sessions: The number of Special Sessions at an Annual Meeting is limited. Special Sessions at annual meetings are held under the supervision of the Program Committee for National Meetings and, for sectional meetings, under the supervision of each Section Program Committee. They are administered by the associate secretary in charge of that meeting with staff assistance from the Meetings and Conferences Department in Providence. (See the list of associate secretaries on page 89 of this issue.)

Each person selected to give an Invited Address is also invited to generate a Special Session, either by personally organizing one or by having it organized by others. Proposals to organize a Special Session are sometimes solicited either by a program committee or by the associate secretary. Other proposals should be submitted to the associate secretary in charge of that meeting (who is an ex officio member of the program committee) at the address listed on page 112. These proposals must be in the hands of the associate secretary at least seven months (for sectional meetings) or nine months (for national meetings) prior to the meeting at which the Special Session is to be held in order that the committee may consider all the proposals for Special Sessions simultaneously. Special Sessions must be announced in the Notices in a timely fashion so that any Society member who so wishes may submit an abstract for consideration for presentation in the Special Session.

Talks in Special Sessions are usually limited to twenty minutes; however, organizers who wish to allocate more time to individual speakers may do so within certain limits. A great many of the papers presented in Special Sessions at meetings of the Society are invited papers, but any member of the Society who wishes to do so may submit an abstract for consideration for presentation in a Special Session, provided it is submitted to the AMS prior to the special early deadline for consideration. Contributors should know that there is a limit to the size of a single Special Session, so sometimes all places are filled by invitation. An author may speak by invitation in more than one Special Session at the same meeting. Papers submitted for consideration for inclusion in Special Sessions but not accepted will receive consideration for a contributed paper session, unless specific instructions to the contrary are given.

The Society reserves the right of first refusal for the publication of proceedings of any Special Session. If published by the AMS, these proceedings appear in the book series Contemporary Mathematics. For more detailed information on organizing a Special Session, see www.ams.org/meet-specialsessionmanual.html.

Contributed Papers: The Society also accepts abstracts for ten-minute contributed papers. These abstracts will be grouped by related Mathematical Reviews subject classifications into sessions to the extent possible. The title and author of each paper accepted and the time of presentation will be listed in the program of the meeting. Although an individual may present only one ten-minute contributed paper at a meeting, any combination of joint authorship may be accepted, provided no individual speaks more than once.

Other Sessions: In accordance with policy established by the AMS Committee on Meetings and Conferences, mathematicians interested in organizing a session (for either an annual or a sectional meeting) on employment opportunities inside or outside academia for young mathematicians should contact the associate secretary for the meeting with a proposal by the stated deadline. Also, potential organizers for poster sessions on a topic of choice should contact the associate secretary before the deadline.

Abstracts: Abstracts for all papers must be received by the meeting coordinator in Providence by the stated deadline. Unfortunately, late papers cannot be accommodated.

Submission Procedures: Visit the Meetings and Conferences homepage on the Web at www.ams.org/meetings and select “Submit Abstracts”.

Site Selection for Sectional Meetings

Sectional meeting sites are recommended by the associate secretary for the section and approved by the Secretariat. Recommendations are usually made eighteen to twenty-four months in advance. Host departments supply local information, ten to fifteen rooms with overhead projectors and a laptop projector for contributed paper sessions and Special Sessions, an auditorium with twin overhead projectors and a laptop projector for Invited Addresses, space for registration activities and an AMS book exhibit, and registration clerks. The Society partially reimburses for the rental of facilities and equipment needed to run these meetings successfully. For more information, contact the associate secretary for the section.
MEETINGS & CONFERENCES OF THE AMS

JANUARY TABLE OF CONTENTS

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 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.

The most up-to-date meeting and conference information can be found online at: www.ams.org/meetings/.

**Important Information About AMS Meetings:** Potential organizers, speakers, and hosts should refer to page 200 in the February 2015 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 similarly coded material (such as accent marks in text) must be typeset in \( \LaTeX \). Visit 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.

The most up-to-date meeting and conference information can be found online at: www.ams.org/meetings/.

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**Conferences in Cooperation with the AMS**


See www.ams.org/meetings/ for the most up-to-date information on these conferences.

**ASSOCIATE SECRETARIES OF THE AMS**

**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 18015-3174; e-mail: steve.weintraub@lehigh.edu; telephone: 610-758-3717.

**Southeastern Section:** Brian D. Boe, Department of Mathematics, University of Georgia, 220 D W Brooks Drive, Athens, GA 30602-7403, e-mail: brian@math.uga.edu; telephone: 706-542-2547.

**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.
Joint Mathematics Meetings 2016

At the AMS booth!

40% Discount on AMS Titles!
All day, every day during JMM
AMS members enjoy a 40% discount on most AMS titles. Non-members receive a 25% discount. Not a member? Stop by our booth to learn about the benefits of AMS membership.

Meet and Greet with Notices Editor-in-Chief, Frank Morgan
Wednesday, January 6 at 1:00 pm
Have some cake, pick up some Notices swag, and talk to Frank about the AMS member journal.

AMS Bookstore Gift Card Raffle
Wednesday, January 6 at 5:00 pm
Enter to win a $100 AMS Bookstore Gift Card. The winner will be announced at 5:00 pm on Wednesday. You do not need to be present to win.

Origami “Flash Fold”
Friday, January 8 at 12:00 noon
Learn to fold a Trisected Bowl and talk to some of the authors of our new publication, Origami®.

“Simon Set” Raffle
Friday, January 8 at 11:00 am
One lucky winner will receive a copy of Barry Simon’s new 5-book reference set, A Comprehensive Course in Analysis. The winner will be announced at 11:00 am on Friday. You do not need to be present to win.

MathSciNet® Demos
Daily at 2:15 pm
Learn about MathSciNet, receive a free gift, and enter the MathSciNet Challenge for a chance to win a $100 American Express gift card.

Ask a Representative About...
MathJax™. A JavaScript display engine for mathematics that works in all browsers.
The AMS Lens eReader. A new online reading experience for research mathematicians.
The “New” AMS Bookstore. New look, new features.
Meetings & Conferences of the AMS

Seattle, Washington

Washington State Convention Center and the Sheraton Seattle Hotel

January 6–9, 2016
Wednesday – Saturday

Meeting #1116
Joint Mathematics Meetings, including the 122nd Annual Meeting of the AMS, 99th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of 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 2015
Program first available on AMS website: November 1, 2015
Issue of Abstracts: Volume 37, Issue 1

Deadlines
For organizers: Expired
For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/national.html.

Joint Invited Addresses
Jennifer Chayes, Microsoft Research, Network Science: From the Online World to Cancer Genomics (MAA-AMS-SIAM Gerald and Judith Porter Public Lecture).
Kristin Estella Lauter, Microsoft Research, How to Keep your Genome Secret (AMS-MAA Invited Address).

Xiao-Li Meng, Harvard University, Statistical Paradises and Paradoxes in Big Data (AMS-MAA Invited Address).

AMS Invited Addresses
Panagiotis Daskalopoulos, Columbia University, Ancient solutions to parabolic partial differential equations.
Alex Eskin, University of Chicago, The SL(2, R) action on moduli space.
W. Timothy Gowers, University of Cambridge, UK, Quasirandom sets, quasirandom graphs, and applications (AMS Colloquium Lectures: Lecture I).
W. Timothy Gowers, University of Cambridge, UK, Arithmetic progressions of length 4, quadratic Fourier analysis, and 3-uniform hypergraphs (AMS Colloquium Lectures: Lecture II).
W. Timothy Gowers, University of Cambridge, UK, Fourier analysis on general finite groups (AMS Colloquium Lectures: Lecture III).
Marta Lewicka, University of Pittsburgh, Prestrained elasticity: curvature constraints and differential geometry with low regularity.
Daniel Alan Spielman, Yale University, Graphs, Vectors, and Matrices (AMS Josiah Willard Gibbs Lecture).
David Vogan, Massachusetts Institute of Technology, Conjugacy classes and group representations (AMS Retiring Presidential Address).
Steve Zelditch, Northwestern University, Chaotic billiards and vibrations of drums.

AMS Special Sessions
If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at
Some sessions are cosponsored with other organizations. These are noted within the parentheses at the end of each listing, where applicable.

Advances in Free Analysis: the Theory and Applications of Noncommutative Functions, Inequalities, and Domains, Joseph A. Ball, Virginia Polytechnic Institute, and Paul S. Muhly, University of Iowa, Iowa City.

Advances in the Theory and Application of Reaction Diffusion Models, Jerome Goddard, II, Auburn University, Montgomery, and Ratnasingham Shivaji, University of North Carolina, Greensboro.

Algebraic Theory of Differential and Functional Equations, Taylor Dupuy, Hebrew University of Jerusalem and University of Vermont, and Alexey Ovchinnikov, CUNY Queens College, New York.

Algebraic and Topological Methods in Combinatorics, Andrew Berget, Western Washington University, Steven Klee, Seattle University, and Isabella Novik, University of Washington, Seattle.

Analysis and Geometry in Nonsmooth Metric Measure Spaces, Luca Capogna, Worcester Polytechnic Institute, and Jeremy Tyson, University of Illinois at Urbana-Champaign.

Analysis, Geometry, and Data, Kevin R. Vixie, Washington State University, Pullman, and Bala Krishnamoorthy, Washington State University, Vancouver.

Analytic Function Spaces and Operators on Them, Tim Ferguson and Hyun Kwon, University of Alabama, Tuscaloosa.

Analytic Methods in Geometry, Eric Bahuaud and Dylan Helliwell, Seattle University.

Applications of Logic, Model Theory, and Theoretical Computer Science to Systems Biology, James Lynch, Clarkson University, and Leo Marcus, Santa Monica, CA (AMS-ASL).

Applied and Computational Topology, Pawel Dlotko, INRIA Saclay, France, Nicholas Scoville, Ursinus College, and Matthew Wright, IMA University of Minnesota.

Arithmetic Dynamics, Matthew Baker, Georgia Institute of Technology, and Joseph Silverman, Brown University.

Big Demand for Big Data: How Do We Create the Big Supply?, Rick Cleary, Babson College, and Xiao-Li Meng, Harvard University.

Classification Problems in Operator Algebras, Marcel Bisschop and Ben Hayes, Vanderbilt University.

Combinatorial Design Theory, Esther R. Lamken, San Francisco.

Commutative Algebra, Karen Smith, University of Michigan, Ann Arbor, Emily Witt, University of Utah, and Irena Swanson, Reed College (AMS-AWM).

Commutative Algebra and Its Interactions with Algebraic Geometry, Daniel Hernández, University of Utah, Jack Jeffries, University of Michigan, Ann Arbor, and Karl Schwede, University of Utah (AMS-AWM).

Commutative Algebra, I (a Mathematics Research Communities Session), Linquan Ma, University of Utah, Sarah Mayes-Tang, Quest University, and Jonathan Montaño, University of Kansas.

Current Areas of Interest in the Mathematical Sciences of Medieval Islam, Mohammad K. Azarian, University of Evansville, and Mohammad Javaheri and Emelie A. Kennedy, Siena College.

Data-Intensive Modeling in Ecology, Nikolay Strigul, Washington State University, Vancouver, and Bala Krishnamoorthy, Washington State University, Vancouver.

Difference Equations and Applications, Michael A. Radin, Rochester Institute of Technology.

Differential Equations, Probability and Sea Ice, I (a Mathematics Research Communities Session), Brian C. Grady, MIT and Woods Hole Oceanographic Institution, Kaitlin Hill, Northwestern University, Ross Lieb-Lappen, Dartmouth College, Christian Sampson, University of Utah, and Alexandrina Volkening, Brown University.

Distribution of Zeros of Entire Functions, Matthew Chasse, Rochester Institute of Technology, Tamás Forgács, California State University, Fresno, and Andrey Piotrowski, University of Alaska Southeast, Juneau.

Early Career Female Mathematicians in Algebra and Topology, Jocelyn Bell, United States Military Academy, West Point, Bethany Kubik, University of Minnesota, Duluth, and Candice Price, Sam Houston State University.

Equations of Fluid Motion, Elaine Cozzi and Radu Dascaliuc, Oregon State University, and James P. Kelliher, University of California Riverside.


Financial Mathematics, I (a Mathematics Research Communities Session), Tretiak Pham, Rutgers University, Wilber A. Ventura, University of Texas at Arlington, and Kim Weston, Carnegie Mellon University.

Fractal Geometry and Dynamical Systems, John Rock, Cal Poly Pomona, Machteld van Frankenhuijsen, Utah Valley University, and Michel L. Lapidus, University of California, Riverside.

Geometric and Categorical Methods in Representation Theory, Anthony Licata, Australian National University, and Julia Pevtsova, University of Washington, Seattle.

Global Harmonic Analysis, Steven Zelditch, Northwestern University, Hart Smith, University of Washington, Seattle, and Chris Sogge, Johns Hopkins University.

Graduate Mathematics Courses and Programs for Secondary Mathematics Teachers, James J. Madden, Louisiana State University, Baton Rouge, and James A. Mendoza Epperson, University of Texas, Arlington.

Graph Products, Richard Hammack and Dewey Taylor, Virginia Commonwealth University.

Higher Genus Curves and Fibrations of Higher Genus Curves in Mathematical Physics and Arithmetic Geometry, Andreas Malmendier, Utah State University, Logan, and Tony Shaska, Oakland University, Rochester.

Innovative Ideas in Enhancing Success in Mathematics Classes, Natali Hritonenko, Prairie View A&M University, Ellina Grigorieva, Texas Woman's University, and Michael A. Radin, Rochester Institute of Technology (AMS-MAA).
Meetings & Conferences

Integrable Systems, Painlevé Equations, and Random Matrices, Anton Dzhamaev, University of Northern Colorado, Christopher M. Ormerod, California Institute of Technology, and Virgil U. Pierce, University of Texas-Pan American.

Interactions between Noncommutative Algebra, Algebraic Geometry, and Representation Theory, Ellen Kirkman, Wake Forest University, and James Zhang, University of Washington.

Knots in Washington (State), Allison Henrich, Seattle University, Sam Nelson, Claremont McKenna College, Jozef Przytycki, George Washington University, and Radmila Sazdanovic, North Carolina State University, Raleigh.

Mathematical Information in the Digital Age of Science, Patrick Ion, University of Michigan, Ann Arbor, Olaf Teschke, zbMATH, Berlin, and Stephen Watt, University of Western Ontario.

Mathematical Programming on Integral Invexity, Ram Verma, Texas State University, San Marcos, and Alexander Zaslavski, Israel Institute of Technology.

Mathematics and Public Policy, Paul Dreyer, RAND Corporation.


Metrical and Topological Fixed Point Theory with Applications, Clement Boateng Ampadu, Boston, MA, Talat Nazir, Mälardalen University, Sweden, and Hudson Akewe, University of Lagos, Nigeria.

Modular Forms, q-Series, and Mathematics Inspired by Ramanujan, Chris Jennings-Shaffer, University of Florida, Gainesville, and Oregon State University, Corvallis, and Holly Swisher, Oregon State University, Corvallis.

Moduli Spaces in Algebraic Geometry, Yaim Cooper, Harvard University.

Moduli Spaces in Symplectic Geometry, Nathaniel Bottman, MIT, Joel Fish, IAS, Princeton, and the University of Massachusetts, Boston, Sheel Ganatra, Stanford University, and Katrin Wehrheim, University of California Berkeley.

Nonlinear Algebra, Bernd Sturmfels, University of California Berkeley, and Rekha Thomas, University of Washington, Seattle.

Nonlinear Waves and Coherent Structures, Natalie Sheils and Chris Swierczewski, University of Washington, Seattle.

Number Theory and Cryptography, Matilde Lalín, University of Montreal, Michelle Manes, University of Hawai‘i, Honolulu, and Christelle Vincent, University of Vermont.

Operators, Function Spaces, and Models, Alberto Condori, Florida Gulf Coast University, Fort Myers, and William Ross, University of Richmond.

Origami Methods and Applications, Erik Demaine, MIT, Thomas C. Hull, Western New England University, and Robert J. Lang, Lang Origami.

Parabolic Geometries, Twistor Theory, and the AdS/CFT Correspondence, Jonathan Holland and George Sparling, University of Pittsburgh, and Daniela Mihai, Carnegie Mellon University.

Partial Differential Equations in Complex Analysis, Debraj Chakrabarti, Central Michigan University, and Yunus Zeytuncu, University of Michigan, Dearborn.

Problems and Challenges in Financial Engineering and Risk Management, Matthew Lorig, University of Washington, Seattle, and Haijun Li and Hong-Ming Yin, Washington State University, Pullman.

Problems in Geometry and Design of Materials, Marta Lewicka, University of Pittsburgh, and Petronela Radu, University of Nebraska.

Pseudorandomness and Its Applications, Timothy Gowers, University of Cambridge, and Jozsef Solymosi, University of British Columbia.

Quantum Walks, Quantum Markov Chains, Quantum Computation and Related Topics, Chaobin Liu, Bowie State University, Takyua Machida, Japan Society for the Promotion of Science, Salvador E. Venegas-Andraca, Technológico de Monterrey, Mexico, and Nelson Petulante, Bowie State University.

Random and Complex Dynamics of Reaction-Diffusion Systems, Michael Anton Hoegele, Universidad de Los Andes, Bogota, Colombia, and Yuncheng You, University of South Florida, Tampa.

Recent Advances in Dynamical Systems and Mathematics in Natural Resource Modeling, Guihong Fan, Columbus State University, Jing Li, California State University Northridge, and Hongying Shu, Tongji University, China.

Recent Advances in Orthogonal Polynomials and Special Functions, Xiang-Sheng Wang, Southeast Missouri State University, Cape Girardeau.

Recent Developments in Dispersive Partial Differential Equations and Harmonic Analysis, William Green, Rose-Hulman Institute of Technology, Terre Haute, and Jennifer Beichman, University of Wisconsin, Madison.

Representation Theory of Algebraic Groups, Daniel K. Nakano, University of Georgia, and Cornelius Pillen, University of South Alabama.

Research by Postdocs of the Alliance for Diversity in Mathematics, Aloyisois Helminck, North Carolina State University, Raleigh, and Michael Young, Iowa State University, Ames.

Research from the 2014 and 2015 Rocky Mountain-Great Plains Graduate Research Workshop in Combinatorics, Michael Ferrera, University of Colorado, Denver, Leslie Hogben, Iowa State University, Ames, Paul Horn, University of Denver, and Derrick Stolee, Iowa State University, Ames.

Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, Darren A. Narayan and Jobby Jacob, Rochester Institute of Technology, Tamas Forgacs, California State University, Fresno, and Ugur Abdulla, Florida Institute of Technology (AMS-MAA-SIAM).

Set-Valued Optimization and Variational Problems with Applications, Baasansuren Jadamba and Akhbar A. Khan, Rochester Institute of Technology, Mau Nam Nguyen, Portland State University, Miguel Sama, Universidad Nacional de Educacion a Distancia, Spain, and Christiane Tammer, Martin Luther University of Halle-Wittenberg.
Special Functions and q-Series, Richard Askey, University of Wisconsin, Madison, Mourad E. H. Ismail, University of Central Florida and King Saud University, Riyadh, and Erik Koelink, Radboud University, Nijmegen, The Netherlands.

Stochastic Effects in Models for Mathematical Biology and Ecology, Olcay Akman, Illinois State University, Timothy D. Comar, Benedictine University, and Daniel Hrozencik, Chicago State University.

Stochastic Models in Population Biology, Brian Dennis, University of Idaho, Moscow, and Eddy Kwessi, Trinity University.

Surreal Numbers, Philip Ehrlich, Ohio University, Athens, and Ovidiu Costin, Ohio State University, Columbus (AMS-ASL).

Tensor Decompositions and Secant Varieties, Zach Teitler, Boise State University.

The History of Mathematics, Patti Hunter, Westmont College, Adrian Rice, Randolph-Macon College, Sloan Despeaux, Western Carolina University, and Deborah Kent, Drake University (AMS-MAA).

The Mathematics of Computation, Susanne C. Brenner, Louisiana State University.

Topological Graph Theory: Structure and Symmetry, Jonathan L. Gross, Columbia University, and Thomas W. Tucker, Colgate University.

Topological Representation Theory, Charles Frohman, University of Iowa, Iowa City, and Helen Wong, Carleton College.

Water Waves, John Carter, Seattle University, Bernard Deconinck, University of Washington, Seattle, and Katie Oliveras, Seattle University.

What's New in Group Theory? Arturo Magidin, University of Louisiana at Lafayette, and Elizabeth Wilcox, Oswego State University of New York.

Invited Addresses

Michele Benzi, Emory University, Title to be announced.

Frank Garvan, University of Florida, Title to be announced.

William Graham, University of Georgia, Title to be announced.

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

Active Learning in Undergraduate Mathematics (Code: SS 22A), Darryl Chamberlain, Jr., Aubrey Kemp, Leslie Meadows, Harrison Stalvey, and Draga Vidakovic, Georgia State University.

Algebraic Structures in Knot Theory (Code: SS 5A), Sam Nelson, Claremont McKenna College, and Mohamed Elhamdadi, University of South Florida.

Algebraic Structures in Mathematical Physics: Lie Algebras, Vertex Algebras, Quantum Algebras (Code: SS 19A), Iana I. Anguelova, College of Charleston, and Bojko Bakalov, North Carolina State University.

Algebraic and Combinatorial Methods in Mathematical Biology (Code: SS 25A), Elena Dimitrova and Svetlana Poznanovic, Clemson University.

Bioinformatics and Molecular Biology: Dynamic Models, Structural Analysis, and Computational Methods (Code: SS 26A), Christine Heitsch, Chi-Jen Wang, and Haomin Zhou, Georgia Institute of Technology.

Combinatorial and Computational Algebra (Code: SS 7A), Huy Tai Ha, Tulane University, Kuei-Nan Lin, Penn State Greater Allegheny, and Augustine O'Keefe, Connecticut College.

Commutative Algebra (Code: SS 6A), Jon F. Carlson, University of Georgia, and Andrew Kustin, University of South Carolina.

Discrete and Applied Algebraic Geometry (Code: SS 18A), Cynthia Vinzant, North Carolina State University, and Josephine Yu, Georgia Institute of Technology.

Elliptic Curves (Code: SS 1A), Abbey Bourdon and Pete L. Clark, University of Georgia.

Experimental Mathematics (Code: SS 23A), Frank Garvan, University of Florida, and Andrew Sills, Georgia Southern University.

Financial Mathematics (Code: SS 27A), Arash Fahim and Alec Kercheval, Florida State University.

Harmonic Analysis and Applications (Code: SS 28A), Irina Holmes, Georgia Institute of Technology, and Brett D. Wick, Washington University.

Interactions Between Algebraic and Tropical Geometry (Code: SS 13A), Matthew Ballard, University of South Carolina, Noah Giansiracusa, University of Georgia, and Jesse Kass, University of South Carolina.

Invariant Measures of Dynamical Systems (Code: SS 24A), Miaohua Jiang and Chris Johnson, Wake Forest University, and Martin Schmoll, Clemson University.

Athens, Georgia

University of Georgia

March 5–6, 2016
Saturday – Sunday

Meeting #1117

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of Notices: January 2016
Program first available on AMS website: To be announced
Issue of Abstracts: Volume 37, Issue 2

Deadlines
For organizers: Expired
For abstracts: January 19, 2016
The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.
Lie Theory, Representation Theory, and Geometry (Code: SS 3A), Shrawan Kumar, University of North Carolina, and Daniel K. Nakano and Paul Sobaje, University of Georgia.

Low-dimensional Topology and Geometry (Code: SS 15A), David Gay and Gordana Matic, University of Georgia.

Mathematical Physics and Spectral Theory (Code: SS 4A), Stephen Clark, Missouri University of Science and Technology, and Roger Nichols, The University of Tennessee at Chattanooga.

Mathematics and Music (Code: SS 14A), Mariana Montiel, Georgia State University, and Robert Peck, Louisiana State University.

Moduli Spaces and Vector Bundles (Code: SS 8A), Patricio Gallardo and Anna Kazanova, University of Georgia.

New Developments in Discrete and Intuitive Geometry (Dedicated to the 75th birthday of Wlodzimierz Kuperberg) (Code: SS 16A), Andras Bezdek, Auburn University, Oleg Musin, University of Texas at Brownsville, and Gabor Fejes Toth, Renyi Institute of Mathematics, Hungary (AMS-AAAAS).

Numerical Methods and Scientific Computing (Code: SS 17A), Michele Benzi, Emory University, and Edmond Chow, Georgia Institute of Technology.

PDE Analysis in Fluid Flows (Code: SS 21A), Geng Chen, Ronghua Pan, and Yao Yao, Georgia Institute of Technology.

Probabilistic and Analytic Tools in Convexity (Code: SS 2A), Joseph Fu, University of Georgia, Galyna Livshyts, Georgia Institute of Technology, and Elisabeth Werner, Case Western Reserve University.

Sharp Estimates and Bellman Functions in Harmonic Analysis (Code: SS 29A), Kabe Moen, University of Alabama, Leonid Slavin, University of Cincinnati, and Alex Stokolos, Georgia Southern University.

Symplectic and Contact Geometry (Code: SS 20A), Yi Lin and Stefan Müller, Georgia Southern University, Michael Usher, University of Georgia, and François Ziegler, Georgia Southern University.

The Combinatorics of Symmetric Functions (Code: SS 9A), Sarah K. Mason, Wake Forest University, and Elizabeth Niese, Marshall University.

Theory and Applications of Graphs (Code: SS 12A), Colton Magnant and Hua Wang, Georgia Southern University.

Topics in Graph Theory (Code: SS 11A), Guantao Chen, Georgia State University, and Songling Shan, Vanderbilt University.

Topology and Dynamical Systems (Code: SS 10A), Alexander Blokh, University of Alabama at Birmingham, Krystyna Kuperberg, Auburn University, and John Mayer and Lex Oversteegen, University of Alabama at Birmingham.

AMS Einstein Public Lecture in Mathematics
The Einstein Public Lecture will be given by Erik Demaine, MIT Computer Science and Artificial Intelligence Laboratory. The title of his talk is Fun with Fonts: Mathematical Typography. The lecture will be given on Saturday, March 5, at 5:15 pm, in the Tate Theater in the Tate Student Center.

A Reception hosted by the Department of Mathematics and the AMS will follow the Einstein Public Lecture.

Accommodations
Participants should make their own arrangements directly with the hotel of their choice. Special discounted rates were negotiated with the hotels listed below. Rates quoted do not include a room tax of 14 percent and US$5.00 per night GA transportation fee. Participants should use the group code for each of the hotels in order to receive the discounted rates. The AMS is not responsible for rate changes or for the quality of the accommodations. Hotels have varying cancellation and early check-out penalties; be sure to ask for details. Additional hotels may be listed on the AMS sectional meeting website beginning in January.

Holiday Inn Athens—University Area (.4 mi from the Miller Learning Center on campus), 197 East Broad Street, Athens, GA 30601; online: www.hi-athens.com or by phone: 706-549-4433. Rates are US$85 for a standard room with 2 double beds, US$99.00 for a deluxe kingbedded room, and US$109.00 for executive and executive king bedded rooms. All rooms include free wireless internet. Please cite the American Mathematical Society code: AMS when making your reservation. Guests are welcome to use the Holiday Inn’s on-site fitness center and outdoor pool as well as their full service business center. The Holiday Inn Athens offers a full service restaurant and free parking. Deadline for reservations is February 12, 2016.

Holiday Inn Express Athens (.5 mi from The Miller Learning Center on campus), 513 West Broad Street, Athens, GA 30601; online: www.hi-athens.com or by phone: 706-353-6800 (cite our group code: AMS). Rates are US$85 per room. Rooms offer either a king bed or two double beds. All rooms offer complimentary wireless internet and complimentary breakfast. Amenities include a fitness room on-site and an outdoor pool. There is also free parking. Deadline for reservations is February 12, 2016.

The Classic City Hilton Garden Inn (.8 mi from The Miller Learning Center on campus), 390 East Washington Street, Athens, GA 30601; online: www.hi-athens.com or by phone: 706-353-6800 (cite our group code: 00AMS). Rates are US$124/room. Rooms offer either a king bed or two queen-sized beds. All rooms offer complimentary wireless internet and complimentary breakfast. Amenities include a fitness room on-site, and an outdoor pool. There is also free parking. Deadline for reservations is February 12, 2016.

Hotel Indigo Athens (.8 mi from the Miller Learning Center on campus), 500 College Avenue, Athens, GA 30601; online: www.indigoathens.com or by phone: 706-546-0430 (cite our group code: AMS). Rates are US$149/room. Each room offers a king bed and a sofa bed. All rooms offer complimentary wireless internet. Hotel Indigo has a full service restaurant, business center and fitness center. Parking is US$10 per day per car. Deadline for reservations is February 3, 2016.
Food Services and Dining

On Campus: The UGA Conference Center offers dining options including the Savannah Grill, Georgia Java, and the Courtyard Cafe. The Conference Center is located half a mile away from the Miller Learning Center at 1197 South Lumpkin Street. Please visit georgiacenter.uga.edu/uga-hotel/dining for details.

Off Campus: There are many dining choices for casual dining and "grab and go" options convenient to campus.

- Copper Creek Brewing Company, 140 E. Washington Street, coppercreekathens.com
- Blind Pig Tavern, 485 Baldwin Street, blindpigtavern.com
- East West Bistro, 351 E. Broad Street, eastwestbistro.com
- Porterhouse Grill, 459 E. Broad Street, porterhouseathens.com
- Madison Bar & Bistro at Hotel Indigo, 500 College Avenue, indigoathens.com
- Please visit visitathens.com for more casual and fine dining options near the University of Georgia.

Registration and Meeting Information

Advance Registration

Advance registration for this meeting will open on January 25, 2016. Advance registration fees will be US$57 for AMS members, US$80 for nonmembers, and US$5 for students, unemployed mathematicians, and emeritus members.

On-site Information and Registration

The Registration Desk and the AMS Book Exhibit will be located on the second floor of the Miller Learning Center.

The Registration Desk will be open on Saturday, March 5, 7:30 am–4:00 pm and Sunday, March 6, 8:00 am–noon. Fees on-site will be US$57 for AMS Members, US$80 for nonmembers, and US$5 for students, unemployed mathematicians, and emeritus members. Fees are payable on-site via cash, check, or credit card.

Invited Addresses, Special Sessions, and Sessions for Contributed Papers will also be held in the Miller Learning Center. The Einstein Lecture will take place in the Tate Theater. A campus map can be viewed at architects.uga.edu/campusmap/.

Other Activities

Book Sales: Stop by the on-site AMS bookstore to review the newest publications and take advantage of exhibit discounts and free shipping on all on-site orders! AMS members receive 40 percent off list price. Nonmembers receive a 25 percent discount. Not a member? Ask a representative about the benefits of AMS membership. Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Special Needs

It is the goal of the AMS to ensure that its conferences are accessible to all, regardless of disability. The AMS will strive, unless it is not practicable, to choose venues that are fully accessible to the physically handicapped.

If special needs accommodations are necessary in order for you to participate in an AMS Sectional Meeting, please communicate your needs in advance to the AMS Meetings Department by:

- Registering early for the meeting
- Checking the appropriate box on the registration form, and
- Sending an email request to the AMS Meetings Department at mmsb@ams.org or meet@ams.org.

AMS Policy on a Welcoming Environment

The AMS strives to ensure that participants in its activities enjoy a welcoming environment. In all its activities, the AMS seeks to foster an atmosphere that encourages the free expression and exchange of ideas. The AMS supports equality of opportunity and treatment for all participants, regardless of gender, gender identity or expression, race, color, national or ethnic origin, religion or religious belief, age, marital status, sexual orientation, disabilities, or veteran status.

More details about this policy and how to address questions and/or make reports is posted at www.ams.org/about-us/governance/policy-statements/welcoming-environment-policy.

Local Information and Maps

This meeting will take place on the main campus of the University of Georgia at the Miller Learning Center (MLC) and Tate Theater for the Einstein Lecture. A campus map can be viewed at architects.uga.edu/campusmap/. Information about the University of Georgia Department of Mathematics can be found on their website at math.uga.edu. Please watch the AMS website at www.ams.org/meetings/sectional/sectional1.html for additional information about this meeting. Please visit the University of Georgia website at uga.edu for additional information about the campus.

Parking

The closest parking to the Miller Learning Center (MLC) is in the Tate Student Center parking deck. It is located next to the MLC on Lumpkin Street, across from the Bolton Dining Commons. Parking in this lot is free on the weekends.

Travel

The meeting will be held at the main campus of the University of Georgia. The Miller Learning Center is located at 48 Baxter Street, Athens, GA 30602.

By Air: Hartsfield-Jackson Atlanta International Airport (www.atlanta-airport.com) is located 80 miles from the University of Georgia campus in Athens. Average travel time between the airport and campus is one-and-one-half hours, though travel time may be affected by Atlanta traffic.
Shuttle: There is scheduled ground shuttle service between Hartsfield-Jackson and various points in Athens. For more information or to make a reservation, please contact Groome Transportation: www.groometransportation.com (706/612-1155). The cost for one-way shuttle service from Hartsfield-Jackson Atlanta International Airport to the University of Georgia is currently US$37.

Taxis: Taxi service is available from Hartsfield-Jackson Atlanta International Airport to the hotels listed above and the University. It is estimated that one way taxi fare will cost approximately US$150–200.

Car Rental: Hertz is the official car rental company for the meeting. To make a reservation accessing our special meeting rates online at www.hertz.com, click on the box “I have a discount”, and type in our convention number (CV):04N30006. You can call Hertz directly at 800-654-2240 (US and Canada) or 1-405-749-4434 (other countries). At the time of reservation, the meeting rates will be automatically compared to other Hertz rates and you will be quoted the best comparable rate available. Rental cars are available through a number of agencies at the airport. Please visit the airport website www.atlanta-airport.com for information on rental car companies in Athens.

Driving Directions

From the Airport
Hartsfield-Jackson Atlanta International Airport (www.atlanta-airport.com) is located 80 miles from the Miller Learning Center on the University of Georgia campus. Average travel time between the airport and the center is one-and-one-half hours, though travel time may be affected by Atlanta traffic.

Directions from Hartsfield-Jackson Atlanta International Airport.

Upon leaving the airport, take Interstate 85 North. Follow I-85 to Georgia Highway 316 (Exit 106). Proceed east on GA 316 for approximately 40 miles until you see signs for Athens Perimeter (GA Loop 10). Important: Make sure not to exit at the exit for Bogart/Monroe at US Highway 78. Following the “University of Georgia/Lexington/Hartwell” sign at the junction of GA 316 and the Athens Perimeter (Loop 10), bear right onto the Athens Perimeter (Loop 10). Continue on Athens Perimeter (Loop 10), and take exit 6. Turn left onto S. Milledge Ave.; turn right onto S. Lumpkin St. Arrive at The Miller Learning Center, which is at the intersection of S. Lumpkin St. and Baxter St.


Weather
Athens tends to be cool and mild in March. Daytime temperatures are in the mid 60s and evening temperatures are in the mid 40s. Visitors should be prepared for inclement weather and check weather forecasts in advance of their arrival.

Social Networking
Attendees and speakers are encouraged to tweet about the meeting using the #AMSmtg.

Information for International Participants
Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the US found at sites.nationalacademies.org/pga/biso/visas/ and travel.state.gov/visa/visa_1750.html. If you need a preliminary conference invitation in order to secure a visa, please send your request to mac@ams.org.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of “binding” or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:
  - family ties in home country or country of legal permanent residence
- property ownership
- bank accounts
- employment contract or statement from employer stating that the position will continue when the employee returns;
  * Visa applications are more likely to be successful if done in a visitor’s home country than in a third country;
  * Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;
  * Include a letter of invitation from the meeting organizer or the US host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;
  * If travel plans will depend on early approval of the visa application, specify this at the time of the application;
  * Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the websites above for the most up-to-date information.

Stony Brook, New York

State University of New York at Stony Brook

March 19–20, 2016
Saturday – Sunday

Meeting #1118
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of Notices: January 2016
Program first available on AMS website: February 9, 2016
Issue of Abstracts: Volume 37, Issue 2

Deadlines
For organizers: Expired
For abstracts: February 2, 2016

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses
Simon Donaldson, Stony Brook University, Survey of progress and problems on manifolds with \( G_2 \) holonomy.
Dmitry Kleinbock, Brandeis University, Homogeneous Dynamics and Intrinsic Approximation.
Irena Lasiecka, University of Memphis, Mathematical theory of PDE-dynamics arising in fluid/flow-structure interactions.

Special Sessions
If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.


Commutative Ring Theory (Code: SS 7A), Alan Loper, Ohio State University, and Nick Werner, State University of New York at Old Westbury.

Complex Geometric Analysis (Code: SS 11A), Xiuxiong Chen, Stony Brook University, Weiyong He, University of Oregon, and Ioana Suvaina, Vanderbilt University.

Evolution of Partial Differential Equations and their Control (Code: SS 15A), George Avalos, University of Nebraska, and Irena Lasiecka and Roberto Triggiani, University of Memphis.

\( G_2 \) Geometry (Code: SS 9A), Sergey Grigorian, University of Texas, Rio Grande Valley, Sema Salur, University of Rochester, and Albert J. Todd, University of South Alabama.

Geometric Measure Theory and Its Applications (Code: SS 2A), Matthew Badger, University of Connecticut, and Christopher J. Bishop and Raanan Schul, Stony Brook University.

Graph Vulnerability Parameters and their Role in Network Analysis (Code: SS 16A), Michael Yatauro, Pennsylvania State University-Brandywine.

Holomorphic Dynamics (Code: SS 4A), Artem Dudko and Raluca Tanase, Stony Brook University.

Homogeneous Dynamics and Related Topics (Code: SS 12A), Dmitry Kleinbock, Brandeis University, and Han Li, Wesleyan University.

Invariants of Closed Curves on Surfaces (Code: SS 1A), Ara Basmajian, Hunter College and Graduate Center, City University of New York, and Moira Chas, Stony Brook University.

Mathematical General Relativity (Code: SS 3A), Lan-Hsuan Huang, University of Connecticut, Marcus Khuri, Stony Brook University, and Christina Sormani, Lehigh College and City University of New York Graduate Center.

Mathematicians in Mathematics Education (Code: SS 8A), Lisa Berger, Stony Brook University, and Melkana Brakalova, Fordham University.

PDE Methods in Geometric Flows (Code: SS 5A), Mihai Bostan and Dragomir Sarić, Queens College of the City University of New York and City University of New York Graduate Center.

Teichmüller Theory and Related Topics (Code: SS 6A), Sudeb Mitra and Dragomir Sarić, Queens College of the City University of New York and City University of New York Graduate Center.

Topology and Combinatorics of Arrangements (in honor of Mike Falk) (Code: SS 14A), Daniel C. Cohen, Louisiana State University, and Alexander I. Suciu, Northeastern University.
Vertex Algebra and Related Algebraic and Geometric Structures (Code: SS 13A), Katrina Barron, University of Notre Dame, Antun Milas, State University of New York at Albany, and Jinwei Yang, University of Notre Dame.

Accommodations
Participants should make their own arrangements directly with the hotel of their choice. Special discounted rates were negotiated with the hotels listed below. Rates quoted do not include the New York state hotel tax (8.625%) and Nassau/Suffolk occupancy tax (3%). Participants must state that they are with the American Mathematical Society (AMS) Meeting at Stony Brook University to receive the discounted rate. The AMS is not responsible for rate changes or for the quality of the accommodations. Hotels have varying cancellation and early check-out penalties; be sure to ask for details.

Danfords Hotel and Marina, 25 East Broadway, Port Jefferson, NY 11777, 1-800-332-6367; www.danfords.com Rates are US$149.95 per night, per room. Amenities include complimentary high-speed WiFi throughout the property, fitness center, on-site business center, on-site restaurant Wave Seafood Kitchen, salon and spa on-site, and parking. This property is located approximately 5 miles (9 minutes) driving distance from the campus. Cancellation and early check-out policies vary and penalties exist at this property; be sure to check when you make your reservation. The deadline for reservations at this rate is February 3, 2016.

The Hilton Garden Inn Stony Brook, 1 Circle Road, Stony Brook, New York, 11794, 631-941-2980; www.hiltongardeninn3.hilton.com/en/hotels/new-york/hilton-garden-inn-stony-brook-IISPSBG1/index.html Rates are US$159 per night for a single or double occupancy deluxe room. Amenities include complimentary high-speed WiFi, exercise room, on-site business center, indoor pool, on-site restaurant, and parking. This property is located on campus, across from Stony Brook University Hospital. Cancellation and early check-out policies vary and penalties exist at this property; be sure to check when you make your reservation. The deadline for reservations at this rate is February 17, 2016.

Holiday Inn Express Stony Brook—Long Island, 3131 Nesconset Highway, Centereach, NY 11720; 631-471-8000; www.stonybrookny.hiexpress.com/ Rates are US$129 per night for single/double occupancy. Amenities include complimentary hot breakfast, complimentary high-speed WiFi, microwave and refrigerator, fitness center, on-site business center, indoor heated pool, game room, outdoor playground, and parking. This property offers complimentary shuttle service based upon availability (between 8AM-9PM) to Islip/MacArthur Airport, Stony Brook University, Port Jefferson Ferry and Stony Brook Train Station. This property is located approximately 3 miles (5 minutes) driving distance from the campus. Cancellation and early check-out policies vary and penalties exist at this property; be sure to check when you make your reservation. The deadline for reservations at this rate is February 18, 2016.

Residence Inn by Marriott, 25 Middle Avenue, Holtsville, New York, 11742; 631-475-9500; www.marriott.com/hotels/travel/isphv-residence-inn-long-island-holtsville/ Rates are US$126 per night for single/double occupancy in a studio suite or US$131 for single/double occupancy in a one bedroom suite. Amenities include complimentary hot breakfast, complimentary high-speed WiFi, fully equipped kitchen, exercise room, tennis, volleyball, and basketball courts, on-site business center, indoor heated pool, and parking. This property is pet friendly. This property is located approximately 9 miles (12 minutes) driving distance from the campus. Cancellation and early check-out policies vary and penalties exist at this property; be sure to check when you make your reservation. The deadline for reservations at this rate is February 18, 2016.

Food Services
On Campus: Campus dining options will include two cafeteria/dining halls which will be open for breakfast and lunch during the meeting. These halls are located in the Student Activity Center and Wang Center.

Off Campus: Quite nearby to campus are two other options:

- Green Cactus, located next to LIRR station, serving fresh Mexican fare: www.greenactusgrill.com
- Curry Club, 10 Woods Corner Road, Setauket-East Setauket, NY (approx. 15-20 min walk, or a short drive) serving Indian fare: www.curryclubsetauket.com

There are many dining choices for dining in nearby Port Jefferson, which is located approximately 5 miles from campus or a 10 minute drive away by car.

Some options include:

- C’est Cheese, American cuisine focusing on artisanal cheese, craft beers and boutique wines, serving lunch and dinner, 216B Main Street, Port Jefferson, NY, 631-403-4944; www.cestcheesperj.com
- Old Fields Restaurant, steaks and burgers, serving lunch and dinner, 318 Wynn Lane, Port Jefferson, NY, (631) 331-9200; www.of1956.com
- Salsa Salsa, Mexican cuisine serving lunch and dinner; 142 Main Street, Port Jefferson, NY, 11777, 631-473-9700; www.salsalsa.net
- Tiger Lily Cafe, vegetarian cuisine, serving breakfast, lunch, and dinner, 156 E. Main Street, Port Jefferson, NY, 631-476-7080; www.tigerlilycafe.com
- Toast Coffeehouse, innovative American cuisine, 242 E. Main Street, Port Jefferson, NY, 631-331-6860; toastcoffeehouse.com

More information on restaurants and local attractions in the Stony Brook area can be found at www.discoverlongisland.com

Registration and Meeting Information
Advance Registration: Advance registration for this meeting opens on January 25. Advance registration fees will be US$57 for AMS members, US$80 for nonmembers, and US$5 for students, unemployed mathematicians, and emeritus members.

On-site Information and Registration: The registration desk will be located in the lobby of the Simons Center for
Meetings & Conferences

Geometry and Physics. The AMS book exhibit and coffee service will be in the Math Tower, Room S240. The Invited Addresses will be held in the Simons Center Auditorium, Room 103. All Special Sessions and Contributed Paper Sessions will take place in Frey Hall. For further information on building locations, a campus map is available at www.stonybrook.edu/sb/maps.shtml. The registration desk will be open on Saturday, March 19, 7:30 am–4:00 pm and Sunday, March 20, 8:00 am–12:00 pm. Fees are US$57 for AMS members, US$80 for nonmembers, and US$5 for students, unemployed mathematicians, and emeritus members. Fees are payable on-site via cash, check, or credit card.

Other Activities
Book Sales: Stop by the on-site AMS bookstore and review the newest titles from the AMS, enjoy up to 25% off all AMS publications, or take home an AMS t-shirt! Complimentary Coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you wish to discuss with the AMS, please stop by the book exhibit.

Film Screening: Stony Brook University will be hosting a screening of the documentary film, Discrete Charm of Geometry on Friday evening in the Simons Center for Geometry and Physics at Stony Brook at 6:00 pm. Information about the film can be found at www.discretization.de/en/news/2015/08/21/discrete-charm-geometry, and additional details about the screening will be posted on the AMS meetings website when they are available.

Special Needs
It is the goal of the AMS to ensure that its conferences are accessible to all, regardless of disability. The AMS will strive, unless it is not practicable, to choose venues that are fully accessible to the physically handicapped.

If special needs accommodations are necessary in order for you to participate in an AMS Sectional Meeting, please communicate your needs in advance to the AMS Meetings Department by:
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- Checking the appropriate box on the registration form, and
- Sending an email request to the AMS Meetings Department at mmsb@ams.org or meet@ams.org.

AMS Policy on a Welcoming Environment
The AMS strives to ensure that participants in its activities enjoy a welcoming environment. In all its activities, the AMS seeks to foster an atmosphere that encourages the free expression and exchange of ideas. The AMS supports equality of opportunity and treatment for all participants, regardless of gender, gender identity, or expression, race, color, national or ethnic origin, religion or religious belief, age, marital status, sexual orientation, disabilities, or veteran status.

Local Information and Maps
This meeting will take place on the main campus of Stony Brook University (State University of New York at Stony Brook). A campus map can be found at www.stonybrook.edu/sb/maps.shtml. Information about the Stony Brook Mathematics Department and Institute for Mathematical Sciences can be found at www.math.stonybrook.edu/. Please watch the website available at www.ams.org/meetings/sectional/sectional.html for additional information on this meeting. Please visit the Stony Brook University website at www.stonybrook.edu for additional information on the campus.

Parking
There is a large parking lot next to Earth and Space Sciences (ESS) It can be viewed at square B4 on the map located at www.stonybrook.edu/sb/map/newmap.pdf. It is free and open to the public on Saturday and Sunday.

Travel
Stony Brook University is situated on the north shore of Long Island in southeastern New York. It is located 60 miles east of New York City.

By Air: Long Island’s Islip-MacArthur Airport is 16 miles from the campus and is serviced by direct flights by major airlines and commuter lines. Taxi service is available to travel to the Ronkonkoma station of the Long Island Railroad (LIRR). Travel on the LIRR (Port Jefferson line) to arrive on campus. Additional information about ground transportation options can be found at www.macarthurairport.com.

New York City Area Airports (JFK, LaGuardia and Newark-Liberty) are 50 miles to the west.

From Kennedy Airport, you can take the AirTrain to Jamaica Station and transfer to the LIRR for the train to Stony Brook (Port Jefferson line). Additional information about ground transportation options can be found at www.panynj.gov/airports/jfk.html.

From LaGuardia Airport, you can take the NYC subway to Jamaica Station and transfer to the LIRR for the train to Stony Brook (Port Jefferson line). Additional information about ground transportation options can be found at www.panynj.gov/airports/laguardia.html.

From Newark Airport, you may take the AirTrain to Newark's train station and transfer to Amtrak to travel to Penn station where you can then transfer to the LIRR for the train to Stony Brook (Port Jefferson line). Additional information about ground transportation options can be found at www.panynj.gov/airports/newark-liberty.html.

By Train: Travel by Amtrak into Penn Station or Grand Central Station in Manhattan. Transfer to the Long Island Railroad's Port Jefferson line to Stony Brook. The LIRR station is at the north end of the campus; bus service to the central campus is provided. Trains to and from Penn generally require transfers at Jamaica or Huntington. Hicksville is also a transfer point on some lines. For more information on train travel on Amtrak please visit www.amtrak.com
LIRR’s Stony Brook station is located on campus, less than a 10-min. walk from the Math Tower. For more information on fares and schedules for the LIRR please visit www.mta.info/lirr. 

**By Bus:** New York City is serviced by all major bus lines. Most buses will arrive at the Port Authority Bus Terminal. Once there visitors can transfer to local bus routes. For information about the Port Authority Bus Terminal, please visit www.panynj.gov/bus-terminals/port-authority-bus-terminal.html. Additionally, 7Bus provides daily round-trip transport between the Stony Brook campus and the Lower East Side of Manhattan and Rego Park, Queens. For more information, visit the 7Bus website at 7bus.com.

**By Car:**

**From New York City:** Take the Long Island Expressway (LIE, I-495) eastbound from the Queens Midtown Tunnel in Manhattan or the Throgs Neck Bridge or Whitestone Bridge in Queens to exit 62, and follow Nicolls Road (Route 97) north for 9 miles. The main entrance to the University is on the left.

**From Islip-MacArthur Airport:** Exit the airport and turn left onto Veterans Memorial Highway (Route 454 West). Merge onto Sunrise Highway (Route 27) and take the second exit onto Nicolls Road. Drive north for 12 miles. The main entrance to the University is on the left.

For alternate driving directions using other routes via GPS, enter the address "100 Nicolls Road, Stony Brook, NY 11790."

**Car Rental:** Hertz is the official car rental company for the meeting. To make a reservation accessing our special meeting rates online at www.hertz.com, click on the box "I have a discount", and type in our convention number (CV): CV#04N30006. You can also call Hertz directly at 800-654-2240 (US and Canada) or 1-405-749-4434 (other countries). At the time of reservation, the meeting rates will be automatically compared to other Hertz rates and you will be quoted the best comparable rate available.

For directions to campus, inquire at your rental car counter.

**Local Transportation**

Walking, biking and personal cars are recommended to get around campus and Stony Brook.

**Bus and Train Service:** Public transportation options to travel to and from the Stony Brook Campus include bus via the Suffolk County Public Bus System and train travel via the LIRR. Information on public transportation options can be found at www.mta.info/lirr (LIRR information) and www.sct-bus.org (Suffolk County bus).

**Weather**

The average high temperature for March is approximately 50 degrees Fahrenheit and the average low is approximately 35 degrees Fahrenheit. Visitors should be prepared for inclement weather and check weather forecasts in advance of their arrival.

**Social Networking**

Attendees and speakers are encouraged to tweet about the meeting using the #AMSmtg.

**Information for International Participants**

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the US found at travel.state.gov/content/visas/english.html and travel.state.gov/content/visas/english/general/all-visa-categories.html. If you need a preliminary conference invitation in order to secure a visa, please send your request to mac@ams.org.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of “binding” or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:
  - family ties in home country or country of legal permanent residence
  - property ownership
  - bank accounts
  - employment contract or statement from employer stating that the position will continue when the employee returns;

* Visa applications are more likely to be successful if done in a visitor’s home country than in a third country;

* Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;

* Include a letter of invitation from the meeting organizer or the US host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;

* If travel plans will depend on early approval of the visa application, specify this at the time of the application;

* Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the websites above for the most up-to-date information.
Salt Lake City, Utah

University of Utah

April 9–10, 2016
Saturday - Sunday

Meeting #1119
Western Section
Associate secretary: Michel L. Lapidus

Announcement issue of Notices: January 2016
Program first available on AMS website: February 11, 2015
Issue of Abstracts: Volume 37, Issue 2

Deadlines
For organizers: Expired
For abstracts: February 2, 2016

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Daniel Bump, Stanford University, From Whittaker Functions to Quantum Groups.

James McKernan, University of California, San Diego, Classification of algebraic varieties.

Stephanie van Willigenburg, University of British Columbia, Vancouver, An Introduction to Quasisymmetric Schur functions.

Ravi Vakil, Stanford University, Cutting and pasting in algebraic geometry (Erdős Memorial Lecture).

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

Algebraic Combinatorics (Code: SS 3A), Susanna Fishel, Arizona State University, Edward Richmond, Oklahoma State University, and Stephanie van Willigenburg, University of British Columbia.

Algebraic Geometry (associated with the Erdős Lecture by Ravi Vakil) (Code: SS 1A), Ravi Vakil, Stanford University, Christopher Hacon, University of Utah, and Karl Schwede, University of Utah.

Automorphic Forms, Combinatorics and Representation Theory (Code: SS 6A), Anna Puskás, University of Alberta, Daniel Bump, Stanford University, Paul Gunnells, University of Massachusetts Amherst, and Solomon Friedberg, Boston College.

CR Geometry and Partial Differential Equations in Complex Analysis (Code: SS 4A), Yuan Yuan, Syracuse University, and Yuan Zhang, Indiana University-Purdue University Fort Wayne.

Combinatorial and Computational Commutative Algebra and Algebraic Geometry (Code: SS 10A), Hirotachi Abo, University of Idaho, Zach Teitler, Boise State University, Jim Wolper, Idaho State University, and Alex Woo, University of Idaho.

Commutative Algebra (Code: SS 7A), Adam Boocher and Linquan Ma, University of Utah.

Descriptive Set Theory and its Applications (Code: SS 9A), Christian Rosendal, University of Illinois at Chicago, and Alexander Kechris, California Institute of Technology.

Ergodic Theory and Dynamical Systems (Code: SS 14A), Jon Chaika, University of Utah, and Yiannis Konstantoulas, University of Utah.

Extremal Problems in Graph Theory (Code: SS 8A), Andre Kundgen and Mike Picollelli, California State University San Marcos.

Fusion Categories and Topological Phases of Matter (Code: SS 11A), Paul Bruillard, Pacific Northwest National Laboratory, and Julia Plavnik, Texas A&M University.

Infinite Dimensional and Stochastic Dynamical Systems (Code: SS 15A), Peter W. Bates, Michigan State University, and Kening Lu, Brigham Young University.

Inverse Problems (Code: SS 2A), Hanna Makaruk, Los Alamos National Laboratory (LANL), and Robert Owczarek, University of New Mexico, Albuquerque and UNM, Los Alamos.

Representations of Reductive p-adic Groups (Code: SS 3A), Shiang Tang, University of Utah, and Gordan Savin, University of Utah.

Structure and Emergent Properties of Biological Networks (Code: SS 16A), Fred Adler, University of Utah, Katrina Johnson, University of Utah, Anna Miller, University of Utah, and Laura Strube, University of Utah.

Topics in Probability (Code: SS 13A), Tom Alberts and Arjun Krishnan, University of Utah.

Topics in Stochastic Partial Differential Equations (Code: SS 12A), Jingyu Huang and Davar Khosnevisan, University of Utah.

Session for Contributed Talks

There also will be a session for 10-minute contributed talks. Please see the abstracts submission form at www.ams.org/cgi-bin/abstracts/abstract.pl. The deadline for all abstract submissions is February 2, 2016.

AMS Erdős Memorial Lecture

The 2016 Erdős Memorial Lecture will be held on Saturday April 9, at 5:10 pm in the building. The lecturer will be Ravi Vakil, Stanford University. The talk is titled Cutting and pasting in algebraic geometry.

The lecture will be followed by a reception, which will take place from 6:15 pm to 7:30 pm in the First Floor Lobby of the building. All are welcome. The AMS thanks our hosts for their gracious hospitality.

Accommodations

Participants should make their own arrangements directly with the hotel of their choice. Special discounted rates were negotiated with the hotels listed below. Other hotels for this meeting may be added to the AMS website; check www.ams.org/meetings/sectional/sectional.html for more information. Rates quoted do not include hotel tax of 12 percent. Participants must state that they are
with the American Mathematical Society (AMS) Math Meeting at the University of Utah to receive the discounted rates. The AMS is not responsible for rate changes or for the quality of the accommodations. Hotels have varying cancellation and early check-out penalties; be sure to ask for details when you make your reservation.

University Guest House, 110 South Fort Douglas Blvd., Salt Lake City, UT 84113; 801-587-1000 (phone); 801-587-2990 (fax); www.universityguesthouse.com. It is about 1.1 miles from the meeting site. Rates are $US$110 + tax per room, per night; with 1 king or 2 queen beds. Amenities include free guest room internet, free overnight parking, a fitness center, and complimentary breakfast. There is a convenience store on-site. This hotel is a non-smoking property. Check-in time is 3:00 pm and check-out time is 12:00 pm. The deadline for reservations at the above rate is March 8, 2016.

Salt Lake Marriott University Park Hotel, 480 Wakara Way, Salt Lake City, UT 84108; 801-581-1000 (phone); 801-584-3325 (fax); www.saltlakecitymarriott.com. It is about 1.6 miles to the meeting site. Rates are $US$115 + tax per room, per night; with 1 king or 2 queen beds. Amenities include free overnight self-parking, fitness center, a coffee maker and mini-refrigerators in all guestrooms. There is a restaurant, Allie’s American Grille, a bar, Pitchers Lounge, and a Starbucks on-site. This hotel is a non-smoking property. Check-in time is 3:00 pm and check-out time is 12:00 pm. The deadline for reservations at the above rate is March 1, 2016.

Hampton Inn & Suites Salt Lake City/University-Foothill Dr., 1345 Foothill Dr. South, Salt Lake City, UT 84108; 801-583-3500 (phone); 801-583-3505 (fax); bit.ly/1nsqVHn. It is about 2.8 miles from the meeting site. Rates are $US$109 + tax per room, per night; with 1 king or 2 queen beds. Amenities include free overnight internet, free overnight parking, a fitness center, a coffee maker and mini-refrigerators in all guestrooms. This hotel is a non-smoking property. Check-in time is 4:00 pm and check-out time is 12:00 pm. The deadline for reservations at the above rate is March 3, 2016.

Double Tree Suites by Hilton Hotel Salt Lake City Downtown, 110 West 600 South, Salt Lake City, Utah, 84101; 801-359-7800 (phone), 801-538-0305 (fax). www.saltlakecitysuites.doubletree.com. It is about 3 miles from the meeting site. Suite rooms are US$99 + tax per room, per night; with 1 king or 2 queen beds. The hotel also offers rates at US$114 for triple or quad suites. Amenities include complimentary guest room internet, a complimentary 24 hour business center, an indoor pool, fitness center, on-site parking, hotel shuttle, wet bar with coffee maker, microwave and refrigerator. There is a restaurant and lounge on-site, as well as room service. This hotel is a non-smoking property. Check-in time is 3:00 pm and check-out time is 11:00 am. The deadline for reservations at the above rate is March 9, 2016.

Food Services

On Campus: The University of Utah offers dozens of dining options within walking distance. Please visit map. utah.edu/ for details, and select the dining options on the interactive map.

Off Campus: There are many dining choices for casual dining and “grab and go” options convenient to campus.

Big Ed’s, 210 University Street E., Salt Lake City, UT 84102


Subway, 221 1300 E., Salt Lake City, UT 84102, www.subway.com

Porcupine Pub - University, 260 1300 E., Salt Lake City, UT 84102, www.porcupinepub.com

B & D Burgers, 222 1300 E., Salt Lake City, UT 84102, www.banddburgers.com/

Registration and Meeting Information

Advanced Registration

Advanced registration for this meeting will open January 25, 2016. Fees will be US$57 for AMS members, US$80 for nonmembers, and US$5 for students, unemployed mathematicians, and emeritus members.

On-site Information and Registration

Registration, the book exhibit, and Invited Addresses will be located in the John Widtsoe Building. The registration desk will be open on Saturday, April 9, 7:30 am–4:00 pm and Sunday, April 10, 8:00 am–noon. Fees are the same as advance registration and will be payable on-site via cash, check, or credit card.

Special Sessions will take place in Alfred Emery, James Talmage, John Widtsoe, LeRoy Cowles, LS Skaggs Building, and William Stewart Buildings.

Special Needs

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More details about this policy and how to address questions and/or make reports is posted at www.ams.
Other Activities

Book Sales: Stop by the on-site AMS bookstore to review our newest publications and take advantage of exhibit discounts! AMS members receive 40 percent off list price. Nonmembers receive a 25 percent discount. Not a member? Ask about the benefits of AMS membership. Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you wish to discuss with the AMS, please stop by the book exhibit.

Parking
Parking is available on-site, behind the John Widtsoe Building. A campus map is available: map.utah.edu/.

Travel

Airport: You should plan to fly into Salt Lake City International Airport (SLC); see www.slcairport.com for details. Taxis are available outside the baggage claim area. Some hotels provide free shuttle services; please check when making your reservations.

Car Rental: Hertz is the official car rental company for the meeting. To make a reservation accessing our special meeting rates online at www.hertz.com, click on the box “I have a discount,” and type in our convention number (CV): 04N30006. You can also call Hertz directly at 800-654-2240 (US and Canada) or 1-405-749-4434 (other countries). At the time of reservation, the meeting rates will be automatically compared to other Hertz rates and you will be quoted the best comparable rate available.

Driving to UoU: Please use your favorite travel website for the best advice on driving to campus. The main address of the campus is 201 Presidents Circle, Salt Lake City, UT 84112. The address for John Widtsoe Building is 1400 East, Salt Lake City, UT 84112 (off Presidents Circle).

Weather
During the month of April the average high temperature is in the 60s, the average low temperature is in the high-30s and there is very little rainfall.

Information for International Participants

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the US found at sites.nationalacademies.org/pga/biso/visas/ and travel.state.gov/visa/visa_1750.html. If you need a preliminary conference invitation in order to secure a visa, please send your request to aba@ams.org.

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  - property ownership
  - bank accounts
  - employment contract or statement from employer stating that the position will continue when the employee returns;

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Social Networking
Participants and speakers are encouraged to tweet about the meeting using #AMSmtg.

Fargo, North Dakota
North Dakota State University

April 16–17, 2016
Saturday – Sunday

Meeting #1120
Central Section
Associate secretary: Georgia Benkart
Announcement issue of Notices: February 2016
Program first available on AMS website: To be announced
Issue of Abstracts: Volume 37, Issue 2

Deadlines
For organizers: Expired
For abstracts: February 23, 2016
The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.
Invited Addresses

Rodrigo Banuelos, Purdue University, Title to be announced.

Laura Matusevich, Texas A&M University, Title to be announced.

Jeff Viaclovsky, University of Wisconsin-Madison, Title to be announced.

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

Algebraic and Geometric Combinatorics (Code: SS 16A),

Kevin Dills and Jessica Striker, North Dakota State University.

Applications of Microlocal Analysis: Eigenfunctions and Dispersive PDE (Code: SS 20A), Hans Christianson and Jason Metcalfe, University of North Carolina.

Combinatorial Ideals and Applications (Code: SS 10A), Laura Matusevich and Christopher O’Neill, Texas A&M University.

Commutative Algebra and Its Interactions with Combinatorics and Algebraic Geometry (Code: SS 4A), Susan Cooper, North Dakota State University, and Adam Van Tuyl, McMaster University.

Commutative Ring Theory (Code: SS 6A), Catalin Ciuperca and Sean Sather-Wagstaff, North Dakota State University.

Contemporary Issues in Mathematics Education (Code: SS 8A), Abraham Ayebo, North Dakota State University, Convexity and Harmonic Analysis (Code: SS 2A), Maria Alfonseca-Cubero, North Dakota State University, and Dmitry Ryabogin, Kent State University.

Discrete Probability (Code: SS 9A), Jonathon Peterson, Purdue University, and Arnab Sen, University of Minnesota.

Dynamics, Inverse Semigroups, and Operator Algebras (Code: SS 15A), Benton Duncan, North Dakota State University, and David Pitts, University of Nebraska-Lincoln.

Ergodic Theory and Dynamical Systems (Code: SS 1A), Dogan Comez, North Dakota State University, and Mrinal Kanti Roychowdhury, University of Texas Rio Grand Valley.

Extremal Graph Theory (Code: SS 13A), Michael Ferrara and Stephen Hartke, University of Colorado Denver.

Frames, Harmonic Analysis, and Operator Theory (Code: SS 7A), Gabriel Picioroaga, University of South Dakota, and Eric Weber, Iowa State University.


Integral Dynamical Systems and Special Functions (Code: SS 5A), Oksana Bihun, University of Colorado, Colorado Springs.

Interactions with Algebraic Geometry (Code: SS 19A), Julie Rana and Kaisa Taipale, University of Minnesota.

Low Dimensional and Symplectic Topology (Code: SS 12A), Anar Akhmedov, University of Minnesota, and Josef G. Dorfmeister, North Dakota State University.

Mathematical Finance (Code: SS 3A), Indranil SenGupta, North Dakota State University.

Matrix and Operator Theory (Code: SS 14A), Shaun Fallat and Douglas Farenick, University of Regina.

Probabilistic and Extremal Combinatorics (Code: SS 17A), Jonathan Cutler, and Jamie Radcliffe, University of Nebraska-Lincoln.

Probability and Complex Analysis Inspired by Schramm and Loewner (Code: SS 21A), Michael Kozdron, University of Regina.

Topological and Smooth Dynamics (Code: SS 18A), Azer Akhmedov and Michael Cohen, North Dakota State University.

Brunswick, Maine
Bowdoin College

September 24–25, 2016
Saturday – Sunday

Meeting #1121

Eastern Section

Associate secretary: Steven H. Weintraub
Announcement issue of Notices: June 2016
Program first available on AMS website: July 27, 2016
Issue of Abstracts: Volume 37, Issue 3

Deadlines

For organizers: February 24, 2016
For abstracts: July 19, 2016

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Tim Austin, New York University, Title to be announced.

Moon Duchin, Tufts University, Title to be announced.

Thomas Lam, University of Michigan, Title to be announced.

Denver, Colorado

University of Denver

October 8–9, 2016
Saturday – Sunday

Meeting #1122

Western Section

Associate secretary: Michel L. Lapidus
Announcement issue of Notices: August 2016
Program first available on AMS website: To be announced
Issue of Abstracts: Volume 37, Issue 3
Meetings & Conferences

Deadlines
For organizers: March 8, 2016
For abstracts: August 16, 2016

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses
- Henry Cohn, Microsoft Research, New England, Title to be announced.
- Ronny Hadani, University of Texas, Austin, Title to be announced.
- Chelsea Walton, Temple University, Philadelphia, Title to be announced.

Special Sessions
If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

- Above and Beyond Fluid Flow studies: In celebration of the 60th birthday of Prof. William Layton (Code: SS 12A), Traian Iliescu, Virginia Polytechnic Institute and State University, Alexander Labovsky, Michigan Technological University, Monika Neda, University of Nevada, Las Vegas, and Leo Rebholz, Clemson University.

- Algebraic Logic (Code: SS 1A), Nick Galatos, University of Denver, and Peter Jipsen, Chapman University.

- Analysis on Graphs and Spectral Graph Theory (Code: SS 2A), Paul Horn and Mei Yin, University of Denver.

- Nonassociative Algebra (Code: SS 3A), Izabella Stuhl, University of Debrecen and University of Denver, and Petr Vojtěchovský, University of Denver.

- Noncommutative Geometry and Fundamental Applications (Code: SS 4A), Frederic Latremoliere, University of Denver.

- Operator Algebras and Applications (Code: SS 5A), Alvaro Arias, University of Denver.

- Quantum Algebra (Code: SS 11A), Chelsea Walton, Temple University, Ellen Kirkman, Wake Forest University, and James Zhang, University of Washington, Seattle.

- Recent Trends in Semigroup Theory (Code: SS 6A), Michael Kinyon, University of Denver, and Ben Steinberg, City College of New York.

- Set Theory of the Continuum (Code: SS 7A), Natasha Dobrinen and Daniel Hathaway, University of Denver.

- Unimodularity in Randomly Generated Graphs (Code: SS 8A), Florian Sobieczky, University of Denver.

- Vertex Algebras and Geometry (Code: SS 9A), Andrew Linshaw, University of Denver, and Thomas Creutzig, University of Alberta.

Zero Dimensional Dynamics (Code: SS 10A), Nic Ormes and Ronnie Pavlov, University of Denver.

Minneapolis, Minnesota
University of St. Thomas
October 28–30, 2016
Friday - Sunday

Meeting #1123
Central Section
Associate secretary: Georgia Benkart
Announcement issue of Notices: August 2016
Program first available on AMS website: To be announced
Issue of Abstracts: Volume 37, Issue 4

Deadlines
For organizers: March 29, 2016
For abstracts: August 30, 2016

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses
- Thomas Nevins, University of Illinois Urbana-Champaign, Title to be announced.
- Charles Rezk, University of Illinois Urbana-Champaign, Title to be announced.
- Christof Sparber, University of Illinois at Chicago, Title to be announced.
- Samuel Stechmann, University of Wisconsin-Madison, Title to be announced.

Raleigh, North Carolina
North Carolina State University at Raleigh
November 12–13, 2016
Saturday - Sunday

Meeting #1124
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of Notices: September 2016
Program first available on AMS website: To be announced
Issue of Abstracts: Volume 37, Issue 4

Deadlines
For organizers: April 12, 2016
For abstracts: September 13, 2016

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional1.html.

Invited Addresses
- Ricardo Cortez, Tulane University, Title to be announced.
- Jason Metcalfe, University of North Carolina at Chapel Hill, Title to be announced.
- Agnes Szanto, North Carolina State University, Title to be announced.

Special Sessions
If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

- Difference Equations and Applications (Code: SS 2A), Michael A. Radin, Rochester Institute of Technology; and Youssef Raffoul, University of Dayton.
- Homological Methods in Commutative Algebra (Code: SS 1A), Alina Iacob and Saeed Nasseh, Georgia Southern University.

Atlanta, Georgia

Hyatt Regency Atlanta and Marriott Atlanta Marquis

January 4–7, 2017
Wednesday – Saturday

Meeting #1125
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 (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Brian D. Boe
Announcement issue of Notices: October 2016
Program first available on AMS website: To be announced
Issue of Abstracts: Volume 38, Issue 1

Deadlines
For organizers: April 1, 2016
For abstracts: To be announced

Call for Proposals
Brian D. Boe, Associate Secretary responsible for the AMS program at the 2017 Joint Mathematics Meetings, solicits proposals for Special Sessions for this meeting (to be held from Wednesday, January 4 through Saturday, January 7, 2017 in Atlanta, GA). Each proposal must include:

1. the name, affiliation, and e-mail address of each organizer, with one organizer designated as the contact person for all communication about the session;
2. the title and a brief (two or three paragraphs) description of the topic of the proposed special session;
3. a sample list of speakers (along with their institutions) whom the organizers plan to invite. (It is not necessary to have received confirmed commitments from these potential speakers.)

Organizers are strongly encouraged to consult the AMS Manual for Special Session Organizers at: www.ams.org/meetings/meet-specialsessionmanual, especially section 4.d, which describes speaker selection.

Proposals for AMS Special Sessions should be sent by e-mail to Prof. Boe (brian@math.uga.edu) and must be received by the deadline for organizers, April 1, 2016. Late proposals will not be considered [with the possible exception of special sessions explicitly associated with one of the plenary lectures/invited addresses at the meeting].

No decisions will be made on Special Session proposals until after the submission deadline has passed.

Special Sessions will in general be allotted between 5 and 10 hours in which to schedule speakers. To enable maximum movement of participants between sessions, organizers must schedule each speaker for either a) 20-minute talk followed by 10-minute break; or b) 45-minute talk followed by 15-minute break. Any combination of 20-minute and 45-minute talks is permitted, but all talks should begin and end at the scheduled time. (In particular, all the talks should start on the hour or half-hour, except on the first afternoon when special sessions must begin at 2:15 pm and hence, talks will start on the quarter or third-quarter hour).

There is a limited amount of space available for Special Sessions on the AMS program. Because of the large number of high-quality proposals expected, not all proposals may be accepted. Please be sure to submit as informative a proposal as possible for review by the Program Committee. It is expected that contact organizers will be notified by May 6, 2016 whether their proposals have been accepted. Specific additional instructions will then be given to the contact persons of the accepted special sessions, shortly after that deadline.
Meetings & Conferences

Charleston, South Carolina

College of Charleston

March 10–12, 2017
Friday – Sunday

Meeting #1126
Southeastern Section
Associate secretary: Brian D. Boe
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: November 10, 2016
For abstracts: To be announced

New York, New York

Hunter College, City University of New York

May 6–7, 2017
Saturday – Sunday

Meeting #1129
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: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: September 14, 2016
For abstracts: March 21, 2017

Bloomington, Indiana

Indiana University

April 1–2, 2017
Saturday – Sunday

Meeting #1127
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 abstracts: To be announced

Montréal, Quebec Canada

McGill University

July 24–28, 2017
Monday – Friday

Meeting #1130
The second Mathematical Congress of the Americas (MCA 2017) is being hosted by the Canadian Mathematical Society (CMS) in collaboration with the Pacific Institute for the Mathematical Sciences (PIMS), the Fields Institute (FIELDS), Le Centre de Recherches Mathématiques (CRM), and the Atlantic Association for Research in the Mathematical Sciences (AARMS).
Associate secretary: Brian D. Boe
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: July 31, 2016
For abstracts: To be announced

Pullman, Washington

Washington State University

April 22–23, 2017
Saturday – Sunday

Meeting #1128
Western Section
Associate secretary: Michel L. Lapidus
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 abstracts: To be announced
Buffalo, New York
State University of New York at Buffalo

September 16–17, 2017
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: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: February 14, 2017
For abstracts: To be announced

San Diego, California
San Diego Convention Center and San Diego Marriott Hotel and Marina

January 10–13, 2018
Wednesday – Saturday
Joint Mathematics Meetings, including the 124th Annual Meeting of the AMS, 101st Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Georgia Benkart
Announcement issue of Notices: October 2017
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: April 1, 2017
For abstracts: To be announced

Orlando, Florida
University of Central Florida, Orlando

September 23–24, 2017
Saturday – Sunday
Southeastern Section
Associate secretary: Brian D. Boe
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: February 23, 2017
For abstracts: July 25, 2017

Baltimore, Maryland
Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel

January 16–19, 2019
Wednesday – Saturday
Joint Mathematics Meetings, including the 125th Annual Meeting of the AMS, 102nd Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Brian D. Boe
Announcement issue of Notices: October 2018
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: April 2, 2018
For abstracts: To be announced

Riverside, California
University of California, Riverside

November 4–5, 2017
Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
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 abstracts: To be announced
Assistant Professor of Applied Mathematics

The Department of Mathematics at ETH Zurich invites applications for the above-mentioned position. The assistant professor will be a member of the Seminar for Applied Mathematics, SAM.

Candidates should have an exceptional research potential in some area of applied mathematics. Particular attention will be given to numerical analysis and computational mathematics, preferably complementing current research directions at the SAM.

The responsibilities of the future professor include research and teaching in numerical analysis and computational mathematics for students of mathematics, engineering and natural sciences at all levels. There is the possibility to lead his or her own research group within the SAM. The new professor will be expected to teach undergraduate level courses (German or English) and graduate level courses (English). This assistant professorship has been established to promote the careers of younger scientists. The initial appointment is for four years with the possibility of renewal for an additional two-year period.

Please apply online at www.facultyaffairs.ethz.ch

Applications should include a curriculum vitae, a list of publications, and a statement of future research and teaching interests. The letter of application should be addressed to the President of ETH Zurich, Prof. Dr. Lino Guzzella. The closing date for applications is 31 January 2016. ETH Zurich is an equal opportunity and family friendly employer and is further responsive to the needs of dual career couples. We specifically encourage women to apply.

Denver, Colorado

Colorado Convention Center

January 15–18, 2020

Wednesday – Saturday

Joint Mathematics Meetings, including the 126th Annual Meeting of the AMS, 103rd Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Michel L. Lapidus

Program first available on AMS website: November 1, 2019
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines

For organizers: April 1, 2019
For abstracts: To be announced

Washington, District of Columbia

Walter E. Washington Convention Center

January 6–9, 2021

Wednesday – Saturday

Joint Mathematics Meetings, including the 127th Annual Meeting of the AMS, 104th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Brian D. Boe

Program first available on AMS website: November 1, 2020
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines

For organizers: April 1, 2020
For abstracts: To be announced
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—Israel M. Gelfand (1913–2009)

In 2014, Mathematical Reviews added 126,077 items to MathSciNet®—that's more than one per minute.

Subjects with the most arXiv.org posts in math proper, first half 2015:

- PDEs: 1716
- Combinatorics: 1659
- Probability: 1548

What’s the Caption?
Submit your entry by January 25 to captions@ams.org. Winning entries will be posted here in April.

 QUESTIONABLE MATHEMATICS

Where ... the ENIAC is equipped with 18,000 vacuum tubes and weighs 30 tons, computers in the future may have only 1,000 vacuum tubes and weigh only 1.5 tons.

—Popular Mechanics, 1949


What crazy things happen to you? Readers are invited to submit original short amusing stories, math jokes, cartoons, and other material to: noti-backpage@ams.org.
1:00 PM  Carina Curto, Pennsylvania State University

What can topology tell us about the neural code?
Surprising new applications of what used to be thought of as “pure” mathematics.

Image: Courtesy of Amanda Burnham

2:00 PM  Yuval Peres, Microsoft Research and University of California, Berkeley, and Lionel Levine, Cornell University

Laplacian growth, sandpiles and scaling limits
Striking large-scale structure arising from simple cellular automata.

Image: Courtesy of Itamar Landau and Lionel Levine

3:00 PM  Timothy Gowers, Cambridge University

Probabilistic combinatorics and the recent work of Peter Keevash
The major existence conjecture for combinatorial designs has been proven!

Image: Courtesy of CMSC - University of Western Australia

4:00 PM  Amie Wilkinson, University of Chicago

What are Lyapunov exponents, and why are they interesting?
A basic tool in understanding the predictability of physical systems, explained.

Image: Thorns, 1996. A symmetric chaotic attractor. Courtesy of Mike Field
NEW AND NOTEWORTHY TITLES FROM THE AMS

WHAT’S HAPPENING IN THE MATHEMATICAL SCIENCES, VOLUME 10
Dana Mackenzie and Barry Cipra
This book is a collection of articles highlighting some of the most recent developments in mathematics, including important achievements in pure mathematics, as well as its fascinating applications.

Random Operators
Disorder Effects on Quantum Spectra and Dynamics
Michael Aizenman, Princeton University, NJ, and Simone Warzel, Technische Universität München, Germany
This book provides an introduction to the mathematical theory of disorder effects on quantum spectra and dynamics.

KNOTS, MOLECULES, AND THE UNIVERSE
An Introduction to Topology
Erica Flapan, Pomona College, Claremont, CA
This book is an elementary introduction to geometric topology and its applications to chemistry, molecular biology, and cosmology.

PARTIAL DIFFERENTIAL EQUATIONS
An Accessible Route through Theory and Applications
András Vasy, Stanford University, CA
This text is intended for readers who want to understand the theoretical underpinnings of modern PDEs in settings that are important for applications.

ORIGAMI
Koryo Miura, University of Tokyo, Japan, Toshikazu Kawasaki, Anan National College of Technology, Tokushima, Japan, Tomohiro Tachi, University of Tokyo, Japan, Ryuei Uehara, Japan Advanced Institute of Science and Technology, Iihikawa, Japan, Robert J. Lang, Langorigami, Alamo, CA, and Patsy Wang-Iverson, Gabriella & Paul Rosenbaum Foundation, Bryn Mawr, PA, Editors
This book allows the reader to visualize the many possibilities that can be achieved through the creative melding of origami with different fields of research.

PROBLEMS IN REAL AND FUNCTIONAL ANALYSIS
Alberto Torchinsky, Indiana University, Bloomington, IN
The purpose of this book is to complement the existing literature in introductory real and functional analysis at the graduate level with a variety of conceptual problems.