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Notices

of the American Mathematical Society

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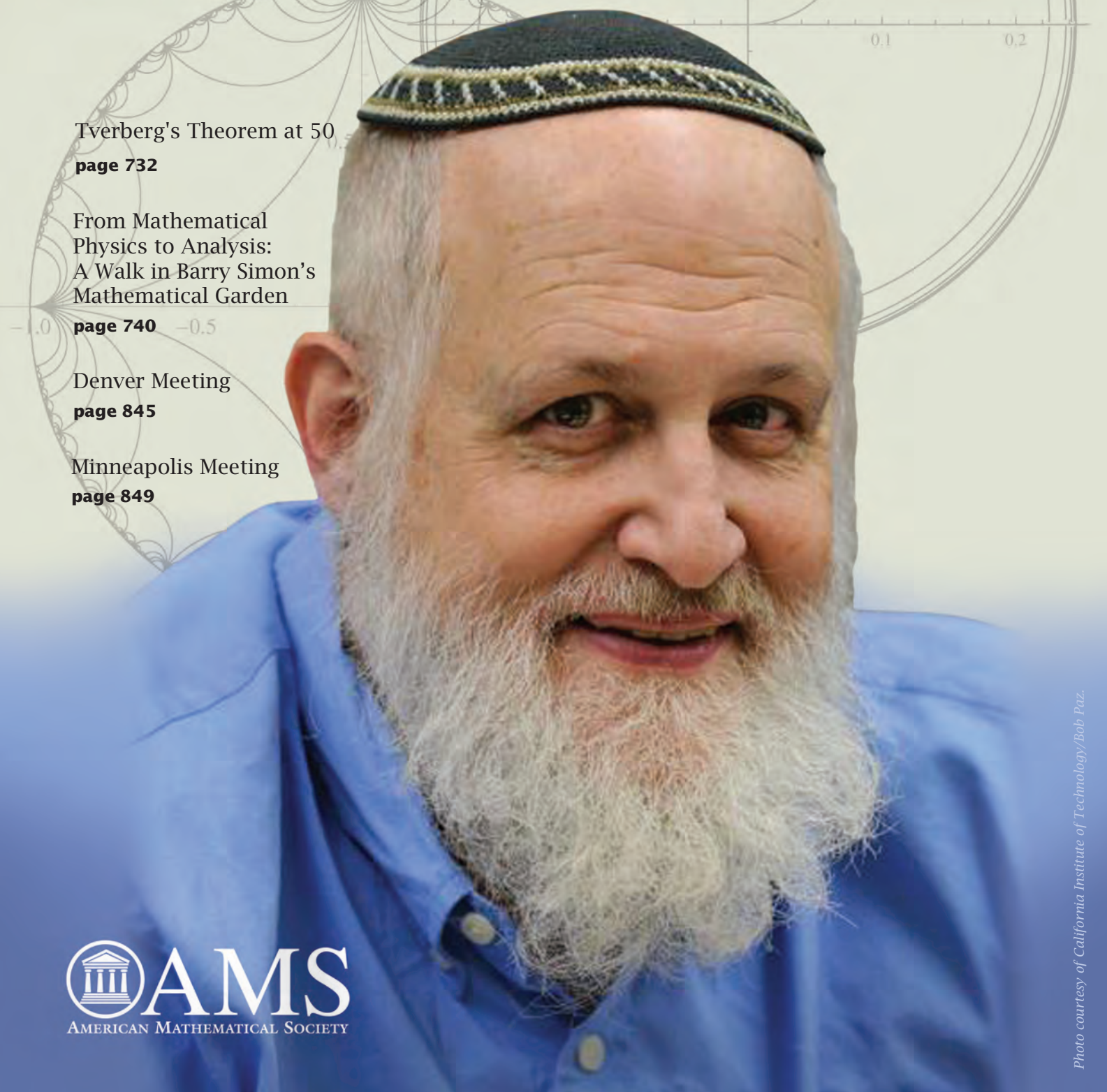

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August 2016

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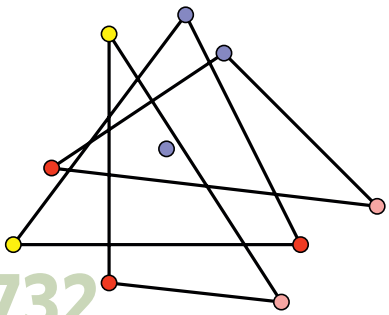

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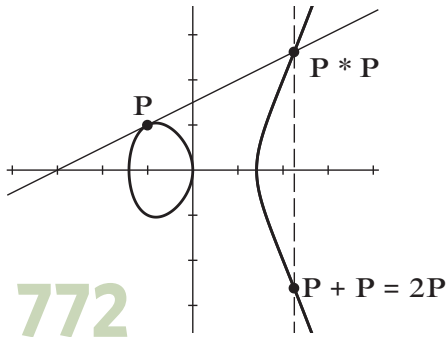
From Mathematical Physics to Analysis: A Walk in Barry Simon's Mathematical Garden

Coordinating Editor Fritz Gesztesy



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WHAT IS... a Diophantine *m*-tuple?

by Andrej Dujella

Our August issue features the recent counterexample to the conjectured topological version of Tverberg's 1966 theorem and 2016 Steele Prize winner Barry Simon on the occasion of his 70th birthday conference this month.
—Frank Morgan, Editor-in-Chief

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The background figures on the cover show reflections in the Poincaré Disk (left) and a spiraling line compactification that adds a circle at infinity (right) © Mihai Stoiciu, from Barry Simon's 5-volume set *A Comprehensive Course in Analysis*.

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AMERICAN MATHEMATICAL SOCIETY

The Case of Academician Nikolai Nikolaevich Luzin

Sergei S. Demidov, *Russian Academy of Sciences, Moscow, Russia* and **Boris V. Lëvshin,** Editors

Translated by Roger Cooke

A campaign to 'Sovietize' all sciences in the USSR took aim at Nikolai Nikolaevich Luzin, the leader of the Soviet school of mathematics, with an accusatory article published in *Pravda*. This book contains the transcripts of the five 1936 meetings of the commission of the Academy of Sciences who were charged with investigating the accusations against Luzin. Ancillary material from the Soviet press of the time is included to place these meetings in context.

History of Mathematics, Volume 43; 2016; 416 pages; Hardcover; ISBN: 978-1-4704-2608-8; List US$59; AMS members US$47.20; Order code HMATH/43

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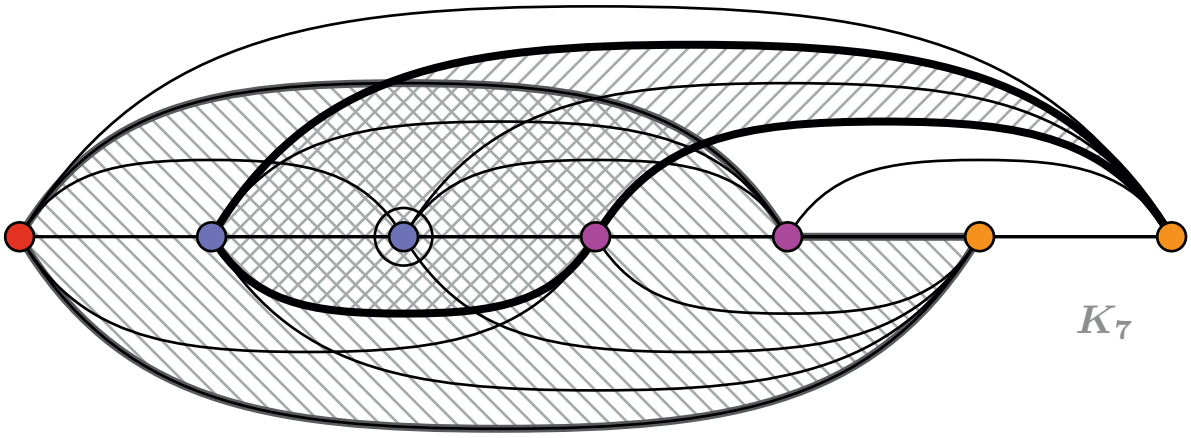
Tverberg's Theorem at 50: Extensions and Counterexamples



For more about this graphic, see p. 739.

Imre Bárány, Pavle V. M. Blagojević, and Günter M. Ziegler

ABSTRACT. *We describe how a powerful new "constraint method" yields many different extensions of the topological version of Tverberg's 1966 Theorem in the prime power case—and how the same method also was instrumental in the recent spectacular construction of counterexamples for the general case.*

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Tverberg's Theorem, whose fiftieth anniversary we celebrate this year, has played a central role both in discrete geometry and in topological combinatorics. The basic statement sounds easy:

Tverberg's Theorem (1966). *Any* $(d+1)(r-1)+1$ *points in* $\mathbb{R}^d$ *may be grouped into* r *disjoint subsets such that the convex hulls of these subsets have a point in common.*

See Figure 1 for an example. The importance and impact of Tverberg's result—which the Norwegian mathematician Helge Tverberg proved in the early morning, freezing, in a hotel room in Manchester—may be seen from its many variations and extensions, among them its "colored" and "topological" versions. Curiously enough, the "topological Tverberg theorem," conjectured by the first author in 1976, has remained a conjecture for decades. The topological tools that we have for such problems, like the 1933 Borsuk-Ulam theorem, usually yield results only when r is a prime power [13].

Now there are two surprising recent developments. First, with Florian Frick [2] we designed a "constraint method" that yields colored versions from the original

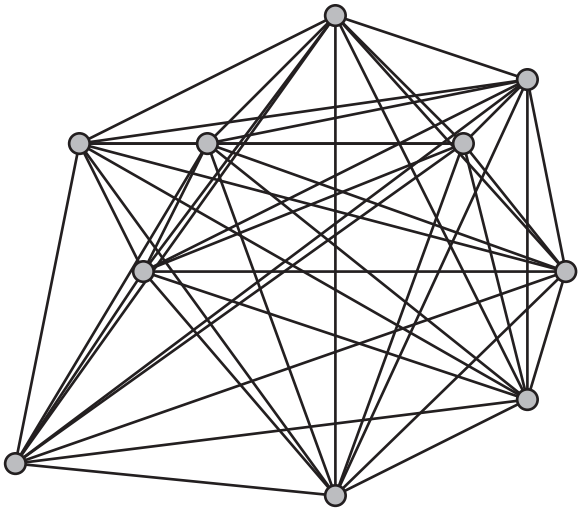

Figure 1. Tverberg's Theorem says that for $d = 2$ and $r = 4$, you can group these ten points into four disjoint subsets such that the convex hulls of these subsets have a point in common. See Figure 4 for a solution.

"topological Tverberg theorem" quite easily. Second, Isaac Mabillard and Uli Wagner in Vienna developed an "r-fold Whitney trick," and Florian Frick in Berlin noticed that combined with the constraint method this yields counterexamples for all $r \geq 6$ that are not prime powers.

This is big news, but major questions remain. For example, the current counterexamples to the topological Tverberg conjecture are in high dimensions. Does it also fail in the plane? Can one quantify the failure of the conjecture? In the prime power case, where the conjecture holds, are there always *many* Tverberg partitions? How can one find them? So many challenging questions remain. Tverberg's theorem and its variants will stay interesting and keep us busy into the future.

Prehistory

There are popular puzzles that lead one to discover that the graph K_5 of Figure 2 (the complete graph on five nodes and all ten pairs of nodes connected by an edge) is not planar; that is, *the complete graph with five nodes cannot be drawn in the plane without intersections.* This is a basic fact from graph theory and a starting point for the Four-Color Theorem, and it is not restricted to straight edges.

Indeed, in any drawing of the graph K_5 there are two *nonadjacent* edges that intersect. This also stays true beyond the usual "nice" drawings typically considered in graph theory, where edges might be drawn as straight lines or as smooth curves and will have at most a finite number of intersection points. It may be viewed as the special case $d = 1$ of a famous result in topology, the Van Kampen-Flores theorem from 1932–33:

Any continuous map of the d-dimensional skeleton of a $(2d+2)$-dimensional simplex Δ_{2d+2} to $\mathbb{R}^{2d}$ sends two points from disjoint faces of Δ_{2d+2} to the same point in $\mathbb{R}^{2d}$.

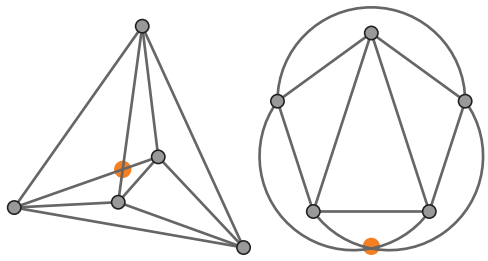

Figure 2. In every drawing of the complete graph K_5, whether by straight lines or by curves, there are two nonadjacent edges that intersect.

We will get back to this later, but our starting point here is even simpler, namely, drawings of K_4, the complete graph on four nodes, as in Figure 3. Here is a basic statement:

In every drawing of K_4, two nonadjacent edges intersect or one vertex is surrounded by the triangle spanned by the other three.

This seems quite obvious, and once again it has a high-dimensional version, Radon's theorem from 1921:

Any set of $d + 2$ points in $\mathbb{R}^d$ contains two disjoint subsets whose convex hulls intersect.

This is easy to prove by linear algebra: If the points are $x_1, \dots, x_{d+2}$ in $\mathbb{R}^d$, then the vectors $(x_1, 1), \dots, (x_{d+2}, 1)$ are linearly dependent in $\mathbb{R}^{d+1}$; any linear dependence is given by reals $\lambda_1, \dots, \lambda_{d+2}$ that are not all zero but sum to zero. So we can scale the dependence such that the positive λ_i's sum to 1 and the negative ones sum to -1. This yields $\sum_{i:\lambda_i>0} \lambda_i x_i = \sum_{j:\lambda_j<0}(-\lambda_j)x_j$, which is what we need.

The result again can be phrased in terms of a map from a simplex to $\mathbb{R}^d$:

Radon's Theorem. *Any affine map $f : \Delta_{d+1} \to \mathbb{R}^d$ sends two points from disjoint faces of the $(d + 1)$-simplex Δ_{d+1} to the same point in $\mathbb{R}^d$.*

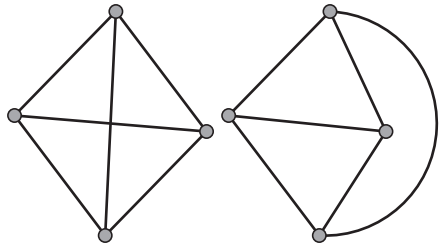

Figure 3. In every drawing of K_4, either two nonadjacent edges intersect or one vertex is inside the triangle spanned by the other three.

For $d = 2$ this yields the statement about straight-line drawings of K_4. The conclusion is, however, true for very general drawings of K_4 in the plane given by any four points and six arbitrary continuous curves that connect them:

In every drawing of K_4, there are two nonadjacent edges that meet in the drawing, or there is one vertex surrounded by the cycle spanned by the remaining three vertices.

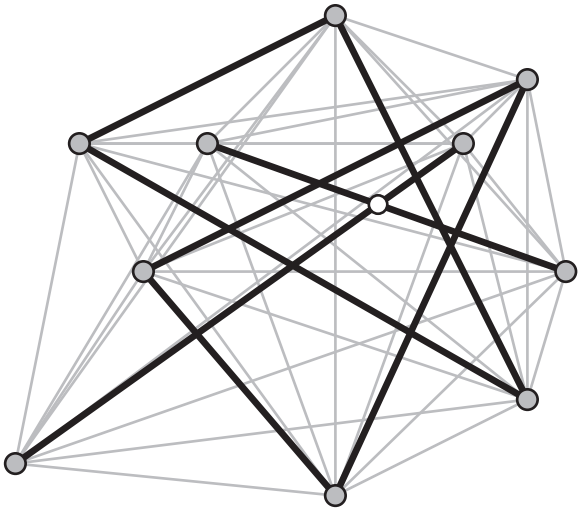

Figure 4. In this Tverberg partition for $r = 4$, the marked intersection of two edges is contained inside the two bold triangles. This solves the puzzle at the beginning of the paper.

"Surrounded" would mean here that the three-edge cycle winds around the vertex, with nonzero winding number—interpret this in Figure 3!

How do we prove this? For $d = 2$ this is easy to verify, since the drawing of K_4 in the plane without intersections is essentially unique. Nevertheless, if you work out details, you will need the Jordan curve theorem, which is less trivial than one might think. But again, there is a higher-dimensional version, published by Ervin G. Bajmóczy and Imre Bárány in 1979:

The Topological Radon Theorem. *Any continuous map $f : \Delta_{d+1} \to \mathbb{R}^d$ sends two points from disjoint faces of the $(d+1)$-simplex Δ_{d+1} to the same point in $\mathbb{R}^d$.*

Tverberg's theorem has been the most significant discovery in combinatorial convexity for the last fifty years.

Bajmóczy and Bárány derived their result from the Borsuk-Ulam theorem, which in one of its many beautiful incarnations says that any continuous map $S^d \to \mathbb{R}^d$ sends two opposite points on the sphere to the same point in $\mathbb{R}^d$. (Gromov [7, p. 445] offers a particularly clever way of getting that: approximate the $(d+1)$-simplex by a strictly convex body, and map each point in the d-sphere to the unique point in the corresponding support hyperplane and then to $\mathbb{R}^d$; then apply the Borsuk-Ulam theorem to the corresponding map $S^d \to \mathbb{R}^d$.)

The topological Radon theorem was one of the starting points of what has since become the field of *topological combinatorics*. Indeed, the Borsuk–Ulam Theorem has an amazing range of applications in discrete geometry, combinatorics, and topology, as explained and illustrated in Matoušek's classic text *Using the Borsuk-Ulam theorem*.

On the other hand, the topological Radon theorem is the first step on the way to the topological Tverberg problem, which asks for multiple intersections in the case of continuous maps $\Delta_N \to \mathbb{R}^d$ for sufficiently large N. For affine maps this is the subject of Tverberg's theorem, whose fiftieth anniversary we are celebrating this year. For continuous maps it has been a mystery for decades, "one of the most challenging problems in this field" according to Matoušek; "a holy grail of topological combinatorics" according to Gil Kalai. Now it has been partially resolved, in an unexpected way, as we shall see.

Tverberg's Theorem—Fifty Years Ago!

In 1957 the Cambridge undergraduate Bryan John Birch proved, in his bachelor's thesis, an r-part version of Radon's result about straight-line drawings of K_4; it is illustrated by Figure 4.

Birch's Theorem. *In every straight-line drawing of K_{3r-2} there are two edges that cross such that the intersection point is contained in $r-2$ triangles spanned by disjoint triples of the other vertices, or there is one vertex of the graph contained in $r-1$ triangles formed by disjoint triples of the other vertices.*

Again, this may be seen as a statement about affine maps, from the simplex Δ_{3r-3} to the plane. Birch also studied a high-dimensional version of his result, but he couldn't prove it, so he finally published it as a conjecture and moved on to what he now calls "elliptic curvery" and became famous for a different conjecture, one of the million-dollar Clay Millennium Problems.

Helge Tverberg proved his theorem fifty years ago. This photo, by Gerard Sierksma, shows him in September 1985 at a conference in Pokrawna, Poland.

Meanwhile, a young Norwegian mathematician, Helge Tverberg, stumbled across the same problem, first re-proving it for the plane, then also for $\mathbb{R}^3$, and then, finally, on a cold early morning in a Manchester hotel room, establishing the general case. Tverberg phrased it as a statement about $(d+1)(r-1)+1$ points in $\mathbb{R}^d$, but again we prefer to state it in terms of affine maps.

Birch's Conjecture/Tverberg's Theorem. *For integers $r \geq 2$, $d \geq 1$, and $N = (d+1)(r-1)$, any affine map $f : \Delta_N \to \mathbb{R}^d$ sends r points from disjoint faces of the N-dimensional simplex Δ_N to the same point in $\mathbb{R}^d$.*

This is rather trivial for $d = 1$; it is Birch's theorem for $d = 2$ and Radon's theorem for $r = 2$. Tverberg's original proof was complicated, showing that the statement remains true when the points move. It has been re-proved in new ways again and again, so it must be interesting.

Tverberg's theorem has been the most significant discovery in combinatorial convexity for the last fifty years. It has a great number of interesting applications in discrete and computational geometry, in combinatorics, and in theoretical computer science. Whenever you encounter a question about convexity properties of a finite point set in $\mathbb{R}^d$, check what Tverberg's theorem has to say.

The theorem also served as a model and inspiration for new results in combinatorial convexity, for instance the following beautiful one by Roman Karasev [9]: *Given $3r$ lines in general position in the plane, it is possible to split them into r disjoint sets each consisting of three lines such that the r triangles determined by the r triples of lines have a point in common.* The result seems to extend to higher dimensions, but this partially remains a conjecture.

Tverberg's theorem prompted the start of several new research directions. In particular its topological and colored versions have created a large body of new knowledge and have led to novel connections between combinatorial convexity and algebraic topology, as we will now describe.

The Topological Tverberg Conjecture—Forty Years Ago

In 1976, forty years ago this year, the first author sent a letter to Helge Tverberg asking for a "topological version" of Tverberg's theorem. In May 1978 Tverberg presented the problem at the "Konvexe Körper" workshop in Oberwolfach, and it appears in the collection of problems distributed to the workshop participants (Figure 5).

14. H. T v e r b e r g : 1. Is it true that whenever P is a convex (r-1)(d+1)-polytope with non-empty interior, and f is a continuous map: bd P → R^d, then there are r disjoint faces $F_1,\dots F_r$, such that $\cap f(F_i) \neq \emptyset$? The case r=2, which generalizes Radons theorem, has been proved by Bajmoczy and Bárány (Budapest, still not published). 2. Determine or estimate, the function f(p,q;d) such that one has: If P ⊂ Q are convex sets in R^d, with volumes p,q, then Q\P contains a convex body of volume f(p,q;d).

Figure 5. The topological Tverberg problem, in mimeographed notes from the 1978 Oberwolfach workshop, provided by Rolf Schneider.

The problem finally appeared in print in 1979. Since then it has been referred to as the "topological Tverberg conjecture" and often also, in acts of gross negligence, as the "topological Tverberg theorem."

The Topological Tverberg Conjecture [8]**.** *For integers $r \geq 2$, $d \geq 1$, and $N = (d+1)(r-1)$, any continuous map $f : \Delta_N \to \mathbb{R}^d$ sends r points from disjoint faces of the N-dimensional simplex Δ_N to the same point in $\mathbb{R}^d$.*

We know that this conjecture holds for affine maps. For continuous maps, it was first proved by Imre Bárány, Senya B. Shlosman, and András Szűcs in 1981 [1]—only, however, under the unnatural-looking restriction that r is a prime. How did this come in?

Sketch of the Proof for r a Prime. Let us assume that there is a counterexample, that is, a continuous map $f : \Delta_N \to \mathbb{R}^d$ that does not send any collection of r points from r disjoint faces of the simplex Δ_N to the same point in $\mathbb{R}^d$. From the counterexample map f one would be able to construct an "r-fold deleted product" map

$$F = f^{\times r} : (\Delta_N)^{\times r}_{\Delta(2)} \to (\mathbb{R}^d)^{\times r}_{\Delta} \to S(W_r^{\oplus d}) \cong S^{N-r}$$

Here $W_r := \{(x_1, \dots, x_r) \in \mathbb{R}^r : \sum x_i = 0\}$. The point is that the symmetric group $\mathfrak{S}_r$ permutes the factors/coordinates for these spaces, and the map F is "equivariant"; it respects the symmetry. Moreover, if r is a prime, then a cyclic subgroup $\mathbb{Z}_r \subset \mathfrak{S}_r$ acts *freely* on the sphere, and thus one can apply an extension of the Borsuk-Ulam theorem for arbitrary free actions that is known as "Dold's theorem": It says that there is no equivariant map from an $(N-r)$-connected space to an $(N-r)$-dimensional one endowed with a free action. So we conclude that the counterexample map cannot exist. □

So it's proved only if r is a prime? To quote Matoušek:

> It seems likely that this theorem remains true for all p, not only primes, but so far nobody has managed to prove this. It has been verified for all prime powers, though.

Indeed, the next step was taken by Murad Özaydin in 1987. In an important and influential paper [12] that was never published, he proved the topological Tverberg conjecture for the case when $r = p^k$ is a prime power. How? He noted that in that case the hypothetical map

$$F = f^{\times r} : (\Delta_N)^{\times r}_{\Delta(2)} \to (\mathbb{R}^d)^{\times r}_{\Delta} \to S(W_r^{\oplus d}) \cong S^{N-r}$$

is equivariant with respect to an elementary abelian subgroup $(\mathbb{Z}_p)^k \subset \mathfrak{S}_{p^k}$ that acts on the sphere $S(W_r^{\oplus d})$ not freely but without fixed points. In this situation some algebraic topology machinery (cohomology of the homotopy orbit space and a related localization theorem in combination with comparison of Serre spectral sequences) still implies that the map cannot exist. A detailed proof can be found in [3].

…it came as quite a surprise that there is a really simple "constraint method" to get virtually all of these extensions…

So it's proved only if r is a prime power? Actually, Özaydin proved more: He showed that if r is not a prime power, then the hypothetical map

$$F : (\Delta_N)^{\times r}_{\Delta(2)} \to S^{N-r}$$

does exist. This still doesn't mean that the topological Tverberg conjecture fails, but it means that the equivariant topology approach, known as the "Configuration Space Test Map Scheme (CS/TM)," fails here miserably. This was

1987, nearly thirty years ago, and we were left without any promising approach or any hope of handling the topological Tverberg conjecture in the cases when the number of overlapping simplices is not a prime power.

Using Constraints

Over the years, there have been a great number of interesting extensions and variations of Tverberg's theorem. In every single case it seemed that one had to work hard, with major topological tools, to get the prime or even the prime-power case—and one could not get beyond that.

So it came as quite a surprise that there is a really simple "constraint method" to get virtually all of these extensions directly from the original topological Tverberg theorem. This observation arose in our collaboration [2] with Florian Frick at a blackboard at Arnimallee 2, a villa that is part of the Mathematical Institute of FU Berlin. We couldn't believe that it was so easy!

Let us illustrate the idea of the constraint method in two examples.

Murad Özaydin proved the topological Tverberg conjecture for the case when r is a prime power.

First, we demonstrate how the generalized Van Kampen-Flores theorem becomes a consequence of the topological Tverberg theorem:[1]

Theorem. *If the topological Tverberg theorem holds for parameters r and $d+1$, then the Generalized Van Kampen-Flores theorem holds for the parameters r and d, for $N=(d+2)(r-1)$.*

The constraint method takes the extra condition that the Van Kampen-Flores theorem asks for and encodes it into a *constraint function*, which becomes an additional component of the Tverberg function, "one dimension higher." Any solution then will consist of r faces of the simplex or, more precisely, points $x_1,\dots,x_r$ on these faces, of equal distance from the skeleton. The pigeonhole principle forces *one*, and thus *all*, of the points to lie in the lower-dimensional skeleton:

Proof. Let $r\geq 2$, $d\geq 1$, $k\geq \lceil \frac{r-1}{r}d\rceil$ be integers, and let $N=(d+2)(r-1)$. Consider a continuous map $g\colon \Delta_N\to \mathbb{R}^{d+1}$ defined by

$$g(x)=(f(x),\operatorname{dist}(x,\operatorname{sk}_k(\Delta_N))).$$

Here $\operatorname{sk}_k(\Delta_N)$ denotes the k-skeleton of the simplex Δ_N. Since $N=((d+1)+1)(r-1)$ and the topological Tverberg theorem holds for r, it can be applied to the map g. Thus we get r pairwise disjoint faces σ_i of the simplex Δ_N with points x_i in the relative interior of σ_i such that $g(x_1)=\cdots=g(x_r)$; that is, f sends all points $x_1,\dots,x_r$ to one point and in addition

$$\operatorname{dist}(x_1,\operatorname{sk}_k(\Delta_N))=\cdots=\operatorname{dist}(x_r,\operatorname{sk}_k(\Delta_N)).$$

Observe that if at least one of the faces σ_i would belong to the k-skeleton, then $\operatorname{dist}(x_i,\operatorname{sk}_k(\Delta_N))=0$ for all $1\leq i\leq r$. Hence, it would follow that $\sigma_i\in\operatorname{sk}_k(\Delta_N)$ for all $1\leq i\leq r$, and the proof of the theorem would be complete.

To conclude the proof we use the pigeonhole principle. Assume that all the faces σ_i are not in the k-skeleton, that is, $\dim\sigma_i\geq k+1$ for every i. Since the faces $\sigma_1,\dots,\sigma_r$ are disjoint they together have at least $r(k+2)\geq r(\lceil\frac{r-1}{r}d\rceil+2)\geq N+2$ vertices, more than the number of vertices of the simplex Δ_N, a contradiction. □

Thus, if the generalized Van Kampen-Flores theorem does not hold for some parameter r, then the topological Tverberg theorem also does not hold for the same parameter.

Is this all? Can the pigeonhole principle create more results? Surprisingly enough, the answer is yes; it can give us much more. Maybe some colored Tverberg theorem?

Another Colored Tverberg Theorem. *For integers $r\geq 1$, $d\geq 1$, and $N=(2d+2)(r-1)$ where r is a prime power, any continuous map $f\colon\Delta_N\to\mathbb{R}^d$, with any coloring of the vertex set of the simplex Δ_N by $d+1$ colors where each of the color classes is of size at most $2r-1$, sends r points from disjoint rainbow faces of the simplex Δ_N—all of whose vertices must have different colors—to the same point.*

Proof. Let $(C_1,\dots,C_{d+1})$ be a coloring of the set of vertices of the simplex Δ_N where $|C_i|\leq 2r-1$ for all i. For each color class C_i we introduce the subcomplex $\Sigma_i:=\{\sigma\in\Delta_N : |\sigma\cap C_i|\leq 1\}$. Then the intersection $\Sigma_1\cap\cdots\cap\Sigma_{d+1}$ is a subcomplex of all rainbow faces of Δ_N. Let $g\colon\Delta_N\to\mathbb{R}^{2d+1}$ be a continuous map defined by

$$g(x)=(f(x),\operatorname{dist}(x,\Sigma_1),\dots,\operatorname{dist}(x,\Sigma_{d+1})).$$

With r as a prime power and $N=((2d+1)+1)(r-1)$, the topological Tverberg theorem can be applied to g. So, there are r pairwise disjoint faces σ_i with points

Isaac Mabillard and Uli Wagner developed the "r-fold Whitney trick" in the hope of constructing counterexamples.

[1] *Later it was noted that Gromov had sketched this already in 2010,* [7, pp. 445–446].

$x_i \in \operatorname{relint}\sigma_i$ such that $g(x_1) = \cdots = g(x_r)$; that is, f sends all points $x_1, \dots, x_r$ to the same point and

$$\begin{aligned} \operatorname{dist}(x_1, \Sigma_1) &= \cdots = \operatorname{dist}(x_r, \Sigma_1), \\ &\cdots \\ \operatorname{dist}(x_1, \Sigma_{d+1}) &= \cdots = \operatorname{dist}(x_r, \Sigma_{d+1}). \end{aligned}$$

For every subcomplex Σ_i one of the faces $\sigma_1, \dots, \sigma_r$ is contained in it. Indeed, if this were not true, then each of the faces $\sigma_1, \dots, \sigma_r$ would have at least two vertices in the color class C_i. Since the faces are disjoint, the color classes C_i have to be of size at least $2r$, a contradiction. Thus, the distances that were previously equal have to vanish, implying that $x_i \in \sigma_i \subseteq \Sigma_1 \cap \cdots \cap \Sigma_{d+1}$ for every i; that is, all the faces $\sigma_1, \dots, \sigma_r$ are rainbow faces. □

Counterexamples

Here comes the second surprise. From 2013 to 2015, Isaac Mabillard and Uli Wagner at IST Austria (in Klosterneuburg, near Vienna) developed an "r-fold Whitney trick" [10], which extends the classical Whitney trick designed for the embeddability problem (i.e., for $r = 2$). Motivated by Özaydin's work, they had hoped to use this to construct counterexamples to the topological Tverberg conjecture. They proved the following essential theorem.

Theorem. *For integers $r \geq 2$, $\ell \geq 3$, and an $((r-1)\ell)$-dimensional simplicial complex K, the following statements are equivalent:*

(i) *There exists an $\mathfrak{S}_r$-equivariant map $K^{\times r}_{\Delta(2)} \to S(W_r^{\oplus r\ell})$.*

(ii) *There exists a continuous map $f\colon K \to \mathbb{R}^{r\ell}$ such that the f-images of any r disjoint faces of K do not intersect.*

Florian Frick realized that the constraint method now yielded counterexamples to the topological Tverberg conjecture.

The "codimension three" condition that is classically inherent in the Whitney trick and is reflected in the statement of the theorem at the time prevented Mabillard and Wagner from obtaining counterexamples to the topological Tverberg theorem for nonprime powers. This was the state of affairs in January–February 2015, which Isaac Mabillard spent at the villa at FU Berlin, where he presented the progress from his PhD work in several seminar lectures.

It turned out that only one more crucial observation was missing: Florian Frick, then a PhD student at TU Berlin and also a frequent visitor to the villa at FU Berlin, realized that the theorem of Mabillard and Wagner, in combination with the work of Özaydin and the constraint method, yields all that is needed for obtaining counterexamples. More precisely, counterexamples to the generalized Van Kampen-Flores conjecture for nonprime powers, which one could get from the Mabillard-Wagner theorem, would imply counterexamples to the topological Tverberg conjecture for nonprime powers [6], [3].

Theorem. *Let $\ell \geq 3$, $r \geq 6$ be integers where r is not a prime power. For **any** integer $N > 0$ there exists a continuous map $f\colon \Delta_N \to \mathbb{R}^{r\ell}$ such that the f-images of any r disjoint faces from the $((r-1)\ell)$-skeleton of the simplex Δ_N do not intersect.*

Sketch of the Proof. The deleted product cell complex $(\operatorname{sk}_{(r-1)\ell}\Delta_N)^{\times r}_{\Delta(2)}$ is a free $\mathfrak{S}_r$-space of dimension at most $d := (r-1)r\ell$. Since r is not a power of a prime, according to a result of Özaydin obtained via equivariant obstruction theory, there exists an $\mathfrak{S}_r$-equivariant map

$$g\colon (\operatorname{sk}_{(r-1)\ell}\Delta_N)^{\times r}_{\Delta(2)} \to S(W_r^{\oplus d}).$$

The theorem of Mabillard and Wagner applied to the $\mathfrak{S}_r$-equivariant map g yields a continuous map $f\colon \operatorname{sk}_{(r-1)\ell}\Delta_N \to \mathbb{R}^{r\ell}$ with the property that the images of any r disjoint faces from the $((r-1)\ell)$-skeleton of the simplex Δ_N do not intersect. □

Thus we know that the generalized Van Kampen-Flores theorem fails for all r that are not prime powers, and consequently the topological Tverberg conjecture fails for all such r. We also get explicit parameters for the counterexamples:

Corollary. *Let $\ell \geq 3$, $r \geq 6$ be integers, and let $N := (r-1)(r\ell+2)$, where r is not a prime power. There exists a continuous map $g\colon \Delta_N \to \mathbb{R}^{r\ell+1}$ such that g images of any r disjoint faces of the simplex Δ_N do not intersect.*

The "smallest" counterexample to the topological Tverberg conjecture that can be obtained from this is (for $r = 6$) a continuous map $f\colon \Delta_{100} \to \mathbb{R}^{19}$ such that the images of any six pairwise disjoint faces in Δ_{100} do not intersect.

In the cases where we know that a solution to Tverberg's theorem exists, is there any efficient way to find it?

In subsequent work, Mabillard and Wagner have improved this to get counterexamples in dimensions $3r$ whenever r is not a prime power, using a more elaborate tool ("prismatic maps") to overcome the codimension 3 restriction. More recently, together with Avvakumov and Skopenkov, they proved a codimension-2 analogue of the r-fold Whitney trick (for $r \geq 3$), leading to counterexamples in dimension $2r$. Thus, the currently smallest counterexample (again for $r = 6$) is a map $\Delta_{65} \to \mathbb{R}^{12}$.

The Next Fifty Years in the Life of Tverberg's Theorem?

What's next? There are enough things to do! Let us point out four.

(1) The topological Tverberg conjecture for $d = 2$ may be seen as a graph drawing problem for the complete graph K_{3r-2}. Let's take $r = 6$: Is it true that in every drawing of K_{16}, there are two nonadjacent edges that meet in the drawing, with an intersection surrounded by four cycles spanned by disjoint triples of the remaining twelve vertices, or there is one vertex surrounded by five cycles spanned by the remaining fifteen vertices?

"Surrounded" here again means that the three-edge cycle winds around the point with nonzero winding number. One may get philosophical here: Is there an essential difference in the Tverberg-type properties between straight-line drawings and general drawings of graphs? For arrangements of lines vs. pseudolines in the plane, substantial combinatorial differences exist; Branko Grünbaum in 1970 had called this "the importance of being straight."

(2) Is it true in the affine case or if r is a prime power that there are always *many* Tverberg partitions and not only one? Gerard Sierksma had conjectured in 1979 that there are always at least $(r-1)!^d$ solutions. Is this true? The best lower bound we have seems to be $\frac{1}{(r-1)!}(r/2)^{(d+1)(r-1)/2}$ for the prime case, by Vučić and Živaljević from 1993.

(3) In the cases where we know that Tverberg's theorem is true and a solution exists, is there any efficient way to find it? Is this (theoretically or practically) hard or easy? See Mulzer and Werner [11] for a discussion and recent references.

(4) The topological Tverberg theorem has an "optimal" colored extension [4] that has the color-free original version as a special case:

Optimal Colored Tverberg Theorem. *For integers $r \geq 1$, $d \geq 1$, and $N = (d+1)(r-1)$ where r is a prime, any continuous map $f : \Delta_N \to \mathbb{R}^d$ with any coloring of the vertex set of the simplex Δ_N where each color class is of size at most $r-1$ sends r points from disjoint rainbow faces of the simplex Δ_N to the same point.*

Note for this the concepts of "coloring" and "rainbow faces" have been redefined a bit: we use more than $d+1$ colors, and the rainbow faces do not pick up all colors. Among all the variations of the topological Tverberg theorem, this theorem is the only one that extends it, except that we proved it (together with Benjamin Matschke) only for the case where r is prime, even in the case where the map is affine. Does it fail otherwise, say for $r = 4$ and "ten colored points in the plane, no four of the same color," as in Figure 6?

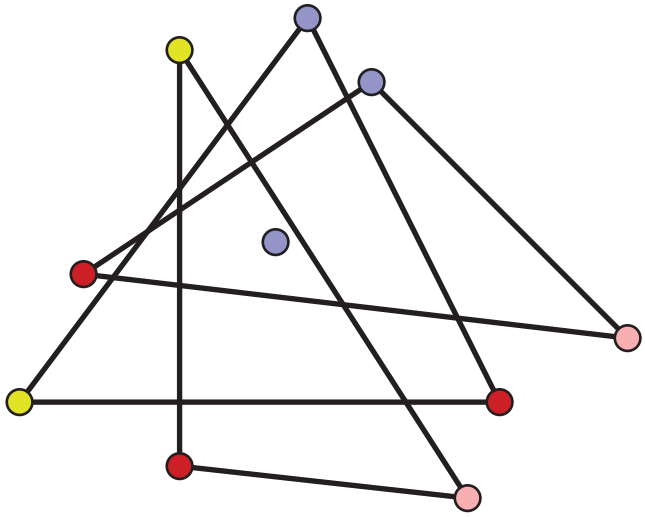

Figure 6. Does the optimal colored Tverberg theorem fail for nonprime r, say for $N + 1 = 10$ colored points in the plane, no $r = 4$ of the same color? This figure is not a counterexample, because the three rainbow triangles surround the point in the center.

Acknowledgments

The authors are grateful to Florian Frick, Andreas Holmsen, Isaac Mabillard, and Uli Wagner for very helpful and insightful comments on this paper.

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About the Opening Graphic

The "Optimal Colored Tverberg Theorem" says—for $d = 2$ and $r = 3$—that any drawing of the complete graph K_7 on seven nodes, no three of the same color, either has two rainbow triangles covering the seventh node, or two rainbow edges that cross in a rainbow triangle spanned by the other three nodes, or both. Our drawing shows an example for the first case. How about the second one?

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From Mathematical Physics to Analysis: A Walk in Barry Simon's Mathematical Garden

Editor's Note: *Fritz Gesztesy kindly accepted our invitation to put together this feature in honor of Barry Simon on the occasion of Simon's 2016 AMS Leroy P. Steele Prize for Lifetime Achievement and his 70th birthday conference this August 28–September 1.*

Fritz Gesztesy

This is a collection of contributions by collaborators, postdocs, and students of Barry Simon of the California Institute of Technology on the occasion of Simon's receiving the 2016 AMS Leroy P. Steele Prize for Lifetime Achievement. The citation for the award mentions his tremendous impact on the education and research of a whole generation of mathematical scientists, and we will underscore this by demonstrating his penetrating influence on topics ranging from quantum field theory, statistical mechanics, the general theory of Schrödinger operators, spectral and inverse spectral theory to orthogonal polynomials.

But we should start at the beginning: Barry was born to parents Minnie and Hy Simon in 1946, and together with his older brother, Rick, grew up in Brooklyn, New York. There he attended James Madison High School, obtaining a perfect score on the MAA's American High School Mathematics Examinaton in 1962 and thus becoming the subject of an article in the *New York Times* at the tender age of sixteen. Under the influence of Sam Marantz, an inspiring physics teacher in high school, he applied to Harvard and was admitted. While at Harvard he was a top five Putnam Competition Winner in 1965 and received his BA summa cum laude in physics in 1966. George Mackey at Harvard recommended Barry pursue a doctorate with Arthur Wightman at Princeton because Wightman was well known for advocating the application of rigorous mathematics in physics.

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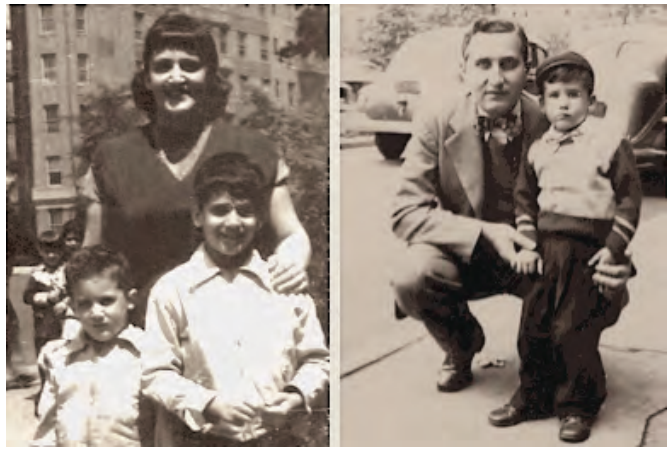

Barry Simon with his mother and brother, Rick (left), and with his father (right) (ca. 1950).

Barry Simon completed his doctorate in physics at Princeton under Wightman's supervision in 1970. The body of his work during the time of his doctoral research was of such importance that he was immediately appointed to assistant professor, jointly in mathematics and physics, at Princeton. He rapidly rose to the rank of full professor by 1976. Several contributions below will attest to the electric atmosphere at Princeton in those days, making it a thriving center for quantum field theory, statistical mechanics, and nonrelativistic quantum mechanics. Barry joined Caltech in 1981, holding the position of IBM Professor of Mathematics and Theoretical Physics since 1984. At Caltech, Barry's interests further broadened into areas such as random and ergodic Schrödinger operators, exotic spectra, inverse spectral theory, and the analytic theory of orthogonal polynomials.

Honorary doctorate, Ludwig-Maximilians-University of Munich, 2014.

… rigorous mathematics in physics

Since many of Barry's major research accomplishments are discussed in depth and put into proper context in the various contributions to follow, we itemize only a few brief comments at this point, focusing on some key results he proved, fundamental concepts he advocated, and some of the important terms he and his collaborators first coined with lasting impact:

- a rigorous framework for resonances, complex and exterior scaling, Fermi's golden rule, proof of the Oppenheimer formula for the Stark effect, convergence of time-dependent perturbation theory;
- constructive (Euclidean) quantum field theory in two space-time dimensions, connections to statistical mechanics, lattice approximations and correlation inequalities, $P(\phi)_2$ spatially cutoff field theories;
- hypercontractive and ultracontractive semigroups;
- magnetic fields, diamagnetic inequality, Kato's inequality;
- a proof of continuous symmetry breaking in classical and quantum statistical models;
- Thomas–Fermi theory, semiclassical bounds, non-Weyl asymptotics;
- asymptotic perturbation theory of eigenvalues: Borel and Padé summability, Zeeman effect, anharmonic oscillators, instanton tunneling, Birman–Schwinger principle, coupling constant thresholds;
- general theory of Schrödinger operators: essential self-adjointness, pointwise bounds on eigenfunctions, path integral techniques, absence of singular continuous spectrum in N-body sytems;
- Berry's phase and holonomy, homotopic interpretation of the Thouless integers and topological structure in the integer quantum Hall effect;
- random and almost periodic Schrödinger and Jacobi operators, exotic spectral phenomena (Cantor, singular continuous, and dense pure point spectra) and their transition to becoming a central object in mathematical physics (the singular continuous revolution), Wonderland theorem, Thouless formula, almost Mathieu equation;
- trace formulas for potential coefficients in terms of the Krein–Lifshitz spectral shift function, uniqueness theorems in inverse spectral theory for Schrödinger and Jacobi operators, oscillation theory in gaps of the essential spectrum, inverse spectral analysis with partial information on the potential;
- a new approach (the analog of the continued fraction method) to inverse spectral theory of Schrödinger operators, his local Borg–Marchenko theorem;
- a systematic application of operator theory techniques to orthogonal polynomials on the real line (OPRL) and on the unit circle (OPUC), CMV matrices, Verblunsky coefficients;
- sum rules for Jacobi matrices and applications to spectral theory (Killip–Simon theorem), perturbations of OPRL and OPUC with periodic recursion coefficients;
- Szegő asymptotics, a proof of Nevai's conjecture and its finite gap extension, the finite gap analog of the Szegő-Shohat-Nevai theorem, the fine structure of zeros of orthogonal polynomials (clock behavior), higher-order Szegő theorems.

Barry Simon's influence on our community by far transcends his approximately four hundred papers, particularly in view of 126 coauthors, 50 mentees, 31 graduate students, and about 50 postdocs mentored. In this context, one must especially mention his twenty books, the first fifteen of which have educated scores of mathematicians and mathematical physicists, two generations by now, and continuing into the foreseeable future.

One cannot overestimate the influence of Reed and Simon's four-volume series, *Methods of Modern Mathematical Physics, I–IV* (1972–79). It took on the same level of importance that Courant–Hilbert's two volumes had for previous generations, and it continues to fill that role

all over the globe to this day. To gauge the importance of Reed and Simon behind the Iron Curtain, we contacted Albrecht Böttcher (TU Chemnitz, Germany). Like so many in our generation, Albrecht has a very personal relationship with Volume I and underscored (his words) "the truly ingenious selection and presentation of the mathematical topics." The latter sentiment, however, is by no means unique to colleagues who read Reed-Simon in Russian translation; it is just as prevalent in the West.

One cannot overestimate the influence of Reed and Simon's Methods of Modern Mathematical Physics, I–IV

Cumulative sales figures for all four volumes to date top 37,000 copies. Barry's other books, most notably *Functional Integration and Quantum Physics* (1979), *Trace Ideals and Their Applications* (1979, 2005), *Orthogonal Polynomials on the Unit Circle, Parts 1, 2* (2005), and *Szegő's Theorem and Its Descendants* (2011), profoundly influenced research in these areas. Finally, we have not even begun to understand the legacy which will be created with his newest five-volume set, *A Comprehensive Course in Analysis* (2015), which offers a panorama from real to complex and harmonic analysis all the way to operator theory.

In short, Barry has been a phenomenal force in mathematical physics, encyclopedic in his knowledge and a grand master of mathematical structure and abstract analysis. Above all, he truly enjoys collaboration and the human interactions that come with it. As a sign of his tremendous influence on our community we note that to date MathSciNet lists 15,325 citations by 6,602 authors, and Google Scholar lists 61,680 citations and an h-index of 104.

Barry has been recognized with honorary degrees from the Technion, Haifa; the University of Wales–Swansea, and LMU–Munich. He was awarded the Stampacchia Prize in 1982 with M. Aizenman, the Poincaré Prize of the International Association of Mathematical Physics in 2012, and the Bolyai Prize of the Hungarian Academy of Sciences in 2015. He is a fellow of the American Physical Society (1981), the American Academy of Arts and Sciences (2005), and the AMS (2013). He has served as vice president of the AMS and of IAMP.

The books Barry Simon has authored …thus far.

Finally, on a personal note: Having been a frequent collaborator of Barry's, I have often been approached with the assumption of being one of Barry's students or postdocs, but this is not the case. On the other hand, like so many of my generation, I learned about the tools of our trade through his writings and especially from Reed and Simon I–IV, so of course it feels like I was Barry's student, even though the proper term appears to be that I'm one of his many mentees. Barry has been a constant inspiration to me for about forty years now; I feel incredibly fortunate that he became my mentor and friend.

Evans M. Harrell

Singular Perturbation Theory and Resonances

The very first article in Barry Simon's publication list, which appeared in *Il Nuovo Cimento* when he was a 22-year-old graduate student, was concerned with singular perturbation theory. This paper showed that a certain regularized, renormalized perturbation expansion for a two-dimensional quantum field theory model converges with a positive radius of convergence. As Barry candidly admitted in that article, in itself the result was of limited significance, but in a subject for which at that time "all the mathematically suitable results…are of a negative nature," it announced a new, more constructive era.

To the reader familiar with Barry Simon's works on mathematical physics of the 1970s, it is striking how many of the hallmarks of his technique are already apparent in this first article. Before entering deeply into the research, Barry first carried out a thorough and penetrating review of the entire literature on the subject. This signature of his method was something those of us who were students at Princeton in the 1970s would witness every time Barry began a new research project: Seeing him emerge from the library shared by Jadwin and Fine Halls with a mountain of books and articles, it was humbling to realize that Barry was not merely brave enough to collect all of the knowledge about the next subject he wished to study, but seemingly overnight he would absorb it in detail and carefully assess each contribution for its mathematical appropriateness. True to form, in that first article, Barry laid out which claims in the literature were established with mathematical rigor, which were plausibly to be believed, perhaps with some extra attention to assumptions, and which were frankly dubious. Finally, Barry's own way of formulating the problem was sparse and clear, and his reasoning incisive.

The perturbation theory that applies to nonrelativistic quantum mechanics is a linear theory, allowing straightforward calculations of systematically corrected eigenvalues

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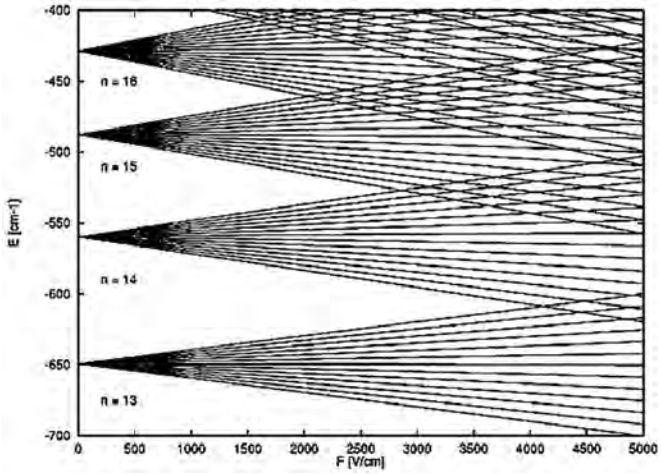
Lorenzo Sadun, Yosi Avron, Evans Harrell, Barry Simon (ca. 1988).



The Stark effect: The spectrum of the hydrogen atom under an increasingly intense electric field, from the Courtney-Spellmeyer-Jiao-Kleppner article appearing in *Physical Review A*, vol. 51 (1995).

and eigenfunctions. Schrödinger's adaptation of the procedures of Rayleigh to calculate the shifts in hydrogen emission spectrum in the presence of an electric field (known as the Stark effect) went a long way in establishing the validity of his new quantum theory. This success is ironic, given that the series for which Schrödinger and Epstein calculated the first terms has radius of convergence zero, and the spectrum of the Stark Hamiltonian for any nonzero value of the electric field is purely continuous, containing no discrete eigenvalues at all. The instant the interaction is switched on, the nature of the spectrum changes radically, and the perturbed eigenvalue becomes a resonance state! The Stark effect is known today to belong to the realm of singular perturbation theory.

Some physicists were "using methods of unknown validity"

In the two decades after Schrödinger's work, mathematicians created a comprehensive theory of linear operators on Hilbert space. In the 1930s and 1940s Rellich and Kato produced a mathematically rigorous theory of regular perturbations of linear operators and some aspects of singular perturbations. In their hands, perturbation theory was concerned with analytic operator-valued functions of a complex variable, defined initially as convergent power series with operator coefficients, which are most typically self-adjoint in applications to quantum mechanics. These functions exhibit the range of behavior of ordinary scalar analytic functions of a complex variable, with manageable complications when the spectrum consists of discrete eigenvalues of finite multiplicity, and some new phenomena when there is an essential spectrum. Physicists and chemists at this time solved problems and developed perturbative techniques that sometimes fell into the domain of regular perturbation, but just as frequently produced series that could be calculated term by term while exhibiting singular features, as in a zero radius of convergence or, worse, convergence but to the wrong answer. (For instance, a resonance eigenvalue associated with tunneling may have a nonzero imaginary part that, typically, is represented in perturbation theory by a series of the form $\sum_n c_n \beta^n$ with $c_n = 0$ for all n.)

At the time Barry Simon hit the scene, an industry was thriving in attempts to get information from such expansions, whether by replacing the series by other expressions, especially Padé approximates $P[m, n]$, which are ratios of polynomials of m and n degrees, or by the use of analytic-function techniques like Borel summability to make sense of divergent series. Many of Barry's early works addressed these topics.

One of the important models in quantum mechanics with a singular perturbation is the quartic anharmonic oscillator. Its Hamiltonian is

$$p^2 + x^2 + \beta x^4, \tag{1}$$

and it was the subject of a landmark study by Bender and Wu in 1968-69 in which, "using methods of unknown validity"—in Barry's memorable phrase—they painted a fascinating and largely correct picture of the analytic structure of the eigenvalues of the anharmonic oscillator as functions of the coupling constant β, considered as a complex variable. Among other things, Bender and Wu conjectured that the power series expansion for the ground-state eigenvalue of (1) had radius of convergence 0. Then-new computational capabilities in symbolic algebra had allowed Bender and Wu and others to calculate perturbation series at high orders, and with the first seventy-five coefficients a_n for the ground-state eigenvalue in hand, Bender and Wu specifically conjectured that

$$a_n \sim \pi^{-\frac{3}{2}} \sqrt{6}\, 3^n \Gamma\left(n + \frac{1}{2}\right). \tag{2}$$

Barry's response to the explorations of Bender and Wu was to pen the definitive rigorous analysis of the analytic

Some of Barry's coauthors, SimonFest 2006, on the occasion of Barry Simon's sixtieth birthday.

properties of the anharmonic oscillator in an extended article in the *Annals of Physics* in 1970. This work is a timeless classic, a textbook model for how to do singular perturbation theory, and it remains one of Barry's most highly cited works. Most of the claims of Bender and Wu were put on a firm footing, and many further facts were established. For example, it was shown that $\beta = 0$ is a third-order branch point and an accumulation point of singularities. Moreover, Barry obtained sufficient control on the growth rate of perturbation coefficients to show that both the Padé and Borel methods were valid to determine the eigenvalues for nonzero values of β. A few years later, with the aid of a dispersion relation derived using this understanding of the Riemann surfaces of the eigenvalues, Barry and coauthors proved the formula (2).

Later, several other models of singular perturbation theory, including the Stark and Zeeman effects, received similar treatments in the hands of Barry and his associates, especially Yosi Avron and Ira Herbst. These gems provided a foundation for developments in singular perturbation theory and deepened the understanding of many of the touchstones of quantum mechanics.

Barry has always been quick to recognize others' good ideas when they appear and generous in promoting them in the community of mathematical physicists and beyond. A very pretty method introduced in that era by Aguilar, Balslev, and Combes in 1971 came to be called complex scaling. The original version made use of the dilatation symmetry and complex analysis to move the essential spectrum of a Schrödinger operator into the complex plane, while leaving discrete eigenvalues unaffected. The unitary group of dilatations can be defined via

$$[U(\theta)f](\mathbf{x}) := e^{\nu\theta/2} f(e^{\theta}\mathbf{x}) \tag{3}$$

in terms of a real parameter θ. If the scaled potential energy depends in an analytic way on θ, then the parameter can be complexified, and it is easy to see that with a compactness condition on the potential energy the essential spectrum of the complex-scaled Laplacian for nonreal θ is simply rotated in the complex plane. Meanwhile, isolated eigenvalues are analytic as functions of θ, but since they are constant for real variations in θ, by unique continuation they are also constant for any variation of θ, except that they can appear or disappear when they collide with the essential spectrum, at which point analytic perturbation theory ceases to apply.

With this procedure the ad hoc tradition in physics of treating resonances as nonreal eigenvalues somehow associated with a self-adjoint Hamiltonian became mathematically solid and canonical. I cannot do better in describing complex scaling further than to point to Chapter XIII.10 of Reed-Simon, to which the reader is referred for further details and context. Barry assiduously promoted this excellent tool for understanding resonances, evangelizing the technique to physicists and chemists, by whom it was adopted and used in realistic problems.

I recall in particular when Barry took a delegation of mathematical physicists to the 1978 Sanibel Workshop on Complex Scaling, organized by the noted quantum chemist Per-Olof Löwdin, at which the discussions between the chemists and the believers in mathematical methods "of known validity" were quite fruitful and informative on all sides. Of course, Barry not only recognized, clarified, and promoted the idea of complex scaling but made his own fundamental advances in the subject, especially by greatly extending the set of problems to which it applied by his discovery that it suffices to perform complex scaling on an exterior region.

A similar tale could be told of Barry's recognition of the importance of the microlocal analysis of tunneling phenomena by Helffer and Sjöstrand in the 1980s, which Barry again promoted, clarified, and in certain ways transformed. But space here is limited, and besides, for the reader interested in learning more about singular perturbation theory and resonances, there is an excellent 1991 review article entitled "Fifty years of eigenvalue perturbation theory," written by a master of the genre, Barry Simon himself.

Percy A. Deift

Princeton in the 1970s; Exponential Decay of Eigenfunctions and Scattering Theory

The 1970s were a very special time for mathematical physics at Princeton. One can read a lively account of those days, written by Barry himself, in the July 2012 edition of the *Bulletin of the International Association of Mathematical Physics*. The main thrust of the activity

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Some of Barry Simon's students, SimonFest 2006, on the occasion of Barry Simon's sixtieth birthday.

was in statistical mechanics, quantum field theory, and nonrelativistic quantum mechanics. The list of people who participated in math-phys at Princeton University in those years as students, postdocs, junior faculty or senior faculty, or just visitors for a day or two reads like a who's who of mathematical physics. Leading the charge were Arthur Wightman, Elliott Lieb, and Barry Simon. But there were also Eugene Wigner, Valentine Bargmann, and Ed Nelson. And in applied mathematics, there was Martin Kruskal, still flush with excitement from his seminal work on the Korteweg-de Vries equation, and across the way at the Institute were Tulio Regge and Freeman Dyson, doing wonderful things. Barry was a dynamo, challenging us with open problems, understanding every lecture instantaneously, writing paper after paper, often at the seminars themselves, all the while supervising seven or eight PhD students.

I was one of those students. I had an appointment to meet with Barry once every two weeks. I would work very hard preparing a list of questions that I did not know how to answer. Say there were ten questions; by the end of the first ten minutes in Barry's office, the first six questions were resolved. Regarding questions seven and eight, Barry would think about them for about two or three minutes and then tell me how to do them. Regarding questions nine and ten, Barry would think about them, also for about two or three minutes, and say, "I don't know how to do them. But if you look in such and such a book or paper, you will find the answer." Invariably he was right. So in less than half an hour, all my questions were resolved, and as I walked out of the door there was the next student waiting his turn!

Barry's first PhD student was Tony O'Connor. O'Connor's thesis concerned exponential decay for eigenfunctions ψ of N-body Schrödinger operators H, $H\psi = \lambda\psi$, for λ below the essential spectrum of H. Here $H = H_0 + V$, where H_0 is the kinetic energy and V is the interaction potential. For Schrödinger operators in one dimension, such results go back to the nineteenth century, but for $N > 1$ particles moving in three dimensions, completely different techniques were necessary. Over the years many people have worked on the problem, including, to name a few, Stanislav Merkuriev in the former Soviet Union, and John Morgan and Thomas and Maria Hoffmann-Ostenhof in the West. O'Connor had the idea of using the analyticity of the Fourier transform and obtained results in the L^2 sense (i.e., $e^{\alpha|\cdot|}\psi \in L^2$, $\alpha > 0$). Such bounds are optimal for isotropic decay.

O'Connor's paper motivated Jean-Michel Combes and Larry Thomas to introduce an approach that has now become standard under the general rubric of "boost analyticity," and in a set of three papers in the mid-1970s, Barry further developed these ideas to obtain pointwise exponential bounds on eigenfunctions under various assumptions on the asymptotic behavior of the interaction potential V, proving eventually that if $V(x)$ was bounded below by $|x|^{2m}$, say, then one obtained superexponential decay for $\psi(x)$,

$$|\psi(x)| \le c\, e^{-\alpha|x|^{m+1}} \quad c,\ \alpha > 0.$$

Schrödinger operators typically involve interaction potentials V which are sums of two-body interactions

$$V(x) = \sum_{1\le i<j\le N} V_{ij}(x_i - x_j)$$

for particles x_i in $\mathbb{R}^3$, $i = 1, \dots, N$. Although typically

$$V_{ij}(y) \to 0 \text{ as } |y| \to \infty,$$

$V(x)$ clearly does not decay if $|x| \to \infty$ in such a way that $x_i - x_j$, say, remains bounded for some $i \ne j$. Such nonisotropy in the potential V suggests that isotropic bounds of the form

$$|\psi(x)| \le c\, e^{-\alpha|x|}$$

are not optimal amongst all possible bounds.

In a fourth paper on exponential decay in 1978, together with Deift, Hunziker, and Vock, Barry constructed optimal nonisotropic bounds for eigenfunctions of the form

$$|\psi(x)| \le c\, e^{(\alpha,x)}$$

for suitable $\alpha = (\alpha_1, \dots, \alpha_N)$, $\alpha_i \in \mathbb{R}^3$. The α's reflect the geometry of the channels where

$$V(x) \nrightarrow 0 \text{ as } |x| \to \infty.$$

Eventually, in 1982, Agmon showed that for a very general class of elliptic operators H in $\mathbb{R}^{3N}$, there was a naturally associated Riemannian metric on $\mathbb{R}^{3N}$ such that eigenfunctions ψ,

$$H\psi = \lambda\psi,$$

with λ below the essential spectrum of H, satisfied the bound

$$|\psi(x)| \le c_\epsilon\, e^{-(1-\epsilon)\,\rho(x)} \quad \forall \epsilon > 0,$$

where $\rho(x)$ is the geodesic distance from x to the origin in $\mathbb{R}^{3N}$ with respect to Agmon's metric. The Agmon metric can be used to derive, and so explain, the bounds in the 1978 work of Deift, Hunziker, Simon, and Vock.

The scattering problem in quantum chemistry, going back to the 1920s, can be stated informally as follows: In a chemical reaction, do molecules go to molecules? In other words, suppose in the distant past that the particle system is described by a collection of noninteracting molecules.

SimonFest in 2006 for Barry Simon's sixtieth birthday. Percy Deift is in the front row, second from the right.

As time goes on, the atoms in the different molecules begin to interact with each other, and the molecules break up. At large positive times, is the particle system again described by molecules?

To be mathematically precise, consider a collection of atoms

$$x_i \in \mathbb{R}^3,\ i = 1, \dots, N,$$

with Hamiltonian

$$H = H_0 + V = H_0 + \sum_{1<j\le N} V_{ij}\,(x_i - x_j)\,,$$

in the center of mass frame. Let $C^{(1)}, \dots, C^{(m)}$ be a decomposition of the atoms into m clusters,

$$\sum_{j=1}^{m} \#(C^{(j)}) = N.$$

Now suppose that for large negative times the clusters $\{C^{(j)}\}$ are far apart and in each cluster $C^{(k)}$ the atoms are in an eigenstate ψ_k of the cluster (read "molecular") Hamiltonian, that is,

$$H^{(k)}\,\psi_k = E_k\,\psi_k, \text{ where } H^{(k)} = H_0^{(k)} + V^{(k)}.$$

Here $H_0^{(k)}$ is the kinetic energy for the cluster and

$$V^{(k)} = \sum_{\substack{1\le i\le j\le \#(C^{(k)})\\ x_i, x_j \in C^{(k)}}} V_{ij}\,(x_i - x_j)$$

is the interaction potential for the atoms in the cluster. So the scattering problem of quantum chemistry becomes the following: At large positive times, is the particle system again described by molecules, that is, by some decomposition of well-separated clusters $\tilde{C}^{(1)}, \dots, \tilde{C}^{(\tilde{m})}$ with the atoms in each cluster $\tilde{C}^{(k)}$ in an eigenstate of the cluster Hamiltonian $\tilde{H}^{(k)}$ (or more precisely, in some linear combination of such molecular configurations)?

In the physical and mathematical literature, the scattering problem is known as the problem of "asymptotic completeness" or the "unitarity of the S-matrix." Much work has been done on this problem by many people over the years, including the time-independent approach of Faddeev and his school, leading up to the eventual resolution of the problem in 1987 by Israel Michael Sigal and Avy Soffer using time-dependent methods pioneered by Enss.

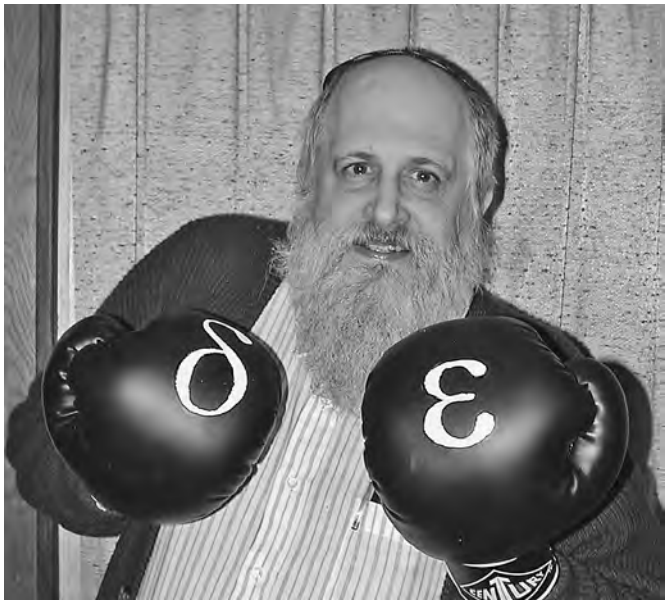
At the mathematical level, the first task in resolving the problem is to prove that such molecular states indeed exist. This boils down to proving that the so-called wave operators $W(H, H_c)$ exist, where H is again the Hamiltonian for the full system and H_c is the Hamiltonian for the molecular system corresponding to the cluster decomposition $C = \left\{C^{(1)}, \dots, C^{(m)}\right\}$. At the technical level this is a relatively easy thing to do. To prove asymptotic completeness, one must show that all states orthogonal to bound states of the full Hamiltonian H are in the linear span of these molecular wave operators $W(H, H_c)$. This is a range question, and range questions in mathematics are generically hard.

Barry is one of the most prolific mathematicians of his generation

In 1978, together with Deift, Simon introduced a new class of wave operators, $W(H_c, J_c, H)$, and showed that asymptotic completeness was equivalent to proving the existence of these wave operators. Here J_c is an auxiliary function reflecting the geometry of the cluster decomposition C. In this way the problem of asymptotic completeness was transformed from a range problem to a potentially simpler existence problem, and this is the path that Sigal and Soffer eventually followed in their resolution of asymptotic completeness. As the ranges of the wave operators $W(H, H_c)$ lie in the absolutely continuous space of H, a key ingredient in proving asymptotic completeness was to show that the singular continuous space for H was trivial. This key component was established by Barry Simon, together with Peter Perry and Israel Michael Sigal, in seminal work in 1980 using remarkable ideas of Eric Mourre [2].

On a Personal Note

Barry is one of the most prolific mathematicians of his generation. It was in the late 1970s, around the time that we were working on nonisotropic bounds for eigenfunctions, that I got a glimpse of the speed with which Barry did things. Soon after Volker Enss introduced his seminal time-dependent ideas on spectral theory and scattering theory, a few of us went to Barry's house in Edison, New Jersey, to discuss a potential project inspired by Enss's work. We spent the afternoon laying out in detail a list of problems that needed to be addressed and left in the late afternoon. The next morning Barry came



From about 1995 to 2000, Barry taught the first term of Caltech's required freshman calculus, where he declared that "epsilon and delta are a calculus student's finest weapons." One year, on the last day, the students presented him with the boxing gloves shown.

into the office: Not only had he solved all the problems on our list, but he had in his hand the first draft of his subsequent paper [3]! We were overwhelmed. For a young person like me, this was most discouraging. And I was doubly discouraged: Barry was younger than I was!

Barry has many fine qualities as a colleague and as a researcher, but I would like to focus on just one of them, viz., Barry's keen sense of fairness and correct attribution of results. People in orthogonal polynomials know well Barry's insistence on calling the recurrence coefficients for orthogonal polynomials on the circle Verblunsky coefficients, in recognition of the almost forgotten seminal work of Samuel Verblunsky. But I would like to tell a different story. In the early 1980s Barry was in Australia, where he met up with Michael Berry, who was also visiting. Berry began telling Barry about some curious and puzzling calculations he had been making in quantum adiabatic theory. Barry immediately understood that what was really going on was a matter of holonomy, and with characteristic speed he wrote and sent off a paper to *Physical Review Letters*, pointedly titled "Holonomy, the Quantum Adiabatic Theorem, and Berry's phase." In this way, a major discovery that could quite easily have become known as "Barry's phase" was fixed in the literature as "Berry's phase," and justly so.

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Lon Rosen

Barry and I were both young pups when we collaborated in the 1970s. It was an intense and exciting experience for me, one which I cherish and now take pleasure in recalling for you. Warning: these personal recollections have no scientific content. If that's what you're looking for, please see my contribution to the *Festschrift in honor of Barry Simon's sixtieth birthday*.

I must confess that my first meeting with Barry was far from auspicious. In 1967 I was in my first year of doctoral studies at the Courant Institute. Feeling isolated, I was reconsidering my decision not to have chosen Princeton for graduate school. I asked a friend to arrange a lunch meeting for me with a typical student of Arthur Wightman's. I knew little about the "typical student" who was chosen (Barry Simon), although I was familiar with his name because Barry and I had both been Putnam Fellows in the 1965 competition.

Some typical student! He practically tore my head off. Whatever I said about my interests or ideas, Barry would trump it. I'd never met anyone else with such extensive knowledge, amazing recall, and proofs at the ready. I still haven't. Thanks to Barry, I stayed put at Courant. Fortunately, James Glimm, who was to be my terrific thesis advisor, soon joined the faculty there. I learned later that Barry had been going through a rough patch in his personal and professional life around the time we met and that the fire-breathing dragon who had me for

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Barry and Martha Simon, LMU Munich, 2014.

lunch was actually a gentle prince in disguise, if I may be permitted a fairy tale metaphor.

Three years later I gave a seminar at Princeton on the subject of higher-order estimates for the $P(\phi)_2$ model. At the conclusion of the seminar Barry showed me a clever bootstrap trick that quickly established my most difficult estimate—or at least a weaker but perfectly acceptable version of it. I was grateful and revised the published paper accordingly.

This experience was not unique to me. As many speakers know, Barry's rapid-strike ability could be unnerving at seminars. He would sit front row centre, working on a paper, only to surface with astute observations, counterexamples, or shorter proofs. This penchant for "tricks" arises, it seems to me, from Barry's imperative to understand everything in the simplest possible way.

Barry's imperative to understand everything in the simplest possible way

Barry and I both attended the Les Houches Summer School of 1970. It was there that I gained an appreciation for Barry's sense of humour. In particular, we had a lot of fun putting on a skit which satirized the lecturing styles and idiosyncrasies of the various celebrated speakers. For example, when Barry began an impersonation by first breaking a half dozen chalk sticks into small pieces, everyone roared, knowing that "Arthur Jaffe" was about to deliver his next lecture.

Sometimes the humour was (possibly) unintentional. Here's a little story which Ed Nelson told me. Barry had returned from a trip to the former Soviet Union, where he had great difficulty in arranging for kosher food. It was apparently necessary for him to haul a suitcase filled with edibles. "Oh well," sighed Barry, "I guess everyone has his cross to bear."

He would often come in with a twinkle in his eye

In 1971 when I joined Barry in Princeton, we began our joint research by working on what I would call "incremental stuff using available techniques," things like coupling constant analyticity of the $P(\phi)_2$ Hamiltonian. One day Arthur Wightman called us together for a presentation by a quiet visitor from Italy, Francesco Guerra, whom I barely knew. Francesco proceeded to the chalkboard and made some extraordinary claims about the vacuum energy density in the $P(\phi)_2$ model. Barry and I gave each other a sideways look as if to say, "he's got to be kidding." He wasn't! Francesco's short proofs were stunning. The irony was not lost on us that they were based on the Euclidean approach of Ed Nelson of Princeton University. In any case, that was the moment that the Euclidean Revolution began for Barry and me. The three of us (GRS) entered a long and fruitful collaboration exploring and exploiting the parallels between the $P(\phi)_2$ field theory model and classical statistical mechanics. As usual, Barry snatched up the new ideas like a dog with a bone.

Barry Simon in Bangkok (ca. 2003).

During the GRS period, Barry had numerous other projects on the go, such as his research in mathematical quantum mechanics and the Reed-Simon magnum opus. Thank goodness he was devoting only a fraction of his time to GRS, whereas I was on it full time. Otherwise, I would never have been able to keep up with him and contribute my fair share. Barry's joy in doing research was infectious. He would often come in with a twinkle in his eye and say something like, "While I was standing in the supermarket line, look what I discovered!" Barry was always appreciative of my efforts and extremely generous to others. I learned a tremendous amount from him both directly during our collaboration and in subsequent years from his prodigious published output.

Jürg Fröhlich

Barry Simon and Statistical Mechanics

Well, this is about my mentor and friend Barry Simon! I first met Barry at a summer school on constructive quantum field theory and statistical mechanics at Les Houches, France, in 1970. We were only twenty-four years old at the time, and I had just started my life as a PhD student of Klaus Hepp, while Barry, a former PhD student of the late Arthur S. Wightman, was already a "Herr Doktor" and—if my memory is correct—an assistant professor at Princeton University. As I wrote on the occasion of his sixtieth birthday celebrations [1], Barry would usually beat me in almost everything! To start with, he was born two and a half months before me.

At Les Houches, the late Oscar E. Lanford III lectured on general functional analysis, including measure theory

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and the theory of operator algebras, tools rightly thought to be essential to understanding quantum theory and statistical mechanics. Besides Barry and me, Alain Connes was a student at that school. Barry and Alain were soon engaged in a competition to simplify Oscar's proofs; Barry would usually win—not only in mathematics but also in the consumption of food.

Our common mentor and friend, the late Edward Nelson, wrote about Barry [1]: "In the late 1960s, Barry was a graduate student in physics at Princeton and attended some courses I taught. I soon learned that I did not need to prepare with great thoroughness; it was enough to get things approximately right and Barry from where he was sitting would tell us how to get them precisely right. I miss Barry." Well, Barry and I miss Ed!

My next encounter with Barry was in 1972 when he taught a graduate course on quantum field theory in the "3ième cycle" of French-speaking Switzerland. That course was the basis for his $P(\phi)_2$-book, which is still remembered in the community. This is perhaps because it contains those famous "Fröhlich bounds" or, more likely, because it is written in a very pedagogical manner—indeed, one of Barry's outstanding strengths was and still is to being able to write mathematical prose in a very clear, pedagogical style.

In the fall of 1974 I accepted the offer of an assistant professorship at the mathematics department of Princeton University which had been prepared by Arthur Wightman and Barry Simon. Major benefits of having had Barry as a colleague were that I never had to submit a grant proposal to the NSF; Barry's proposal not only covered his own needs but also the ones of the late Valja Bargmann and me, and should one successfully collaborate with him, he would always write the paper (except for appendices on tedious technicalities, such as cluster expansions, which he gracefully assigned to his collaborators).

Barry needed only roughly 5 percent of the time ordinary mortals need to write a paper

Barry needed only roughly 5 percent of the time ordinary mortals need to write a paper. He did his writing while listening to seminar talks. Although he appeared to be absorbed in his activity (carried out by moving his left hand along rather peculiar trajectories), he would nevertheless be able to point out errors to the lecturer or ask relevant questions at the end. Barry was simply brilliant in "multitasking."

Let me briefly describe two of our joint papers. The first one is entitled "Pure states for general $P(\phi)_2$-theories: Construction, regularity and variational equality" and was published in the *Annals of Mathematics* in 1977. In this paper, ideas and concepts from classical statistical mechanics were transferred to Euclidean field theory with the purpose of learning something new about the latter. General concepts were illustrated on simple examples of Euclidean field theory in two dimensions, which, mathematically, may be defined as generalized stochastic processes—more precisely, Markovian random fields—over $\mathbb{R}^2$ constructed as perturbations of Gaussian processes by local multiplicative functionals. From such processes interacting scalar quantum field theories on two-dimensional Minkowski space can be reconstructed, furnishing examples of what has become known as constructive quantum field theory. CQFT was first advocated by Arthur Wightman in the early 1960s with the purpose of showing that quantum theory and the special theory of relativity are compatible with each other, and was subsequently pursued by Edward Nelson, James Glimm, Arthur Jaffe, and their followers.

The modern mathematically rigorous approach to statistical mechanics was developed by, among many other people, Roland L. Dobrushin, Oscar E. Lanford, and, most importantly, David Ruelle. Our paper is unthinkable without their work and without the discoveries of K. Symanzik, E. Nelson, F. Guerra, L. Rosen, and B. Simon in Euclidean field theory, some of whose works are classics. They had shown that in the Euclidean region (time purely imaginary) of complexified Minkowski space, a quantum field theory of Bose fields looks like a model of classical statistical mechanics. In my paper with Barry this fact is exploited in an essential way.

We were to "win the jackpot" with the paper "Infrared bounds, phase transitions and continuous symmetry breaking," which was the result of joint work with our friend Tom Spencer and was published in *Communications in Mathematical Physics* in 1976.[1] Barry, Tom, and I decided to attempt to understand phase transitions accompanied by the spontaneous breaking of continuous symmetries and long-range correlations (i.e., a divergent correlation length), in models of classical lattice spin systems and lattice gases. We exploited ideas from quantum field theory; in particular, we discovered an analogue of the so-called Källen-Lehmann spectral representation of two-point correlation functions in quantum field theory. For this representation to hold true it is necessary that the model under scrutiny satisfy the *Osterwalder-Schrader positivity*, also called *reflection positivity*, a property originating in axiomatic quantum field theory (as described in well-known books by Streater and Wightman and by Jost).

Here is an example: With each site x of the lattice $\mathbb{Z}^d$ we associate a random variable $\vec{S}_x \in \mathbb{R}^N$, a classical "spin," whose a priori distribution is given by a probability measure, $d\mu(\cdot)$ on $\mathbb{R}^N$, invariant under rotations of $\mathbb{R}^N$; for instance,

$$d\mu(\vec{S}) = \text{const.}\ \delta(|\vec{S}|^2 - 1)d^N S. \tag{4}$$

Let Λ be a finite cube in $\mathbb{Z}^d$. The energy of a configuration, $\vec{S}_\Lambda := \{\vec{S}_x\}_{x\in\Lambda}$, of "spins" is given by a functional (called "Hamiltonian"),

$$H(\vec{S}_\Lambda) := -\sum_{x,y\in\Lambda} J(x-y)\vec{S}_x \cdot \vec{S}_y. \tag{5}$$

[1] *At the beginning of my career I was privileged to have several mentors, among whom Tom was undoubtedly the most important one!*

Birmingham, AL, Meeting on Differential Equations, 1983. Back row: Fröhlich, Yajima, Simon, Temam, Enss, Kato, Schechter, Brezis, Carroll, Rabinowitz. Front row: Crandall, Ekeland, Agmon, Morawetz, Smoller, Lieb, Lax.

Here $J(x)$ is a function in $\ell_1(\mathbb{Z}^d)$ assumed to be *reflection-positive* and invariant under permutations of lattice directions. By a theorem of Bochner, these properties imply that it has an integral representation,

$$J(x_1,\vec{x}) = \int_{-1}^{1} \lambda^{|x_1|-1} e^{i\vec{k}\cdot\vec{x}} d\rho(\lambda,\vec{k}), \quad x_1 \neq 0, \tag{6}$$

with $\vec{x} = (x_2,\dots,x_d)$, where $d\rho(\lambda,\vec{k})$ is a positive measure on $[-1,1]\times\mathbb{T}^{d-1}$, for example, $J(x) = \delta_{|x|,1}$. In (5) we impose periodic boundary conditions at the boundary of Λ. The distribution of configurations $\vec{S}_\Lambda$ of "spins" in thermal equilibrium at inverse temperature β is given by the Gibbs measure

$$dP_\beta(\vec{S}_\Lambda) := Z_{\beta,\Lambda}^{-1} exp[-\beta H(\vec{S}_\Lambda)] \prod_{x\in\Lambda} d\mu(\vec{S}_x), \tag{7}$$

where $Z_{\beta,\Lambda}$ is a normalization factor (called "partition function"). Let $\langle\cdot\rangle_{\beta,\Lambda}$ denote an expectation with respect to dP_β. For "wave vectors" k in the lattice dual to Λ, we define $\omega_{\beta,\Lambda}(k)$ to be the Fourier transform of the correlation function $\langle\vec{S}_0\cdot\vec{S}_x\rangle_{\beta,\Lambda}$, $0, x\in\Lambda$.

Simon, Spencer, and I proved that

$$0 \le \omega_{\beta,\Lambda}(k) \le \frac{N}{2\beta(\hat{J}(0)-\hat{J}(k))} \quad \text{for } k\neq 0, \forall\beta, \tag{8}$$

where $\hat{J}(k)$ is the Fourier transform of $J(x)$, $x\in\Lambda$. This so-called "infrared bound" is inspired by the Källen-Lehmann representation of two-point functions in canonical relativistic quantum field theory. The realization that (6) implies the upper bound in (8) is the basic result in our work. It is then an exercise to show that if the "coupling function" $J(\cdot)$ is such that

$$|\Lambda|^{-1}\sum_{k\neq 0}[\hat{J}(0)-\hat{J}(k)]^{-1} \le \text{const.}, \tag{9}$$

uniformly in Λ, then in the thermodynamic limit $\Lambda \nearrow \mathbb{Z}^d$, phases with broken $O(N)$-symmetry coexist and are permuted among themselves under the action of the symmetry group $O(N)$, provided β is large enough. (By (4), $\langle|\vec{S}_0|^2\rangle_{\beta,\Lambda} = 1$; this and (8), (9) imply that the weight of the mode at $k=0$ in $\omega_{\beta,\Lambda}(k)$ is $\propto|\Lambda|$.) For small β, however, the Gibbs state is well known to be *unique*.

It turns out that the bound (8) has many further applications. It is an important ingredient in a beautiful analysis of critical behavior in the Ising model (by Aizenman, Duminil-Copin, and Sidoravicius) and in showing that the large-distance scaling limit of the nearest-neighbor Ising and the classical XY-model is *Gaussian* in dimension $d>4$ ("triviality of $\lambda\phi_d^4$-theory" in $d\ge 4$ dimensions); see [2], [3].

In 1980 Barry proved a correlation inequality, sometimes referred to as the "Simon-Lieb inequality," useful to establish decay of correlations in models of classical ferromagnetic lattice spin systems, e.g., the one sketched above with $N=1$ or 2. Two years later, the basic idea expressed in his inequality became a very useful ingredient in the analysis of multiscale problems, such as Anderson localization (as in work by Tom Spencer and me).

To conclude, let me draw the reader's attention to Barry Simon's book *The Statistical Mechanics of Lattice Gases*.

References

[1] math.caltech.edu/SimonFest/stories.html

[2] M. Aizenman, Geometric analysis of ϕ^4-fields and Ising models, *Commun. Math. Phys.* **86** (1982), 1–48.

[3] J. Fröhlich, On the triviality of $\lambda\phi_d^4$-theories and the approach to the critical point in $d\ge 4$ dimensions, *Nucl. Phys. B* **200** (1982), 281–296.

Mike Reed

On Barry Simon

When people ask, "How long did it take for you and Barry Simon to write those four volumes of *Methods of Modern Mathematical Physics*?" I usually say, "About ten years," since we started in the late 1960s when Barry was a graduate student and I was a lecturer at Princeton, and we finished in the late 1970s. Writing those books took 50 percent of my research time for ten years but only 10 percent of Barry's research time, and that wasn't because I contributed more—far from it. The reason is that no one works faster than Barry. He instantly sees the the significance of new ideas (whether in mathematics or physics), understands the technical structures necessary to bring the ideas to fruition, and immediately starts writing.

Barry's legendary speed sometimes got him into trouble. I remember going to seminars at Princeton with Barry carrying new preprints from more senior mathematicians. As the seminar proceeded, Barry would read the preprint, absorb the idea, understand the correct machinery to prove a stronger result, and begin writing. No one is more generous than Barry at giving credit to others; he always does and did. Nevertheless, when Barry's paper with a stronger result and a better proof would appear before

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Barry Simon and Michael Reed, Durham, NC, 2007.

the original result, the preprint's author would sometimes have hard feelings. These feelings would usually dissipate when he or she actually met Barry and discovered how open and generous he is.

We wrote the books because we saw that the physics of quantum mechanics and quantum field theory raised deep and interesting analysis questions. Of course our ancestors knew this too. But we saw how hard it was for mathematicians to understand the issues and fully engage because it was so difficult to read the physics literature and translate the ideas and computations into mathematical questions. Originally, we were going to write one small volume that would give the functional analysis background followed by short chapters introducing mathematicians to problems in modern physics. But we were driven by Barry's deep knowledge and intuition about physics and our shared enthusiasm to do and say more, and the result is the four volumes that we wrote.

We had a terrific time! This was long ago, so our handwritten manuscripts were typed. Then we would take the typed manuscript, usually 500–700 pages, and read it aloud. This was the only way to go slowly enough to check the English, the mathematics, and the physics. One would read, both would think, and the other would write down corrections. Typically it took three weeks full time to read a manuscript. For a couple of them, I lived with Barry. We'd get up in the morning, get to work, and give up when we were tired in the evening. We were blessed by the tolerance and good cooking of Barry's wife, Martha. It was very rare that we'd be irritated or angry at each other, because we both have strong personalities that are not easily troubled and we were completely focused on the mathematics and the science. We did all the problems in all the volumes, except the starred ones that we sure were correct but couldn't immediately see how to do.

He respects others, whatever their talent, whatever their station in life

Of course, we were pleased and proud that so many colleagues and students found our books useful. We both still teach out of them and field email questions about the problems. Since we were so young when they were written, we got lots of funny remarks at conferences from mathematicians who didn't know us, such as, "You can't be the Simon who wrote those books; you're too young," and, "Hah! I always thought that Reed was Simon's first name."

There are lots of things to celebrate about Barry Simon: his stupendous achievements, his many students, his sense of humor, his generosity to colleagues. I celebrate his deep sense of common humanity with other human beings. He respects others, whatever their talent, whatever their station in life, and this sense of common humanity makes him very special.

This article will continue next month with contributions by S. Jitomirskaya, Y. Avron, D. Damanik, J. Breuer, Y. Last, and A. Martinez-Finkelshtein.

The Leroy P. Steele Lifetime Achievement

2016 Barry Simon
2015 Victor Kac
2014 Phillip A. Griffiths
2013 Yakov G. Sinai
2012 Ivo M. Babuška
2011 John W. Milnor
2010 William Fulton
2009 Luis Caffarelli
2008 George Lusztig
2007 Henry P. McKean
2006 Frederick W. Gehring, Dennis P. Sullivan
2005 Israel M. Gelfand
2004 Cathleen Synge Morawetz
2003 Ronald Graham, Victor Guillemin
2002 Michael Artin, Elias Stein
2001 Harry Kesten
2000 Isadore M. Singer
1999 Richard V. Kadison
1998 Nathan Jacobson
1997 Ralph S. Phillips
1996 Goro Shimura
1995 John T. Tate
1994 Louis Nirenberg
1993 Eugene B. Dynkin

Barry Simon's Students at Princeton

Anthony O'Connor, 1972
Jay Rosen, 1974
Robert Israel, 1975
Percy Deift, 1976
Evans Harrell II, 1976
George Hagedorn, 1978
Mark Ashbaugh, 1980
Antti Kupiainen, 1980
Steven Levin, 1980
Peter Perry, 1981
Keith Miller, 1982

Barry Simon's Students at the California Institute of Technology

Byron Siu, 1984
Nestor Caticha Alfonso, 1985
Barton Huxtable, 1987
Kristiana Odencrantz, 1987
Clemens Glaffig, 1988
Askell Hardarson, 1988
John Lindner, 1989
Vojkan Jaksic, 1992
Yunfeng Zhu, 1996
Alexander Kiselev, 1997
Andrei Khodakovsky, 1999
Rowan Killip, 2000
Andrej Zlatos, 2003
Irina Nenciu, 2005
Mihai Stoiciu, 2005
Manwah Wong, 2009
Rostyslav Kozhan, 2010
Anna Maltsev, 2010
Milivoje Lukic, 2011
Brian Zachary Simanek, 2012

Credits

p. 740 Childhood photo of Simon with family, courtesy of Barry Simon.
p. 741 Photo of Simon receiving his honorary doctorate, photographer Heinrich Steinlein. Used with permission.
p. 742 Photo of Simon's books, courtesy of Barry Simon.
p. 743 Photo of Sadun, Avron, Harrell, and Simon, courtesy of Evans Harrell.
p. 743. The Stark Effect, used with permission of The American Physical Society.
p. 744 Photo of Simon's coauthors, courtesy of The California Institute of Technology.
p. 745 Photo of Simon's students, courtesy of The California Institute of Technology.
p. 746 Photo of 2006 SimonFest, courtesy of The California Institute of Technology.
p. 747 Photo of Simon in boxing gloves, courtesy of Barry Simon.
p. 747 Photo of Barry and Martha Simon, photographer Heinrich Steinlein. Used with permission.
p. 748 Photo of Simon in Bangkok, courtesy of Barry Simon.
p. 750 Photo of Birmingham Meeting on Differential Equations, courtesy of Barry Simon.
p. 751 Photo of Simon and Reed, courtesy of Barry Simon.

CALL FOR NOMINATIONS

AWM–AMS Noether Lecture

The Association for Women in Mathematics (AWM) established the Emmy Noether Lectures in 1980 to honor women who have made fundamental and sustained contributions to the mathematical sciences. In April 2013, this one-hour expository lecture was renamed AWM–AMS Noether Lecture. The first jointly sponsored lecture was held in January 2015 at the Joint Mathematics Meetings (JMM) in San Antonio, Texas. Emmy Noether was one of the great mathematicians of her time, someone who worked and struggled for what she loved and believed in. Her life and work remain a tremendous inspiration.

The mathematicians who have given the Noether Lectures in the recent past include: Karen Smith, Wen-Ching Winnie Li, Georgia Benkart, Raman Parimala, Barbara Keyfitz, Susan Montgomery. Additional past Noether lecturers can be found at **https://sites.google.com/site/awmmath/programs/noether-lectures/noether-lecturers**.

The letter of nomination should include a one-page outline of the nominee's contribution to mathematics, giving four of her most important papers and other relevant information. Nominations must be submitted by October 15, 2016 and will be held active for three years.

The nomination procedure is described here: **https://www.sites.google.com/site/awmmath/programs/noether-lectures.**

If you have questions, call 703-934-0163 or email awm@awm-math.org.

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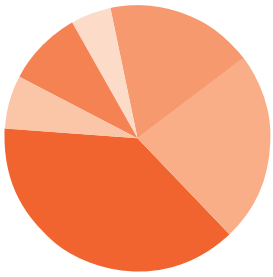


Report on the 2014–2015 New Doctoral Recipients

William Yslas Vélez, Thomas H. Barr and Colleen A. Rose

This report presents a 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 through June 30, 2015. Information in this report was provided by 312 of the 318 doctoral-granting departments surveyed, with additional information provided by the individual new doctoral recipients. The report includes an analysis of the fall 2015 employment plans of 2014–15 doctoral recipients and a demographic profile summarizing characteristics of their citizenship status, gender, and racial/ethnic group.

Detailed information, including tables which traditionally appeared in this report, is available on the AMS website at `www.ams.org/annual-survey/survey-reports`.

Doctoral Degrees Awarded

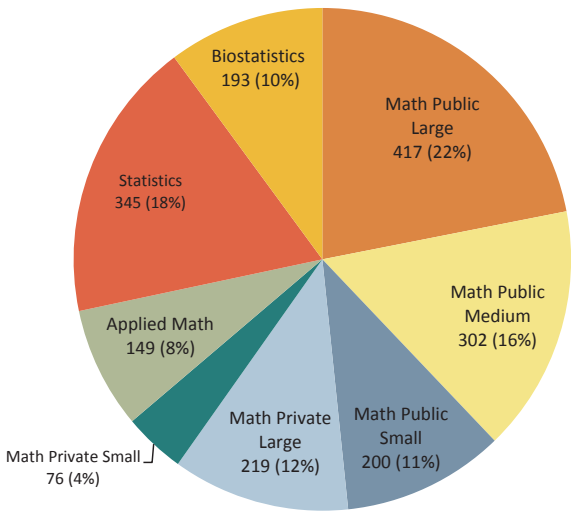
In mathematical sciences 1,901 PhDs were awarded by 286 doctoral-granting departments; 26 departments awarded no doctoral degrees. This year's count represents the first decline in the number of PhDs awarded since 2001–02.

The highest percentage, 34% (652) of the new PhDs had a dissertation in statistics/biostatistics, followed by algebra/number theory with 14% (268) and applied mathematics with 12% (221).

Comparing PhDs awarded in 2014–15 to 2013–14 the number of PhDs awarded:

- Decreased about 1% from 1,926 to 1,901. Of the 286 departments that responded both this year and last year the number of PhDs awarded decreased to 1,863 from 1,925
- Decreased in all groups except Math Public Large, Math Public Small, and Biostatistics
- Decreased 19% in Math Private Small and 14% in Applied Math
- Increased 5% in Math Public Large and 19% in Biostatistics
- Math Public Small awarded the same number of PhDs as last year

Figure A.1: Number and Percentage of Degrees Awarded by Department Grouping*

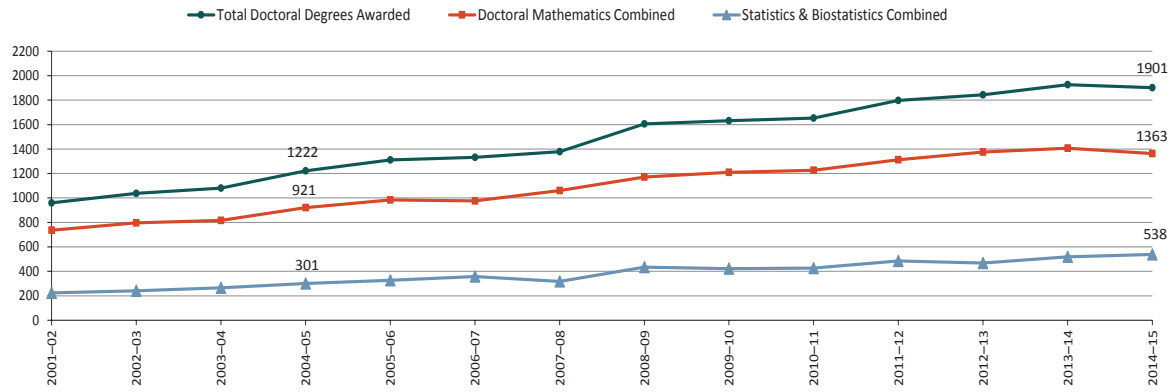


Total Degrees Awarded: 1,901

*See page 765 for a description of the department groupings.

William Yslas Vélez is a professor in the Department of Mathematics at University of Arizona. Thomas H. Barr is AMS special projects officer. Colleen A. Rose is AMS survey analyst.

Figure A.2: New PhDs Awarded by Group



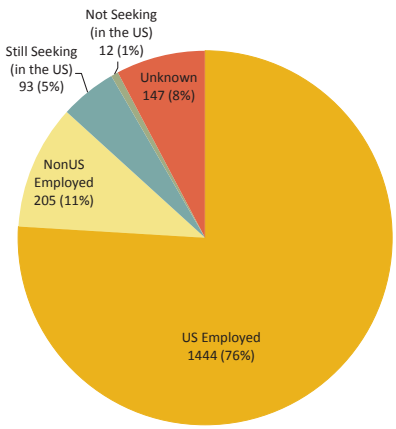
Comparing PhDs awarded in 2014–15 with those awarded in 2004–05:

- PhDs awarded have increased more than 56% over the last 10 years.
- Degrees awarded by Doctoral Math and by Statistics/Biostatistics combined have increased 48% and 79%, respectively.

Employment

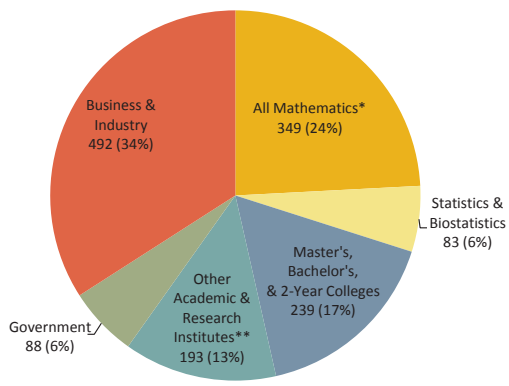
The overall US unemployment rate for the new doctoral recipients is 6.1%, essentially the same as the 2013–14 rate. (Details on the calculations are on page 764.) The employment plans are known for 1,754 of the 1,901 new doctoral recipients. The number of new doctoral recipients employed in the US is 1,444, up 2% from last year's number of 1,412. Among those new PhDs employed in Doctoral Math departments, 75% are in postdoc positions, up from 71% last year. The number of new PhDs taking positions in Business & Industry has increased to 492 this year compared to 409 last year. All groups except Math Public Small showed an increase in Business & Industry, and 43% of the increase was accounted for by the Math Public Large Group.

Figure E.1: Employment Status



- 50% (726) of those who are employed in the US are US citizens, down from 53% last year.
- 78% (718) of non-US citizens whose employment status is known are employed in the US, the remaining 208 non-US citizens are either employed outside of the US or are unemployed.
- 9% (141) of the new PhDs who are employed are working at the institution that granted their degree, up from 8% last year. These individuals constitute 16% of total US academic employed.
- 56% of those still seeking employment in the US are US citizens.

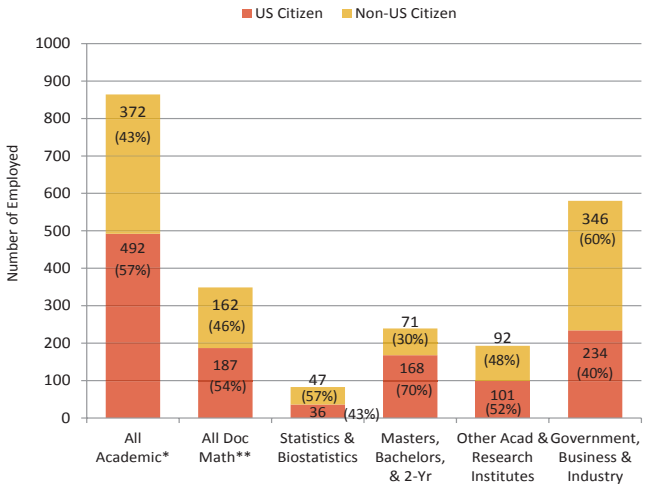
Figure E.2: US Employed by Type of Employer



*Includes all Math Public, Math Private, and Applied Math departments.
**Other Academic consists of departments outside the mathematical sciences including numerous medical-related units.

- US academic hiring decreased 7% to 864 compared to 926 last year.
- Government hiring increased 14% (from 77 to 88); all doctoral-granting groups except Math Public Large, Math Private Large, and Applied Math showed an increase in the number of PhDs taking positions in this sector.

Figure E.3: Employment in the US by Type of Employer and Citizenship Total: 1,444

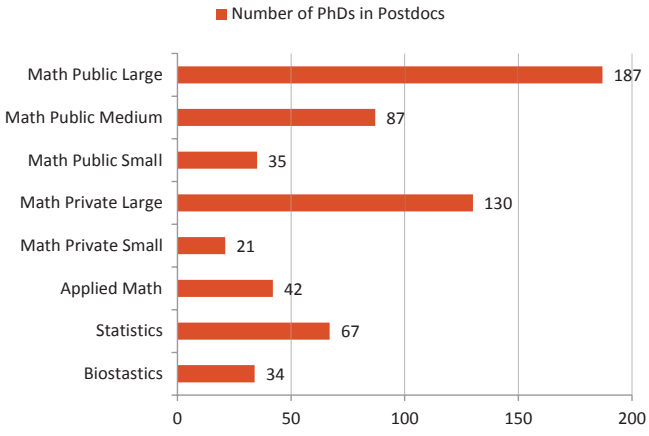


* Includes all Math sciences departments plus other academic and research institutes/nonprofit.
**Includes all Math Public, Math Private, and Applied Math departments.

Of the US citizens whose employment status is known, 88% (726) are employed in the US, and of these:

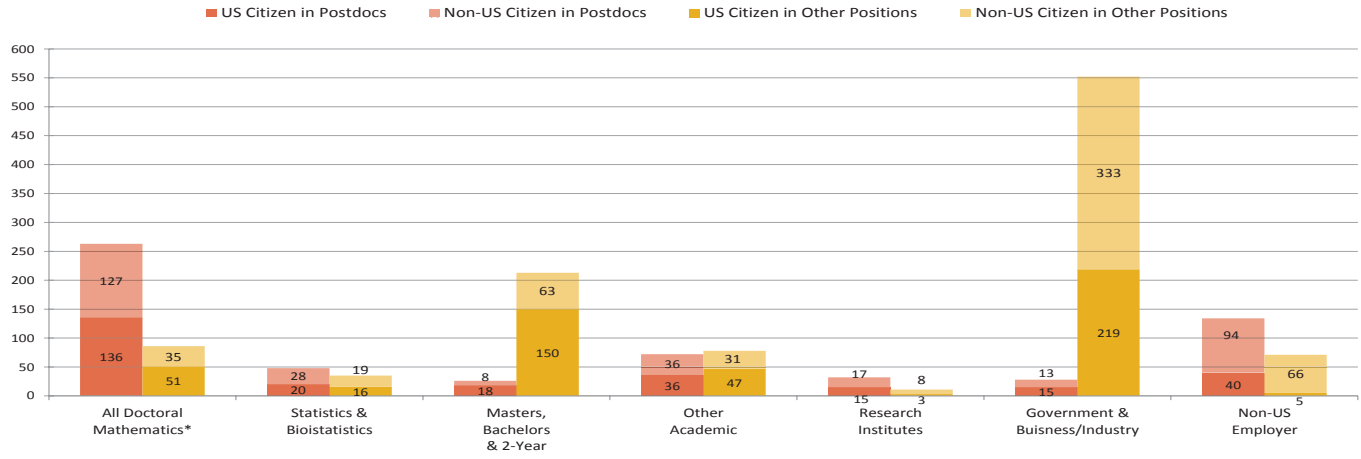
- 31% are employed in PhD-granting departments
- 37% are employed in all other academic categories
- 32% are employed in government, business and industry

Figure E.4: PhDs Employed in Postdocs by Degree-Granting Department Group



- Total known to be employed: 1,649
- 37% (603) of the new PhDs that are employed are reported to be in postdoc positions, down slightly from 626 in 2013–14.
- 59% of the new PhDs awarded by the Math Private Large group are employed in postdocs, while only 18% of new PhDs awarded by the Math Public Small group and 18% of PhDs awarded by the Biostatistics group are in postdocs.
- 51% of the new PhDs having US academic employment are in postdocs, up from 48% last year.

Figure E.5: New PhDs Employment by Citizenship, Type of Position and Type of Employer



*Includes all Math Public, Math Private, and Applied Math departments.

- 22% of the new PhDs in postdoc positions are employed outside the US; last year, this percentage was 24%.
- 75% of the new PhDs employed in Doctoral Math departments are in postdoc positions, up from 71% last year.

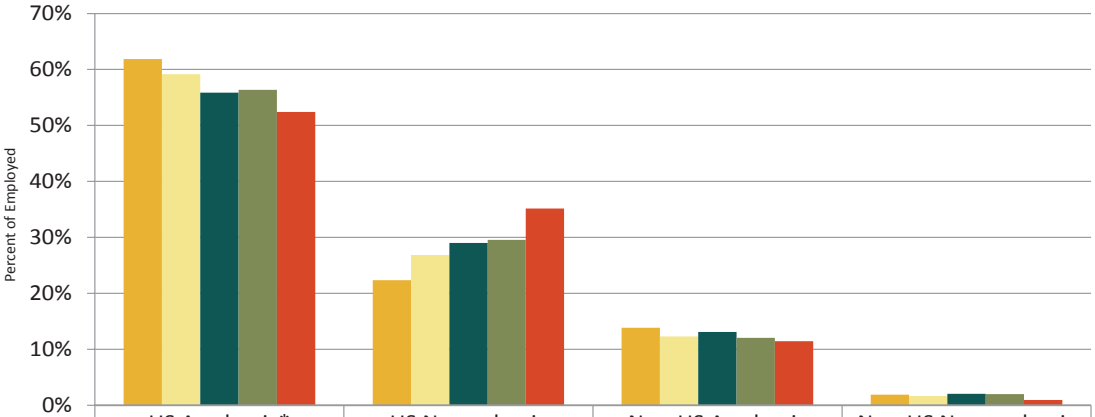
Figure E.6 displays the US unemployment rate for new doctorates; details on the calculations are on page 764

Figure E.6: Percentage of New Doctoral Recipents Unemployed 2006–15*

Among new doctorates reported to be in the US and whose employment status is known:

- Overall unemployment is 6.5%.
- 6.7% of US citizens are unemployed, compared to 7.2% in fall 2014.
- 5.4% of non-US citizens are unemployed, compared to 4.9% in fall 2014.
- New doctorates from the Math Public Small Group reported the highest unemployment rate at 13.1%, up from 5.3% last year.
- New doctorates from the Biostatistics Group reported the lowest unemployment at 1.9%.

Figure E.7: Percentage of Employed New PhDs by Type of Employer



	US Academic*	US Noncademic	Non-US Academic	Non-US Nonacademic
Fall 2011	62%	22%	14%	2%
Fall 2012	59%	27%	12%	2%
Fall 2013	56%	29%	13%	2%
Fall 2014	56%	30%	12%	2%
Fall 2015	52%	35%	11%	1%

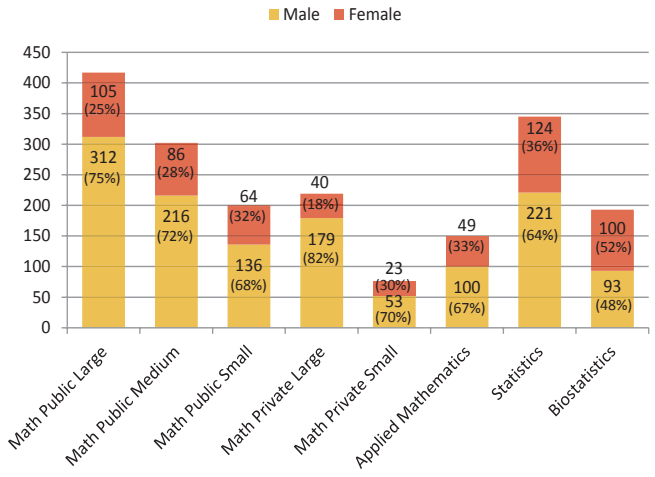
* Includes other academic departments and research institutes/other non-profits.

- US nonacademic hiring has jumped to 35% (a five-year high), while US academic hiring continues to decrease, dropping to 52% (a five-year low).
- Detailed information on new PhDs employed in the US by degree-granting department group is available on the AMS website at `www.ams.org/annual-survey`.

Demographics

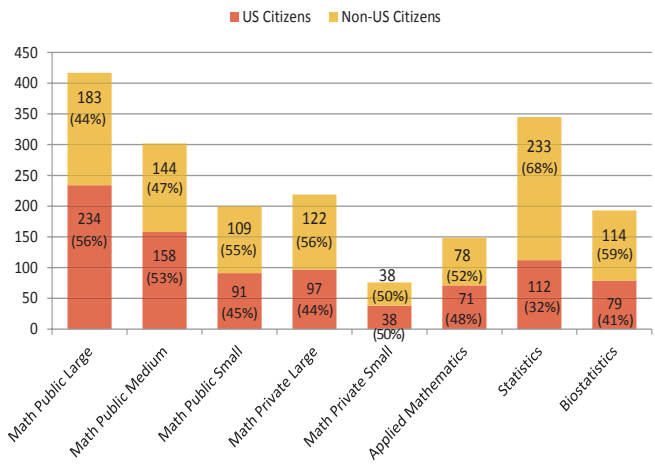
Gender and citizenship was known for all 1,901 new PhDs reported for 2014–15. The percentage of US citizens is 46%, down from 48% last year. Females accounted for 31% of the US citizen total, up from 28% last year. Non-US citizens receiving a PhD increased to 54% from 52% last year. 9% (64) of the non-US citizens employed in the US have permanent visa status, down from 11% last year.

Figure D.1: Gender of Doctoral Recipients by Degree-Granting Grouping



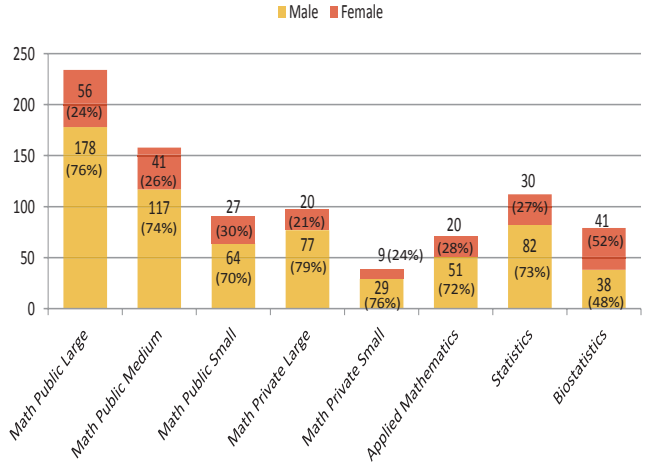
- Females account for 31% (591) of 1,901 PhDs, down from 32% last year.

Figure D.2: Citizenship of Doctoral Recipients by Degree-Granting Grouping



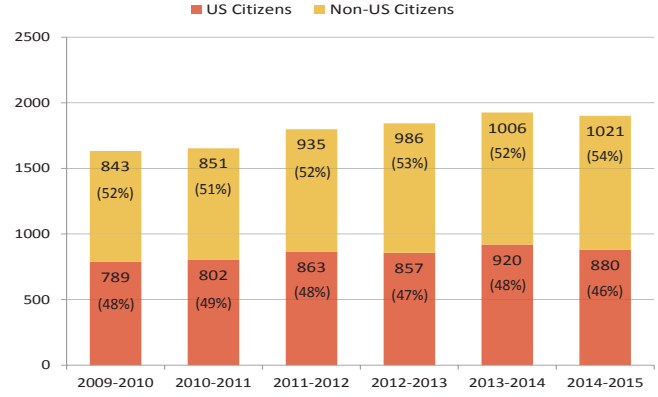
- 56% of all the PhDs awarded by the Math Public Large group were to US citizens, while only 33% of the PhDs awarded by the Statistics group were to US citizens.
- All groups except Math Public Large, Math Public Medium and Statistics awarded more PhDs to Non-US citizens than US citizens.

Figure D.3: Gender of US Citizen Doctoral Recipients by Degree-Granting Grouping



- 49% of the males and 41% of the females are US citizens.
- Females accounted for 28% of the US citizens.
- Among the US citizens: 4 are American Indian or Alaska Native, 65 are Asian, 20 are Black or African American, 26 are Hispanic or Latino, 6 are Native Hawaiian or Other Pacific Islander, 740 are White, and 19 are of unknown race/ethnicity.
- Math Public Large awarded the highest number (19) of PhDs to US citizen minorities, while Math Public Small awarded the smallest number (2), followed by Math Private Large with 3.

Figure D.4: Citizenship of New PhD Recipients, 2009–14



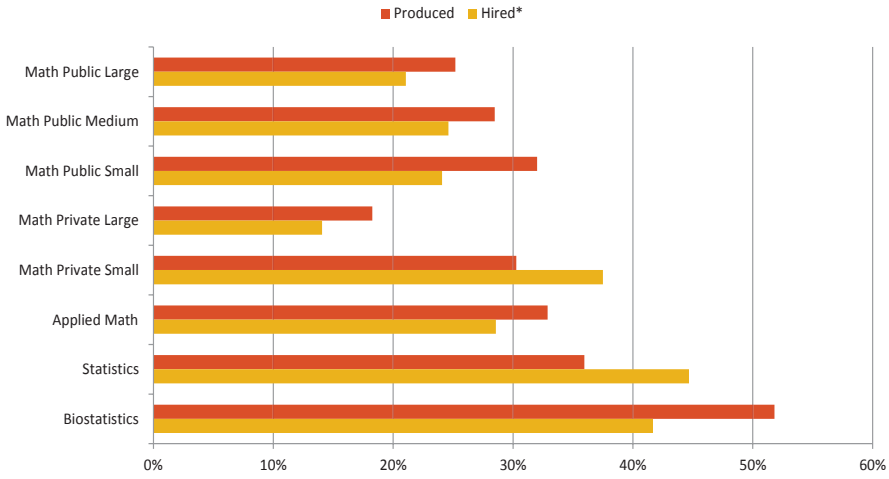
Looking at the last six years we see that:

- The proportion of PhDs awarded to US citizens is at a six-year low, 46% (880). While this is a 4% decrease from last year, it is a 12% increase from fall 2009–10.
- Non-US citizen counts continue to increase reaching a six-year high of 1,021. While this is a 21% increase from fall 2009–10, it represents a 1% increase from last year.

Female New Doctoral Recipients

After increasing last year to 32%, the proportion of female new doctoral recipients decreased to 31% this year. Of the 864 new PhDs hired into academic positions, 31% (268) were women, down from 32% last year. Twenty-five percent of those hired into postdoc positions were women, with 45% of the women in postdocs being US citizens, up from 43% last year. The US unemployment rate for females is 5.0%, compared to 6.6% for males and 6.1% overall.

Figure F.1: Females as a Percentage of New Doctoral Recipients Produced by and Hired by Department Grouping



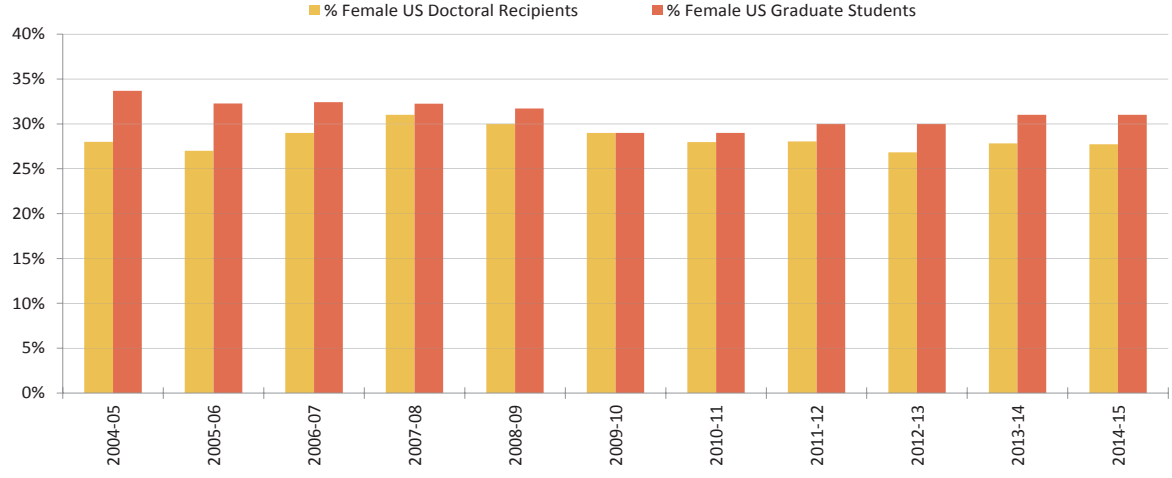
* Females as a percentage of total hires by the department grouping.

Table F.1: Number of Female New Doctoral Recipients Produced by and Hired by Department Groupings

Department Grouping	Females Produced	Females Hired
Math Public Large	105	24
Math Public Medium	86	16
Math Public Small	64	13
Math Private Large	40	9
Math Private Small	23	9
Applied Math	49	8
Statistics	124	21
Biostatistics	100	15
Total	**591**	**115**

- 42% of those hired by the Bachelor's Group were women (down from 44% last year) and 26% of those hired by the Master's Group were women (down from 34% last year).
- 26% of those hired into Research Institutes/Other non-profit positions were women (down from 33% last year).
- 42% of those hired into Government positions were women (up from 34% last year).
- 63% of the women employed in all doctoral groups are in postdoc positions, compared to 75% of males employed in these groups.

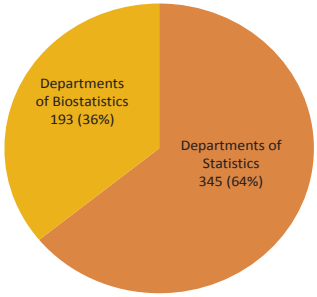
Figure F.2: Females as a Percentage of US Citizen Doctoral Recipients



PhDs Awarded by Statistics and Biostatistics Departments

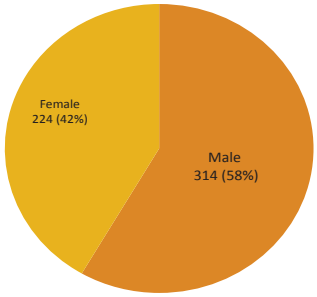
This section contains information about new doctoral recipients in 58 statistics and 47 biostatistics departments. Statistics and biostatistics departments produced 538 new doctorates, of which all had dissertations in statistics/biostatistics. This is a 4% increase in the number reported for fall 2014, which was 519. In addition, Math Public, Math Private and Applied Math departments combined had 113 PhD recipients with dissertations in statistics. 36% (191) of the new PhDs awarded by statistics and biostatistics departments are US citizens (while in the other groups combined, 51% are US citizens). The US unemployment among this group of new PhDs is 3.1%, up from 2.5%.

Figure S.1: PhDs Awarded by Statistics/Biostatistics Departments



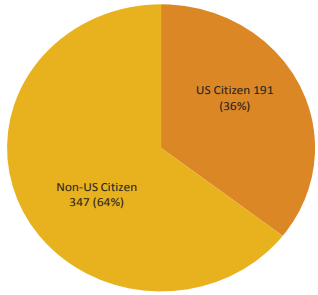
- 28% of all mathematical sciences PhDs awarded were in statistics/biostatistics.
- Females account for 36% of statistics and 52% of biostatistics PhDs awarded.

Figure S.2: Gender of PhD Recipients from Statistics/Biostatistics Departments



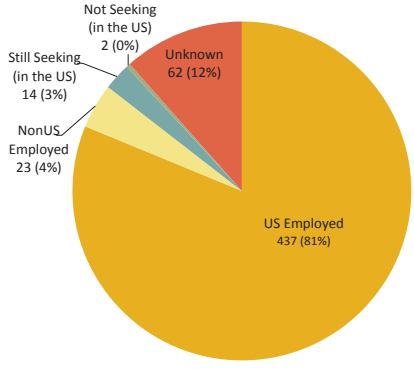
- Females accounted for 42% of the 538 PhDs in Statistics and Biostatistics, compared to Doctoral Math, where 27% are female.

Figure S.3: Citizenship of PhD Recipients from Statistics/Biostatistics Departments



- 37% of Statistics/Biostatistics US citizen PhD recipients are females, while in Doctoral Math 25% of the US citizens are females.

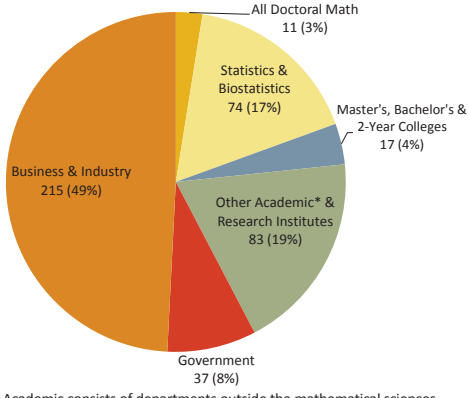
Figure S.4: Employment Status of PhD Recipients from Statistics/Biostatistics Departments



Total PhDs Awarded: 538

- 3.1% of Statistics/Biostatistics PhDs are unemployed compared to 7.3% among Doctoral Math. This is up from 2.5% in 2013–14.
- Unemployment among new PhDs with dissertations in statistics/biostatistics is 3.4%, up from 2.6%. Among all other dissertation groupings, 6.2% are unemployed.

Figure S.5: US-Employed PhD Recipients from Statistics/Biostatistics Departments by Type of Employer



*Other Academic consists of departments outside the mathematical sciences including numerous medical-related units.

Total US Employed: 437

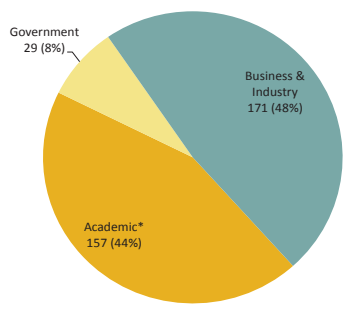
- 49% of Statistics/Biostatistics PhDs are employed in Business/Industry, compared to 29% in Math.
- 43% of those hired by Statistics and Biostatistics were females, compared to 23% in Math.

Information from the Employment Experiences of New Doctorates (EENDR) Survey

This section contains additional information on employment gathered from a subset of the 2014–15 new PhDs on the EENDR Survey. It expands on the details of employment which are not available through the departments.

The EENDR survey was sent to the 1,686 new PhDs for which departments provided current contact information by early October of 2015. Of these individuals, 823 (49%) responded. The employment status is known for 817 of these individuals; the US unemployment among this group is 2.4%. Of the 793 who reported being employed, 29% indicated they were actively looking for new employment.

Figure EE.1: EENDR Respondents Reporting Permanent US Employment by Sector

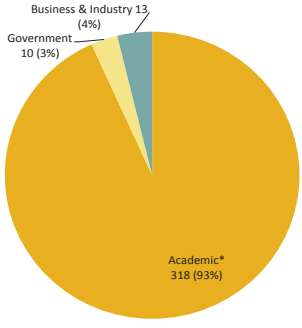


* Includes research institutes and other non-profits.

Of the 357 permanently employed:

- 35% are women.
- 58% of those reporting academic employment hold tenured/ tenure-track positions (down from 71% last year).

Figure EE.2: EENDR Respondents Reporting Temporary US Employment by Sector

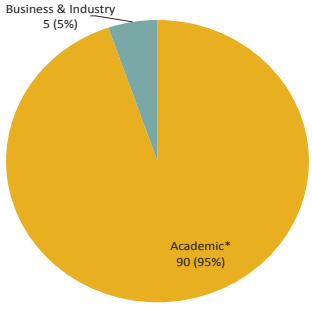


* Includes research institutes and other non-profits.

Of the 341 temporarily employed:

- 30% are women.
- 47% were unable to find a suitable permanent position (up from 43% last year).
- 76% are employed in postdocs and 40% of these reported they could not find a suitable permanent position.

Figure EE.3. EENDR Respondents Employed Outside the US by Sector



* Includes research institutes and other non-profits.

Of the 95 employed outside the US:

- 26% are women.
- 34% are US citizens.
- 76% are employed in postdocs.

Table EE.1: Number and Percentage of EENDR Respondents Employed in the US by Job Status

Year	Perm Total	%	Temp Total	%	Temporary Perm Not Avail	Temporary % of Temp Total	Temporary Postdocs Total	Temporary Postdocs % of Temp Total	Temporary Postdocs Perm Not Avail	Temporary Postdocs % of Temp Postdocs	#(%) Unknown
Fall 2011	251	44%	319	56%	133	42%	225	71%	87	39%	0
Fall 2012	261	44%	328	56%	127	39%	242	74%	108	45%	0
Fall 2013	374	53%	335	47%	173	52%	247	74%	106	43%	0
Fall 2014	363	51%	343	49%	148	43%	260	76%	88	34%	0
Fall 2015	357	51%	341	49%	160	47%	258	76%	102	40%	0

A comparison of the employment status of EENDR respondents employed in the US over the last five years, reveals that:

- 51% of those employed for fall 2015 are in permanent positions. While this is lower than the proportion reported for fall 2013, it is higher than the low of 44%.
- The proportion of those in temporary positions is the same as last year (51%), but lower than the five-year high of 56%.
- 47% of those holding temporary positions were unable to find suitable permanent positions. While this is up from last year, it is lower than the five-year high of 52%.
- 40% of those holding postdoc positions were unable to find suitable permanent positions. This figure is up six percentage points from 2013–14 five-year low of 34%.

Information from the Employment Experiences of New Doctorates (EENDR) Survey

Table EE.2: Percentage of EENDR Respondents Employed in the US by Employment Sector within Job Status

Year	Permanent			Temporary		
	Acad	Govn	B/I	Acad	Govn	B/I
Fall 2011	61%	8%	31%	94%	5%	1%
Fall 2012	61%	8%	32%	92%	5%	2%
Fall 2013	53%	7%	40%	92%	4%	4%
Fall 2014	54%	6%	40%	92%	5%	3%
Fall 2015	44%	8%	48%	93%	3%	4%

Looking at Table EE.2, we see that

- Permanent employment in the academic sector continues a downward trend, dropping to a five-year low of 44%, whereas employment in business/industry continues to climb jumping to 48%.
- Temporary employment has increased slightly in both the academic and business/industry sectors, while decreasing in government.

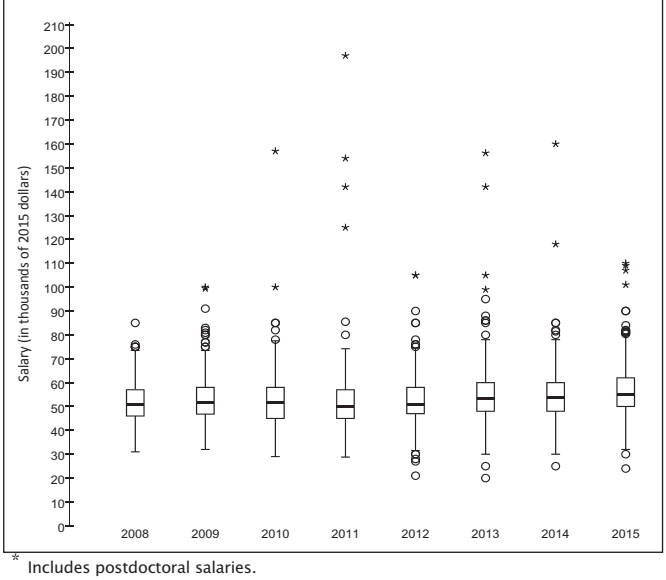
Starting Salaries of the 2014–2015 Doctoral Recipients

The starting salary figures were compiled from information gathered on the EENDR questionnaires sent to 1,686 individuals using addresses provided by the departments granting the degrees; 823 individuals responded between late October and April. Responses with insufficient data or from individuals who indicated they had part-time or non-US employment were excluded. Numbers of usable responses for each salary category are reported in the following tables.

Readers should be warned that the data in this report are obtained from a self-selected sample, and inferences from them may not be representative of the full population. Detailed information, including boxplots which traditionally appeared in this report, is available on the AMS website at `www.ams.org/annual-survey/survey-reports`.

Academic Teaching/Teaching and Research 9–10-Month Starting Salaries* (in thousands of dollars)

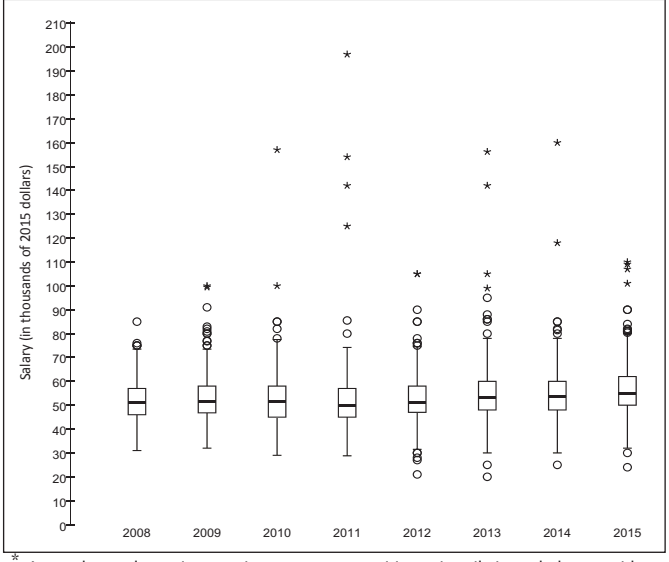
PhD Year	Min	Q_1	Median	Q_3	Max
Total (167 male/80 female)					
2015 M	24.0	50.0	54.0	60.0	101.0
2015 F	32.0	50.0	57.0	65.5	110.0
One year or less experience (147 male/76 female)					
2015 M	24.0	50.0	54.2	61.0	101.0
2015 F	32.0	50.3	57.5	65.5	110.0



* Includes postdoctoral salaries.

Academic Postdoctorates Only* 9–10-Month Starting Salaries (in thousands of dollars)

PhD Year	Min	Q_1	Median	Q_3	Max
Total (72 male/26 female)					
2015 M	33.6	50.0	57.0	60.3	84.0
2015 F	40.0	54.0	61.0	69.6	80.0
One year or less experience (68 male/26 female)					
2015 M	33.6	50.0	57.0	61.1	84.0
2015 F	40.0	54.0	61.0	69.6	80.0

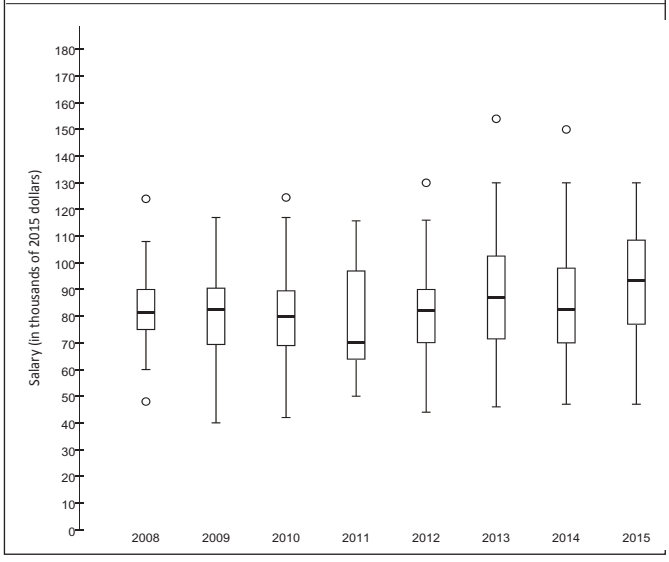


* A postdoctoral appointment is a temporary position primarily intended to provide an opportunity to extend graduate training or to further research experience.

Starting Salaries of the 2014–2015 Doctoral Recipients

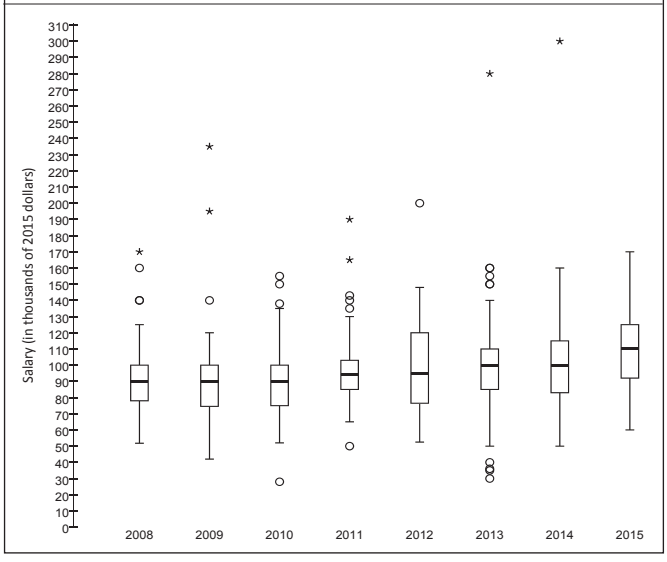
Government
11–12-Month Starting Salaries
(in thousands of dollars)

PhD Year	Min	Q_1	Median	Q_3	Max
Total (25 male/11 female)					
2015 M	47.0	80.8	94.3	110.0	116.0
2015 F	58.6	61.7	89.0	93.8	130.0
One year or less experience (23 male/4 female)					
2015 M	47.0	82.4	94.3	110.0	115.0
2015 F	58.6	62.2	69.2	80.4	96.5



Business and Industry
11–12-Month Starting Salaries
(in thousands of dollars)

PhD Year	Min	Q_1	Median	Q_3	Max
Total (116 male/58 female)					
2015 M	60.0	94.8	111.0	125.0	160.0
2015 F	60.0	87.5	106.0	120.0	170.0
One year or less experience (98 male/43 female)					
2015 M	60.0	92.5	105.5	125.0	160.0
2015 F	65.0	87.0	105.0	117.5	145.0



Remarks on Starting Salaries

Key to Tables and Graphs. Salaries are those reported for the fall immediately following the survey cycle. Years listed denote the survey cycle in which the doctorate was received—for example, survey cycle July 1, 2014–June 30, 2015 is designated as 2015. Salaries reported as 9–10 months exclude stipends for summer grants or summer teaching or the equivalent. M and F are male and female, respectively. Male and female figures are not provided when the number of salaries available for analysis in a particular category was five or fewer. All categories of "Teaching/Teaching and Research" and "Research Only" contain those recipients employed at academic institutions only.

Graphs. The graphs show standard boxplots summarizing salary distribution information for the years 2008 through 2015. Values plotted for 2008 through 2015 are converted to 2015 dollars using the implicit price deflator prepared annually by the Bureau of Economic Analysis, US Department of Commerce. These categories are based on work activities reported in EENDR. Salaries of postdoctorates are shown separately. They are also included in other academic categories with matching work activities.

For each boxplot the box shows the first quartile (Q1), the median (M), and the third quartile (Q3). The interquartile range (IQR) is defined as Q3–Q1. Think of constructing invisible fences: 1.5 IQR below Q1 represents the lower fence and 1.5 IQR above Q3 represents the upper fence. Whiskers are drawn from Q3 to the largest observation that falls below the upper invisible fence and from Q1 to the smallest observation that falls above the lower invisible fence. Think of constructing two more invisible fences, each falling 1.5 IQR above or below the existing invisible fences. Any observation that falls between the fences on each end of the boxplots is called an outlier and is plotted as ○ in the boxplots. Any observation that falls outside of both fences either above or below the box in the boxplot is called an extreme outlier and is marked as ✱ in the boxplot.

Remarks on US Unemployment Rate Calculations

In the unemployment calculations provided in this report, the individuals employed outside the US have been removed from the denominator used in the calculation of the rate, in addition to the routine removal of all individuals whose employment status is unknown. This is a change from Annual Survey Reports prior to 2009. As a consequence, the unemployment rate now being reported more accurately reflects the US labor market experienced by the new doctoral recipients. This change tends to increase the rate of unemployment over that reported in prior years.

Another small change from prior years is that, those individuals reported as not seeking employment have also been removed from the denominator. The number of individuals so designated is small each year, and the impact of this change is to produce a slight increase in the rate over that reported in prior years.

The unemployment rates for years prior to 2009 shown in this report have been recalculated using this method. One can view a comparison of the unemployment rates using the earlier method and the currentmethod by visiting the AMS website at `www.ams.org/annual-survey/surveyreports.html`.

Departmental Groupings and Response Rates

Starting with reports on the 2012 AMS-ASA-IMS-MAA-SIAM Annual Survey of the Mathematical Sciences, the Joint Data Committee has implemented a new method for grouping the doctorate-granting mathematics departments. These departments are first grouped into those at public institutions and those at private institutions. These groups are further subdivided based on the size of their doctoral program as reflected in the average annual number of PhDs awarded between 2000 and 2010, based on their reports to the Annual Survey during this period. Furthermore, doctorate-granting departments which self-classify their PhD program as being in applied mathematics will join with the other applied mathematics departments previously in Group Va to form their own group. The former Group IV will be divided into two groups, one for departments in statistics and one for departments in biostatistics.

For further details on the change in the doctoral department groupings, see the article in the October 2012 issue of *Notices of the AMS* at `www.ams.org/notices/201209/rtx120901262p.pdf`.

Department Grouping Response Rates

Doctorates Granted
Departmental Response Rates by Grouping

Math Public Large	26 of 26 including	0 with no degrees
Math Public Medium	40 of 40 including	0 with no degrees
Math Public Small	62 of 64 including	7 with no degrees
Math Private Large	24 of 24 including	0 with no degrees
Math Private Small	29 of 29 including	4 with no degrees
Applied Math	30 of 30 including	1 with no degrees
Statistics	58 of 58 including	5 with no degrees
Biostatistics	44 of 47 including	9 with no degrees
Total	312 of 318 including	26 with no degrees

As of press time for this issue of *Notices*, the following departments had not responded to the survey. Therefore, any PhDs which may have been awarded by these departments are not included in this report.

Mathematics Departments

University of Oklahoma
Utah State University

Biostatistics Departments

University of Cincinnati, Medical College
University of Illinois at Chicago
University of Louisville
University of South Carolina

Department Groupings

In this report, *Mathematical Sciences* departments are those in four-year institutions in the US that refer to themselves with a name that incorporates (with a few exceptions) "Mathematics" or "Statistics" in some form. For instance, the term includes, but is not limited to, departments of "Mathematics," "Mathematical Sciences," "Mathematics and Statistics," "Mathematics and Computer Science," "Applied Mathematics," "Statistics," and "Biostatistics." Also, *Mathematics* (*Math*) refers to departments that (with exceptions) have "mathematics" in the name; *Statistics* refers to departments that incorporate (again, with exceptions) "statistics" in the name but do not use "mathematics." The streamlining of language here militates against the possible objection to foreshortening the full subject names.

Starting with reports on the 2012 AMS-ASA-IMS-MAA-SIAM Annual Survey of the Mathematical Sciences, the Joint Data Committee implemented a new method for grouping doctorate-granting Mathematics departments. These departments are first grouped into those at public institutions and those at private institutions. These groups are further subdivided based on the size of their doctoral program as reflected in the average annual number of PhDs awarded between 2000 and 2010, based on their reports to the Annual Survey during that period.

For further details on the change in the doctoral department groupings, see the article in the October 2012 issue of *Notices of the AMS* at `www.ams.org/journals/notices/201209/rtx120901262p.pdf`.

Math Public Large consists of departments with the highest annual rate of production of PhDs, ranging between 7.0 and 24.2 per year.
Math Public Medium consists of departments with an annual rate of production of PhDs, ranging between 3.9 and 6.9 per year.
Math Public Small consists of departments with an annual rate of production of PhDs of 3.8 or less per year.
Math Private Large consists of departments with an annual rate of production of PhDs, ranging between 3.9 and 19.8 per year.
Math Private Small consists of departments with an annual rate of production of PhDs of 3.8 or less per year.
Applied Mathematics consists of doctoral-degree-granting applied mathematics departments.
Statistics consists of doctoral-degree-granting statistics departments.
Biostatistics consists of doctoral-degree-granting biostatistics departments.
Masters contains US departments granting a Master's degree as the highest graduate degree.
Bachelors contains US departments granting a Baccalaureate degree only.
Doctoral Math contains all US math public, math private, and applied math mathematics departments granting a PhD as the highest graduate degree.
Mathematics contains all US math public, math private, and applied math, Master's, and Bachelor's groups above.

Listings of the actual departments that compose these groups are available on the AMS website at `www.ams.org/annual-survey/groups`.

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European Mathematical Society

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The EMS Monograph Award is assigned every year to the author(s) of a monograph in any area of mathematics that is judged by the selection committee to be an outstanding contribution to its field. The prize is endowed with 10,000 Euro and the winning monograph will be published by the EMS Publishing House in the series "EMS Tracts in Mathematics".

Previous prize winners were Patrick Dehornoy et al. for the monograph *Foundations of Garside Theory,* Augusto C. Ponce (*Elliptic PDEs, Measures and Capacities. From the Poisson Equation to Nonlinear Thomas–Fermi Problems*), Vincent Guedj and Ahmed Zeriahi (*Degenerate Complex Monge–Ampere Equations*), and Yves de Cornulier and Pierre de la Harpe (*Metric Geometry of Locally Compact Groups*). All books were or will be published in the Tracts series.

The deadline for the next award, to be announced in 2018, is **30 June 2017**.

Submission of manuscripts

The monograph must be original and unpublished, written in English and should not be submitted elsewhere until an editorial decision is rendered on the submission. Monographs should preferably be typeset in TeX. Authors should send a pdf file of the manuscript by email to:

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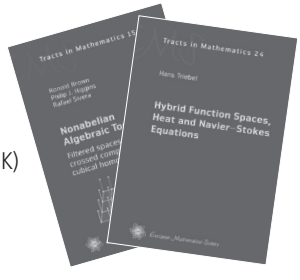
EMS Tracts in Mathematics



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Helen Moore Interview

Helen Moore *is Associate Director of Quantitative Clinical Pharmacology, Bristol-Myers Squibb in Princeton, New Jersey.*
Her e-mail address is: dr.helen.moore@gmail.com.

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

Moore: I have loved math since I was young. Solving challenging problems gave me a rush. I loved competitions because I got to think about math outside the standard curriculum. My high school, North Carolina School of Science and Mathematics (NCSSM), had an active math club, and we did competitions every other week. I was disappointed to get to college and find out there was only one math competition per year, the Putnam Exam. I started my own math contest my first year in college (University of North Carolina at Chapel Hill), which lasted beyond my graduation. Four contests per semester, a week to solve the problems, with book prizes for top scorers awarded each year by the math department.

Diaz-Lopez: *Who encouraged or inspired you?*

Moore: Although my parents did nothing related to academics or mathematics, they supported my academic endeavors and allowed me to move away from home at the age of sixteen to attend NCSSM. My teachers and classmates at NCSSM provided an enriching experience and continue to do so. Beyond the classes (math, English, physics, Russian, music,…), it was an incredible experience to live with others who loved math and learning. While in graduate school (Stony Brook University), I met a group of women in other departments (physics, astronomy, computer science, and geology) and made great friends. In academic jobs, I would find a "study buddy" to discuss my research/progress with. I co-founded a book group of women scientists that continues today, more than ten years later. Those friendships and others helped me when times were tough.

There were also teachers, before high school, during high school, in college and in graduate school, who encouraged me. If you were ever a teacher of mine and you are reading this, please accept my deep gratitude! I try to honor their contributions by paying it forward. I give a lot of talks to high school and college students about the mathematics used in medicine.

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

Moore: I am using control theory to optimize combinations of therapies for a model of in-host leukemia-immune dynamics. We have so many therapies we could combine, we can't do all the studies necessary to explore those combinations. For example, suppose there are twelve molecules in development, and we will test one dose level of each. Even if we administer just two molecules at a time, we have twelve choose two, or sixty-six, experiments to run. But in fact, we want to test several dose levels of each molecule, with different intervals between the doses, and we also want to study three molecules at a time. We don't have the time or other resources to run that many studies. So we will use mathematical modeling to help decide which compounds to test together and how much and how often to dose (refer to Figures 1 and 2 for examples).

We (and some other companies) also have a group that builds large ODE systems models (quantitative systems pharmacology, or QSP, models) to identify potential drug targets, to predict toxicity, and to explore mechanistic hypotheses. Semi-mechanistic disease models and model-based meta-analyses are additionally used for prediction purposes. People doing this work often have a math or engineering background, but have also learned a lot about a disease area.

More commonly, others doing quantitative work in biopharma are using more-traditional pharmacometrics: they are fitting nonlinear mixed-effects models to data with various algorithms, testing for covariate relationships with a variety of functional forms, using a Schwarz-Bayesian or other criterion to select a model, bootstrapping parameter estimates, cross-validating model predictions, simulating

DOI: http://dx.doi.org/10.1090/noti1405

outcomes for different dose regimens, and answering questions that may arise from the internal team or a regulatory agency. Interpreting the quantitative results is important, so pharmacometricians need a good understanding of the techniques behind the results. There are also plenty of technical gaps in the field, and opportunities for numerical and theoretical contributions.

In biopharma, everything we do is driven by questions about treatments. For example, can we improve our predictions of which patients will respond to a particular therapy? At Bristol-Myers Squibb, we are collecting a tremendous amount of data, and using machine learning to make these predictions either before or soon after a patient starts a therapy. Because such questions drive the quantitative approach, modelers at the company need to have broad expertise across areas. The areas that excite me the most include: systems modeling, multi-scale modeling issues, error propagation, numerical analysis, system and parameter identifiability, sensitivity analysis, control theory, fixed and random effects modeling, optimization, statistical modeling, and machine learning.

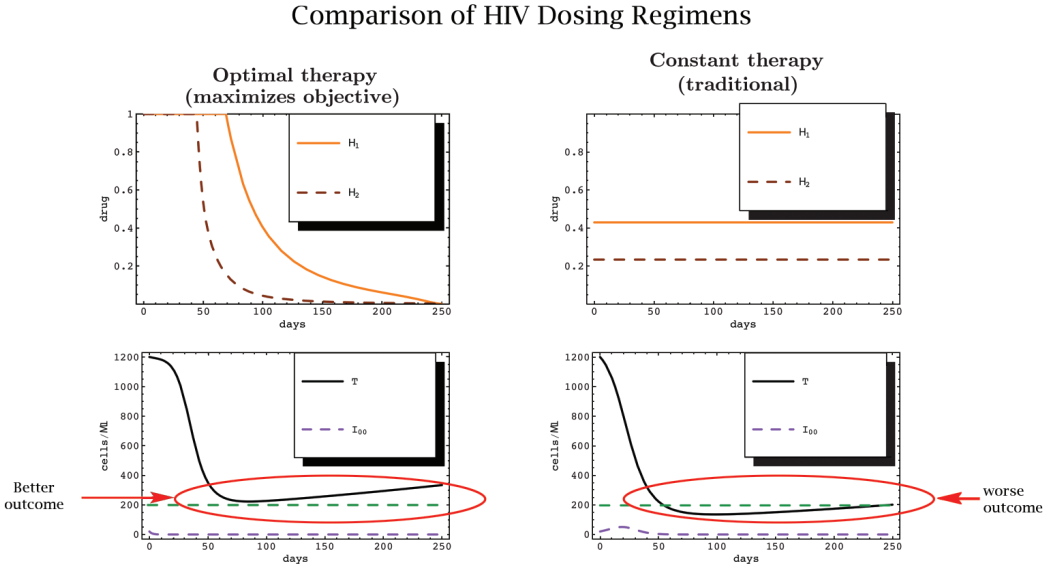


Figure 1. Multi-drug resistance was incorporated in a dynamical system model for HIV-immune cell interactions with five cell populations. Treatment goals were quantified in an objective functional, and control theory applied to this model predicted optimal regimens for combinations of therapies. The upper left shows one of the optimized regimens, and the upper right shows a constant dosing regimen. In the lower panels, the black curves represent a type of healthy immune system T cell ("the good guys"). The purple dashed curves represent cells infected by HIV ("the bad guys"), and are controlled under both regimens. With the optimized regimen, the healthy T cell curve stays above 200 cells/μL, the clinical definition of AIDS, and is 75 percent higher at the end of treatment than the healthy T cell curve on the right resulting from the constant dosing regimen. Please refer to: `www.ams.org/books/conm/410/conm410.pdf` **for additional details.**

Diaz-Lopez: *You have worked in both academia and industry. How do you compare them, and what are the major challenges you have faced in each?*

Moore: In academia, I had a lot of freedom to decide what I would work on. The NSF [National Science Foundation] grant I got was important for my career, because it allowed me to travel to conferences, to buy a computer and software, and to have some time off from teaching. But grants can be time-consuming to apply for and hard to get. Additionally, when I shifted from pure mathematics to applied mathematics, a big challenge was getting enough appropriate data to be able to collaborate well with other academics.

In industry, we have a wealth of data, and decisions about resources are made much more quickly. When I first entered industry, I received modeling project assignments. Although I had flexibility in exactly how I answered the questions asked, I needed to meet the goals and timelines set by others. But now I give internal presentations to explain the ideas I have, and to pitch proposals for ways I could use mathematics to solve high-priority

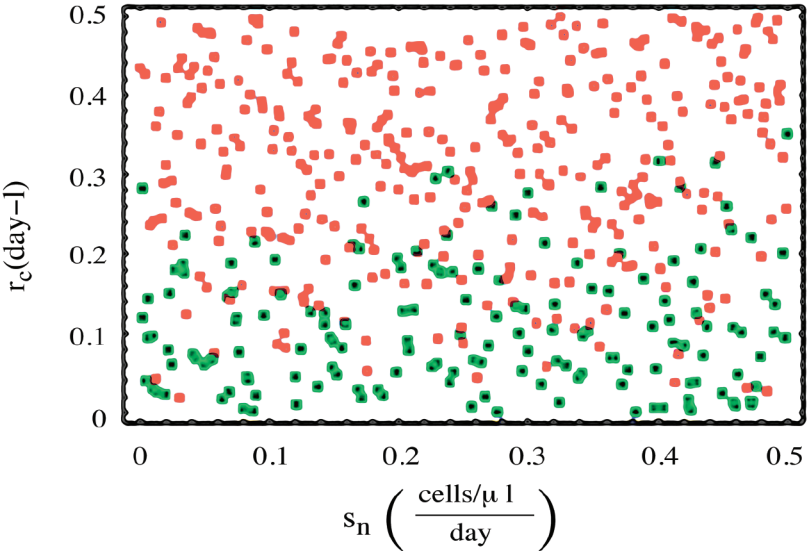


Figure 2. In-host leukemia-immune cell interactions were modeled by a dynamical system with 12 parameters. Five hundred sets of parameter values were selected. The squares in this plot represent the sampled values of the parameters r_c and s_n; their color indicates whether the leukemic cell levels rose above 20,000 cells/μL (orange) or stayed below that (green). The pattern of the colors suggests that changes in r_c values could affect whether the leukemia levels stay below the threshold, and that the value of the parameter s_n does not affect this outcome. Please refer to `www.sciencedirect.com/science/article/pii/S0022519303004454` **for statistical tests of significance.**

questions. My work absolutely must be understood by decision-makers whose expertise is different from my own. I am fortunate to have a manager and others in our department and company who support my ideas.

Companies and groups within them differ in their attitudes toward publications. Generally poster presentations at conferences are valued. However, the only articles I have been able to publish so far while in industry are those I worked on in the evenings and weekends with academic collaborators. I am optimistic that I will have publications based on my industry work in the near future.

Diaz-Lopez: *What advice do you have for graduate students?*

Moore: For someone who wants to do the kind of work I do, I recommend: get a masters degree in statistics along with your PhD in math; learn a programming language such as R or MATLAB; and after finishing your PhD, do a postdoc in an experimental or engineering lab. If there are certain types of jobs you are interested in, look at the current openings to find out exactly which skills and experience companies are looking for. You will need to get both the quantitative/theoretical training plus learn about biology/diseases and have experience putting those together. In my opinion, the connection between mathematical modeling and data is statistics, so statistical knowledge will be expected of a modeler.

Many have said the best way to get a job in industry is to already have a job in industry. A summer internship at a company is a good way to get that industry experience. To look for internships or regular openings, search SIAM [Society for Industrial and Applied Mathematics] Jobs, and look at individual company web sites. You can find lists of biopharma companies by size and region. Some internship and postdoctoral openings get posted to the Society for Mathematical Biology and SIAM Life Sciences email lists. Attend a conference or local meeting in the field you are interested in; in my field that would be the American Conference on Pharmacometrics or one of the affiliated regional meetings. Hand out business cards, post a profile with a photo on LinkedIn, and send link requests to people you meet with a reminder about how you met. You could also work with a recruiter who specializes in your field; you can find one by searching online.

Diaz-Lopez: *All mathematicians feel discouraged occasionally. How do you deal with discouragement?*

Moore: I go running and talk with friends and family. When I lost my husband to cancer, that's how I survived. Now I feel like I can survive anything.

Diaz-Lopez: *If you were not a mathematician, what would you be?*

Moore: I would still want to do something creative; I might be a guitarist/singer/songwriter or a writer.

Diaz-Lopez: *If you could recommend one lecture (book, paper, article, etc.) to graduate students, what would it be?*

Moore: I highly recommend Peter Bonate's book *Pharmacokinetic-Pharmacodynamic Modeling and Simulation*. It is the most mathematically informative work in our field, and Bonate points out "open problems" by discussing strengths and weaknesses of current methods.

Diaz-Lopez: *Any final comment or advice?*

Moore: If you have the desire to help people, working in the biopharma industry is a great opportunity to do that. We could use more people who are really bright and creative, have strong mathematical or quantitative backgrounds, and are willing to learn about and work on problems in biopharma.

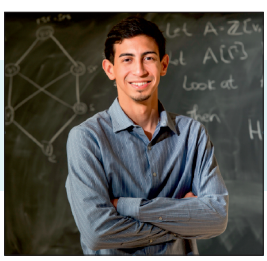
Credits

Page 768 photo, courtesy of Helen Moore.

Figure 1 adapted from Gu and Moore, Optimal therapy regimens for treatment-resistent mutations of HIV, *Contemp. Math.* 410 (2006), 139–151.

Figure 2 adapted from Moore and Li, A mathematical model for chronic myelogenous leukemia (CML) and T-cell interactions, *J. Theor. Bio.* 227 (2004), 513–523.

Page 770 photo, courtesy of Alexander Diaz-Lopez.



Alexander Diaz-Lopez, having earned his PhD at the University of Notre Dame, is now visiting assistant professor at Swarthmore College. Diaz-Lopez is the first graduate student member of the *Notices* Editorial Board.

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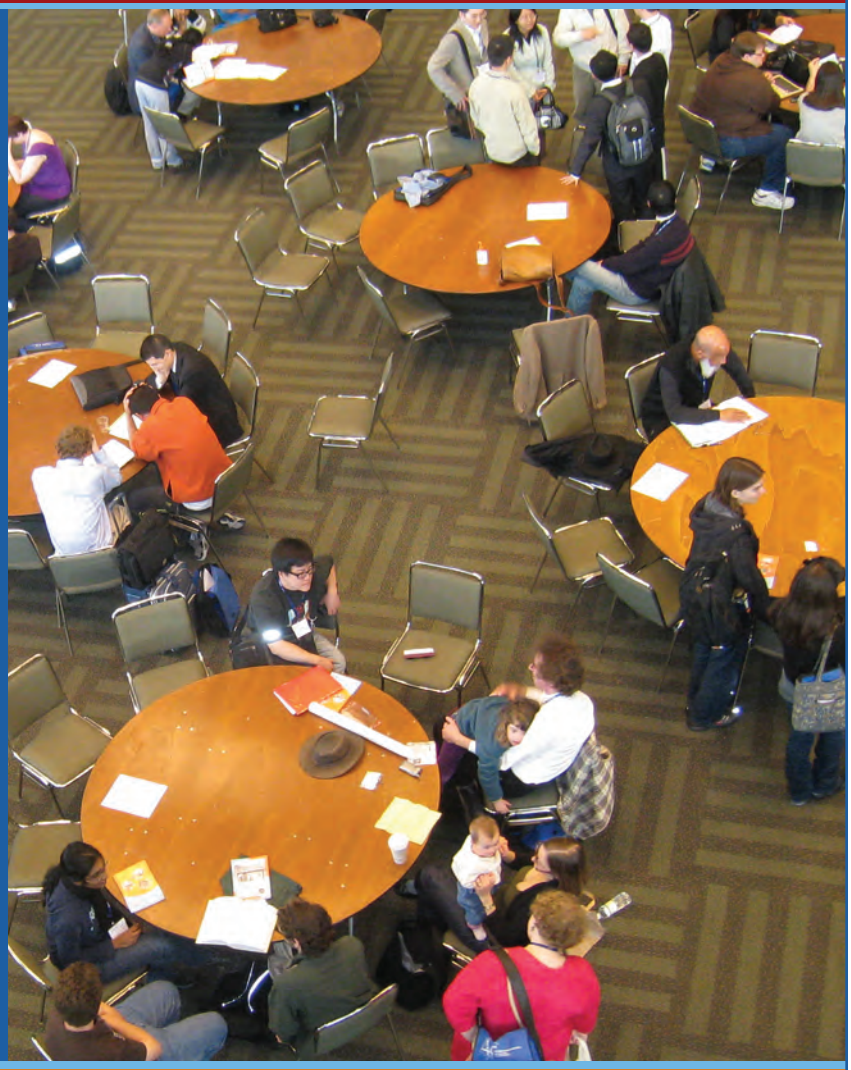

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WHAT IS...

a Diophantine m-tuple?

Andrej Dujella

Communicated by Florian Luca and Cesar E. Silva

A Diophantine m-tuple is a set of m distinct positive integers with the property that the product of any two of its distinct elements plus 1 is a square. If a set of nonzero rationals has the same property, it is called a rational Diophantine m-tuple. Fermat found the first Diophantine quadruple in integers $\{1, 3, 8, 120\}$. Indeed, we have

$$1 \cdot 3 + 1 = 2^2, \quad 1 \cdot 8 + 1 = 3^2, \quad 1 \cdot 120 + 1 = 11^2,$$
$$3 \cdot 8 + 1 = 5^2, \quad 3 \cdot 120 + 1 = 19^2, \quad 8 \cdot 120 + 1 = 31^2.$$

Euler was able to extend Fermat's quadruple to the rational quintuple $\{1, 3, 8, 120, 777480/8288641\}$.

The ancient Greek mathematician Diophantus found the first example of a rational Diophantine quadruple

$$\left\{\frac{1}{16}, \frac{33}{16}, \frac{17}{4}, \frac{105}{16}\right\}.$$

Some of the famous mathematicians of the past, such as Diophantus, Fermat, and Euler, as well as some modern ones such as Fields Medalist Alan Baker, have made important contributions to problems related to Diophantine m-tuples, but many problems still remain open.

It is natural to ask how large sets of Diophantine m-tuples can be. This question is almost completely solved in the integer case. On the other hand, it seems that in the rational case we do not have even a widely accepted conjecture. In particular, no absolute upper bound for the size of rational Diophantine m-tuples is known. The study of this question leads to surprising connections with elliptic curves.

Note that in the definition of (rational) Diophantine m-tuples we excluded the requirement that the product of an element with itself plus 1 is a square. It is obvious that for integers such a condition cannot be satisfied. But for rationals there is no obvious reason why the sets (called strong Diophantine m-tuples) that satisfy these stronger conditions would not exist. For each element a of such a set we have that $a^2 + 1$ is a square; therefore $a = X/Y$, where (X, Y, Z) is a Pythagorean triple, i.e., $X^2 + Y^2 = Z^2$. It is known that there exist infinitely many strong Diophantine triples, while no example of a strong Diophantine quadruple is known.

In the integer case, it is easy to prove that there exist infinitely many integer Diophantine quadruples (there are parametric families for Diophantine quadruples involving polynomials and Fibonacci numbers, such as $\{k, k+2, 4k+4, 16k^3 + 48k^2 + 44k + 12\}$ and $\{F_k, F_{k+2}, F_{k+4}, 4F_{2k+1}F_{2k+2}F_{2k+3}\}$ for $k \geq 1$), while the folklore conjecture is that there does not exist a Diophantine quintuple. The first important result concerning this conjecture was proved in 1969 by Baker and Davenport. Using Baker's theory on linear forms in logarithms of algebraic numbers and a reduction method based on continued fractions, they proved that if d is a positive integer such that $\{1, 3, 8, d\}$ forms a Diophantine quadruple, then d has to be 120. This implies that Fermat's set $\{1, 3, 8, 120\}$ cannot be extended to a Diophantine quintuple. It was proved in 2004 that a Diophantine sextuple does not exist and that there are only finitely many Diophantine quintuples. Since then, the bound on the number of possible Diophantine quintuples has been improved by several authors (at the moment the best bound seems to be $5.441 \cdot 10^{26}$ due to Cipu and Trudgian), but the question of the existence of Diophantine quintuples is still open.

It is known that any Diophantine triple $\{a, b, c\}$ can be extended to a Diophantine quadruple $\{a, b, c, d\}$. Indeed, with $ab + 1 = r^2$, $ac + 1 = s^2$, $bc + 1 = t^2$, we may take

$$d = a + b + c + 2abc + 2rst,$$

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and then $ad+1=(at+rs)^2, bd+1=(bs+rt)^2, cd+1=(cr+st)^2$. Quadruples of this form are called regular, and the stronger version of the Diophantine quintuple conjecture is that all Diophantine quadruples are regular. Fujita proved that any Diophantine quintuple contains a regular Diophantine quadruple.

Here we sketch the ideas used in the proof of finiteness of Diophantine quintuples and other similar results. Extending the Diophantine triple $\{a,b,c\}$, $a<b<c$, to a Diophantine quadruple $\{a,b,c,d\}$ leads to the system $ad+1=x^2$, $bd+1=y^2$, $cd+1=z^2$, and by eliminating d, we get the system of simultaneous Pellian equations:

$$cx^2-az^2=c-a,\quad cy^2-bz^2=c-b.$$

Solutions of Pellian equations are contained in finitely many binary recursive sequences. Thus, the problem leads to finding intersections of binary recursive sequences, i.e., finitely many equations of the form $v_m=w_n$. These sequences satisfy $v_m\approx\alpha\beta^m$, $w_n\approx\gamma\delta^n$ for certain algebraic numbers $\alpha,\beta,\gamma,\delta$ (e.g. in the case of the Diophantine triple $\{1,3,8\}$ treated by Baker and Davenport, $\alpha=(3+\sqrt{3})/3$, $\beta=2+\sqrt{3}$, $\gamma=(4\pm\sqrt{2})/4$, $\delta=3+2\sqrt{2}$), which implies $m\log\beta-n\log\delta+\log\frac{\alpha}{\gamma}\approx 0$. But a consequence of Baker's theory is that a linear combination, with integer coefficients, of logarithms of algebraic numbers which is nonzero cannot be very close to 0. We therefore obtain upper bounds for m,n. To obtain lower bounds, we can use the congruence method, introduced in joint work with Pethő in 1998, and consider $v_m\equiv w_n \pmod{c^2}$. If m,n are small (compared with c), then $\equiv$ can be replaced by $=$, and this (hopefully) leads to a contradiction (if $m,n>2$, i.e., if d does not correspond to a regular quadruple). Therefore, we obtain lower bounds for m,n (small powers of c). Comparing the upper and lower bounds we get a contradiction for large c.

It is likely that we cannot surpass Fermat by constructing Diophantine quintuples. However, in the rational case, there exist larger sets with the same property. Euler found infinitely many rational Diophantine quintuples. The question of the existence of rational Diophantine sextuples remained open for more than two centuries. In 1999 Gibbs found the first rational Diophantine sextuple

$$\left\{\frac{11}{192},\frac{35}{192},\frac{155}{27},\frac{512}{27},\frac{1235}{48},\frac{180873}{16}\right\},$$

while in 2016 Dujella, Kazalicki, Mikić, and Szikszai proved that there exist infinitely many rational Diophantine sextuples. For example, there are infinitely many such sextuples containing the triple $\{15/14,-16/21,7/6\}$, with the simplest example being

$$\left\{\frac{15}{14},-\frac{16}{21},\frac{7}{6},-\frac{1680}{3481},-\frac{910}{1083},\frac{624}{847}\right\}.$$

No example of a rational Diophantine septuple is known. Moreover, we do not know any rational Diophantine quintuple (or even quadruple) that can be extended to two different rational Diophantine sextuples.

We now describe connections between rational Diophantine m-tuples and elliptic curves. Let $\{a,b,c\}$ be a rational Diophantine triple. In order to extend this triple to a quadruple, we have to find a rational x such that $ax+1$, $bx+1$, and $cx+1$ are all squares of rationals. By multiplying these three conditions, we obtain a single condition

$$y^2=(ax+1)(bx+1)(cx+1),$$

which is in fact the equation of an elliptic curve (nonsingular cubic curve with a rational point). We will explain below which points on the curve satisfy the original system of equations and give extensions to Diophantine quadruples.

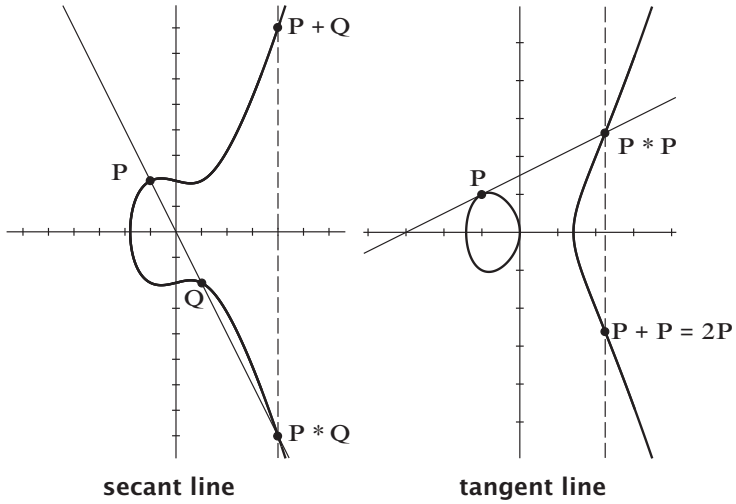

Figure 1. If P and Q have different x-coordinates, then the straight line through P and Q intersects the curve in exactly one more point, denoted by $P*Q$, and we define $P+Q$ as $-(P*Q)$ (where $-(P*Q)$ is the point with the same x-coordinate but negative y-coordinate as $P*Q$). If $P=Q$, then we replace the secant line by the tangent line at the point P.

The set $E(\mathbb{Q})$ of rational points on an elliptic curve E over $\mathbb{Q}$ (affine points $[x,y]$ satisfying the equation along with the point at infinity) forms an abelian group with the law of addition defined by the secant and tangent method as described in the figure.

Moreover, by the Mordell-Weil theorem, the abelian group $E(\mathbb{Q})$ is finitely generated, and hence it is the product of the torsion group and $r\geq 0$ copies of the infinite cyclic group: $E(\mathbb{Q})\cong E(\mathbb{Q})_{\text{tors}}\times\mathbb{Z}^r$.

Let us denote the curve $y^2=(ax+1)(bx+1)(cx+1)$ by $\mathcal{E}$. We say that $\mathcal{E}$ is induced by the Diophantine triple $\{a,b,c\}$. There are three rational points on $\mathcal{E}$ of order 2, namely $A=[-1/a,0]$, $B=[-1/b,0]$, $C=[-1/c,0]$, and also two other obvious rational points:

$$P=[0,1],$$

$$S=[1/abc,\sqrt{(ab+1)(ac+1)(bc+1)}/abc].$$

Note that the x-coordinate of the point $P-S$ is exactly the number d from the definition of regular Diophantine quadruples. In general, P and S will be independent points of infinite order. But an important question, with

significant consequences, is whether they can have finite orders and which orders are possible.

Now we can answer the question which points on $\mathscr{E}$ give extensions to Diophantine quadruples. Namely, the x-coordinate of a point $T \in \mathscr{E}(\mathbb{Q})$ satisfies the original three conditions if and only if $T - P \in 2\mathscr{E}(\mathbb{Q})$. It can be verified that $S \in 2\mathscr{E}(\mathbb{Q})$. This implies that if $x(T)$ satisfies the original conditions, then also the numbers $x(T \pm S)$ satisfy them. It can be shown that $x(T)x(T \pm S) + 1$ is always a perfect square.

Thus, $\{a, b, c, x(T - S), x(T), x(T + S)\}$ is "almost" a rational Diophantine sextuple. The only missing condition is that

$$x(T - S)x(T + S) + 1$$

is a square, and this last condition is satisfied if the point S is of order 3. In that way, the problem of construction of rational Diophantine sextuples becomes closely connected with elliptic curves with torsion group $\mathbb{Z}/2\mathbb{Z} \times \mathbb{Z}/6\mathbb{Z}$. Elliptic curves induced by Diophantine triples were used by Dujella and Peral in 2014 in constructing elliptic curves with given torsion and high rank (details of the current rank records can be found at the webpage `web.math.hr/~duje/tors/tors.html`). It is interesting that any elliptic curve over $\mathbb{Q}$ with torsion group $\mathbb{Z}/2\mathbb{Z} \times \mathbb{Z}/8\mathbb{Z}$ can be induced by a Diophantine triple.

There are several natural generalizations of the notion of Diophantine m-tuples. We can replace squares by k-th powers for fixed $k \geq 3$ (in a joint work with Bugeaud we showed that there are no such quadruples for $k \geq 177$) or by perfect powers (Luca showed in 2005 that the cardinality of such a set is uniformly bounded assuming the abc-conjecture).

We can replace the number 1 in the conditions "$ab + 1$ is a square" by a fixed integer n. Such sets are called $D(n)$-m-tuples. It is easy to show that there are no $D(n)$-quadruples if $n \equiv 2 \pmod 4$. Indeed, assume that $\{a_1, a_2, a_3, a_4\}$ is a $D(n)$-quadruple. Since the square of an integer is $\equiv 0$ or $1 \pmod 4$, we have that $a_i a_j \equiv 2$ or $3 \pmod 4$. This implies that none of the a_i's is divisible by 4. Therefore, we may assume that $a_1 \equiv a_2 \pmod 4$. But now we have that $a_1 a_2 \equiv 0$ or $1 \pmod 4$, a contradiction.

On the other hand, it can be shown that if $n \not\equiv 2 \pmod 4$ and $n \notin S = \{-4, -3, -1, 3, 5, 8, 12, 20\}$, then there exists at least one $D(n)$-quadruple. For $n \in S$, the question of the existence of $D(n)$-quadruples is still open. No $D(-1)$-quintuple exists, and there are only finitely many such quadruples (and all of them must contain the element 1); among the main contributors here are Filipin and Fuchs. These results solve an old problem investigated by Diophantus and Euler by showing that there does not exist a set of four positive integers with the property that the product of any two of its distinct elements plus their sum is a perfect square. Indeed, since $xy + x + y = (x + 1)(y + 1) - 1$, the existence of such a set would imply the existence of $D(-1)$-quadruples with elements ≥ 2.

Instead of over the integers and rationals, the problem can be considered over any commutative ring with unity. There are interesting results, due to Franušić and Soldo, over rings of integers of certain quadratic fields which show that there is a close connection between existence of a $D(n)$-quadruple and representability of n as a difference of two squares in the ring. Note that integers $\equiv 2 \pmod 4$ are exactly those that cannot be represented as a difference of two squares of integers.

More details on Diophantine m-tuples and the complete list of references can be found at the webpage `web.math.hr/~duje/dtuples.html`.

ABOUT THE AUTHOR

Andrej Dujella received a PhD in mathematics from the University of Zagreb in 1996.

His research interests include Diophantine equations, elliptic curves, polynomial root separation, and applications of Diophantine approximation to cryptography.

Credits

Figure 1 and p. 774 photo, courtesy of Andrej Dujella.

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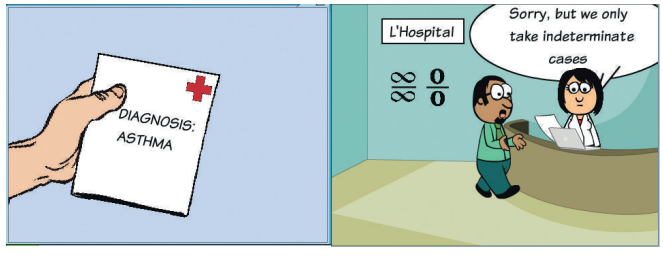

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FROM THE AMS SECRETARY

ATTENTION ALL AMS MEMBERS

Voting Information for 2016 AMS Election

AMS members who have chosen to vote online will receive an email message on or shortly after August 15, 2016, from the AMS Election Coordinator, Survey & Ballot Systems.

The From Line will be "AMS Election Coordinator", the Sender email address will be noreply@directvote.net, and the Subject Line will be "AMS 2016 Election—login information below". If you use a spam filter you may want to use the above address or subject information to configure your spam filter to ensure this email will be delivered to you.

The body of the message will provide your unique voting login information and the address (URL) of the voting website.

AMS members who have chosen to vote by paper should expect to receive their ballot by the middle of September. Unique voting login information will be printed on the ballot, should you wish to vote online.

At midnight (US Eastern Time) on November 4, 2016, the website will stop accepting votes. Paper ballots received after this date will not be counted.

Additional information regarding the 2016 AMS Election is available on the AMS website: www.ams.org/election-info
or by contacting the AMS: election@ams.org, 800-321-4267 (US & Canada), 401-455-4000 (worldwide).

Thank you and . . . please remember to vote.

Carla D. Savage

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AMS Executive Director Donald E. McClure Retires

Allyn Jackson

AMS Executive Director Donald E. McClure will retire in the summer of 2016. For seven and a half years, McClure has provided steady, thoughtful guidance to the AMS, ensuring that the Society continues to thrive in its main role of supporting mathematics and the mathematical community, while also succeeding in its role as a major publisher in the field. McClure's instinctive understanding of how best to align these two roles has been key to his success at the helm of the AMS.

McClure is wise and thoughtful, knowledgeable and strategic

Carla Savage of North Carolina State University has worked closely with McClure since she became Secretary of the AMS in 2013. She praised him as wise and thoughtful, patient and persuasive, knowledgeable and strategic. "He is articulate and respectful and represents the AMS very well to members, volunteers, and external organizations," she said. "He weighs all decisions according to the benefits to mathematics, mathematicians, and the Society. I've never seen him lose sight of these goals."

McClure is professor emeritus of applied mathematics at Brown University. He has a long record of service to the AMS, including hands-on work as a member of the Data Committee and of the Board of Trustees. He also served as AMS Associate Treasurer from 2003 until the time he became AMS Executive Director. This experience meant that he started his position at the AMS with a good deal of understanding of Society operations. He also brought considerable business acumen, having founded, with his Brown colleague Stuart Geman, a successful software development company.

Allyn Jackson is senior writer and deputy editor for the Notices. *Her email address is* axj@ams.org.

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Donald E. McClure

The Best of Times and the Worst of Times

One could say that McClure joined the AMS staff at the best of times and the worst of times. His predecessor, John H. Ewing, had left the Society in arguably the best possible shape, both financially and in its ability to serve mathematics. But McClure succeeded Ewing in January 2009, in the midst of the worst global economic crisis of recent times. The Society's long-term investment portfolio had declined 30 percent, and the portion of the portfolio that provides funds to support programs and services had dropped 50 percent. As academia struggled to absorb the impact of the crisis, mathematicians faced a bleak employment outlook, budget cuts in their departments, and shrinking library budgets.

In this difficult climate, McClure articulated the main priorities of the AMS to be holding down the cost of

His calm and steady approach helped the Society weather tough economic times

books and journals, helping young mathematicians in the job market, and advocating support for mathematics by the federal government. The AMS enacted these priorities by, for example, freezing journal subscription prices and individual membership dues for a time. Another example is the organization of events at the Joint Mathematics Meetings (JMM) aimed at giving new PhDs information about opportunities outside of academia.

"Don was always thoughtful and deliberate in his decisions and statements, and considered all sides of every issue before making a decision that would impact the AMS," said AMS Treasurer Jane Hawkins of the University of North Carolina. She also noted that his calm and steady approach gained the confidence of the Board of Trustees and helped the Society weather the tough economic times. Over the past seven and a half years, as the economic climate improved, AMS investments have rebounded.

Still, the challenges faced by young mathematicians entering the profession have not abated, and the AMS programs to support them are still very much needed. Having served on the influential AMS Task Force on Employment in the early 1990s, as well as the Committee on the Profession, McClure developed insights into how to support young mathematicians.

As executive director, he oversaw expansion of AMS travel grants for graduate students, to allow them to attend not only the JMM but also AMS sectional meetings. This program now provides a total of 300 grants annually. Also during McClure's tenure, the Mathematics Research Communities program has continued to blossom. This program helps young mathematicians create peer networks that will sustain them as they develop their research careers. A new program established under McClure, in which then-Associate Executive Director Ellen Maycock played a key role, is the AMS Graduate Student Chapters. The program provides a modest amount of funding for activities that support the students' growth as mathematicians. Today there are about 40 Graduate Student Chapters.

Students have a stronger presence in the AMS today than in the past, particularly through their participation in the JMM. Events geared specifically toward students are now standard JMM fare. And the meetings are extremely popular. McClure's tenure coincided with the largest-ever JMM, in Boston in 2012, which drew 7,200 attendees.

Publishing Business Doing Well

"Day to day, year in and year out, Don has managed the difficult task of harmonizing the business of AMS publishing and MathSciNet® with the needs of the professional society so that it serves the interest of the entire mathematics community," said AMS President Robert Bryant of Duke University. "We are all grateful for his thoughtful advice and unflagging dedication to the Society."

Under McClure's leadership, the AMS publication operation has done well. The Society has continued to publish outstanding books, including books aimed at students at all levels. In McClure's time, the AMS introduced two children's books, both by Richard Schwartz, a colleague of McClure's at Brown University. One of Schwartz's books, *Really Big Numbers*, published in 2014, received the inaugural Mathical Book Prize of the Mathematical Sciences Research Institute and the Children's Book Council. Another 2014 book published by the AMS, *Hilbert's Fifth Problem and Related Topics* by Terence Tao, received the PROSE Award (American Publishers Award for Professional and Scholarly Excellence) for the best book published in mathematics that year.

Major strides were made in AMS eBooks while McClure was executive director; among the series now available electronically are *Memoirs* and *Mathematical Surveys and Monographs*. AMS journal page output was greatly increased to reduce backlogs, without proportional increases in subscription prices. Also under McClure's leadership, the AMS invested substantial time and effort in retro-digitization, and now all issues of its four primary research journals are available online.

In 2012, McClure developed a proposal for creating "gold" open-access versions of *Transactions* and *Proceedings*, so that authors publishing in these journals have an open-access option available. This has allowed the AMS to take a measured step into the rapidly changing world of open-access publishing and have a basis for planning possible future moves in this direction.

The most important publication of the AMS, *Mathematical Reviews*, had a couple of landmarks during McClure's tenure: Its seventieth and seventy-fifth anniversaries, and its last print issue, which came out at the end of 2012. *Math Reviews* and its online portal MathSciNet® have kept pace with the enormous growth in the mathematical literature, adding over 80,000 reviews each year. Several new features have been added to MathSciNet®, one of the most significant being the use of MathJax™ to render LaTeX on-screen, which has greatly enhanced the ease of use and readability of MathSciNet®.

Seeds for the Future

Two efforts in which McClure was deeply involved, and which will benefit the Society in the years to come, are the establishment of the AMS Development Department and the completion of a strategic planning process. Since it started in 2011, the Development Department has been highly effective in securing resources to support new prizes and activities. Two examples are the Chevalley Prize in Lie Theory, given for the first time this year, and the soon-to-be-established Bertrand Russell Prize, which will recognize the various ways that mathematics research and contributions promote good in the world and further fundamental human values. (McClure credits the great help of David Vogan of the Massachusetts Institute

of Technology, who served as AMS President during 2013–2014, in the creation of these prizes.)

McClure's ability to listen and weigh different points of view counts as one of his strengths

Bryant praised McClure's leadership during the strategic planning activity, which began in 2013. "Don worked tirelessly to keep everyone engaged and moving forward and made sure that all our voices were heard," said Bryant. "This left us with what I think is a very clear picture of the challenges and opportunities that the AMS faces as well as a clear set of goals and strategies for reaching those goals. The membership of the AMS will reap the benefits of this for many years to come."

One priority emerging from the strategic planning activity was the need to promote diversity in mathematics. Moving quickly in response, this spring the Society established the AMS Department of Education and Diversity. After a national search for the director of this department, Helen G. Grundman of Bryn Mawr College was hired for the position and began working full-time in June.

Running the AMS has not been a one-man show, and McClure's ability to listen and weigh different points of view counts as one of his strengths. Vogan said of McClure, "What was most valuable to me personally was his calm and his perspective. He managed serious disagreements by understanding rather well all the points of view involved, and by never (apparently!) being annoyed."

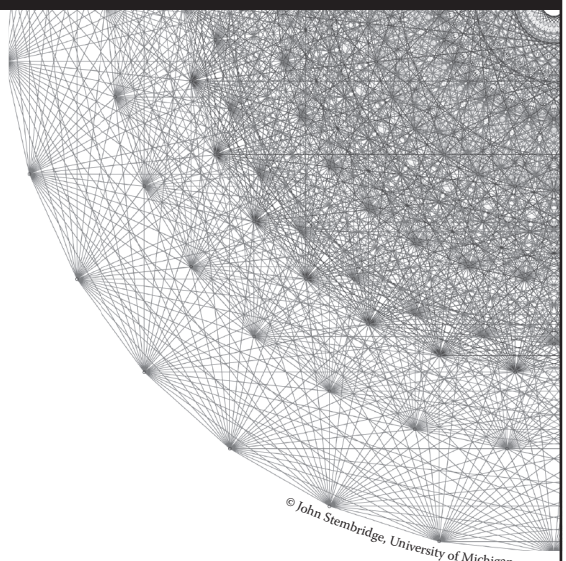
McClure's good judgment in dealing with people extends to good judgment in hiring. In his time at the AMS, he filled several positions in the senior ranks of AMS staff: Edward Dunne as Executive Editor of *Mathematical Reviews*, Robert Harington as Associate Executive Director for Publishing, T. Christine Stevens as Associate Executive Director for Meetings and Professional Services, Robin Marek as Director of Development, and Emily Riley as Chief Financial Officer. Savage said that "hiring these amazing people who do so much for the AMS, and do it so well, is probably Don's most important accomplishment." They join long-time AMS senior staff members Sergei Gelfand (Publisher), Thomas Blythe (Chief Information Officer), and Samuel M. Rankin III (Director of the AMS Washington Office) to make a very strong team to head AMS operations.

"Don understands everything about the AMS in wonderful detail, and is an expert at knowing which parts will benefit from attention and which parts just need to be allowed to work," said Vogan. "The AMS has been fortunate to benefit from his intelligence, his wisdom, his kindness, and his humor."

Credits

Photo of Donald E. McClure courtesy of Marè Studios.

American Mathematical Society



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COMMUNICATION

Chinese Mathematics and ICCM

Editor's Note: Notices *invites occasional contributions, such as this piece, from its sister publications.*

Lizhen Ji

Introduction

China is big and growing, and Chinese mathematics is also expanding and merging with world mathematics. What is special about the community of Chinese mathematicians? How has Chinese mathematics evolved and interacted with the outside world? How will it impact the future of mathematics and the global mathematics community in the world?

Though these questions are complex, one good way to understand them is to take a look at an organization which represents Chinese mathematicians and their friends and collaborators around the world: the International Congress of Chinese Mathematicians (ICCM), which holds its seventh international conference this August in Beijing.

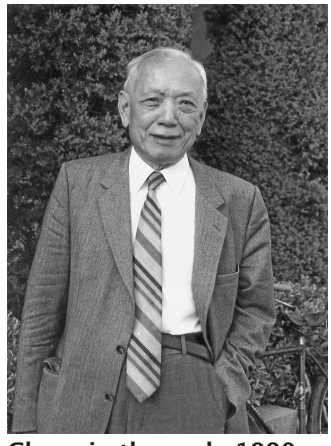
A Glimpse at the History of Chinese Mathematics

China has a long history, and Chinese mathematics also has a long history. Though Chinese mathematics was directly motivated by applications in astronomy, agriculture, and commerce, there were systematic expositions of theories and results developed by Chinese people. The most famous is the book *Nine Chapters on the Mathematical Art*.

Since mathematics was not emphasized as a subject by itself in China, mathematics developed slowly, and it reached its peak, the golden age of Chinese mathematics, in the thirteenth century. Unfortunately, Chinese mathematics paused or even declined after that, while the West was moving forward rapidly thanks to the Renaissance, the Age of Enlightenment, and the Industrial Revolution.

The gap between China and the West was wide at the beginning of the twentieth century. Shortly after that, several brilliant Chinese mathematicians emerged on the world stage of mathematics: S. S. Chern, L. K. Hua, W. L. Chow, C. C. Lin, and P. L. Hsu. They built a bridge across the gulf between Chinese mathematics and Western mathematics. Visits to China of several distinguished Western mathematicians such as Wiener, Hadamard, Blaschke, and Osgood were crucial for their success.

Modern Chinese mathematics reached another minor golden age in the 1950s and early 1960s. Then political turmoil settled in.



Chern in the early 1990s.

The History of ICCM

With the open door policy in the 1980s, the Chinese economy and hence Chinese mathematics and sciences developed rapidly. By the 1990s the time was ripe to establish an international platform for mathematicians of Chinese descent and their friends to share and exchange their achievements and ideas. The International Congress of Chinese Mathematicians was established in 1998.

The first ICCM was held in Beijing on December 12, 1998. It has been held every three years since then: 2001 in Taipei, 2004 in Hong Kong, 2007 in Hangzhou, 2010 in Beijing, and 2013 in Taipei. In 2016 it will return to Beijing for the 7th ICCM.

The invited talks of ICCM consist of plenary talks, 45-minute talks, and Morningside Lectures. The idea of the Morningside Lectures is to invite distinguished mathematicians to give lectures which may stimulate research in areas of mathematics that are not strongly represented in China. For example, in 1998 there were thirteen plenary talks, fifty-five invited 45-minute talks, all given by Chinese mathematicians whether they were working in China or outside, and four Morningside Lectures given by distinguished non-Chinese mathematicians R. Borcherds, J. Coates, R. Graham, and D. Stroock.

Similar in format to the International Congress of Mathematicians, the morning of the first day was devoted to awarding the Morningside Medal and the Chern Prize to Chinese mathematicians who have made significant

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Hua smokes while working (early 1950s).

contributions to pure or applied mathematics. The Morningside Foundation in Hong Kong provided the funding for the Morningside Medals, which are open to people under the age of forty-five. There are other prizes for non-Chinese mathematicians such as the International Cooperation Award.

The first ICCM was attended by more than 400 people, the second by more then 500, the third by more than 800, the fourth by more than one 1,500, the fifth by more than 1,600, and the sixth by more than 800. It is expected that more than 1,600 people will attend the seventh this August.

The Mission of ICCM

The mission of ICCM was explained briefly by its president, S. T. Yau, in 1998: "It was a historic event. It was the first occasion where the majority of Chinese mathematicians from all over the world gathered together to present their research. The results and the presentations were spectacular." The key point is to increase the interchange and cooperation between Chinese mathematicians. This is also the guiding principle of the Morningside Center of Mathematics, Beijing, which was established in 1996 and whose new building was dedicated during the first ICCM.

What a jubilant and grand event it was!

The mission of ICCM is perhaps best explained by a Chinese essay written by Yau for the first ICCM. Here is an excerpt followed by more in translation.

第一届全世界华裔数学家大会献辞

丘成桐

公元一九九八年冬，华裔数学家，会于京师，讲学修睦也。聚三地之精英，集九州岛之豪士。四方学者，同根同心。献明月之章，传不朽之作，吁嶬乎盛哉！

In the winter of 1998, mathematicians of Chinese descent met in the capital Beijing, giving lectures and collaborating with each other. The elites from the three regions converged, and the giants over the nine states came together. Scholars from four corners, with the same root and the same heart, presented their illuminating papers, and handed down their everlasting work. What a jubilant and grand event it was!

Chinese mathematics originated from the Nine Chapters *and prospered in the hands of Chern and Hua. Liu made notes for the* Nine Chapters, *Zu cut the circle, Chern produced classes, and Hua sieved and added. These are the wisdoms of our ancestors, and they are still the essential lights today. When the Second World War broke out in Europe, China was faced with national calamities. At that time, Sun and Yang cultivated men of ability and virtue in Tianjin and Shanghai, and Jiang and Xiong passed on personal teachings in Tsinghua. Later, they gave lectures in Yunnan and established institutions in the south of the Yangtze River. This fine tradition of passing on wisdom has been carried forward for three generations, and students and old friends of these masters are all over the world now. After leaving China, Chern continued to be an influential leader and nurtured a group of mathematicians overseas. Hua returned to Beijing to save the learning of mathematics from destruction and continue the lineage that had been cut off, eventually accomplishing the great cause in the Mainland. At this time, students of Hua and Xiong got the essence of the theory of numbers, and laid the foundation for complex variables. Students of Su and Feng expounded on the subtle meaning of equations, and initiated the research into computational mathematics. So elegant and outstanding were their achievements that they not only lived up to the standards of the ancestors, but also called for continuation of this heritage. Unfortunately, what followed was ten years of turbulence, which sent tremors across all nine states of China. People from all levels were put to torture. Heaven and Earth were in grief. Fathers and sons, teachers and students, as well as old friends were forced to take different roads.*

Chern and Hua with their wives at the headquarters restaurant of Beijing Duck, 1972.

The elder did not dare to propose any plan, and the learner did not dare to harbor any ambition. It was after the villain was captured by the General that the nation regained peace. Deng Xiaoping initiated the opening up of China, and from then on, the country has been revitalized.… longing to return, and scholars have come eastward. As a result, virtuous and talented people frequently appear in Taiwan, and achievements are continually made by people in Hong Kong. Both Taiwan and Hong Kong are internationally known for their academic excellence.…

Yau (middle) and donor Mr. Chan (seated, right) with 2011 Chern Prize winners Jiu-koung Yu (seated, left) and Song-Sun Lin (standing, left).

What Has Happened at ICCM?

The ICCM both facilitates interaction between Chinese and Western mathematics and celebrates major achievements of Chinese mathematicians and their friends.

Much has happened at past ICCMs. Attendees have included representatives of American, European, Japanese, Korean, and Singaporean mathematical societies, as well as such distinguished mathematicians as Gerd Faltings and Peter Lax. Symposia and public talks have covered everything from the effect of technology on Asian economies and challenges facing higher education to the mathematics of gambling and the intersection of math and poetry. The 2007 ICCM in Hangzhou included a panel discussion on women in mathematics.

Awards have been established to recognize mathematics research by high school students; outstanding doctoral, master's, and undergraduate theses; and individuals who have promoted the development of mathematics in China. At the 2013 ICCM in Taipei, a Morningside Special Achievement Award in Mathematics was presented to Yitang Zhang for his breakthrough on the twin prime number problem, and the International Cooperation Prize was awarded to Jean-Pierre Serre.

From the beginning the ICCM has been expertly organized. The opening ceremony of the first ICCM was held in the Great Hall of the People, which is an hour's drive from the Morningside Center—if there's no traffic. When more than a dozen buses left the Morningside Center bound for the Great Hall on the opening day of the 1998 ICCM, all the traffic lights along the route were green, and congress participants enjoyed a speedy, nonstop ride.

Publications of ICCM

The main publications of ICCM are the *Proceedings* and *Notices* of ICCM. The former gives a faithful record of the scientific activities of each ICCM and also includes pictures of awardees and ceremonies, and the latter provides a platform for mathematicians from all over the world to share their thoughts and ideas on recent major progress in mathematics, issues, and problems facing mathematics.

Impact of ICCM

ICCM gives an identity to the loose group of mathematicians of Chinese descent around the world and provides a unique opportunity for them to gather together and exchange ideas in mathematics. Such a global interaction is very helpful to everyone, especially to those people coming from places in China that are not well exposed to modern mathematics.

The Morningside Lectures given by many distinguished mathematicians who are not of Chinese descent keep the Chinese mathematicians informed of the most recent developments in mathematics in other parts of the world.

The Morningside Medal and other prizes recognize works of promising young Chinese mathematicians and motivate them to continue their excellent work.

Acknowledgements

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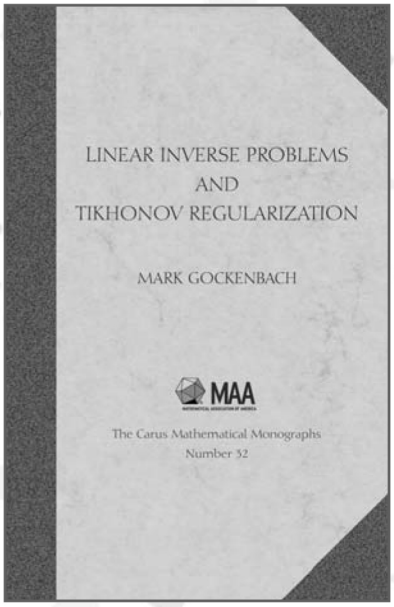

Linear Inverse Problems and Tikhonov Regularization

Mark Gockenbach
Carus Mathematical Monographs

Inverse problems occur frequently in science and technology, whenever we need to infer causes from effects that we can measure. Mathematically, they are difficult problems because they are unstable: small bits of noise in the measurement can completely throw off the solution. Nevertheless, there are methods for finding good approximate solutions.

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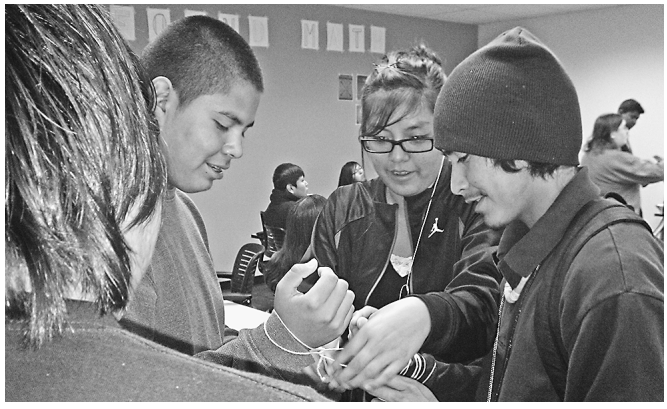
Baa Hózhó Math: Math Circles for Navajo Students and Teachers

Dave Auckly, Bob Klein, Amanda Serenevy, and Tatiana Shubin

The authors describe their mathematics program for the Navajo Nation of Native Americans in the southwest United States.

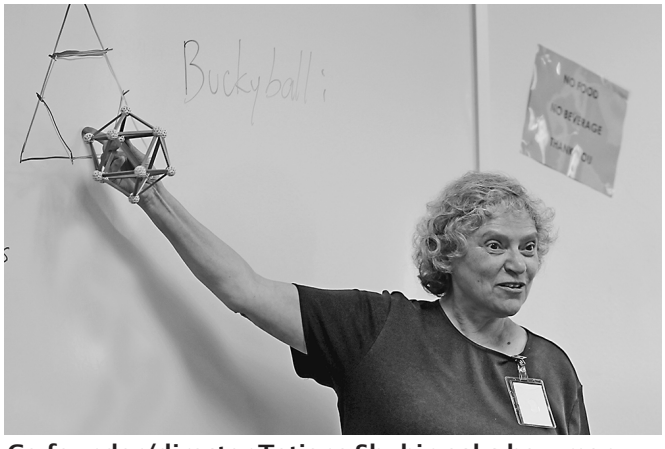
It's 8:00 am on Tuesday morning, and two vans have arrived at Diné College having just completed 6:30 am trips from Many Farms and Fort Defiance, Arizona, to bring thirty middle and high school students to the Navajo Baa Hózhó Math Camp. Baa Hózhó means "balance" or "harmony." The kids race into the building, grab breakfast, and find seats in the classroom to eat and play with Rubik's cubes and other puzzles and to catch up with friends. Shortly they will be busy with two math circle sessions, physical activity, sessions on Navajo culture and language, and lunch—all before the 4:00 pm trip home.

At 9:00 am, the math circle sessions begin, and Tatiana Shubin, a mathematician from San Jose State University and co-founder/director of the Navajo Nation Math Circles (NNMC) project, holds up a stick-and-ball model of a Buckyball, built of twenty hexagons and twelve pentagons. She asks, "How many diagonals are there for this object?" Students stare at the object for a minute, then begin group discussions and calculations that will take more than an hour. Shubin smiles, knowing that this is what she had in mind when she first dreamed of sharing math with the Navajo people.



Navajo students Jamie Tsosie, Mya Chee, and Waylon Begay getting untied before breakfast.

In another room, middle school student Nataani Yazzie is smiling as Dave Auckly, a mathematician from Kansas State University and co-founder/director, is racing around the classroom acting like a pirate. He is delighting the



Co-founder/director Tatiana Shubin asks how many diagonals a Buckyball has.

David Auckly is professor of mathematics at Kansas State University. His email is dav@ksu.edu. *His research interests cover a broad range of geometry/topology and overlap with PDE, mathematical physics, and algebraic geometry. He has also been very involved in many special educational programs.*

Bob Klein is associate professor and undergraduate chair of the Department of Mathematics at Ohio University. His email address is kleinr@ohio.edu. *Bob is also working on math circle projects in SE Ohio, Guatemala, and Nepal (see* mathunbounded.org/ *for details).*

Amanda Serenevy is director of Riverbend Community Math Center in South Bend, Indiana. Her email address is amanda@riverbendmath.org.

Tatiana Shubin is professor in the Department of Mathematics and Statistics at San Jose State University. Her email address is tatiana.shubin@sjsu.edu. *Among other things, she has been running San Jose Math Circle since 1998.*

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Co-founder/director Dave Auckly works with Tyline Descheny and Michael Begay on a version of the Ham Sandwich theorem.

students with his energy while intriguing them with a combinatorics problem set in the context of pirate treasure: strands of multicolored pearls assembled according to a simple set of rules. Auckly has been with the project since Tatiana asked him if he knew anyone in the Navajo Nation back in 2011 and together they plotted how to create a permanent Math Circles program for students and teachers there. He has been managing many of the administrative details throughout the calendar year to arrange mathematician visits, finances, and the yearly math festivals.

In the two weeks of camp, the students will go on a campout; meet another ten to twelve mathematicians and scientists from institutions around the United States; learn Navajo games, language, and culture; eat; play; and grow in their abilities and confidence with problem solving. In particular, they will interact with project co-founder/director Henry Fowler. Fowler, a mathematician and Navajo scholar from Diné College, shared Tatiana's enthusiasm for the project from the first time she told him about it. He has dedicated his professional life to helping his people realize their potential in mathematics and science.

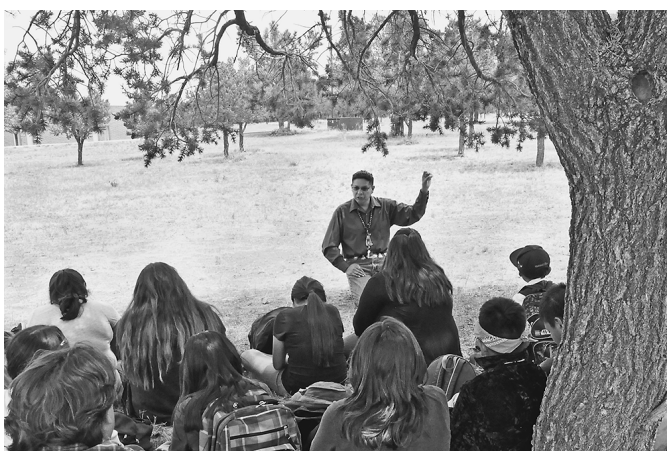
Mathematics is very close to Navajo culture: both are deeply rooted in the love of beauty

But the students at the summer camp are participating in something much bigger than a two-week summer camp. They are part of the Navajo Nation Math Circles project. A group of their math teachers (from kindergarten through high school) will be gathering on Saturday for a Math Teachers' Circle workshop, one of many throughout the year led by mathematicians who also visit schools to lead math circle sessions. The teachers will also participate in a math festival held annually by the NNMC and attended last year by more than seven hundred fifty students and parents.

The goal of the project has always been to bring the spirit of mathematics to the Navajo Nation and to spark interest and joy in problem solving in the students and teachers who participate. Mathematics is very close to Navajo culture: both are deeply rooted in the love of beauty.

Beginnings

Shubin had visited the Navajo Nation before and was deeply moved by the culture, environment, and people. Remembering how the network of math circles in Russia and Kazakhstan had spurred her own interest in mathematics, she wanted to bring them to the Navajo Nation. She dreamed of spending her sabbatical leave on the project. In January 2012 Auckly and Shubin designed a broad-reaching and sustainable program for teachers and students in the Navajo Nation. The program would include mathematical visitors who would lead teacher workshops and special math circles at local schools. Auckly immediately began the work of raising funds to support the project, the beginning of what would be more than a dozen successful grant proposals.



Co-founder/director Henry Fowler (top). Below, Fowler, the son of a Navajo code talker, discusses Navajo culture with students.

Auckly and Shubin needed an invitation to the reservation, however. One can't just show up and announce, "I'm here to do math circles." Jennifer White, an acquaintance of Auckly's, introduced Shubin to Henry Fowler. Fowler introduced Shubin to school principals and math departments and helped to lay the groundwork for establishing math circles in schools across the reservation.

The second year of the project saw the addition of two additional co-directors: Bob Klein, associate professor at Ohio University, and Amanda Serenevy, executive director of the Riverbend Community Math Center in South Bend, Indiana. Klein grew up in Albuquerque, New Mexico, so the project has helped him reconnect with the Southwest, as well as provide him an opportunity to investigate the NNMC model for developing and sustaining math circles globally. This work has informed his development of similar projects in Guatemala (with Javier Ronquillo Rivera) and Nepal (with Rabi and Mohan K.C., and Prabha Shrestha).

Serenevy was one of the first visitors to the project and is an energetic math circle leader who formed the Riverbend Community Math Center in fall 2006. She is one of few people in the world who runs math circles as a full-time job. Serenevy contributes a wealth of experience working with teachers and students on collaborative problem solving and visits regularly throughout the school year and summer.

A Comprehensive Project

The project has eight components that interact to improve mathematics education in the Navajo Nation. The components are:

1. a ***mathematical visitor program*** sending mathematicians to Navajo schools to lead in-school and after-school math activities in math circles;

2. a two-week nonresidential ***Baa Hózhó Summer Camp*** for students in grades 6–12;

3. public ***math festivals*** to introduce engaging mathematical activities to large numbers of Navajo students;

4. a year-long ***student mentoring program*** that pairs Navajo students with professional mathematicians;

5. a series of ***professional development workshops*** for Navajo teachers;

6. a ***teacher mentoring program*** that connects small groups of teachers to mathematicians;

7. a summer ***teacher development program***, and

8. ***math circles for students***, which meet regularly at schools and are led by teachers.

This structure is amazing in its effectiveness: Math festivals advertise the project to students and teachers, demonstrating that math can be fun; the math circles during and after school get kids even more interested—they want to work on more math problems; the teachers' workshops provide an opportunity for local teachers to garner more ideas, share their experiences, and air their concerns; the summer math camp, teacher mentoring pro-gram, student mentoring program, and summer teacher development program all provide more in-depth math training for those who truly get hooked.

In the words of students Buddy Joe and Charmayne Seaton and teacher Dana Busenbark:

"I brag about this math camp, because it's really a lot of fun. It's not like regular classrooms where you're reading a textbook and listening to a teacher in front of the class writing on the board. It's a lot of fun; we get involved in the lesson. It's a lot different."

—Buddy Joe, student, Fort Defiance, Arizona

"I thought I was dumb, that I wasn't really smart. But then I actually got to know myself and I realized that I am smart. I can do it if I put my mind to it. And I believe that for everyone. If you have a goal in mind and you really want it, you can do it. You just have to believe in yourself, and you just have to push."

—Charmayne Seaton, student, Ganado, Arizona

"I talk with others about the math camp because it provides [the] Navajo Nation students that we teach with opportunities to meet others that they may not know, learn about jobs that require math skills, and most importantly to think outside the box. So often, our students think in black and white and do not consider other options. The math camp gives them an opportunity to discuss options and open their minds to new ideas."

—Dana Busenbark, teacher, Fort Defiance, Arizona

The impact is already being felt at the postsecondary level. Since the project was formed, Diné College has seen a marked increase in the demand for mathematics. The college has introduced two new mathematics classes and runs more sections of existing math classes. In the fall of 2013 the college had one section of precalculus with twenty-three students. In 2014–15 the college offered precalculus to thirty-five students, calculus to eighty-two students, and linear algebra to six students. The college just introduced its first mathematics degree program. This new program in mathematics education has fifteen students.

Charmayne Seaton has attended many NNMC programs. She calls Shubin her "auntie" as a sign of the bond they share. She says that she longed to escape from her family's home at Ganado, but since attending the math camp at Diné College, her goal is to get into a university, then return home to help her people.

Shubin, Auckly, Klein, and Serenevy have been working for the past five years to bring these programs to the Diné people in the Navajo Nation. The Navajo Nation is an area the size of West Virginia in the Four Corners region of the American Southwest. It is home to around 200,000 Navajos, and it is very isolated. Industry is nearly absent, and there are high levels of poverty. The hope is that the program will grow into a model that may be used to help other underserved populations.

The majority of funding for the NNMC project has come from the National Science Foundation and National Security Agency, with additional funding from the American Institute of Mathematics, the Mathematical Sciences

Research Institute, the Mathematical Association of America, a number of colleges and universities, and a few foundations. A stable funding model has been elusive, though the model represents a high impact-to-cost ratio, a cause for optimism. External funding is important because the average family income in the Navajo Nation is less than $16,000 per year, so NNMC provides all programs to members of the community for free. Meals and transportation are included with longer programs.

With a dozen visits by mathematicians to the NNMC project, more than one thousand students from across the Navajo Nation have engaged with working mathematicians and scientists from across the United States. Mathematicians come during the school year and stay about a week, visiting several schools during each visit, running math circle sessions on topics that have included hat color logic problems, RSA encryption, the Collatz conjecture, sum free partitions, mathematical origami, rational tangles, chromatic numbers, distance puzzles, Fibonacci tiling patterns, Liar's Bingo (binary representations), Friends and Enemies (a dynamical systems game), repeating decimals, the orbit-stabilizer theorem, Nim games, and Intersection Math.

Benefits run both ways as visiting mathematicians and scientists have the opportunity to meet and learn more about the Navajo people and the beautiful Diné Bikéyah, or Navajo Country. As Blake Thornton, mathematician at Washington University, St. Louis, wrote, "I worked really hard the entire week, but I had a great time. I would love to go back." Many mathematicians do come back. Matthias Kawski has driven up from Arizona State University many times.

Parents and guardians of the student participants in the project work hard to encourage and support the participation of the students in the summer camp and festival, sometimes driving them several hours each way to participate.

Sample from Thornton's visit: You tell a group of ten students that you will put a party hat with a number 1–10 on the head of each student. (However, not all numbers need to be used. It might be the case that one hat has a 1 on it and the rest have a 7.) When this is done each student will be able to see the hats on all of the other students, but not the hat on his or her own head. Without communicating, the students will each write a guess of the number on their own hat. At the same time, the students will show their guess. If just one student correctly guesses the number on his or her hat it will be considered a win for all. The students may plan before the hats are placed on their heads and agree what they will do. Is there a way the students can be sure to win? If so, how?

Summer Camp

To help participants develop relationships with their peers and therefore the ability to collaborate and to feel comfortable sharing ideas, leaders divide participants into two teams for the duration of the camp. Students quickly identify with those teams in playful camaraderie. The camp consists of whole-group sessions and sessions split by teams (such as the math circle sessions, where this approach means working with smaller groups of about fifteen students).

Participants have a range of mathematics backgrounds and come from grades 6–12. They submit an application and references from teachers and are chosen based not only on the strength of those references but also on the desire and "heart" evident in their answers to questions like "Why do you want to participate in the Baa Hózhó Math Camp?"

Joe Buhler of the Institute for Defense Analyses working with Dawnae Etsitty.

Each Friday of the summer camp, a guest of honor spends part of the day interacting with students and gives an inspirational talk that combines mathematical content with their personal and professional story. Guests of honor have included Robert Megginson, one of very few Native Americans with a PhD in mathematics; John Herrington, the first Native American in space; and Sandra Begay and Julius Yellowhair, both Navajos who work as senior scientists at Sandia Labs.

While the focus is on collaborative problem solving, representing an authentic model for mathematical investigation, the project also has a fun and playful competition structure in place: Math Wrangles, a form of mathematical debate. The process of preparing for the Math Wrangle has greatly increased the confidence of participants and offered project leaders a way to assess overall effectiveness of the camp and to watch the development of participants' abilities.

Teacher Mentoring and Workshops

The teacher mentoring program has been refined by the NNMC directors into what seems for now to be an effective format. The directors initially hoped that by letting teachers watch mathematicians make presentations to their students and by offering teacher workshops, the Navajo teachers would begin leading math circle sessions at their own schools. This has proved difficult, because while teachers see the value of the math circle sessions, they do not feel prepared to run such sessions on their own. The teacher mentoring program explicitly addresses this.

Leegene Barlow and Elene Morris working on a problem.

Mentoring takes place via teleconference with a group of teachers who work through a math circle session together with a project director. When they work through a problem for the first time, the teachers act in the role of students. Teachers get written support materials, including handouts, notes on the relevant mathematical background and big ideas, presentation tips, and evaluations for teachers and mentors to use in examining the efficacy of the sessions. A second (and possibly third) teleconference with the teachers ensures that they are comfortable leading the session. Then a team of two to four teachers leads the session with a group of students. Last year the project included twelve Navajo-led math circle sessions.

When Navajo teachers lead math circles, students see a member of their tribe modeling mathematical inquiry, serving to counter stereotypes and promote positive attitudes toward mathematics.

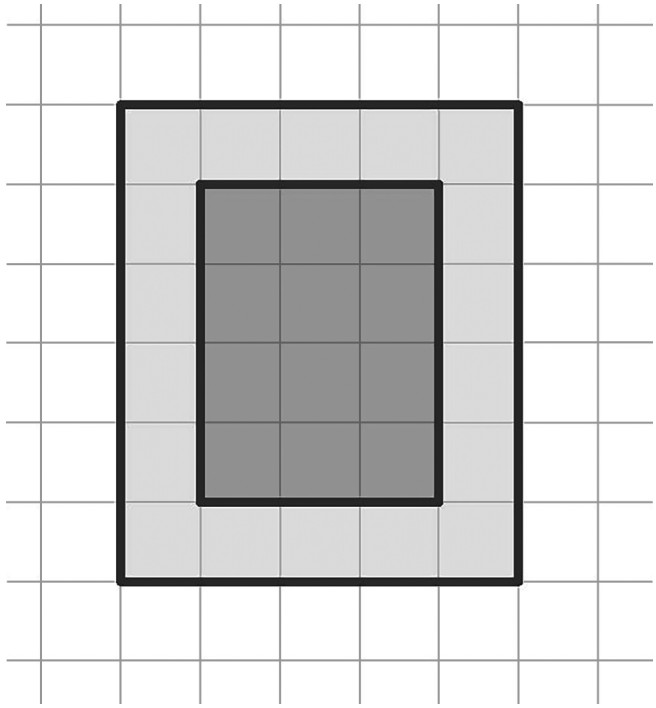
Keeping mathematics and culture mutually reinforcing is an important part of the project approach. Dawnlei Ben is largely responsible for creating the Navajo cultural component of the math camp. Ben grew up in Canyon de Chelly in a house with no running water or heating. "I'm okay with that. We have cornfields, apples, plums, peaches, apricots on our land," she says. Ben was raised with traditional teachings and wants to impart what she learned to children so the culture can survive. At the camp she has taught Navajo remedies, toolmaking, and games.

The Documentary

When George Csicsery heard of the Navajo Nation Math Circles project he envisioned a documentary film about the meeting of two worlds: that of some of the country's most accomplished mathematicians and math educators with the children and teachers in underserved Navajo schools. The resulting *Navajo Math Circles* film premiered in Seattle, Washington, on January 6, 2016, at the Joint Mathematics Meetings. Nine of the Navajo participants attended this screening, including three students, two teachers, two parents, as well as many of the mathematicians involved in the project. The DVD contains the 58-minute film as well as five extra features totaling another 34 minutes.

Screenings of *Navajo Math Circles* are being scheduled throughout the United States, and the film is being promoted for broadcast on public television stations.

Sample Wrangle Problem: Using a sheet of grid paper, Dana marked a rectangle and drew a picture inside the rectangle (in the example below it is dark gray). Then she surrounded the rectangle by a one-square-wide border consisting of grid squares (in the example below it is light gray). It turned out that the area of the border is exactly the same as the area of the inside rectangle. What size is the rectangle? List all possible sizes and prove that other sizes won't work. The example below doesn't work.



At least once per semester, visiting mathematicians lead teacher training workshops for groups of teachers from across the reservation. At one of these workshops, Shubin, Auckly, Serenevy, and Klein facilitated sessions designed to help the more than forty teachers use problem-solving prompts in their classrooms and to deepen their understanding of the math behind the problems. In Exploding Dots, for instance, Shubin helped teachers think about how to explain place value, addition, multiplication, subtraction, and division, and standard manipulations of polynomials to their students, but in a new and thought-provoking way. Auckly led Toilet Paper Math, a session for elementary school teachers in which he demonstrated several ways to use toilet paper as a playful, yet useful, manipulative to help the teachers describe various number concepts to their students. Serenevy presented sessions on introducing serious mathematical play in lower elementary classrooms, conceptual approaches to operations with numbers, and mathematical modeling using spreadsheets.

Interviews with the teachers and the visiting mathematicians made clear the value of this training, a sense of conditions at schools on the reservation, and participants' and facilitators' hopes for bringing improvements to their classrooms using fun and interesting mathematical investigations.

Project leaders hope that this model and these experiences will be shared by more mathematicians, teachers, and students in many other places in this country and beyond.

A day at the festival, in pictures. From the top down: 1. Participants; 2. Counting tree rings; 3. Ballast puzzles; 4. Life-size counting problems.

When saying goodbye the Navajo wish for others to "Walk in beauty," and the directors of the Navajo Nation Math Circle project similarly wish that the story of this project inspires others to use math circles to help everyone to walk in beauty and to do so with mathematics.

For more information about the Navajo Nation Math Circles project or to contribute, please visit: navajomathcircles.org

For more information about the production and a detailed synopsis or for updates on upcoming screenings of *Navajo Math Circles*, please visit navajomathcirclesfilm.com, where a sample video covering the summer activities of 2014 can be viewed.

Credits

Page 784 photo of Navajo students, courtesy of Tatiana Shubin.
Page 784 photo of Tatiana Shubin, courtesy of George Csicsery.
Page 785 photo of Dave Auckly, courtesy of George Csicsery.
Page 785 photos of Henry Fowler, courtesy of George Csicsery.
Page 787 photo of Joe Buhler and students, courtesy of George Csicsery.
Page 788 photo of Leegene Barlow and Elene Morris, courtesy of George Csicsery.
Page 789 festival photos, courtesy of Barsine Benaly.

Doctoral Degrees Conferred

2014–2015

ALABAMA

Auburn University (13)

DEPARTMENT OF MATHEMATICS AND STATISTICS

Bao, Feng, Efficient numerical algorithms for solving nonlinear filtering problems

Bragan, Kelly, Topics in edge-regular graphs

Brauss, Daniel, Implementation of a finite element method for the velocity-current magnetohydrodynamics equations

Brice, Daniel, On derivations of parabolic subalgebras of reductive Lie algebras

Chaffee, Joseph, 3-cycle systems and structure within graph decompositions

Chase, Timothy, Monotonic covering properties

Clontz, Steven, Applications of limited information strategies for topological games

Erzurumluoglu, Araz, Fair factorizations and fair holey factorizations with two associate classes and prescribed regularity

Hammer, James, Factor pair Latin squares

Nguelifack, Brice, Generalized signed-rank estimator for nonlinear models with multidimensional indices and two-phase linear models

Rawal, Nar, Principal eigenvalue theory for time periodic nonlocal dispersal operations and applications

Tadesse, Dawit, High-dimensional classification methods for sparse data and their applications in text and data mining

Xie, Xiaoxia, Nonlocal dispersal equations and convergence to random dispersal equations

University of Alabama (6)

DEPARTMENT OF MATHEMATICS

Banjade, Debendra, Wolff's ideal problem in the multiplier algebra on Dirichlet space

Duong, Nguyen, Twisting bordered Khovanov homology

Shahmurov, Rishad, Linear and nonlinear Rayleigh-Bénard convection in absence of horizontal boundaries

Song, Yuanyuan, Stability analysis of a bilayer coating a cylindrical tube

Tian, Wufeng, Fast alternating direction implicit schemes for geometric flow equations and nonlinear Poisson equations in biomolecular solvation analysis

Ying, Mengyi, Interval method for special constrained global optimization problems

University of Alabama at Birmingham (10)

DEPARTMENT OF BIOSTATISTICS

George, Brandon, A spatiotemporal model for repeated imaging data

Li, Peng, The small sample inferences of cluster-randomized trials

Loop, Matthew, Spatial analysis of hypertension prevalence using a large US cohort

Merrill, Peter, Non-compliance in clinical trials: The perils of statistical methods

Ranjan, Ashutosh, Power issues and internal pilot design in cluster-randomized trials with unequal cluster sizes

Salter, Amber, Practical extensions of the continual reassessment method

Tripathi, Arvind, Count models with multiple inflations

Wang, Guoqiao, An evaluation of sample size re-estimation adaptive designs and delayed-start designs for Alzheimer's disease

DEPARTMENT OF MATHEMATICS

Fadl Allah, Alzaki, Elliptic equations and systems with nonlinear boundary conditions

Muthoka, Terrence, American options and semilinear parabolic partial differential equations in weighted Sobolev spaces

University of Alabama–Huntsville (1)

DEPARTMENT OF MATHEMATICAL SCIENCES

Albashaireh, Reem, Traveling wave solutions of a chemotaxis model: Existence and stability

ARIZONA

Arizona State University (11)

MATHEMATICS, COMPUTATIONAL AND MODELING SCIENCES

Bliss, Nadya, Statistical signal processing for graphs

SCHOOL OF MATHEMATICAL AND STATISTICAL SCIENCES

Alvarez, Roberto, A two-strain spatiotemporal mathematical model of cancer with free boundary condition

Everett, Rebecca, Applications of the Droop cell quota model to data based cancer growth and treatment models

Holeva, Thomas, A kinetic approach to anomalous diffusion in biological trapping regions

Packer, Aaron, Cell quota based population models and their applications

Peace, Angela, Stoichiometric producer-grazer models incorporating the effects of excess food-nutrient content on grazer dynamics

Robinson, Benjamin, Operator-valued frames associated with measure spaces

Temkit, M'hamed, Experimental designs for generalized linear models and functional magnetic resonance imaging

Wang, Ran, On choosability and paintability of graphs

Zhou, Yuqin, Mathematical and statistical insights in evaluating state dependent effectiveness of HIV prevention interventions

Zinzer, Scott, One- and two-variable p-adic measures in Iwasawa theory

The above list contains the names and thesis titles of recipients of doctoral degrees in the mathematical sciences (July 1, 2014, to June 30, 2015) reported in the 2016 Annual Survey of the Mathematical Sciences by 197 departments in 143 universities in the United States. Each entry contains the name of the recipient and the thesis title. The number in parentheses following the name of the university is the number of degrees listed for that university.

University of Arizona (15)

DEPARTMENT OF MATHEMATICS

Blackburn, Chantel, Mathematics according to whom? Two elementary teachers and their encounters with the mathematical horizon

Hinkel, Dustin, Constructing simultaneous Diophantine approximations of certain cubic numbers

Jiang, Jianping, Random walks and their scaling limits

Lafferty, Matthew, Eichler-Shimura cohomology groups and the Iwasawa main conjecture

Maienschein, Thomas, Desingularizing the boundary of the moduli space of genus one stable quotients

Powell, Kevin, Modular symbols modulo Eisenstein ideals for Bianchi spaces

Prasad, Priya, Connection, motivation, and alignment: Exploring the effects of content-based mathematics professional development

Todd, George, Linear relations between multizeta values

Waters, Patrick, Combinatorics of the Hermitian 1-matrix model

PROGRAM IN APPLIED MATHEMATICS

Birrell, Jeremiah, Non-equilibrium aspects of relic neutrinos: From freeze-out to the present day

McDaniel, Austin, The effects of time delay on noisy systems

Rosenthal, William Steven, Data assimilation in systems with strong signal features

Whalen, Patrick, Full field propagation models and methods for extreme nonlinear optics

STATISTICS GIDP

Kim, Hyeonju, Probabilities of ruin in economics and insurance under light- and heavy-tailed distributions

Sohn, Michael, Novel computational and statistical approaches in metagenomic studies

ARKANSAS

University of Arkansas at Fayetteville (1)

DEPARTMENT OF MATHEMATICAL SCIENCES

Wanjohi, Richard, Online detection of outliers and structural breaks using sequential Monte Carlo Methods

CALIFORNIA

California Institute of Technology (9)

DEPARTMENT OF COMPUTING AND MATHEMATICAL SCIENCES

Cubillos, Max, General-domain compressible Navier-Stokes solvers exhibiting quasi-unconditional stability and high-order accuracy in space and time

Mason, Gemma, Full and model-reduced structure-preserving simulation of incompressible fluids

DEPARTMENT OF MATHEMATICS

Chiriac, Liubomir, Special Frobenius traces in Galois representations

Dawra, Nakul, On the link Floer homology of L-space links

Elliot, Ross, Topological strings, double affine Hecke algebras, and exceptional knot homology

Fan, Sin Tsun Edward, On the construction of higher étale regulators

Kasatkin, Victor, Some constructions related to noncommutative tori, Fredholm modules and the Beilinson-Bloch regulator

Linghu, Daiqi, Chains of non-regular de Branges spaces

Skinner, Brian, Logarithmic potential theory on Riemann surfaces

Claremont Graduate University (10)

INSTITUTE OF MATHEMATICAL SCIENCES

Hallett, Melodie, Novel random forest and variable importance methods for correlated survival data, with applications to tooth prognosis

Heckman, David, Variations on Markov chain Monte Carlo Methods: Continuous and discrete optimization of scheduling problems

Liu, Zheng, A bond option pricing formula in the extended CIR model

Lyons, Daniel, Dynamics and bifurcations in coupled bistable systems with applications to engineering devices

Najera Chesler, Aisha, Non-linear analysis and modeling of FHR and ECOG: Predicting fetal distress in labor

Sanchez, Eduardo, Mimetic finite differences and parallel computing to stimulate carbon dioxide subsurface mass transport

Suarez Solano, Jean, Regularization of singular sources for PSIC computations of particle-laden flows with shocks

Sun, Xun, On the geometry of cyclic and permutation invariant lattices

Wang, Wei, Boosting performance and endurance of flash-based storage systems: From embedded systems to enterprise servers

Xu, Shujing, Effects of history and lift force on particle trajectories in oscillatory rotating fluids

Naval Postgraduate School (1)

DEPARTMENT OF APPLIED MATHEMATICS

Boucher, Randy, Galerkin optimal control

Stanford University (10)

DEPARTMENT OF MATHEMATICS

Bernstein, Megan Maria, Random walks on the symmetric group, likelihood orders, and involutions

Henderson, Christopher Kling, Propagation phenomena in reaction advection diffusion equations

Katshelson, Vitaly, Diffraction of elastic waves by edges

Kim, Seung Ki, On the shape of a high dimensional random lattice

Lin, Yuncheng, On higher q,t Catalan numbers

Pang, Chung Yin Amy, Hopf algebras and Markov chains

Pardon, John Vincent, A new construction of virtual fundamental cycles in symplectic geometry

Sapir, Jenya Markovna, Non-simple geodesics on surfaces

Shao, Xuancheng, Dichotomy between structure and randomness in combinatorial number theory

Yang, Haizhao, Oscillatory data analysis and fast algorithms for integral operators

University of California, Berkeley (38)

DEPARTMENT OF MATHEMATICS

Achinger, Piotr, $K(\pi,1)$ spaces in algebraic geometry

Beal, Khalilah, Viscosity solution methods in risk analysis

Berger, Emily, Probabilistic methods for single individual haplotype reconstruction

Chih, Ellen, Indivisible characteristics of recursively enumerable sets

Galkowski, Jeffrey, Distribution of resonances in scattering by thin barriers

Haberman, Boaz, Inverse problems with rough data

Harris, Kelley, Inference of population history and mutation biology from human genetic variation

Harrop Griffiths, Benjamin, Quasilinear dynamics of KdV-type equations

Hilaire, Christian, The Ricci flow on Riemannian groupoids

Honigs, Katrina, Derived equivalent varieties and their zeta functions

Jin, Long, Scattering resources for convex obstacles

Jin, Xin, Symplectic approaches in geometric representation theory

Kalman, Adam, Newton polytopes of cluster variables

Lanoue, Daniel, The metric coalescent

Lee, Heather, Homological mirror symmetry for open Riemann surfaces from pair-of-pants decompositions

Merberg, Adam, Noncommutative generalized Brownian motions with multiple processes

Morrison, Ralph, Tropical and non-Archmidean curves

Pejic, Michael, Quantum Bayesian networks with application to problems displaying Parrondo's paradox

Peterson, Eric, Cotangent spectra and the determinantal sphere

Preskill, Benjamin, The jump splice method for elliptic interface problems and the incompressible Navier-Stokes equations

Rosen, Zvi, Algebraic matroids in applications

Sylvan, Zachary, On partially warpped Fukuya categories

Tsou, Benjamin, Eigenvalue distributions of symmetric group representations

Vu, Thanh, Combinatorial patterns in syzygies

Wang, Luming, Discontinuous Galerkin methods on moving domains with large deformations

Wayman, Eric, A skew-product decomposition on a manifold equipped with a group action, a Lorentz model with variable density in a conservative force field, and reconstruction of a manifold from the intrinsic metric of an associated Markov chain

Zhang, Te, Weak convergence and rapidly oscillating pendula

DEPARTMENT OF STATISTICS

Broderick, Tamara, Clusters and features from combinatorial stochastic processes

Li, Hongwei, Theoretical analysis and efficient algorithms for crowdsourcing

Lopes, Miles, Some inference problems in high-dimensional linear models

Racz, Miklos, Influences in voting and growing networks

Ruddy, Sean, Shrinkage of dispersion parameters in the double exponential family of distributions, with applications to genomic sequencing

BIOSTATISTICS

Balzer, Laura, Design and analysis of cluster randomized trials with application to HIV prevention and treatment

Boley, Nathan, Methods for the analysis of high throughput sequencing data

LeDell, Erin, Scalable ensemble learning and computationally efficient variance estimation

Lendle, Samuel, Targeted minimum loss based estimation: Applications and extensions in causal inference and big data

Stoiber, Marcus, Biological networks: Dynamics, mechanisms and responses

Zheng, Wenjing, Semiparametric and robust methods for complex parameters in causal inference

University of California, Davis (16)

DEPARTMENT OF MATHEMATICS

Lewis, Owen, Mathematical investigation of hydrodynamic contributions to amoeboid cell motility in physarum polycephalum

Li, Binglin, Towards a theory of Abel-Jacobi maps and limit linear series for curves of compact types

Lu, Steven, No quantum Brooks' theorem

Scrimshaw, Travis, Crystals and rigged configurations

Tavernetti, William, Modeling and simulation of thermal ignition, flame fronts, reactive flows and transonic combustion

Waagen, Alexander, Phase transitions on static and evolving networks: Effect of competition, zealotry, and growth

Watson, Richard, The structure of transient memory in a simple model of inhibitory neural feedback

Wertz, Tim, Localized operators and eigenvector localization

DEPARTMENT OF STATISTICS

Becker, Gabriel, Rethinking dynamic documents for data analytic research

Ganguly, Apratim, Applications and theoretical properties of local geometry based structure learning methods in Gaussian graphical models

He, Jinjiang, Functional correlations to quantify functional connectivity in brain imaging

Lai, Chu Shing (Randy), Generalized fiducial inference and its applications

Melcon, Erin, Penalty parameter selection in generalized linear models and linear mixed models

Udaltsova, Irina, Bayesian estimation of $\log(N > S) - \log S$

Wong, Ka Wai (Raymond), Fiber direction estimation in diffusion MRI

Zhang, Xiaoke, A unified theory and a time-varying additive model for functional and longitudinal data

University of California, Irvine (10)

DEPARTMENT OF MATHEMATICS

Eskew, Monroe, Measurability properties on small cardinals

Forero Cuervo, Andres, Consistency strength of stationary catching

Hill, Joshua, On calculating the cardinality of the value set of a polynomial (and some related problems)

Keti, Matt, Reed-Solomon codes and the deep hole problem

Konstorum, Anna, Mathematical modeling of tumor-microenvironment dynamics

Liu, Hsiao-Fan, Geometric curve flows

Rische, Jacquelyn, Mathematical modeling of language learning

Smith, Luke, Refining multivariate value set bounds

Yan, Huaming, Mathematical modeling of branching morphogenesis and vascular tumor growth

Zou, Changjian, Inverse problems in acoustic and electromagnetic scattering

University of California, Los Angeles (33)

DEPARTMENT OF BIOSTATISTICS, FIELDING SCHOOL OF PUBLIC HEALTH

Boren, David, Agent-based modeling for HIV prevention

Fischer, Heidi Jean, Statistical methods for ultrafine particle distributions

Harrell, Lauren, Analysis strategies for planned missing data in health sciences and education research

Konikoff, Jacob, Cross-sectional HIV incidence estimation: Techniques and challenges

Qiu, Jiaheng, Finding optimal experimental designs for models in biomedical studies via particle swarm

Rizzo Varela, Shemra, Uncertainty in meta-analysis: Bridging the divide between ideal and available extracted data

DEPARTMENT OF MATHEMATICS

Benatar, Jacques, The existence of small prime gaps in subsets of the integers

Bhaskar, Siddharth, Recursion versus tail recursion over abstract structures

Burungale, Ashay, On the non-triviality of arithmetic invariants modulo p

Davis, Damek, On the design and analysis of operator-splitting schemes

Denomme, Robert, Character formulas for 2-Lie algebras

Feldman, William, Asymptotic behavior of nonlinear PDE: Dynamic stability of a droplet model and boundary data homogenization

Gan, Wenying, Several problems in extremal combinatorics

Guan, Feng, Affine structure on the Teichmüller spaces and period maps for Calabi-Yau manifolds

Hachtman, Sherwood, Calibrating determinacy strength in Borel hierarchies

Hu, Huiyi, Graph based models for unsupervised high dimensional data clustering and network analysis

Kim, Sungjin, Average of the first invariant factor of the reductions of the Abelian varieties of CM type

Krause, Benjamin, Some results in pointwise ergodic theory

Leary, Brian, On maximal amenable subalgebras of amalgamated free product von Neumann algebras

Liu, Yajing, Applications of the link surgery formula in Heegaard Floer homology

Mackey, Alan, Part I: Steady states in two-species particle aggregation; Part II: Sparse representations for multiscale PDE

Malyshev, Anton, Combinatorics of finitely generated groups

Merkurjev, Ekaterina, Variational and PDE-based methods for big data analysis, classification and image processing using graphs

Miner, Samuel, Limit shapes of restricted permutations

Nelson, Brent, Non-tracial free transport and applications

O'Connor, Daniel, Primal-dual decomposition by operator splitting and applications to image deblurring

Radke, Eric, Net weighting methods and other novel approaches in variation-aware placement and sizing

Rajagopalan, Anand, Outlier eigenvalue fluctuations of perturbed iid matrices

Scaduto, Christopher, Instantons and odd Khovanov homology

Walsberg, Erik, Metric geometry in a tame setting

Wang, Yuting, Virtual node algorithms for simulating and cutting deformable solids

Xu, Samantha, Hamiltonian systems and Gibbs measures

Zipkin, Joseph, Mathematical models and methods for behavior in social networks: Urban crime, self-exciting interactions, and information spread

University of California, Riverside (9)

Department of Mathematics

Lunde, Mathew, Self-extensions and prime factorizations of representations of quantum affine algebras

Park, Jason, Random measure algebras under convolution

Safii, Soheil, Equivariant and isovariant function spaces

Thistlethwaite, Oliver, Seiberg-Witten invariants, Alexander polynomials, and fibred classes

Wand, Jeffrey, Demazure flags of local Weyl modules

West, Jacob, Higher Auslander-Reiten theory

Department of Statistics

Crackel, Roberto, Likelihood free inference for a flexible class of bivariate beta distributions

Xiao, Zhen, Parameter estimation in differential equation based models

Zheng, Zongpeng (Patrick), Projection, search, and optimality in factorial experiments

University of California, San Diego (15)

Department of Mathematics

Cheng, Shi, Analysis and numerical treatment of elliptic equations with stochastic data

Compeau, Phillip, Scalable online algorithmic biology education and DCJ-Indel sorting

Deotte, Chris, Domain partitioning methods for elliptic partial differential equations

Hennig, Johanna, Locally finite dimensional Lie algebras

Kasa, Michael, Toward Gromov-Witten invariants relatively coherent logarithmic schemes

Kempton, Mark, High dimensional spectral graph theory and non-backtracking random walks on graphs

Lobue Tiefenbruck, Janine, Combinatorial properties of quasi-symmetric Schur functions and generalized Demazure atoms

Louie, Janelle, Classification of convex ancient solutions to curve shortening flow on the sphere

Meng, Wang, On the detection of sparse mixtures

Parks, Helen, Structural approaches to large-scale systems: Variational integrators for interconnected Lagrange-Dirac systems and structured model reduction on Lie groups

Shustrova, Anna, Primal-dual interior methods for quadratic programming

Tiee, Christopher, Computation and visualization of geometric partial differential equations

Wen, Jiayi, Mathematical modeling and computational methods for electrostatic interactions with applications to biological molecules

Wilson, Andrew, Generalized shuffle conjectures for the Garsia-Haiman delta operator

Zimmermann, David, Logarithmic Sobolev inequalities for Gaussian convolutions of compactly supported measures

University of California, Santa Barbara (14)

Department of Mathematics

Ackermann, Robert, On pseudo-Anosov maps, symplectic, Perron-Frobenius matrices, and compression bodies

Chapman, Kyle, An ergodic algorithm for sampling equilateral knots with thickness

Jonov, Boyan, Longtime behavior of small solutions to viscous perturbations of nonlinear hyperbolic systems in 3-D

Leitner, Arielle, Limits under conjugacy of the diagonal Cartan group in $SL_n(\mathbb{R})$

Leyton Chisholm, Elizabeth, Braid groups and Euclidean simplices

Ream, Robert, Index estimates and existence of minimal surfaces in manifolds with controlled curvature

Salazar, Daniel, Modeling and computation of immersed, flexible boundaries in complex fluids

Department of Statistics and Applied Probability

Chiu, Chi-Yang, Nonparametric mixed-effects density regression

Fahham Saporito, Yuri, Topics on functional Itô calculus and multiscale stochastic volatility modeling

Hancock, David, Investigating optimal investment problems for portfolios of cointegrated assets, with transaction costs

Lin, Junjing, Some contributions to nonparametric Bayesian methods

Lu, Chunhsiung, Stochastic filtering problem with financial application to high frequency trading

Sheinson, Michael, Sequential Monte Carlo methods: Applications to disease surveillance and fMRI data

Swenson, Julianne, Contributions to Bayesian statistics vector autoregressive time series, instrumental variables, recommendation systems

University of California, Santa Cruz (10)

Applied Mathematics and Statistics Department

Chesi, Simone, Attitude control of nanosatellite using shifting masses

DeYoreo, Maria, A Bayesian framework for fully nonparametric ordinal regression

Phelps, Christopher, Computational optimal control of nonlinear systems with parameter uncertainty

Richardson, Robert, Flexible integro-differential equations for Bayesian modeling of spatio-temporal data

Walton, Claire, The design and implementation of motion planning problems given parameter uncertainty

Xiao, Sai, Bayesian non-parametric modeling for some classes of temporal point processes

Department of Mathematics

Goren, Yusuf, Counting periodic orbits: Conley conjecture for Lagrangian correspondences and resonance relations for closed Reeb orbits

Owen, Mitchell, Families of half-integer weight Eisenstein series

Tabing, Felicia, String homology and Lie algebra structures

Yuan, Wei, The geometry of vacuum static space and deformations of scalar curvature

University of Southern California (12)

Department of Mathematics

Bessam, Diogo, Large deviations rates in a Gaussian setting and related topics

Daley, Timothy, Non-parametric models for large capture-recapture experiments with applications to DNA sequencing

Ekren, Ibrahim, Path-dependent partial differential equations and related topics

Islak, Umit, Concentration inequalities with couplings from Stein's method

Newman, Burton, Growth of torsion in quadratic extensions of quadratic cyclotomic fields

Pei, Yuan, Certain regularity problems in fluid dynamics

Sokolov, Grigory, Multi-population optimal change-point detection

Tian, Yin, Categorification of $\mathfrak{sl}(1,1)$ via contact topology

Timmer, Joseph, Frobenius-Schur indicators of Hopf algebras arising from factorizations of the symmetric group

Warner, Harry Jared, Springer isomorphisms and the variety of elementary subalgebras

Zheng, Zemin, Feature selection and interaction screening in high-dimensional modeling

Zhuo, Jia, Probabilistic numerical methods for fully nonlinear PDEs and related topics

COLORADO

Colorado School of Mines (2)

DEPARTMENT OF APPLIED MATHEMATICS AND STATISTICS

Nealy, Jennifer, A study of normal mode solutions for seismo-acoustic propagation scenarios

Zaharatos, Brian, Statistical modeling of photovoltaic device performance

Colorado State University (13)

DEPARTMENT OF MATHEMATICS

Adkins, Melissa, Modeling local pattern formation on membrane surfaces using non-local interactions

Freese, Hilary, Abelian surfaces with real multiplication over finite fields

Hughes, Justin, Group action on neighborhood complexes of Cayley graphs

Lane-Harvard, Elizabeth, Strongly regular graphs from large arcs

Miles, Eric, Bridgeland stability of line bundles on surfaces

Motta, Francis, Optimally topologically transitive orbits, complex Hadamard matrices and an ion bombardment

Osnaqq, Silvia, Low rank representations of matrices using nuclear norm heuristics

Previte, Corrine, The $\mathcal{D}$-neighborhood complex of graphs

Schmidt, Eric, Number-theoretic properties of the binomial distribution with applications in arithmetic geometry

Schwickerath, Anthony, Linear models, signal detection, and the Grassmann manifold

Zhang, Chuan, Storing cycles in Hopfield-type neural networks

DEPARTMENT OF STATISTICS

Bugbee, Bruce, Semiparametric regression in the presence of complex variance structures arising from small angle x-ray scattering data

Herndon, Wade, Testing and adjusting for informative sampling in survey data

University of Colorado, Boulder (13)

DEPARTMENT OF APPLIED MATHEMATICS

Appelhans, David, Trading computation for communication: A low communication algorithm for the parallel solution of PDEs using range decomposition, nested iteration, and adaptive mesh refinement

Brutz, Michael, Mathematical modelling and analysis of several diffusive processes

Chen, Yuanting, Bayesian semi-parametric modeling of time-to-event data

Hao, Sijia, Numerical methods for solving linear elliptic PDEs: Direct solvers and high order accurate discretizations

Keck, Dustin, Aggregation dynamics: Numerical approximations, inverse problems, and generalized sensitivity

Leibs, Christopher, First-order systems least-squares finite element methods and nested iteration for electromagnetic two-fluid kinetic-based plasma models

Monnig, Nathan, From nonlinear embedding to graph distances: A spectral perspective

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DEPARTMENT OF MATHEMATICS

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DEPARTMENT OF STATISTICS AND ACTUARIAL SCIENCE

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Bae, Harold, Understanding the genetic basis of complex polygenic traits through Bayesian model selection of multiple genetic models and network modelling of family-based genetic data

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Yip, Wai-Ki, Statistical methods for analyzing DNA methylation data and subpopulation analysis of continuous, binary and count data for clinical trials

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Watson, Samuel, Conformal loop ensembles and the Gaussian free field

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Drellich, Elizabeth, Combinatorics of equivalent cohomology: Flags and regular nilpotent Hessenberg varieties

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Al-Aqtash, Ansam, The minimum semidefinite rank of signed graphs

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Diaz, Pedro, On the Delta Conjecture and the Graph Complement Conjecture for minimum semidefinite rank of a graph

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Liu, Zhipeng, Discrete Toeplitz determinants and their applications

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Wayne State University (3)

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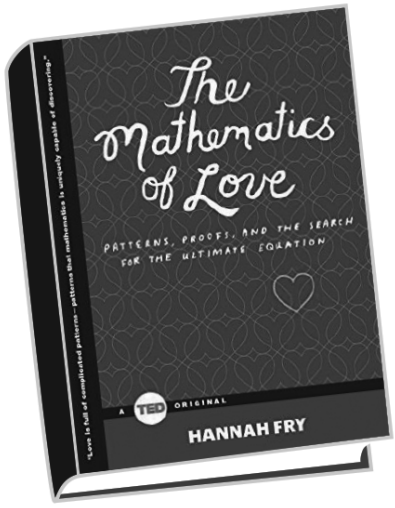

The Mathematics of Love

Reviewed by Mark Colyvan

The Mathematics of Love: Patterns, Proofs, and the Search for the Ultimate Equation
Hannah Fry
Simon and Schuster, February 2015
US$16.99, xii + 113 pages
Hardcover ISBN 978-1-4767-8488-5

On the face of it, affairs of the human heart are far removed from the world of mathematics. On the one hand, the mathematicians among us might see the lack of precision in love as reason enough to dismiss it from the proper domain of mathematical analysis. On the other hand, the romantics among us might see the cold, calculating nature of mathematics as an inappropriate tool for the study of love. *The Mathematics of Love* goes some way toward dispelling both these lines of thought and shows how mathematics can, indeed, shed light on love, sex, and romance.

Mathematics can indeed shed light on love, sex, and romance

The book is not written for a mathematical audience; it's written for a lay audience and presupposes very little by way of mathematical training. The few technical details presented are introduced with such care and patience that even those averse to mathematics should not be put off—such people may even warm to mathematics once some of what it can do is better appreciated. Indeed, this is a large part of Hannah Fry's mission in this book: "my great hope is that a little bit of insight into the mathematics of love might just inspire you to have a little bit more love for mathematics" (p. xii). The fact that the book is not written for a mathematical audience does not mean, however, that there is no interest here for mathematicians. The book is engaging, humorous, and full of nice examples of applications of various branches of mathematics to human relationships. It would make a good supplementary text for teaching purposes at both the high school and the undergraduate levels.

The book consists of nine chapters, along with a brief introduction and epilogue. The first chapter deals with the chances of finding love and introduces the reader to some elementary probability theory. The second chapter considers the question of how important beauty is in attracting a suitable partner. This chapter is more concerned with the relevant psychology than any area of mathematics. Chapter three concerns optimising a night out, with the aim of finding a partner. Here the reader is introduced to elementary game theory and the Gale–Shapley matching algorithm. Chapter four addresses online dating and considers one of the more successful algorithms: the OKCupid matching algorithm. The fifth chapter concerns dating and game theory. Chapter six looks at network theory and its applications to sex. Chapter seven looks at settling down, optimal stopping theory, and the secretary problem. Chapter eight looks at how mathematics can help in wedding planning: expected utility theory for

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choosing guest numbers and optimisation theory for seating arrangements. Chapter nine looks at the mathematics and psychology of living happily ever after.

I can't do justice to all these topics here, but I will say a bit about the game theory applications found in chapter five. The central issue here is that of achieving a stable, monogamous relationship. In particular, what prevents a partner defecting from a relationship by having an affair? The situation can be modelled in game theory as cooperative games such as the Prisoner's Dilemma or the Stag Hunt (Skyrms 2004). In the Prisoner's Dilemma the four outcomes are: (i) both partners cooperate in the monogamous relationship, (ii) partner 1 defects and has an affair while the other remains faithful, (iii) partner 2 defects while the other partner remains faithful, and (iv) both partners defect and have affairs. The payoffs for each of these four states depend on many things, including the psychology of the two parties and the level of knowledge each has about the faithfulness of the other. A plausible preference structure is as follows: partner 1 has from best to worse (ii), (i), (iv), (iii) and partner 2 has from best to worst (iii), (i), (iv) and (ii). As is well known, this is the Prisoner's Dilemma game, which has a Pareto optimal solution (i) that fails to coincide with the Nash equilibrium (iv). If this is the correct model of monogamous relationships, they'd be hard to achieve and maintain because of the attraction of the Nash equilibrium. Fortunately, for the romantics among us, things look brighter when we iterate such games. When we iterate such cooperative games, defection is suboptimal and cooperation is the preferred strategy. Indeed, as Axelrod points out in his 1984 book *The Evolution of Cooperation*, the game need not even be iterated; all that's required is that the agent in question believes that there is a non-trivial chance of iterations. Axelrod calls this "the shadow of the future" hanging over present decisions.

A concern might be raised about this approach to relationships: It's immoral to cheat on your partner, at least once both parties have agreed to be faithful, and this does not seem to be addressed by the game theory models. The thought here is that the game theory, by focusing on self-interest, treats agents as being very shallow and misses the all-important ethical dimension. But it can be argued that ethics is just more game theory (Colyvan 2010). The idea here is straightforward: ethics is all just a big cooperative game. This is to be contrasted with other ethical theories such as deontology, according to which some acts such as lying are prohibited, some such as preventing suffering are obligatory, and some such as studying mathematics are permissible—neither prohibited nor obligatory. Take the prohibited acts. It might be thought that there is something intrinsically wrong with lying, irrespective of its consequences. But according to the game theory account, all that matters are the costs and benefits to the self-interested individual. Of course being self-interested does not prohibit taking on board consequences for others: An agent might choose to ensure the well-being of those around her but the reason for this will be cashed out in terms of the benefit this brings to her. Such an account of ethics is certainly controversial, but on such an account, there is no clash between the game-theory approach to relationships and ethics. It's all just game theory.

In general, I like the choice of topics in this book. Personally, I'd have liked a bit more detail on each of the topics, but that would have taken away from the admirable brevity of the book—it can easily be read in one sitting in a couple of hours. There are some useful suggestions for further reading, and this allows the author to survey the most interesting material without getting bogged down in technical details. One obvious item, however, does not appear in the further reading lists: Clio Cresswell's excellent 2003 book *Mathematics and Sex*. It is a little surprising that Cresswell's book is not mentioned, since it covers some of the topics in question in more detail and also covers other topics not found in the book under review. It would have made excellent further reading. Moreover, Cresswell's book is also aimed at a popular audience, and there are so few popular treatments of the mathematics of love and sex.

In summary, *The Mathematics of Love* is a delightful little book and a fun read. I recommend it wholeheartedly. I doubt that the readers of this journal will learn any new mathematics from it, but it is a good book to plunder for examples in your teaching and to recommend to your non-mathematician friends. While you might not learn any new mathematics, you might just learn a little about love.

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Photograph of Mark Colyvan courtesy of Mark Colyvan.

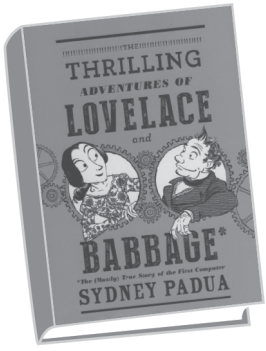
ABOUT THE REVIEWER

Mark Colyvan is the author of *The Indispensability of Mathematics* (Oxford University Press, 2001) and *An Introduction to the Philosophy of Mathematics* (Cambridge University Press, 2012). When he's not working on mathematical philosophy, logic, and the like, he likes to play around with and restore old guitars.

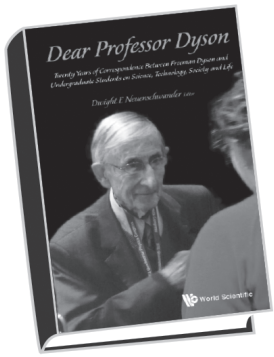
A man is known by the books he reads. —Emerson

New and Noteworthy Titles on Our Bookshelf
August 2016

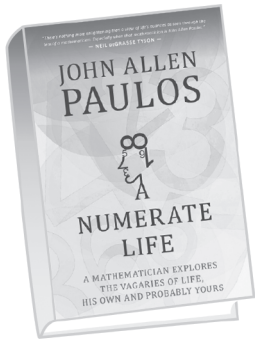
The Thrilling Adventures of Lovelace and Babbage: The (Mostly) True Story of the First Computer, by Sydney Padua (Pantheon, April 2015). In February of this year, Sydney Padua received the Neumann Prize of the British Society for the History of Mathematics for this comic book treatment of the lives of two nineteenth-century mathematicians whose work foreshadowed modern computers, Ada Lovelace and Charles Babbage. Padua, an animator and story artist, did extensive research on the lives of this pair of pioneers before creating this whimsical re-imagining of history. Lovelace is sometimes called the world's first computer programmer because she is the first to have come up with an algorithm to be carried out on a machine, and also because of her visionary ideas about computing. Babbage conceived of the idea of the Difference Engine, which was to be a hand-crank computer, but he was unable to actually build it. The two became friends and, sharing many of the same scientific interests, had a close working relationship. Padua takes as her starting point the question of what might have happened if Lovelace and Babbage had actually managed to build the Difference Engine. In the comic book, the pair uses the Difference Engine to do all kinds of wonderful tricks, such as eradicating spelling errors and fighting crime—as well as doing a bit of mathematics. According to *Discover* magazine, "Padua blends fanciful situations, mathematical truths and a heap of historical facts to create an outlandish, enlightening tale."



Dear Professor Dyson: Twenty Years of Correspondence Between Freeman Dyson and Undergraduate Students on Science, Technology, Society and Life, edited by Dwight E. Neuenschwander (World Scientific, 2016). For the past 30 years, Southern Nazarene University in Bethany, Oklahoma, has offered a course called "Science, Technology, and Society." The main textbook has been Freeman Dyson's now-classic *Disturbing the Universe* (1979). Twenty years ago, when physicist Dwight Neuenschwander was teaching the course, he suggested the students write down comments and questions for Dyson. The students did so, and Neuenschwander packaged up the pages with a cover letter and sent them off to Dyson. This was 1993; at sixty-nine years of age, Dyson was world famous and a year from retirement from his professorship at the Institute for Advanced Study in Princeton. "Professor Dyson is a busy and important man," Neuenschwander writes in the book. "He has never heard of our little school on the prairie, which sits on US Route 66 in the center of what used to be called Indian Territory." Would the great man respond? Indeed he would, and he did so in a warm and grandfatherly fashion that showed how touched he was by the interaction with the students. Thus began a twenty-year exchange of letters, which are reproduced in *Dear Professor Dyson*, together with a good deal of material that provides context and background for the letters. The topics range from nuclear weapons to religion, from the environment to how to live a meaningful life. While mathematics is not a central theme, there is much here that would appeal to mathematical readers, including Dyson's steadfast honesty, rigorous intellect, and unconventional mindset.



A Numerate Life: A Mathematician Explores the Vagaries of Life, His Own and Probably Yours, by John Allen Paulos (Prometheus Books, November 2015). John Allen Paulos's first popular book was *I Think, Therefore I Laugh* (1985), which examined humor from a philosophical viewpoint. His best-known book is likely his 1989 *Innumeracy: Mathematical Illiteracy and Its Consequences*, which was praised by a wide variety of critics, who appreciated Paulos's witty and clear writing as well as his insight into an endemic problem that afflicts even highly educated people. Paulos has produced a steady stream of well-received books with mathematical themes, including three that were reviewed in the *Notices: Irreligion* (reviewed by Olle Hägström, August 2008), *Once Upon a Number* (reviewed by Colin Adams, September 1999), and *A Mathematician Reads the Newspaper* (reviewed by Gina Kolata, March 1996). His ninth book, *A Numerate Life*, appeared last year. Partly a memoir, the book mixes mathematics, philosophy, and literature to describe an approach to life that employs the habits of mind of a mathematician: logical deduction, reasoning, skepticism, and plain old common sense. For a taste of what the book is like, readers can check out an excerpt that appeared in the online magazine *Salon* with the title "The Bush presidency was my fault: I am so sorry my work stopped the Florida recount" (November 29, 2015). The tag line for the excerpt reads: "Fifteen years ago, a Florida judge cited my stats theory and the recount ended. The Iraq War still torments me."



Mathematics People

Ooguri Receives Chunichi Cultural Award

Hirosi Ooguri

Hirosi Ooguri of the California Institute of Technology has been honored with the 2016 Chunichi Cultural Award. The award carries a cash prize of 2 million yen (approximately US$20,000).

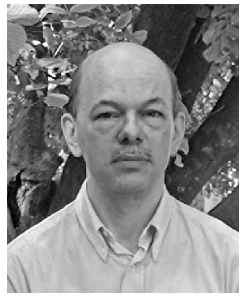
According to the prize citation, Ooguri was honored for the "development of innovative methods of modern mathematics in high energy theory." His work involves "creating new theoretical tools in quantum field theory and superstring theory." He is especially known for his work on topological string theory, "which has had broad applications ranging from black hole physics to algebraic geometry and knot theory in mathematics."

Ooguri is a past recipient of the AMS Eisenbud Prize (2008), a Humboldt Research Award (2008), the Nishina Memorial Prize (2009), a Simons Investigator Award (2012), and the Kodansha Prize for Science Books of Japan (2014) for his popular science book, *Introduction to Superstring Theory*. He is a fellow of the AMS and of the American Academy of Arts and Sciences (AAAS). He also served as scientific advisor for a 3D movie, *The Man from the 9 Dimensions*, which tells the story of the quest for the "theory of everything" and premiered in Tokyo. About the film, he says, "We expect a diverse audience, from first graders to senior citizens. Some would be hearing about elementary particles for the first time, and others know something about physics and want to learn more. I wanted to make sure that everyone can enjoy the movie and learn something from it."

Founded in 1947 by Japanese newspaper *Chunichi Shimbun* to commemorate the enacting of the Japanese constitution, the award celebrates individuals or organizations who have made significant contributions to the arts, humanities, and natural or social sciences.

—From a California Institute of Technology news release

Turaev and Virelizier Awarded Balaguer Prize



Vladimir Turaev

Alexis Virelizier

Vladimir Turaev of Indiana University and Alexis Virelizier of Université Lille 1 have been awarded the 2016 Ferran Sunyer i Balaguer Prize for their monograph *Monoidal Categories and Topological Field Theory*. The monograph introduces monoidal categories and Penrose's graphical calculus; gives an algebraic description of the center of monoidal categories based on the theory of Hopf monads as developed by Virelizier and coauthors; explains topological quantum field theories, including fundamental earlier work of Reshetihkin-Turaev and Turaev-Viro; and shows how to present ribbon graphs by diagrams on skeletons of 3-manifolds and define graph topological quantum field theories by means of state sums on such skeletons. Their main result interprets such graph theories as surgery theories, thereby proving a conjecture stated by Turaev in 1995.

Turaev tells the *Notices*: "I was born in St. Petersburg, Russia, into a family of theatre workers: my father was a puppeteer and a theatre producer, while my mother gave public lectures on literature and theatre. In the age of eleven years, I entered the Russian system of mathematical circles and olympiads, which fostered my interest in mathematics. The choice of mathematics as a job was the smartest decision I made in my life. Among other clever things I did was having three kids (I wish I had more), writing seven books, collaborating with several extraordinary mathematicians, learning three languages, and visiting a number of wonderful countries."

Verilizier tells the *Notices*: "I was born in Carcassonne in the south of France. My father was an engineer and my mother took care of the family. My passion for

mathematics goes back to my childhood, and I had the chance to make it my job. My wife Chrystelle and I decided to name our son Evariste, a name not well known to the general public but very famous in the mathematical community!"

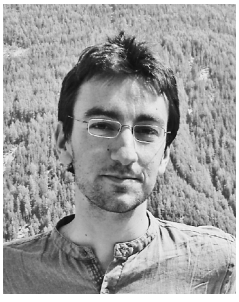
The prize carries a cash award of 15,000 euros (approximately US$16,800). It is awarded for a mathematical monograph of an expository nature presenting the latest developments in an active area of research in mathematics in which the recipient has made important contributions. The winning monograph will be published by Birkhäuser Verlag in the series Progress in Mathematics.

—From a Balaguer Foundation announcement

2016 Rollo Davidson Prize Awarded

OMER ANGEL of the University of British Columbia, JEAN-CHRISTOPHE MOURRAT of ENS Lyon, and HENDRIK WEBER of the University of Warwick have been awarded the 2016 Rollo Davidson Prize. Angel was honored "for his many contributions to stochastic geometry and in particular to random maps and triangulations." Outside of mathematics, Angel enjoys hiking and juggling. Mourrat was recognized "for significant new results in stochastic homogenization and in singular stochastic partial differential equations and associated scaling limits." Weber was honored "for a series of significant new results in the theory of singular stochastic partial differential equations and associated scaling limits." The Rollo Davidson Trust was founded in 1975 and awards the annual prize to young mathematicians working in the field of probability.

Omer Angel


Jean-Christophe Mourrat

Hendrik Weber

—From a Davidson Trust announcement

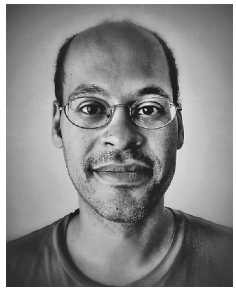
PECASE Awards Announced

Three young researchers, nominated by the National Science Foundation, whose work involves the mathematical sciences have received Presidential Early Career Awards for Scientists and Engineers (PECASE) from President Obama.

J. ELISENDA GRIGSBY of Boston College was honored for her work on the invariants of 3-manifolds. She was also honored for her services to the mathematics community: for running advanced workshops, training graduate and undergraduate students; for her contributions to increasing participation of women in the mathematical sciences; and for introducing talented middle-school girls to research mathematics. Grigsby is a runner who has done marathons in New York City, San Francisco, and Boston. She hopes to get back into marathoning when her children, now two and five, are older. She also blogs (about math and her children) at `elioop.blogspot.com`.

J. Elisenda Grisby

DANIEL KRASHEN of the University of Georgia was honored for his work on local-to-global principles and for his service, including organizing conferences and workshops, training graduate students, and serving as a role model for underrepresented minorities in mathematics. Krashen's main nonmathematical hobby is music. He plays a variety of musical instruments, and played bass, flute and keyboards in a funk band during graduate school. He is married to the algebraic geometer Angela Gibney, and they have two daughters, ages eight and ten, who are considering careers in space exploration (this week at least).


Daniel Krashen

JAKITA NICOLE OWENSBY THOMAS of Spelman College was honored for her outstanding research on variations by which African American middle-school girls develop computational algorithmic thinking through game design and increase their awareness of career applications in industry.

—From a White House announcement

Prizes of the Mathematical Society of Japan

The Mathematical Society of Japan (MSJ) has awarded several prizes for 2016.

The Spring Prize has been awarded to HIROSHI IRITANI of Kyoto University for his outstanding contributions to research on Gromov-Witten invariants and mirror symmetry. The Spring Prize is awarded to mathematicians under the age of forty who have obtained outstanding mathematical results.

The 2016 Algebra Prize has been awarded to HIDENORI KATSURADA of the Muroran Institute of Technology for work on *L*-functions and periods of automorphic forms of several variables; to KAZUHIKO KURANO of Meiji University for contributions to intersection theory over local rings and its applications to the theory of Cohen-Macaulay modules; and to MASA-HIKO SAITO of Kobe University for

work on moduli spaces of connections and differential equations of Painlevé type.

The Ikushi Prize of the Japan Society for the Promotion of Science (JSPS) has been awarded to KAZUMASA FUJIWARA of Waseda University for his work on mathematical foundations of semirelativistic nonlinear fields. The Ikushi Prize was established to encourage young researchers, particularly PhD students.

The MSJ Prizes for Excellent Young Applied Mathematicians for 2015 have been awarded to: MICHITAKA FURUYA, Tokyo University of Science, for some approaches for comparing rainbow domination numbers; HIDEKI MURAKAWA, Kyushu University, for mathematics of cell-cell adhesion: experiments, modeling, and analysis; TAKESHI GOTODA, Kyoto University, for mathematical analysis of entropy dissipation via triple collapse of point vortices; and HARUNORI MONOBE, Meiji University, for work on condition for existence of traveling wave solutions, composed of convex curves, to an interface equation.

—From MSJ announcements

Witten Receives Young Investigator Award

Daniela M. Witten

DANIELA M. WITTEN of the University of Washington has been selected the recipient of the 2015 Raymond J. Carroll Young Investigator Award "for her efforts in making seminal contributions to the development and application of statistical machine learning techniques to the analysis of high dimensional data, particularly in the application of these techniques to genomic data." The Carroll Young Investigator Award is given every two years to a statistician who has made important contributions to the area of statistics.

—From a Texas A&M University announcement

Maidorn Awarded PIMS Education Prize

Patrick Maidorn

PATRICK MAIDORN of the University of Regina has been awarded the 2016 PIMS Education Prize of the Pacific Institute for the Mathematical Sciences. According to the prize citation, Maidorn is "very active in mathematics education and outreach. As well as his role in organizing math camps and school visits, he has brought the international Mathematical Kangaroo contest to Regina and played a key role in its organization. He is also a lead exam writer for the Saskatchewan Math Challenge." He also takes part in the Problem Solving Workshops, hosted by the University of Regina math department, for students in grades seven through ten who want to improve their math skills. The PIMS Education Prize recognizes individuals within the PIMS community who have played a major role in encouraging activities that enhance public awareness and appreciation of mathematics, as well as fostering communication among various groups concerned with mathematical education at all levels.

—From a PIMS announcement

Hertz Foundation Fellowships Awarded

FELIPE HERNANDEZ of the Massachusetts Institute of Technology and SARAH MCFANN of the University of Alabama are among the 2016 class of Hertz Foundation Fellows. Hernandez works in applied mathematics. McFann's research is in mathematical and computational modeling of complex biological systems. Hertz Foundation fellowships provide financial and fellowship support to PhD students in the physical, biological, and engineering sciences, free of most traditional restrictions.

—From a Hertz Foundation announcement

AWM Essay Contest Winners Announced

The Association for Women in Mathematics (AWM) has announced the winners of its 2016 essay contest, "Biographies of Contemporary Women in Mathematics." The grand prize was awarded to PRIYANKA NANAYAKKARA of the University of California Los Angeles for her essay "Engaging with the Ensemble: Alissa Crans' Journey through Mathematics." The essay also won first place in the undergraduate category and will be published in the *AWM Newsletter*. First place in the high school category went to EMILY JIA of the Illinois Math and Science Academy in Aurora, Illinois, for her essay "To Count the Natural Numbers," about Tanya Khovanova of the Massachusetts Institute of Technology. First place in the middle school category was awarded to ADUN OLADEJI, homeschooled, of Alpharetta, Georgia, for her essay "Another Contest Won," about Laura Zehender of the online mathematics school Art of Problem Solving (AoPS).

—From an AWM announcement

USA Mathematical Olympiad

The 2016 USA Mathematical Olympiad (USAMO) was held April 19–20, 2016. The students who participated in the Olympiad were selected on the basis of their performances on the American High School and American Invitational

Mathematics Examinations. The twelve highest scorers in this year's AMO, listed in alphabetical order, were:

ANKAN BHATTACHARYA, Lawrence Technological University, Southfield, Michigan

RUIDI CAO, Missouri Academy of Science, Mathematics, and Computing, Maryville, Missouri

HONGYI CHEN, University of Colorado, Boulder, Colorado

JACOB KLEGAR, Choate-Rosemary Hall, Wallingford, Connecticut

JAMES LIN, Winchester High School, Winchester, Massachusetts

ALLEN LIU, Penfield Senior High School, Penfield, New York

JUNYAO PENG, Princeton International School of Mathematics and Science, Princeton, New Jersey

KEVIN REN, Torrey Pines High School, San Diego, California

MIHIR SINGHL, Palo Alto High School, Palo Alto, California

KEVIN SUN, Phillips Exeter Academy, Exeter, New Hampshire

ALEC SUN, Phillips Exeter Academy, Exeter, New Hampshire

YUAN YAO, Phillips Exeter Academy, Exeter, New Hampshire

The twelve USAMO winners will attend the Mathematical Olympiad Summer Program (MOSP) at the University of Nebraska, Lincoln, in June 2016. Ten of the twelve will take the team selection test to qualify for the US team. The six students with the highest combined scores from the test and the USAMO will become members of the US team and will compete in the International Mathematical Olympiad (IMO) to be held in Hong Kong in July 2016.

–From Mathematical Association of America announcements

Moody's Mega Math Challenge

The winners of the 2016 Mega Math Challenge for high school students have been announced. The topic for this year was "Modeling New Approaches to Mobility."

The Champion Team Prize of US$20,000 in scholarship money was awarded to a team from Saint John's School in Houston, Texas. The team members were MARGARET TRAUTNER, ERIC GAO, ANIRUDH SURESH, DANIEL SHEBIB, and NANCY CHENG. Their coach was Dwight Raulston.

The First Runner-Up Team Prize of US$15,000 in scholarship money was awarded to a team from Carmel High School in Carmel, Indiana. The team members were SIMON LANGOWSKI, MILES DAI, JOSEPH PHILLEO, and TIGER HUANG. Their coach was Peter Beck.

The Third Place Team Prize of US$10,000 in scholarship money was awarded to a team from Governor Livingston High School in Berkeley Heights, New Jersey. The team members were NIYANT NARANG, GIANNA MIGGINS, MICHAEL WU, ANNA SONG, and ALEXANDER JU. Their coach was Steven Hess.

Finalist Team Prizes of US$5,000 in scholarship money were awarded to three teams. The team from La Salle Academy in Providence, Rhode Island, consisted of ALLISON PAUL, JOSHUA RENO, EILEEN PHOU, AUDREY CRYAN, and ERIC SALISBURY. They were coached by Michael McNamara. The team from Montgomery Blair High School in Silver Spring, Maryland, consisted of RAYMOND LIN, ETHAN HOLLAND, VICTORIA TSAI, JAMIE VINSON, and ESHAN TEWARI. They were coached by William Rose. A team from North Carolina School of Science and Mathematics in Durham, North Carolina, consisted of SIMON MARLAND, VINIT RANJAN, KATHERINE YANG, SUNWOO YIM, and KELLY ZHANG. Their coach was Dan Teague.

The Mega Math Challenge invites teams of high school juniors and seniors to solve an open-ended, realistic, challenging modeling problem focused on real-world issues. The top five teams receive awards ranging from US$5,000 to US$20,000 in scholarship money. The competition is sponsored by the Moody's Foundation, a charitable foundation established by Moody's Corporation, and organized by the Society for Industrial and Applied Mathematics (SIAM).

—From a Moody's Foundation/SIAM announcement

NCTM Lifetime Achievement Awards

The National Council of Teachers of Mathematics (NCTM) has chosen two educators to receive Lifetime Achievement Awards for 2016. They are EDWIN DICKEY of the University of South Carolina and BARBARA REYS of the University of Missouri.

Edwin Dickey

Barbara Reys

According to the prize citations, Dickey's "career has been spent encouraging students to become STEM teachers, implementing instructional technology to facilitate learning, and leveraging his abilities to contribute to a multitude of professional organizations" and "has demonstrated an enduring commitment to the professional growth of his students, colleagues, and teachers." He "has always been intrigued by the intersection of mathematics and technology. He was fascinated by the mechanical calculator that his high school teacher had brought into the classroom and later, as teacher himself, purchased his school's first Apple II computer. Dickey was motivated by the opportunities afforded by technology to improve mathematics education." He has presented conference papers in thirteen different countries, "demonstrating his commitment to sharing his expertise with the international community." Dickey is a native of Brazil and was educated in US Dependent Schools in Europe. The father of two grown children, he and his wife, Karen, enjoy traveling, cooking, and eclectic dining often while visiting family and friends around the world. Dickey told the *Notices*: "I failed kindergarten. When I

arrived in the US from Brazil, my year in kindergarten… was not recognized and I was required to repeat the grade, this time in English. What better foundation for life than have *two* years of kindergarten in two different languages." He also says "in mathematics and in life, we *all* experience failures and it is from those failures along with some successes that we realize ourselves and our contributions."

Reys' "early experience teaching mathematics at every grade, from grade 1 to high school, grounded her later work in teacher preparation and instilled in her a great respect for the hard work of classroom teachers…. She was the founder of the University of Missouri Mathematics Teacher Organization (UM2TO—one of the first NCTM Student Affiliates). She and her husband [Robert Reys] also founded the STaR Program—an early-career induction program for mathematics educators working in higher education." Furthermore, "she chaired the commission that developed standards for the preparation of elementary mathematics specialists and created a program in Missouri to certify EMS professionals on the basis of these standards." She has been instrumental in efforts to help schools implement innovative curriculum materials and in advocating for a common set of curriculum standards across states. She also directed the Center for the Study of Mathematics Curriculum, a partnership between the University of Missouri and the Columbia Public Schools. Reys is one of nine children, all of whom live in central Missouri. Her first grandchild was born one month after her retirement from the University of Missouri.

—From an NCTM announcement

National Academy of Sciences Elections

The National Academy of Sciences (NAS) has elected its new members and foreign associates for 2016. Following are the new members whose work involves the mathematical sciences:

Ian Agol, University of California Berkeley
Constantine M. Dafermos, Brown University
Vladimir Drinfeld, University of Chicago
Steven N. Evans, University of California Berkeley
Igor R. Klebanov, Princeton University
Maryam Mirzakhani, Stanford University
Susan A. Murphy, University of Michigan, Ann Arbor
Larry A. Wasserman, Carnegie Mellon University
Alexander B. Zamolodchikov, Russian Academy of Sciences and Rutgers, The State University of New Jersey

Elected as foreign associates were:

Yuval Perez, Microsoft Research
Hugh Possingham, University of Queensland
Nancy M. Reid, University of Toronto
Claire Voisin, CNRS, Institut de Mathématiques de Jussieu, France

—From an NAS announcement

2016 Royal Society Elections

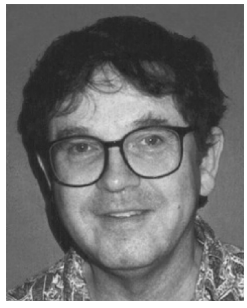
The following mathematical scientists have been elected Fellows of the Royal Society of London for the year 2016:

Martin Bridson, University of Oxford
Marcus Du Sautoy, University of Oxford
Artur Ekert, University of Oxford and National University of Singapore
Lakshminarayanan Mahadevan, Harvard University
Caroline Series, University of Warwick

Elected as a Foreign Member was Gerd Faltings, Max Planck Institute for Mathematics.

—From a Royal Society announcement

David D. Bleecker (1948–2016)



David Bleecker

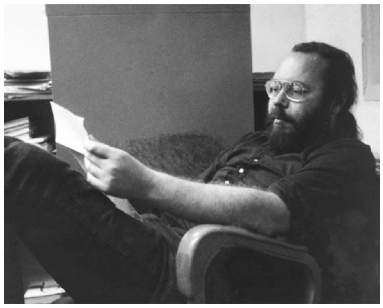
David Bleecker was born in Summit, New Jersey, in 1948. He received his PhD from the University of California at Berkeley under Shiing-Shen Chern in 1973 and spent his career at the University of Hawaii. Chern praised the rigor of Bleecker's exposition and his perspicuous writings.

Bleecker was as a mathematician distinctive in his painstaking precision and thoroughness, which was accompanied by an almost religious fervor about the possibility of explaining even the most intricate mathematical constructions to colleagues and students. Young learners could grasp basic ideas of geometric analysis from his article on the optimal bending of a flat taco to yield maximal filling, which gained him, jointly with Lawrence J. Wallen, the George Pólya Award of the Mathematical Association of America in 1999. According to David, everyone interested in modern physics should be able to understand the underlying variational principles. So David wrote a very successful monograph, *Gauge Theory and Variational Principles* (Addison-Wesley 1981, Dover 2005). Jointly with George Csordas he wrote an almost encyclopedic rigorous introduction, *Basic partial differential equations* (Van Nostrand 1992). In the same vein, the thin atmosphere of the heights of the Atiyah-Singer index theory and its meaning in gauge-theoretic physics and low-dimensional geometry were made breathable and enjoyable for a wider circle of readers in joint work with Bernhelm Booss-Bavnbek in the monumental *Index Theory with Applications in Mathematics and Physics* (International Press 2013).

Due to health issues, David retired in 2010. We can only imagine what he would have accomplished with more time.

—Bernhelm Booss-Bavnbek (Roskilde, Denmark) and George Csordas (Hawaii, USA)

Between the Lines, Horst Elmar Winkelnkemper (1940–2016)



Winkelnkemper in his office in his early days at the University of Maryland.

Horst Elmar Winkelnkemper was born in Germany and grew up in Mexico. He attracted the attention of Solomon Lefschetz and entered graduate school at Princeton in the early 1960s. Elmar tried to understand the robust activity of Bill Browder's school at the time: constructing and controlling closed manifolds above dimension four via geometric constructions called surgery. Elmar formulated mantras such as, "A manifold is like a quadratic form," and "Transversality unlocks the secrets of the manifold." When these mantras were expressed in lectures at MIT, Is Singer thought "Winkelnkemper" was an invented author of these mathematical insights.

A first result of Elmar was that if the signature of its quadratic form were nonzero, then the degree of a self mapping of a manifold must be a perfect square. Later his thesis showed that the cobordism groups of manifolds with self diffeomorphisms had infinitely many linearly independent invariants. Elmar then used diffeomorphisms of manifolds with boundary which are the identity on the boundary to describe "Open Book" decompositions of closed manifolds of one dimension higher. Elmar and Bill Thurston used open book decompositions to show that each three-manifold has a contact structure. In the next period Giroux showed that all contact structures in dimension three are approximated by Elmar's open books. One may speculate that a signed version of this approximation result could provide a picture of the moving vorticity of three-dimensional fluid, a currently intractable problem.

Elmar's "Graph of a Foliation" clarified the holonomy structure of foliations, allowing noncommutative geometry to enter that area.

In recent work, Elmar defied the logic result that many questions about finitely presented groups are undecidable. He showed that each positive definite symmetric integer matrix with determinant one which is not equivalent over the integers to the identity matrix determines an Artin presentation of a nontrivial perfect group. The proof is a remarkable combination. Elmar constructs a four-manifold whose boundary would be a homotopy three-sphere if the group were trivial. This four-manifold, materializing the quadratic form, is impossible by Taubes' augmentation of Donaldson's theory of instantons. Elmar felt strongly the depth of these connections.

To many Elmar Winkelnkemper passionately shared deep convictions and intuition even in areas outside his expertise, and it seemed to this author he could find veins of gold by an uncanny, almost mystical intuition, reminiscent of the great Israel Gelfand.

—Dennis Sullivan, professor of mathematics, State University of New York, Stony Brook and Einstein Chair, CUNY Graduate Center
dennis@math.sunysb.edu

Credits

Photo of Omer Angel, courtesy of David Tsabar.
Photo of Hendrik Weber, courtesy of Annette Anderson.
Photo of Elisenda Grigsby, courtesy of Puneet Batra.
Photo of Daniel Krashen, courtesy of Max S. Gerber.
Photo of Daniella M. Witten, courtesy of Ari Steinberg.
Photo of Ed Dickey, courtesy of Rick Smoak.
Photo of Barbara Reys, courtesy of T. Brown.
Photo of David D. Bleecker, courtesy of Dale Myers
Photo of Horst Elmar Winkelnkemper, courtesy of Jack Calcut.

American Mathematical Society

MSRI Mathematical Circles Library

Mathematical Circles are gatherings of motivated students and teachers looking for new challenges in mathematics as well as a deeper understanding of the subject. While solving problems is emphasized, the circles pay considerable attention to mathematical ideas and techniques.

This book series is designed as a resource for leaders and participants in mathematical clubs and circles. Books may also be of interest to parents and teachers.

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Mathematics Opportunities

Math in Moscow Scholarship Program

The Math in Moscow program at the Independent University of Moscow (IUM) provides students with a semester-long, mathematically intensive program of study in the Russian tradition of teaching mathematics—the emphasis being on problem solving rather than memorizing theorems. All instruction is in English. With funding from the National Science Foundation (NSF), the AMS awards five scholarships each semester to US students. The deadline for applications for the scholarship program for the spring 2017 semester is **September 15, 2016**. Information and application forms for Math in Moscow are available at www.mccme.ru/mathinmoscow, and application forms for the AMS scholarships at www.ams.org/programs/travel-grants/mimoscow.

—AMS Membership and Programs Department

Call for Nominations for 2016 Abel Prize

The Norwegian Academy of Science and Letters awards the Abel Prize each year to recognize outstanding scientific work in the field of mathematics, including mathematical aspects of computer science, mathematical physics, probability, numerical analysis and scientific computing, statistics, and also applications of mathematics in the sciences. The prize carries a cash award of 6 million NOK (approximately US$718,000). Nominations should be postmarked by **September 15, 2016**. For more information, see www.abelprize.no/c53676/artikkel/vis.html?tid=53705.

—From a Norwegian Academy announcement

*Joint DMS/NIGMS Initiative to Support Research at the Interface of the Biological and Mathematical Sciences

The Division of Mathematical Sciences in the Directorate for Mathematical and Physical Sciences at the National Science Foundation (NSF) and the National Institute of General Medical Sciences (NIGMS) at the National Institutes of Health support research in mathematics and statistics on questions in the biological and biomedical sciences. This program is designed to encourage new collaborations, as well as to support existing ones. The deadline date for full proposals is **September 14, 2016**. For more information see the website www.nsf.gov/funding/pgm_summ.jsp?pims_id=5300&org=NSF&sel_org=NSF&from=fund.

—From an NSF announcement

*Research Experiences for Undergraduates

The Research Experiences for Undergraduates (REU) program supports active research participation by undergraduate students in any of the areas of research funded by the National Science Foundation (NSF). Student research may be supported in two forms: REU sites and REU supplements. The full program announcement can be found at the website www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517 . The deadline date for proposals from

**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.

institutions wishing to host REU sites in the mathematical sciences is **August 24, 2016**.

Deadline dates for REU supplements vary with the research program; contact the program director for more information. Students apply directly to the REU sites (not NSF) and should consult the directory of active REU sites on the Web at www.nsf.gov/crssprgm/reu/list_result.jsp?unitid=5044.

—From an NSF announcement

POST PUBLICATION NOTE: The NSA Grant announcement that appeared in the print version of the August (63:07) Notices has been removed from this online version of record due to expiry of the program.

Call for Nominations for Gerald Sacks Prize

The Association for Symbolic Logic invites nominations for the Gerald Sacks Prize for the most outstanding doctoral dissertation in mathematical logic. The deadline is **September 30, 2016**. See www.aslonline.org/info-prizes.html or www.aslonline.org/Sacks_nominations.html.

—From an ASL announcement

Call for Nominations for AWM Falconer Lectureship

The Association for Women in Mathematics (AWM) and the Mathematical Association of America (MAA) annually present the Etta Z. Falconer Lecture to honor women who have made distinguished contributions to the mathematical sciences or mathematics education. These lectures are presented at MAA MathFest each summer. The deadline for nominations is **September 1, 2016**. For more information see the website https://sites.google.com/site/awmmath/programs/falconer-lectures.

—From an AWM announcement

Call for Nominations for AWM Schafer Prize

The Association for Women in Mathematics (AWM) calls for nominations for the Alice T. Schafer Mathematics Prize to be awarded to an undergraduate woman for excellence in mathematics. The nominee may be at any level in her undergraduate career but must be an undergraduate when nominated. The deadline for nominations is **October 1, 2016**. For more information, see the website https://sites.google.com/site/awmmath/programs/schafer-prize.

—From an AWM announcement

Mathematics of Planet Earth Competition

Mathematics of Planet Earth (MPE) invites the scientific community to enter the Second International Competition to design museum exhibits on Mathematics of Planet Earth. Exhibits can take the form of interactive programs, hands-on physical exhibits, short films, or image galleries and must address some planetary theme in which mathematics plays a role. Deadline for entries is **June 30, 2017**. See www.mathofplanetearth.org/competition.

—From an MPE announcement

News from MSRI

The Mathematical Sciences Research Institute (MSRI) invites applications for research professors, research members and postdoctoral fellows in the following programs:

- Geometric Functional Analysis and Applications (August 14–December 15, 2017)
- Geometric and Topological Combinatorics (August 14–December 15, 2017)
- Group Representation Theory and Applications (January 16–May 25, 2018)
- Enumerative Geometry Beyond Numbers (January 16–May 25, 2018).

Research professorships are intended for senior researchers who will be making key contributions to a program, including the mentoring of postdoctoral fellows, and who will be in residence for three or more months. Research memberships are intended for researchers who will be making contributions to a program and who will be in residence for one or more months. Postdoctoral fellowships are intended for recent PhDs. Interested candidates must apply online beginning August 1, 2016. To receive full consideration, applications must be complete, including all letters of support, by the following deadlines: research professorships, **October 1, 2016**; research memberships, **December 1, 2016**; postdoctoral fellowships, **December 1, 2016**. See www.msri.org/application.

—From an MSRI announcement

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 fall of 2016. Following are the names of the undergraduate students and their institutions:

SAMUEL DEHORITY, University of North Carolina at Chapel Hill
IVAN GONZALEZ, Florida International University
JOSHUA NUNLEY, University of Arkansas at Fayetteville
ANTONIO RUIZ, Florida International University
UYEN THIEU, Amherst College.

All received scholarship awards of US$10,200. 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 and the article "Bringing Eastern European Mathematical Traditions to North American Students" from the *Notices* November 2003 issue (www.ams.org/notices/200310/comm-humke.pdf.)

—AMS Membership and Programs Department

From the AMS Public Awareness Office

"Lizard Tetrus," by Carlo Séquin, University of California, Berkeley.

Resources to start out the academic year: The AMS has many online resources to enhance faculty and student experiences.

Mathematical Imagery shows the connections between math and art at www.ams.org/mathimagery.

The **Feature Column** explores mathematical topics, such as knot theory and work by L'Hôpital, in depth at www.ams.org/featurecolumn.

Math in the Media offers summaries of math coverage in popular media at www.ams.org/mathmedia.

Programs for New Faculty links to fellowships and grants, meetings and conferences, publications, and employment services at www.ams.org/new-faculty.

AMS blogs have observations on teaching and learning math, the experiences of early-career mathematicians, math in the blogosphere, mentoring, visualizing mathematics, and an inside look at MathSciNet® blogs.ams.org/. Follow **AMS on social media** www.ams.org/social to see, share, and comment on posts about new offerings.

—Annette Emerson and Mike Breen
AMS Public Awareness Officers
paoffice@ams.org

Deaths of AMS Members

WILLIAM O. ALLTOP, of Ridegrest, California, died on August 3, 2015. Born on May 25, 1936, he was a member of the Society for 52 years.

ALPHONSE BUCCINO, of Baltimore, Maryland, died on July 6, 2015. Born on March 14, 1931, he was a member of the Society for 55 years.

BARRY COOPER, professor, University of Leeds, died on October 26, 2015. Born on October 9, 1943, he was a member of the Society for 43 years.

JACQUELINE P. CRISCENTI, of Needham, Massachusetts, died on May 24, 2015. Born on October 11, 1924, she was a member of the Society for 66 years.

PIERRE E. DOLBEAULT, of France, died on June 12, 2015. Born on October 10, 1924, he was a member of the Society for 63 years.

JAMES ROBERT DORROH, of Baton Rouge, Louisiana, died on June 26, 2015. Born on April 20, 1937, he was a member of the Society for 53 years.

CLINTON GASS, of Logan Utah, died on July 27, 2015. Born on January 9, 1920, he was a member of the Society for 54 years.

MAURICE H. HEINS, of Wayzata, Minnesota, died on June 4, 2015. Born on November 19, 1915, he was a member of the Society for 75 years.

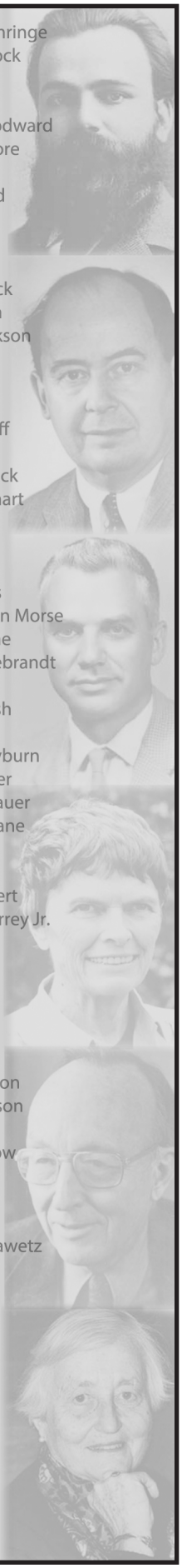
LOUIS N. HOWARD, of Chapel Hill, North Carolina, died on June 28, 2015. Born on March 12, 1929, he was a member of the Society for 63 years.

AMS Presidents

A Timeline

AMS presidents play a key role in leading the Society and representing the profession. Browse through the timeline to see each AMS president's page, which includes the institution and date of his/her doctoral degree, a brief note about his/her academic career and honors, and links to more extensive biographical information.

John Howard Van Amringe
John Emory McClintock
George William Hill
Simon Newcomb
Robert Simpson Woodward
Eliakim Hastings Moore
Thomas Scott Fiske
William Fogg Osgood
Henry Seely White
Maxime Bôcher
Henry Burchard Fine
Edward Burr Van Vleck
Ernest William Brown
Leonard Eugene Dickson
Frank Morley
Gilbert Ames Bliss
Oswald Veblen
George David Birkhoff
Virgil Snyder
Earle Raymond Hedrick
Luther Pfahler Eisenhart
Arthur Byron Coble
Solomon Lefschetz
Robert Lee Moore
Griffith Conrad Evans
Harold Calvin Marston Morse
Marshall Harvey Stone
Theophil Henry Hildebrandt
Einar Hille
Joseph Leonard Walsh
John von Neumann
Gordon Thomas Whyburn
Raymond Louis Wilder
Richard Dagobert Brauer
Edward James McShane
Deane Montgomery
Joseph Leo Doob
Abraham Adrian Albert
Charles Bradfield Morrey Jr.
Oscar Zariski
Nathan Jacobson
Saunders Mac Lane
Lipman Bers
R H Bing
Peter David Lax
Andrew Mattel Gleason
Julia Bowman Robinson
Irving Kaplansky
George Daniel Mostow
William Browder
Michael Artin
Ronald L. Graham
Cathleen Synge Morawetz
Arthur M. Jaffe
Felix E. Browder
Hyman Bass
David Eisenbud
James G. Arthur



www.ams.org/presidents

American Mathematical Society

NEW YORK UNIVERSITY

DIRECTOR, COURANT INSTITUTE OF MATHEMATICAL SCIENCES

New York University invites applicants for the position of Director of the Courant Institute of Mathematical Sciences, who will also be a professor of Mathematics and/or Computer Science. The Courant Institute consists of two departments – Mathematics and Computer Science – and promotes a broad and integrated view of these disciplines. For more than seventy-five years, Courant faculty have achieved international distinction in these areas, and Courant students and postdoctoral fellows have pursued successful careers in academia, research laboratories, and industry throughout the world. The Courant Institute occupies a unique organizational position within NYU, and maintains close ties with NYU schools and departments in science, engineering, medicine, business, education, and the arts, reflective of its broad view of the mathematical sciences.

The directorship is a dean-level position, reporting to the President and Provost, and serving as an integral part of NYU's leadership team. In addition to academic leadership, the Director has oversight of Institute finances and staff, and participates actively in development. The Director acts as a representative of, and ambassador for, the Courant Institute in its interactions with NYU administration and other academic units within NYU, funding agencies, foundations, private industry, and the research communities in mathematics and computer science.

The successful candidate will have a record of distinguished scholarship of international stature and a unified and enthusiastic perspective regarding the mathematical and computational sciences; and proven administrative abilities and experience in a leadership role for an organization of researchers and associated staff.

The new Director is expected to be in place by September 2017, if not earlier.

The Chair of the Search Committee is S.R. Srinivasa Varadhan, Professor of Mathematics. Inquiries may be made to **director.search@cims.nyu.edu**.

New York University has engaged Isaacson, Miller, a national executive search firm, to assist with this search. Nominations and applications, including a current curriculum vitae and a cover letter that discusses the applicant's interest in the position and the experience and strengths the applicant would bring to the role, should be directed to **http://www.imsearch.com/searches/details/content/S5-840**.

NYU is committed to hiring from the most talented and diverse pool of candidates. The Search Committee will begin reviewing applications and nominations immediately.

NYU is an Equal Opportunity/Affirmative Action Employer and Minorities/Females/Vet/Disabled are encouraged to apply.

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INDIANA

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The Notre Dame Institute for Advanced Study (NDIAS) supports research of both applied and theoretical research questions, in all disciplines. NDIAS fosters transformational research, encouraging work that addresses questions of value. Fellows receive stipends up to $60,000, subsidized housing, research funding, a faculty office, and multiple opportunities for engagement in an academic community of scientists, artists, and scholars at the University of Notre Dame. All those with promising and appropriate projects, whether distinguished and established or beginning a career, are invited to apply. Application deadline: October 15, 2016. For further information, please see ndias.nd.edu. Direct questions to ndias@nd.edu or 574-631-1305.

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PUBLICATIONS FOR SALE

The New Mathematical Science
by Dr. Mehran Basti

Differential Equations and Polynomials
Volumes 1 & 2
Abstract available at
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Additional Work: **DNA of Mathematics**
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US 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 classads@ams.org. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.

MATHEMATICS CALENDAR

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). 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 and location of the event.

The complete listing of the Mathematics Calendar is available at: www.ams.org/meetings/calendar/mathcal

All submissions to the Mathematics Calendar should be done online via: www.ams.org/cgi-bin/mathcal/mathcal-submit.pl

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

July 2016

11 – 15 **EVEQ 2016—International Summer School on Evolution Equations**
Location: *Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic.*
URL: eveq.karlin.mff.cuni.cz

25 – 27 **Global Conference on Applied Physics & Mathematics 2016**
Location: *Macroarea di Scienze Matematiche, Fisiche e Naturali, Università degli Studi di Roma "Tor Vergata", Rome, Italy.*
URL: www.scienceknowconferences.com

25 – 28 **Celebrating Twenty Years of the Lambert W function**
Location: *The University of Western Ontario, London, Ontario, Canada.*
URL: www.apmaths.uwo.ca/~djeffrey/LambertW/LambertW.html

August 2016

1 – 7 **Deep Learning Summer School 2016**
Location: *Université de Montréal, Montréal, QC, Canada.*
URL: https://sites.google.com/site/deeplearningsummerschool2016/home

22 – 26 **Probabilistic Methods in Spectral Geometry and PDE**
Location: *Université de Montréal, Montréal, QC, Canada.*
URL: www.crm.umontreal.ca/2016/Geometry16/index_e.php

22 – 26 **International Congress on Fundamental and Applied Sciences**
Location: *Yildiz Technical University, Istanbul, Turkey.*
URL: www.icfas2016.yildiz.edu.tr

September 2016

5 – 9 **Workshop on Geometry of Lagrangian Grassmannians and nonlinear PDEs**
Location: *Institute of Mathematics, Polish Academy of Sciences, Warsaw, Poland.*
URL: www.impan.pl/en/sites/gmoreno/home/workshop-2016

12 – 16 **Summer School of Mathematics for Economics and Social Science: "Stochastic Processes and Stochastic Calculus with application to Economics and Finance."**
Location: *Organized by the Centro di Ricerca Matematica Ennio De Giorgi at the Conservatorio Santa Chiara, San Miniato, Italy (www.fcsc.it).*
URL: crm.sns.it/event/392

12 – 16 **HITCHIN70: Celebrating Thirty Years of Higgs Bundles and Fifteen Years of Generalized Geometry**
Location: *ICMAT, Madrid, Spain.*
URL: www.icmat.es/congresos/2016/hitchin70

12 – 16 **Modern Advances in Geometry and Topology**
Location: *V. N. Karazin Kharkiv National University, Kharkiv, Ukraine.*
URL: magt.karazin.ua

26 – 30 **Machine Learning Meets Many-Particle Problems**
Location: *Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, CA.*
URL: www.ipam.ucla.edu/mpsws1

October 2016

15 – 16 **Binghamton University Graduate Conference in Algebra and Topology**
Location: *Binghamton University, Binghamton, NY.*
URL: sites.google.com/a/binghamton.edu/bugcat2016

November 2016

3 – 4 **Geometry and Lie Theory: Applications to Classical and Quantum Mechanics**
Location: *Norwegian University of Science and Technology (NTNU), Trondheim, Norway.*
URL: www.math.ntnu.no/~mariusth/Eldar70/

11 – 12 **International Conference on Computer Science, Engineering and Applied Science (ICCSEAS 2016)**
Location: *Osaka, Japan.*
URL: www.iccseas.com

15 – 16 **International Conference on Computer Science and Technology (ICCST 2016)**
Location: *Hotel Grand Hilton Seoul, 353 Yeonhui-Ro, Seodaemungu, Seoul, 120-710, South Korea.*
URL: www.i2cst.com

16 – 19 **Second Summer/Winter School on Dynamical Approaches in Spectral Geometry: "Dynamical Methods in Open Quantum Systems"**
Location: *University of Göttingen, Germany.*
URL: www.uni-math.gwdg.de/bahns/Spirit2016

18 – 19 **International Conference on Computer Systems and Mathematical Sciences (ICCSMS-2016)**
Location: *Institute of Technology and Science Mohan Nagar, Ghaziabad India.*
URL: www.its.edu.in/iccsms-2016

21 – 22 **International Conference Computer Science, Engineering and Application (ICCSEA 2016)**
Location: *Hotel The Westin Taipei, 133 Nanjing East Road, Section 3, Taipei 104.*
URL: www.iccsea.com

28 – December 2 **Maths Fest 2016: Advances in Ergodic Theory, Hyperbolic Dynamics & Statistical Laws**
Location: *University House, The Australian National University, Canberra, ACT Australia.*
URL: mathsfest.amsi.org.au/advances-ergodic-theory-hyperbolic-dynamics-statistical-laws

December 2016

5 – 8 **Maths Fest 2016: Sixtieth Annual Meeting of the Australian Mathematical Society**
Location: *The Australian National University, Canberra, ACT, Australia.*
URL: maths.anu.edu.au/events/austms-meeting-2016

8 – 12 **Geometric Analysis and Control Theory**
Location: *Sobolev Institute of Mathematics SB RAS–Novosibirsk State University, Novosibirsk, Russia.*
URL: gct.math.nsc.ru/?event=geometric-analysis-and-control-theory-rus&lang=en

9 – 13 **Maths Fest 2016: Nonlinear and Geometric Partial Differential Equations**
Location: *The Australian National University, Canberra, ACT, Australia.*
URL: mathsfest.amsi.org.au/nonlinear-geometric-partial-differential-equations/

February 2017

6 – 10 **AIM Workshop: Painleve equations and their applications**
Location: *American Institute of Mathematics, San Jose, CA.*
URL: aimath.org/workshops/upcoming/painleveapp

16 – 17 **February Fourier Talks 2017**
Location: *University of Maryland, College Park, MD, USA.*
URL: www.norbertwiener.umd.edu/FFT/2017/index.html

March 2017

15 – 17 **International MultiConference of Engineers and Computer Scientists**
Location: *Hong Kong, China.*
URL: www.iaeng.org/IMECS2017/index.html

15 – 17 **International Conference on Engineering Physics 2017 (ICEP'17)**
Location: *Hong Kong. China.*
URL: www.iaeng.org/IMECS2017/ICEP2017.html

April 2017

24 – 28 **AIM Workshop: Arithmetic Golden Gates**
Location: *American Institute of Mathematics, San Jose, CA.*
URL: aimath.org/workshops/upcoming/arithgoldgates

May 2017

22 – 26 **AIM Workshop: Connecting Communities Via the Block Model**
Location: *American Institute of Mathematics, San Jose, CA.*
URL: aimath.org/workshops/upcoming/blockmodel

22 – June 2 **2017 Georgia International Topology Conference**
Location: *University of Georgia, Athens, Georgia, USA.*
URL: research.franklin.uga.edu/topology

June 2017

12 – 23 **Summer Graduate School: Subfactors**
Location: *Mathematical Sciences Research Institute Berkeley, CA.*
URL: www.msri.org/summer_schools/791

26 – July 7 **Soergel Bimodules**
Location: *Mathematical Sciences Research Institute, Berkeley, CA.*
URL: www.msri.org/summer_schools/790

July 2017

24 – 28 **AIM Workshop: Topology of the Biomolecular World**
Location: *American Institute of Mathematics, San Jose, CA.*
URL: aimath.org/workshops/upcoming/topbiomolec

August 2017

7 – 11 **International Conference on Clifford Algebras and Their Applications in Mathematical Physics (ICCA11)**
Location: *Ghent University, Ghent, Belgium.*
URL: www.icca11.ugent.be

14 – 18 **AIM Workshop: Nonstandard Methods in Combinatorial Number Theory**
Location: *American Institute of Mathematics, San Jose, CA.*
URL: aimath.org/workshops/upcoming/nscombinatorial

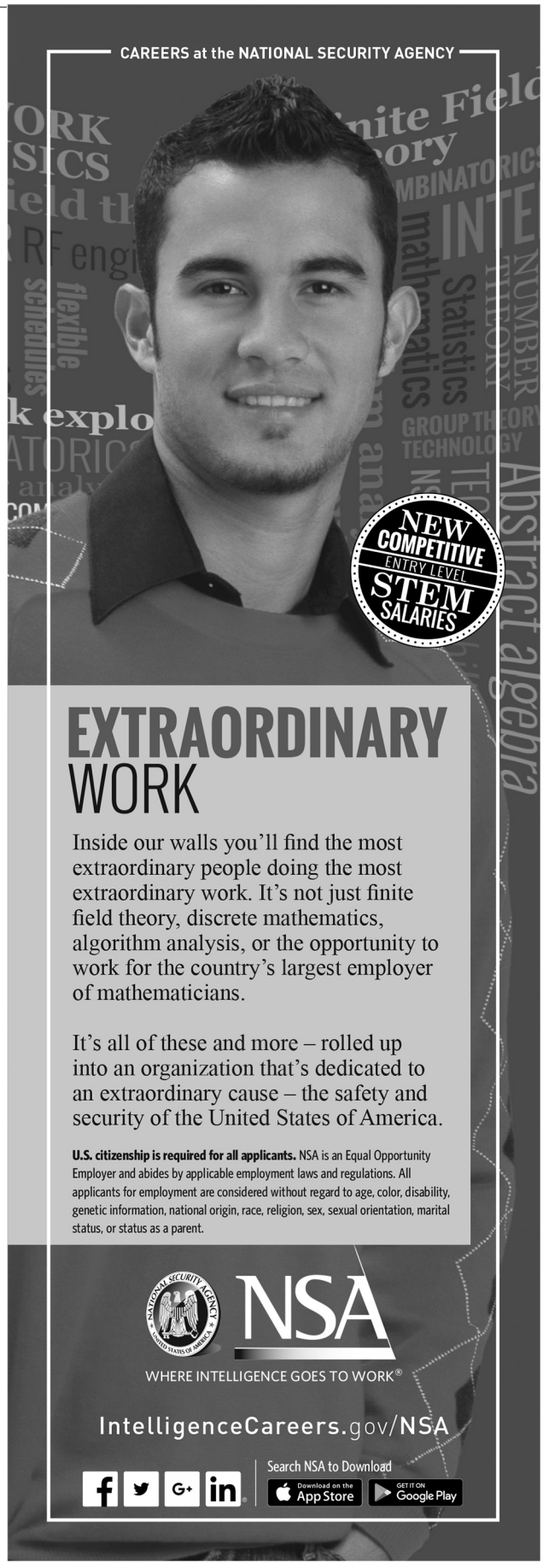
September 2017

11 – December 15 **Complex High-Dimensional Energy Landscapes**
Location: *Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, CA.*
URL: www.ipam.ucla.edu/el2017

18 – 22 **7th International Conference on Advanced Computational Methods in Engineering**
Location: *Congress Center Het Pand, Ghent, Belgium.*
URL: www.acomen.ugent.be/

October 2017

16 – 20 **Stochastic Sampling and Accelerated Time Dynamics on Multidimensional Surfaces**
Location: *Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, CA.*
URL: www.ipam.ucla.edu/elws2



New Publications Offered by the AMS

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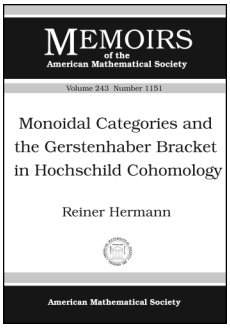
Algebra and Algebraic Geometry



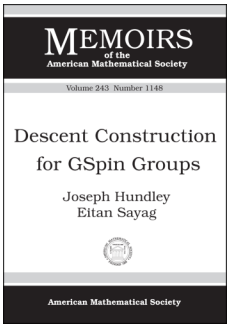
Monoidal Categories and the Gerstenhaber Bracket in Hochschild Cohomology

Reiner Hermann, *Norwegian University of Science and Technology, Trondheim, Norway*

Contents: Introduction; Prerequisites; Extension categories; The Retakh isomorphism; Hochschild cohomology; A bracket for monoidal categories; Application I: The kernel of the Gerstenhaber bracket; Application II: The **Ext**-algebra of the identity functor; Appendix A. Basics; Bibliography.

Memoirs of the American Mathematical Society, Volume 243, Number 1151

August 2016, 146 pages, Softcover, ISBN: 978-1-4704-1995-0, 2010 *Mathematics Subject Classification:* 16E40; 14F35, 16T05, 18D10, 18E10, 18G15, **Individual member US$51.60**, List US$86, Institutional member US$68.80, Order code MEMO/243/1151



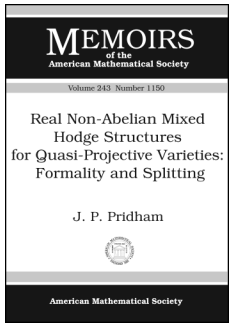
Descent Construction for GSpin Groups

Joseph Hundley, *State University of New York at Buffalo, New York*, and **Eitan Sayag**, *Hebrew University of Jerusalem, Israel*

Contents: Introduction; *Part 1. General matters:* Some notions related to Langlands functoriality; Notation; The Spin groups $GSpin_m$ and their quasisplit forms; "Unipotent periods"; *Part 2. Odd case:* Notation and statement; Unramified correspondence; Eisenstein series I: Construction and main statements; Descent construction; Appendix I: Local results on Jacquet functors; Appendix II: Identities of unipotent periods; *Part 3. Even case:* Formulation of the main result in the even case; Notation; Unramified correspondence; Eisenstein series; Descent construction; Appendix III: Preparations for the proof of Theorem 15.0.12; Appendix IV: Proof of Theorem 15.0.12; Appendix V: Auxiliary results used to prove Theorem 15.0.12; Appendix VI: Local results on Jacquet functors; Appendix VII: Identities of unipotent periods; Bibliography.

Memoirs of the American Mathematical Society, Volume 243, Number 1148

August 2016, 125 pages, Softcover, ISBN: 978-1-4704-1667-6, 2010 *Mathematics Subject Classification:* 11F70, 11F55, **Individual member US$50.40**, List US$84, Institutional member US$67.20, Order code MEMO/243/1148



Real Non-Abelian Mixed Hodge Structures for Quasi-Projective Varieties: Formality and Splitting

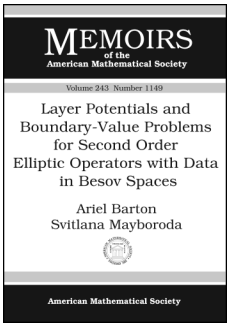
J. P. Pridham, *University of Edinburgh, United Kingdom*

Contents: Introduction; Splittings for MHS on real homotopy types; Non-abelian structures; Structures on cohomology; Relative Malcev homotopy types; Structures on relative Malcev homotopy types; MHS on relative Malcev homotopy types of compact Kähler manifolds; MTS on relative Malcev homotopy types of compact Kähler manifolds; Variations of mixed Hodge and mixed twistor structures; Monodromy at the Archimedean place; Simplicial and singular varieties; Algebraic MHS/MTS for quasi-projective varieties I; Algebraic MHS/MTS for quasi-projective varieties II—non-trivial monodromy; Canonical splittings; SL_2 splittings of non-abelian MTS/MHS and strictification; Bibliography.

Memoirs of the American Mathematical Society, Volume 243, Number 1150

August 2016, 178 pages, Softcover, ISBN: 978-1-4704-1981-3, 2010 *Mathematics Subject Classification:* 14C30; 14F35, 32S35, 55P62, **Individual member US$55.80**, List US$93, Institutional member US$74.40, Order code MEMO/243/1150

Differential Equations



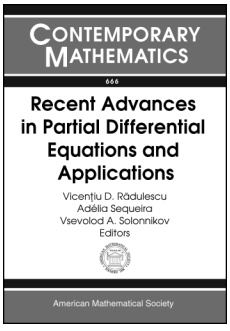
Layer Potentials and Boundary-Value Problems for Second Order Elliptic Operators with Data in Besov Spaces

Ariel Barton, *University of Arkansas, Fayetteville*, and **Svitlana Mayboroda**, *University of Minnesota, Minneapolis*

Contents: Introduction; Definitions; The Main theorems; Interpolation, function spaces and elliptic equations; Boundedness of integral operators; Trace theorems; Results for Lebesgue and Sobolev spaces: Historic account and some extensions; The Green's formula representation for a solution; Invertibility of layer potentials and well-posedness of boundary-value problems; Besov spaces and weighted Sobolev spaces; Bibliography.

Memoirs of the American Mathematical Society, Volume 243, Number 1149

August 2016, 110 pages, Softcover, ISBN: 978-1-4704-1989-9, 2010 *Mathematics Subject Classification:* 35J25; 31B20, 35C15, 46E35, **Individual member US$49.80**, List US$83, Institutional member US$66.40, Order code MEMO/243/1149



Recent Advances in Partial Differential Equations and Applications

Vicenţiu D. Rădulescu, *King Abdulaziz University, Jeddah, Saudi Arabia*, **Adélia Sequeira**, *Universidade de Lisboa, Portugal*, and **Vsevolod A. Solonnikov**, *Steklov Mathematical Institute, St. Petersburg, Russia*, Editors

This volume contains the proceedings of the International Conference on Recent Advances in PDEs and Applications, in honor of Hugo Beirão da Veiga's 70th birthday, held from February 17–21, 2014, in Levico Terme, Italy.

The conference brought together leading experts and researchers in nonlinear partial differential equations to promote research and to stimulate interactions among the participants. The workshop program testified to the wide-ranging influence of Hugo Beirão da Veiga on the field of partial differential equations, in particular those related to fluid dynamics.

In his own work, da Veiga has been a seminal influence in many important areas: Navier-Stokes equations, Stokes systems, non-Newtonian fluids, Euler equations, regularity of solutions, perturbation theory, vorticity phenomena, and nonlinear potential theory, as well as various degenerate or singular models in mathematical physics. This same breadth is reflected in the mathematical papers included in this volume.

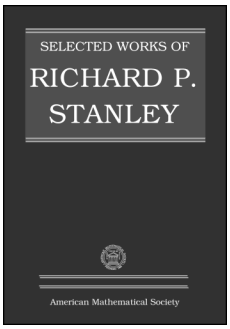
This item will also be of interest to those working in applications.

Contents: A. Sequeira, **J.-P. Dias**, **A. Valli**, **P. Secchi**, **L. Berselli**, and **F. Crispo**, Tributes to Hugo Beirão da Veiga; **H. A. Baba**, **C. Amrouche**, and **M. Escobedo**, Analyticity of the semi-group generated by the Stokes operator with Navier-type boundary conditions on L^p-spaces; **P. Antonelli** and **P. Marcati**, Some results on systems for quantum fluids; **C. Bardos** and **T. T. Nguyen**, Remarks on the inviscid limit for the compressible flows; **V. Benci** and **L. L. Baglini**, A generalization of Gauss' divergence theorem; **L. C. Berselli** and **S. Spirito**, Weak solutions to the Navier-Stokes equations constructed by semi-discretization are suitable; **D. Breit**, Existence theory for generalized Newtonian fluids; **G. Buttazzo** and **B. Velichkov**, The spectral drop problem; **D. Chae**, On the vanishing theorems for the discretely self-similar solutions to the Hall equations; **F. Crispo** and **P. Maremonti**, A high regularity result of solutions to a modified p-Navier-Stokes system; **R. Farwig**, **C. Simader**, **H. Sohr**, and **W. Varnhorn**, General properties of the Helmholtz decomposition in spaces of L^q-type; **E. Feireisl** and **Y. Sun**, Conditional regularity of very weak solutions to the Navier-Stokes-Fourier system; **F. Flandoli**, Possible effect of noise on stretching mechanism; **G. P. Galdi** and **C. R. Grisanti**, On the plane steady-state flow of a shear-thinning liquid past an obstacle in the singular case; **V. Georgiev** and **A. R. Giammetta**, Sectorial Hamiltonians without zero resonance in one dimension; **Z. Grujić**, Vortex stretching and anisotropic diffusion in the 3D Navier-Stokes equations; **P. Kaplický**, On L^q estimates for planar flows up to boundary; **B. Ducomet** and **S. Nečasová**, Non equilibrium diffusion limit in a barotropic radiative flow; **R. Rautmann**, Decomposition of the homogeneous space $\hat{W}^{1,2}$ with respect to the Dirichlet form $\langle \nabla u, \nabla v \rangle$ and applications; **S. Rionero**, Convection in ternary porous layers with depth-dependent permeability and viscosity; **F. Miranda** and **J. F. Rodrigues**, On a variational inequality for incompressible non-Newtonian thick flows; **E. Molitor** and **M. Růžička**, On inhomogeneous p-Navier–Stokes systems; **Y. Shibata**, On the global well-posedness of some free boundary problem for a compressible barotropic viscous fluid flow; **V. A. Solonnikov**, On a free boundary problem of magnetohydrodynamics for a viscous incompressible fluid not subjected to capillary forces; **A. F. Vasseur**, Relative entropy and contraction for extremal shocks of conservation laws up to a shift.

Contemporary Mathematics, Volume 666

July 2016, approximately 401 pages, Softcover, ISBN: 978-1-4704-1521-1, LC 2015036428, 2010 *Mathematics Subject Classification:* 35-06, 76-06; 35A01, 35B40, 35J60, 35K55, 35L70, 65N06, 76D05, **AMS members US$86.40**, List US$108, Order code CONM/666

Discrete Mathematics and Combinatorics



Selected Works of Richard P. Stanley

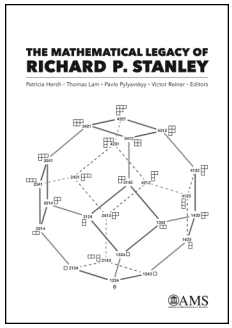
Patricia Hersh, *North Carolina State University, Raleigh, NC*, **Thomas Lam**, *University of Michigan, Ann Arbor, MI*, **Pavlo Pylyavskyy**, *University of Michigan, Ann Arbor, MI*, and **Victor Reiner**, *University of Minnesota, Minneapolis, MN*, Editors

Richard Stanley's work in combinatorics revolutionized and reshaped the subject. Many of his hallmark ideas and techniques imported from other areas of mathematics have become mainstays in the framework of modern combinatorics. In addition to collecting several of Stanley's most influential papers, this volume also includes his own short reminiscences on his early years, and on his celebrated proof of The Upper Bound Theorem.

Contents: The early years; How the upper bound conjecture was proved; Theory and application of plane partitions: Part 1; Theory and application of plane partitions. Part 2; Modular elements of geometric lattices; Supersolvable lattices; Linear homogeneous diophantine equations and magic labelings of graphs; Acyclic orientations of graphs; Combinatorial reciprocity theorems; The upper bound conjecture and Cohen-Macaulay rings; Combinatorial reciprocity theorems; Binomial posets, Möbius inversion, and permutation enumeration; Eulerian partitions of a unit hypercube, voir note ci-après; Hilbert functions of graded algebras; The number of faces of a simplicial convex polytope; Differential posets; Weyl groups, the hard Lefschetz theorem, and the Sperner property; Two combinatorial applications of the Aleksandrov-Fenchel inequalities; Linear diophantine equations and local cohomology; Some aspects of groups acting on finite posets; with **A. Björner and A. Garsia**, An introduction to Cohen-Macaulay partially ordered sets; An introduction to combinatorial commutative algebra; On the number of reduced decompositions of elements of Coxeter groups; A baker's dozen of conjectures concerning plane partitions; Unimodality and Lie superalgebras; Two poset polytopes; Generalized H-vectors, intersection cohomology of toric varieties, and related results; Differentiably finite power series; Log-concave and unimodal sequences in algebra, combinatorics, and geometry; Some combinatorial properties of Jack symmetric functions; Subdivisions and local h-vectors; with **S. Billey and W. Jokusch**, Some combinatorial properties of Schubert polynomials; with **S. Fomin**, Schubert polynomials and the nilCoxeter algebra; Flag f-vectors and the cd-index; A symmetric function generalization of the chromatic polynomial of a graph; Irreducible symmetric group characters of rectangular shape; Increasing and decreasing subsequences and their variants; Promotion and evacuation; A conjectured combinatorial interpretation of the normalized irreducible character values of the symmetric group.

Collected Works, Volume 25

August 2016, approximately 783 pages, Hardcover, ISBN: 978-1-4704-1682-9, LC 2016006716, 2010 *Mathematics Subject Classification:* 05A15, 05B35, 05Exx, 06A07, 06A11, 13F55, 52B05, 52B20, 52B22, 52C35, **AMS members US$128**, List US$160, Order code CWORKS/25



The Mathematical Legacy of Richard P. Stanley

Patricia Hersh, *North Carolina State University, Raleigh, NC*, **Thomas Lam**, *University of Michigan, Ann Arbor, MI*, **Pavlo Pylyavskyy**, *University of Minnesota, Minneapolis, MN*, and **Victor Reiner**, *University of Minnesota, Minneapolis, MN*, Editors

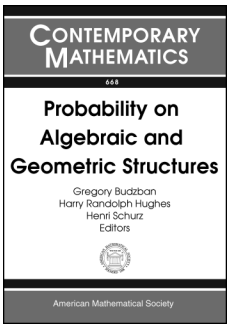
Richard Stanley's work in combinatorics revolutionized and reshaped the subject. His lectures, papers, and books inspired a generation of researchers. In this volume these researchers explain how Stanley's vision and insights influenced and guided their own perspectives on the subject. As a valuable bonus, this book contains a collection of Stanley's short comments on each of his papers.

This book may serve as an introduction to several different threads of ongoing research in combinatorics as well as giving historical perspective.

Contents: R. P. Stanley, Publications; **C. A. Athanasiadis**, A survey of subdivisions and local h-vectors; **M. Beck**, Stanley's major contributions to Ehrhart theory; **L. J. Billera**, "Even more intriguing, if rather less plausible..." Face numbers of convex polytopes; **S. C. Billey** and **P. R. W. McNamara**, The contributions of Stanley to the fabric of symmetric and quasisymmetric functions; **A. Björner**, "Let Δ be a Cohen-Macaulay complex . . ."; **F. Brenti**, Stanley's work on unimodality; **P. Diaconis**, Five stories for Richard; **A. Garsia**, **J. Haglund**, **G. Xin**, and **M. Zabrocki**, Some new applications of the Stanley-Macdonald Pieri rules; **I. M. Gessel**, A historical survey of P-partitions; **I. P. Goulden** and **D. M. Jackson**, Transitive factorizations of permutations and geometry; **T. Hibi**, Stanley's influence on monomial ideals; **M. Hochster**, Cohen-Macaulay varieties, geometric complexes, and combinatorics; **C. Krattenthaler**, Plane partitions in the work of Richard Stanley and his school; **C. Lenart**, Combinatorial representation theory of Lie algebras. Richard Stanley's work and the way it was continued; **J. Propp**, Lessons I learned from Richard Stanley; **A, Schilling**, Richard Stanley through a crystal lens and from a random angle; **J. Shareshian** and **M. L. Wachs**, From poset topology to q-Eulerian polynomials to Stanley's chromatic symmetric functions; **P. Śniady**, Stanley character polynomials; **S. Sundaram**, Some problems arising from partition poset homology.

August 2016, approximately 352 pages, Hardcover, ISBN: 978-1-4704-2724-5, LC 2016004438, 2010 *Mathematics Subject Classification:* 05A15, 05B35, 05Exx, 06A07, 06A11, 13F55, 52B05, 52B20, 52B22, 52C35, **AMS members US$47.20**, List US$59, Order code MBK/100

Probability and Statistics



Probability on Algebraic and Geometric Structures

Gregory Budzban, *Southern Illinois University, Carbondale, IL*, **Harry Randolph Hughes**, *Southern Illinois University, Carbondale, IL*, and **Henri Schurz**, *Southern Illinois University, Carbondale, IL*, Editors

This volume contains the proceedings of the International Research Conference "Probability on Algebraic and Geometric Structures", held from June 5–7, 2014, at Southern Illinois University, Carbondale, IL, celebrating the careers of Philip Feinsilver, Salah-Eldin A. Mohammed, and Arunava Mukherjea.

These proceedings include survey papers and new research on a variety of topics such as probability measures and the behavior of stochastic processes on groups, semigroups, and Clifford algebras; algebraic methods for analyzing Markov chains and products of random matrices; stochastic integrals and stochastic ordinary, partial, and functional differential equations.

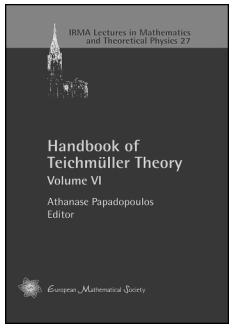
Contents: A. Anckar and **G, Högnäs**, The fine structure of the stationary distribution for a simple Markov process; **D. Bell**, Superdegenerate hypoelliptic differential operators; **G. Budzban** and **A. Mukherjea**, Some remarks on the convolution equation $\mu * \beta = \mu$ and product semigroups; **S. Chakraborty**, Limit distributions of products of i.i.d. random $2x2$ stochastic matrices: An open problem; **A. Cosso**, **C. Di Girolami**, and **F. Russo**, Calculus via regularizations in Banach spaces and Kolmogorov-type path-dependent equations; **P. Feinsilver**, Matrices with zero row sums, tree theorems and Markov chain on trees; **P. Graczyk** and **P. Sawyer**, Convolution of orbital measures on symmetric spaces: A survey; **G. Högnäs** and **B. Jung**, Exit times for some autoregressive processes with non-Gaussian noise distributions; **I. Kemajou-Brown**, Brief history of optimal control theory and some recent developments; **J. Kocik**, Krawtchouk matrices, Feynman path integral and the split quaternions; **R. Léandre**, The Itô-Stratonovich formula for an operator of order four; **C. R. E. Raja** and **R. Schott**, Random walks on motion groups; **H. Schurz** and **A. Talafha**, Existence, uniqueness, and energy of modified stochastic sine-Gordon equation with multiplicative noise on one-dimensional domain; **L. Siriwardena** and **H. R. Hughes**, Squared Bessel process with delay; **G. S. Staples**, Kravchuk matrices and induced operators on Clifford algebras.

Contemporary Mathematics, Volume 668

July 2016, 221 pages, Softcover, ISBN: 978-1-4704-1945-5, LC 2015039277, 2010 *Mathematics Subject Classification:* 05C50, 15A66, 49N90, 54C40, 60B15, 60G50, 60H07, 60H15, 60H30, 60J05, **AMS members US$86.40**, List US$108, Order code CONM/668

New AMS-Distributed Publications

Analysis



Handbook of Teichmüller Theory: Volume VI

Athanase Papadopoulos, *Université de Strasbourg, France*, Editor

This volume is the sixth in a series dedicated to Teichmüller theory in a broad sense, including various moduli and deformation spaces, and the study of mapping class groups.

It is divided into five parts:

- Part A: The metric and the analytic theory
- Part B: The group theory
- Part C: Representation theory and generalized structures
- Part D: The Grothendieck–Teichmüller theory
- Part E: Sources

The topics surveyed include Grothendieck's construction of the analytic structure of Teichmüller space, identities on the geodesic length spectrum of hyperbolic surfaces (including Mirzakhani's application to the computation of Weil-Petersson volumes), moduli spaces of configurations spaces, the Teichmüller tower with the action of the Galois group on dessins d'enfants, and several other actions related to surfaces. The last part contains three papers by Teichmüller's famous paper *Extremale quasikonforme Abbildungen und quadratische Differentiale.*

The handbook is addressed to researchers and to graduate students.

This item will also be of interest to those working in geometry and topology.

A publication of the European Mathematical Society. Distributed within the Americas by the American Mathematical Society.

IRMA Lectures in Mathematics and Theoretical Physics, Volume 27

May 2016, 652 pages, Hardcover, ISBN: 978-3-03719-161-3, 2010 *Mathematics Subject Classification:* 30-00, 32-00, 57-00, 32G13, 32G15, 30F60; 11F06, 11F75, 14D20, 11G32, **AMS members US$86.40**, List US$108, Order code EMSILMTP/27

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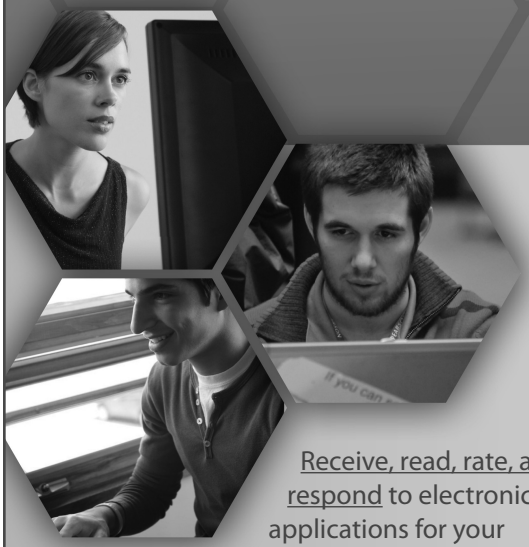

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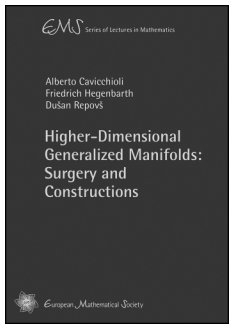
Geometry and Topology



Higher-Dimensional Generalized Manifolds: Surgery and Constructions

Alberto Cavicchioli, *Università degli Studi di Modena e Reggio Emilia, Italy*, **Friedrich Hegenbarth**, *Univerità degli Studi di Milano, Italy*, and **Dušan Repovš**, *University of Ljubljana, Slovenia*

Generalized manifolds are a most fascinating subject to study. They were introduced in the 1930s, when topologists tried to detect topological manifolds among more general spaces. (This is now called the manifold recognition problem.) As such, generalized manifolds have served to enhance our understanding of the nature of genuine manifolds. However, it soon became more important to study the category of generalized manifolds itself.

A breakthrough was made in the 1990s, when several topologists discovered a systematic way of constructing higher-dimensional generalized manifolds, based on advanced surgery techniques. In fact, the development of controlled surgery theory and the study of generalized manifolds developed in parallel. In this process, earlier studies of geometric surgery turned out to be very helpful.

Generalized manifolds will continue to be an attractive subject to study, for there remain several unsolved fundamental problems. Moreover, they hold promise for new research, e.g. for finding appropriate structures on these spaces which could bring to light geometric (or even analytic) aspects of higher-dimensional generalized manifolds.

This is the first book to systematically collect the most important material on higher-dimensional generalized manifolds and controlled surgery. It is self-contained and its extensive list of references reflects the historic development. The book is based on the authors' graduate courses and seminars, as well as their talks given at various meetings, and is suitable for advanced graduate students and researchers in algebraic and geometric topology.

This item will also be of interest to those working in algebra and algebraic geometry.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

EMS Series of Lectures in Mathematics, Volume 23

May 2016, 154 pages, Softcover, ISBN: 978-3-03719-156-9, 2010 *Mathematics Subject Classification:* 57P05, 57P10, 57P99, 57R65, 57R67; 18F15, 19J25, 57N15, 57N60, 57N65, **AMS members US$30.40**, List US$38, Order code EMSSERLEC/23

MEETINGS & CONFERENCES OF THE AMS

AUGUST 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 88 in the January 2016 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts: Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset in LaTeX. Visit **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.

MEETINGS IN THIS ISSUE

2016

September 24–25	Brunswick, Maine	p. 844
October 8–9	Denver, Colorado	p. 845
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November 12–13	Raleigh, North Carolina	p. 854

2017

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April 1–2	Bloomington, Indiana	p. 859
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May 6–7	New York, New York	p. 860
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2020

January 15–18	Denver, Colorado	p. 863

2021

January 6–9	Washington, DC	p. 863

Conferences in Cooperation with the AMS

Indian Mathematics Consortium

December 14–17, 2016

Banaras Hindu University

Varanasi, India

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.

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices.* However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See www.ams.org/meetings/.

Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL .

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: To be announced
Issue of *Abstracts*: Volume 37, Issue 3

Deadlines

For organizers: Expired
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, *Szemerédi's Theorem: combinatorics, ergodic theory and algebra.*

Moon Duchin, Tufts University, *Counting in groups: fine asymptotic geometry.*

Thomas Lam, University of Michigan, *Combinatorics of electrical networks.*

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 Enumerative Combinatorics (Code: SS 12A), **Thomas Lam**, University of Michigan.

Autonomous and Non-autonomous Discrete Dynamical Systems with Applications (Code: SS 2A), **M.R.S. Kulenović** and **O. Merino**, University of Rhode Island.

Combinatorial Aspects of Nilpotent Orbits (Code: SS 18A), **Anthony Iarrobino**, Northeastern University, **Leila Khatami**, Union College, and **Julianna Tymoczko**, Smith College.

Combinatorics, at the Crossroads of Algebra, Geometry, and Topology (Code: SS 11A), **Ivan Martino**, University of Fribourg (Switzerland), and **Alexander I. Suciu**, Northeastern University.

Convex Cocompactness (Code: SS 14A), **Tarik Aougab** and **Sara Maloni**, Brown University.

Decomposing 3-manifolds (Code: SS 8A), **Tao Li**, Boston College, and **Scott Taylor**, Colby College.

Financial Mathematics (Code: SS 13A), **Maxim Bichuch**, Johns Hopkins University, and **Stephan Strum** and **Xuwei Yang**, Worcester Polytechnic Institute.

Geometric Aspects of Harmonic Analysis (Code: SS 6A), **Matthew Badger** and **Vasileios Chousionis**, University of Connecticut.

Geometric Group Theory (Code: SS 4A), **Charles Cunningham**, Bowdoin College, **Moon Duchin**, Tufts University, and **Jennifer Taback**, Bowdoin College.

Geometry of Nilpotent Groups (Code: SS 5A), **Moon Duchin**, Tufts University, **Jennifer Taback**, Bowdoin College, and **Peter Wong**, Bates College.

Mathematics and Statistics Applied to Biology and Related Fields (Code: SS 7A), **Meredith L. Greer**, Bates College.

New Developments in Graphs and Hypergraphs (Code: SS 16A), **Deepak Bal** and **Jonathan Cutler**, Montclair State University, and **Jozef Skokan**, London School of Economics.

Noncommutative Ring Theory and Noncommutative Algebra (Code: SS 1A), **Jason Gaddis**, Wake Forest University, and **Manuel Reyes**, Bowdoin College.

Nonlinear Partial Differential Equations in Material Science and Mathematical Biology (Code: SS 3A), **Leonid Berlyand**, Pennsylvania State University, **Dmitry Golovaty**, University of Akron, and **Alex Misiats**, New York University.

Nonlinear Waves and Dynamical Systems (Code: SS 9A), **Christopher Chong**, Bowdoin College.

Plethysm and Kronecker Products in Representation Theory (Code: SS 17A), **Susanna Fishel**, Arizona State University, and **Sheila Sundaram**, Pierrepont School.

Topological Phases of Matter and Quantum Computation (Code: SS 15A), **Paul Bruillard** and **Carlos Ortiz**, Pacific Northwest National Laboratory, and **Julia Plavnik**, Texas A&M University.

Undergraduate Research (Code: SS 10A), **Christopher Chong** and **Adam Levy**, Bowdoin College.

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

Deadlines

For organizers: Expired
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, *Quantum Symmetry.*

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 Combinatorics (Code: SS 23A), **Anton Betten**, Colorado State University, **Jason Williford**, University of Wyoming, and **Bangteng Xu**, Eastern Kentucky 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.

Aspects of PDE Arising from Modeling of the Flows in Porous Media (Code: SS 19A), **Akif Ibraguimov**, Texas Tech University, **Viktoria Savatorova**, University of Nevada, Las Vegas, and **Aleksey Telyakovskiy**, University of Nevada, Reno.

Discontinuous Galerkin methods for partial differential equations: Theory and applications (Code: SS 15A), **Mahboub Baccouch**, University of Nebraska at Omaha.

Floer Theoretic Invariants of 3-manifolds and Knots (Code: SS 22A), **Jonathan Hanselman**, University of Texas at Austin, and **Kristen Hendricks**, University of California, Los Angeles.

Foundations of Numerical Algebraic Geometry (Code: SS 14A), **Abraham Martin del Campo**, CIMAT, Guanajuato, Mexico, and **Frank Sottile**, Texas A&M University.

Groups and Representation Theory (Code: SS 20A), **C. Ryan Vinroot**, College of William and Mary, **Julianne Rainbolt**, Saint Louis University, and **Amanda Schaeffer Fry**, Metropolitan State University of Denver.

Integrable Systems and Soliton Equations (Code: SS 17A), **Anton Dzhamay**, University of Northern Colorado, and **Patrick Shipman**, Colorado State University.

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.

Nonlinear Wave Equations and Applications (Code: SS 18A), **Mark J. Ablowitz**, University of Colorado, Boulder, and **Barbara Prinari**, University of Colorado, Colorado Springs.

Nonlinear and Stochastic Partial Differential Equations (Code: SS 13A), **Michele Coti Zelati**, University of Maryland, **Nathan Glatt-Holtz**, Virginia Polytechnic Institute and State University, and **Geordie Richards**, University of Rochester.

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.

Random Matrices, Integrable Systems, and Applications (Code: SS 16A), **Sean D. O'Rourke**, University of Colorado Boulder, and **David Renfrew**, University of California, Los Angeles.

Recent Advances in Structural and Extremal Graph Theory (Code: SS 21A), **Michael Ferrara**, **Stephen Hartke**, **Michael Jacobson**, and **Florian Pfender**, University of Colorado Denver.

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** and **Nicolas Guay**, University of Alberta.

Zero Dimensional Dynamics (Code: SS 10A), **Nic Ormes** and **Ronnie Pavlov**, University of Denver.

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 Colorado state and local taxes (14.75 percent). Participants must state that they are with the **American Mathematical Society (AMS) Meeting at University of Denver** 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 checkout penalties; be sure to ask for details.**

Courtyard by Marriott Denver Cherry Creek, 1475 S. Colorado Boulevard, Denver, CO, 80222; 303-757-8797; www.courtyardcherrycreek.com/. Rates are **US$119** per night for a single or double occupancy room. Amenities include complimentary high-speed Wi-Fi in public areas and guest rooms, business center, heated indoor pool and whirlpool, fitness center, in-room microwave and refrigerator, and on-property restaurant, *The Bistro*, offering evening room service. This property is located approximately 2 miles from 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 **August 31, 2016.**

Fairfield Inn and Suites by Marriott Denver Cherry Creek, 1680 South Colorado Boulevard, Denver, CO, 80222; 303-691-2223; www.marriott.com/hotels/travel/denfi-fairfield-inn-and-suites-denver-cherry-creek/. Rates are **US$112** per night for a single occupancy, king bedroom or double bedroom and **US$127** per night for a single occupancy king suite bedroom. Amenities include complimentary hot buffet breakfast, complimentary high-speed Wi-Fi, indoor pool, fitness center, and business center. This property is located approximately 2 miles from 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 a reduced rate is **September 14, 2016**.

Hampton Inn and Suites by Hilton Denver- Cherry Creek, 4150 E. Kentucky Ave, Glendale,CO 80246; 303-692-1800; hamptoninn3.hilton.com/en/hotels/colorado/hampton-inn-and-suites-denver-cherry-creek-DENCCHX/index.html/. Rates are **US$149** per night for single or double occupancy rooms. Amenities include complimentary hot breakfast, free high-speed Wi-Fi, fitness room, indoor pool, and business center. This property is located approximately 3 miles from 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 **September 7, 2016.**

Hyatt Place Denver Cherry Creek, 4150 East Mississippi Avenue, Glendale, CO; 303-782-9300; www.denvercherrycreek.place.hyatt.com/en/hotel/home.html/. Rates are **US$115** per night for a single occupancy room. Amenities include a complimentary hot breakfast, complimentary high-speed Wi-Fi, fitness center, on-site *Coffee to Cocktails* bar and business center. This property is located approximately 2 miles from 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 **September 22, 2016.**

La Quinta Inn Denver Cherry Creek, 1975 South Colorado Boulevard, Denver, CO, 80222; 303-758-8886; www.laquintadenvercherrycreek.com/. Rates are **US$89** per night for a room with two double beds or for a room with one king bed, this rate is applicable for single or double occupancy, with no additional charges for up to four guests in the room. Amenities include complimentary Bright Side breakfast and complimentary high-speed Wi-Fi. This property is located approximately 1.5 miles from 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 **September 16, 2016.**

Food Services

On Campus: The University has several retail dining outlets on campus, please see https://dudining.sodexomyway.com/dining-choices/retail.html/.

Off Campus: Denver offers a variety of restaurants, many near the university, especially on University Boulevard and along East Evans Avenue. The following is a short list. For a more extensive list, see www.denver.org/restaurants/denver-dining/.

University Boulevard

Asbury Provisions, 2043 S. University Blvd., (303) 282-5485, www.asburyprovisions.com; craft beers, comfort food. Opens at 4:00 pm.

Ali Baba Grill, 2060 S. University Blvd., (303) 282-5008, www.alibabagrill.com; Lebanese and Persian cuisine.

Blackjack Pizza, 2443 S. University Blvd, (303) 722-5222, www.blackjackpizza.com; pizza.

Bruegger's Bagels, 2000 S University Blvd., (303) 777-7600, www.brueggers.com/; bagels, sandwiches.

Crimson and Gold Tavern, 2017 S. University Blvd., (720) 379-5454, www.candgdenver.com; American pub food; sports bar.

Deli Zone, 2439 S. University Blvd., (303) 927-6304 delizone.com; breakfast, deli.

Ginza Sushi and Grill, 2104 S. University Blvd., (303) 778-1111, www.ginzadenver.com/lunch.php?key=lunch&cat=lunchbento; Japanese.

Jason's Thai Asian Bistro, 2022 S. University Blvd., (303) 777-0348, www.jasonsthai.com; Chinese, Thai, Sushi.

Mustard's Last Stand, 2081 S. University Blvd., (303) 444-5841, mustardslaststandcolorado.com; hot dogs, burgers.

The Pioneer, 2401 S University Blvd., (720) 536-4802, thepioneerbar.com; Mexican, American, Bar.

Pita Fresh, 2075 S. University Blvd., (303) 955-8711, Sandwiches. Lebanese, Mediterranean, halal.

South Philly Cheese Steaks, 2070 S. University Blvd., (720) 328-0018, yojeet.com; sandwiches.

Starbucks, 2000 S University Blvd., (303) 733-9377, www.starbucks.com/; coffee.

Wendy's, 2485 S University Blvd., (720) 570-7921, locations.wendys.com; fast food, burgers.

E. Evans Avenue

Anthony's Pizza and Pasta, 1628 E. Evans, (303) 744-3137, www.anthonyspizzaandpasta.com; Pizza; Italian.

Einstein Bros. Bagels, 1213 E. Evans, (303) 722-9300, locations.einsteinbros.com/co/denver/1213-e-evans-ave.html; bagels, sandwiches.

Illegal Pete's. 1744 E Evans, (720) 974-2198, www.illegalpetes.com; Mexican, fast food, local chain.

Jelly U Café, 1700 E. Evans, (720) 596-4108, eatmorejelly.com; American, serves breakfast, salads, sandwiches.

Jerusalem Restaurant, 1890 E. Evans, (303) 777-8828, www.jerusalemrestaurant.com; Mediterranean, Middle Eastern.

Kaladi Brothers Coffee Roasters, 1730 E. Evans, (720) 570-2166, kaladicoffee.com; Coffee.

Noodles and Company, 1737 E. Evans, (303) 722-1912, www.noodles.com/locations/university-of-denver/; counter-serve chain serving international noodle and pasta dishes.

Pete's University Café, 2345 E. Evans, (303) 733-7376, www.petesrestaurants.com/PetesUniversityParkCafe.html; American, serves breakfast and lunch.

Spanky's Urban Roadhouse, 1800 E. Evans, (303) 733-6886, www.spankysur.com; American, upscale pub fare.

Snarf's Sandwiches, 1729 E .Evans, (303) 777-1664, eatsnarfs.com; regional chain sandwich shop.

Twisters Restaurant, 1535 E. Evans, 303) 722-2175, www.mytwisters.com; burgers and burritos.

Registration and Meeting Information

Advanced Registration: Advanced registration for this meeting opens on **August 1st.** Advanced registration fees will be **US$59** for AMS members, **US$85** for nonmembers, and **US$10** for students, unemployed mathematicians, and emeritus members.

On-site Information and Registration: All meeting activities, including the registration desk, AMS book exhibit, coffee service, all Invited Addresses, Special Sessions, and Contributed Paper Sessions, will take place in Sturm Hall. For further information on building locations, a campus map is available at www.du.edu/utilities/maps/.

The registration desk will be open on Saturday, October 8, 7:30 am–4:00 pm and Sunday, October 9, 8:00 am–12:00 pm. The same fees apply for on-site registration, as for advanced registration. Fees are payable on-site via cash, check, or credit card.

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

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.

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 e-mail 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 campus of the University of Denver. Campus maps can be found at www.du.edu/utilities/maps/. Information about the University of Denver mathematics department can be found at

www.du.edu/nsm/departments/mathematics/. Please visit the University of Denver website at www.du.edu/ for additional information about the campus.

Please watch the AMS website at www.ams.org/meetings/sectional/sectional.html for additional information on this meeting.

Parking

Information about parking on campus can be found here: www.du.edu/parking/. A parking map can be found here: www.du.edu/media/documents/maps/map-parking.pdf.

Travel

The campus of the University of Denver is located in the Denver Metropolitan area. The address is 199 S. University Blvd, Denver, CO 80208. It lies just south and west of the intersection of I-25 and University Boulevard. The airport is northeast of the city center.

By Air: Denver International Airport (DEN) is served by most major airlines. Please visit the airport's web site for a list, as well as terminal maps and information about ground transportation: www.flydenver.com/.

There are several options available for transportation to/from the airport.

Car Rental: All major car rental companies serve the Denver International Airport. The rental agencies provide courtesy shuttle service to and from Jeppesen Terminal on Level 5, Island 4, outside doors 505-513 (east side) and 504-512 (west side).

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.

Public Transportation is available via Denver's Regional Transportation (RTD) system. The Denver Airport Station (Light Rail/Buses) is on Level 1 of the airport's Transit Center. Baggage Claim is located on Level 5 of the Jeppesen Terminal. Follow the signs to the Transit Center, and take the escalator down to Level 1. See www.rtd-denver.com/a-line-airport.shtml for more information.

Please plan ahead if you wish to use public transportation. There is a trip planner at www.rtd-denver.com/, and you may also call (303) 299-6000 for assistance. The fare for all trips by bus or light rail to and from the airport is currently US$9.00.

To get to the University of Denver via Light Rail, take the University of Colorado A train to Union Station, then change to the E train and stop at the University of Denver station. This trip will take a little more than an hour, and the rail station is at the northern end of campus.

Shuttles

SuperShuttle, 7500 E. 41st Avenue, Denver, CO 80216, 1-800-BLUE-VAN or (303) 370-1300. Book online at www.supershuttle.com/Locations/DenverDEN. A one-way trip to the University is currently US$26.00.

Other shared ride services are listed on the Denver International Aiport's page at www.flydenver.com/parking_transit/transit/shared-vans.

Taxis

Taxis are available at Jeppesen Terminal, Level 5, Island 1, outside Doors 505, 507 and 511 (Terminal East), and Doors 506, 510 and 512 (Terminal West). Taxi fare to downtown Denver will cost an average of US$60.00, plus a $4.57 airport access fee.

To call a taxi from campus:

Metro Taxi (303) 333-3333
Yellow Cab (303)777-7777

Driving Directions:

The University of Denver is easily accessible from I-25, the main route running through the Denver metro area north/south. The campus lies just south and west of the intersection of I-25 and University Boulevard.

Driving Directions from Denver International Airport: Upon leaving the airport, take Pena Boulevard to I-70 West (exit to the left), and then continue on I-70 to I-25 South, which will be Exit 274. Take I-25 to University Blvd (Exit 205), and turn right (south) on University Blvd.

The campus runs along the right-hand (west) side of University Boulevard., between Buchtel Boulevard. and Harvard Avenue.

From the south: Take I-25 north and take the University Boulevard exit (Exit 205). Turn left onto South University Boulevard and drive south approximately 0.1 miles.

From the north: Take I-25 south toward Colorado Springs. Take the University Boulevard exit (Exit 205). Turn right onto South University Boulevard and drive south approximately 0.1 miles.

Local Transportation

Denver has a good public transportation system, please see www.denver.org/about-denver/transportation/public-transportation/.

The University of Denver station, which is located at 1901 E. Buchtel Boulevard (Buchtel and University) is served by the Denver Light Rail system (www.rtd-denver.com/lightrail.shtml). The station is on the E/F/H lines. The #24 bus also stops there. This bus travels up and down University Boulevard. The station is approximately a ten-minute walk from the center of campus.

Weather

The average high temperature for October is approximately 66 degrees Fahrenheit, and the average low is approximately 33 degrees Fahrenheit. Visitors should check weather forecasts in advance of their arrival and be prepared to dress in layers. Denver has an arid climate with little annual precipitation, which results in sunny days and cold nights. Take note of the city of Denver's "High Altitude Tips" at www.denver.org/about-denver/facts-info/high-altitude-tips/.

Social Networking:

Attendees and speakers are encouraged to tweet about the meeting using the hashtag #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.

Minneapolis, Minnesota

University of St. Thomas (Minneapolis campus)

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: Expired
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, *Algebraic Symplectic Varieties, Classical and Quantum*.

Charles Rezk, University of Illinois Urbana–Champaign, *On Some Approximations to Homotopy Theory*.

Christof Sparber, Department of Mathematics, Statistics & Computer Science, University of Illinois at Chicago, *Semiclassical quantum dynamics via Bohemian trajectories*.

Samuel Stechmann, University of Wisconsin–Madison, *Stochastic PDEs for Tropical Weather and Climate*.

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.

Advances in Algebraic Coding Theory (Code: SS 11A), **Sarah E. Anderson**, University of St. Thomas, and **Katie Haymaker**, Villanova University.

Chip-Firing and Divisors on Graphs and Complexes (Code: SS 3A), **Caroline Klivans**, Brown University, and **Gregg Musiker** and **Victor Reiner**, University of Minnesota.

Combinatorial Matrix Theory (Code: SS 18A), **Adam Berliner**, St. Olaf College, **Brenda Kroschel**, University of St. Thomas, and **Nathan Warnberg**, University Wisconsin–LaCrosse.

Combinatorial Representation Theory (Code: SS 5A), **Michael Chmutov**, University of Minnesota, **Tom Halverson**, Macalester College, and **Travis Scrimshaw**, University of Minnesota.

Discrete Structures: Analysis and Applications (IMA Reunion) (Code: SS 15A), **Leslie Hogben** and **Ryan Martin**, Iowa State University, and **Elisabeth Werner**, Case Western Reserve University.

Effective Mathematics in Discrete and Continuous Worlds (Code: SS 16A), **Wesley Calvert**, Southern Illinois University, and **Timothy McNicholl**, Iowa State University.

Enumerative Combinatorics (Code: SS 4A), **Eric Egge**, Carleton College, and **Joel Brewster Lewis**, University of Minnesota.

Extremal and Probabilistic Combinatorics (Code: SS 13A), **Andrew Beveridge**, University of Nebraska–Lincoln, **Jamie Radcliffe**, University of Minnesota, Twin Cities, and **Michael Young**, Iowa State University.

Geometric Flows, Integrable Systems and Moving Frames (Code: SS 2A), **Joseph Benson**, St. Olaf College, **Gloria Mari-Beffa**, University of Wisconsin–Madison, **Peter Olver**, University of Minnesota, and **Rob Thompson**, Carleton College.

Integrable Systems and Related Areas (Code: SS 8A), **Sam Evens**, University of Notre Dame, **Luen-Chau Li**, Pennsylvania State University, and **Zhaohu Nie**, Utah State University.

Knotting in Physical Systems, in celebration of Kenneth C. Millett's 75th birthday (Code: SS 14A), **Jorge Alberto Calvo**, Ave Maria University, and **Eric Rawdon**, University of St. Thomas.

Mathematics and Physics of Tornado Modeling (Code: SS 21A), **Pavel Belik**, Augsburg College, and **Douglas P. Dokken**, **Kurt Scholz**, and **Misha Shvartsman**, University of St. Thomas.

Modeling and Predicting the Atmosphere, Oceans, and Climate (Code: SS 1A), **Sam Stechmann**, University of Wisconsin–Madison.

Multi-scale Phenomena in Linear and Nonlinear Partial Differential Equations (Code: SS 23A), **Zaher Hani**, Georgia Tech, and **Christof Sparber**, University of Illinois at Chicago.

New Developments in the Analysis of Nonlocal Operators (Code: SS 6A), **Donatella Danielli** and **Arshak Petrosyan**, Purdue University, and **Camelia Pop**, University of Minnesota.

Noncommutative Algebras and Their Representations (Code: SS 20A), **Miodrag Iovanov** and **Ryan Kinser**, University of Iowa, and **Peter Webb**, University of Minnesota.

Quantum Field Theories and Geometric Representation Theory (Code: SS 22A), **Emily Cliff**, University of Oxford, and **Thomas Nevins**, University of St. Thomas.

Representation Theory, Automorphic Forms and Related Topics (Code: SS 7A), **Kwangho Choiy**, Southern Illinois University, **Dihua Jiang**, University of Minnesota, and **Shuichiro Takeda**, University of Missouri.

Symplectic Geometry and Contact Geometry (Code: SS 9A), **Tian-Jun Li** and **Cheuk Yu Mak**, University of Minnesota, and **Ke Zhu**, Minnesota State University.

The Topology of 3- and 4-Manifolds (Code: SS 17A), **Maggy Tomova** and **Alexander Zupan**.

Topology and Arithmetic (Code: SS 10A), **Tyler Lawson** and **Craig Westerland**, University of Minnesota, Twin Cities.

Topology and Physics (Code: SS 12A), **Ralph Kaufmann**, Purdue University, and **Alexander Voronov**, University of Minnesota, Twin Cities.

Women in Analysis and Partial Differential Equations (Code: SS 24A), **Svitlana Mayboroda**, University of Minnesota.

p-Adic Analysis in Number Theory (Code: SS 19A), **C. Douglas Haessig**, University of Rochester, and **Steven Sperber**, University of Minnesota.

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 local and state taxes, which at the time of publication were 9.75 percent state tax, 3.125 percent city tax, and .3 percent county tax. Participants must state that they are with the **American Mathematical Society (AMS) 2016 Fall Central Sectional Meeting at the University of St. Thomas** 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 checkout penalties; be sure to ask for details.**

Crowne Plaza Minneapolis Downtown Northstar, 618 Second Ave South Minneapolis, MN 55402; 612-338-2288; `www.cpminneapolis.com/index.asp` Rates are **US$109** per night for a single or double occupancy room. Amenities include on-site restaurants *Cafe Northstar* and *Krona Bar and Grill*, in-room dining, fitness center, and business center. This property is located .5 miles from 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 **September 28, 2016.**

Doubletree Suites by Hilton Minneapolis, 1101 LaSalle Avenue, Minneapolis, MN, 55403; 612-332-6800; `doubletree3.hilton.com/en/hotels/minnesota/doubletree-suites-by-hilton-hotel-minneapolis-MSPLSDT/index.html` Rates are **US$135** per night for a single or double occupancy room. This is an all-suite property, featuring separate sleeping and living spaces. Amenities include in-room mini-refrigerator and microwave; complimentary high-speed Wi-Fi in first floor public areas; on-site restaurant, *Lot 57*; *Starbucks* on property; fitness center; and business center. This property is located across the street 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 **September 27, 2016.**

Doubletree By Hilton Minneapolis—Park Place, 1500 Park Place Blvd., Minneapolis, MN, 55416; `952-542-8600; doubletree3.hilton.com/en/hotels/minnesota/doubletree-by-hilton-hotel-minneapolis-park-place-MSPPHDT/index.html` Rates are **US$115** per night for a standard king or double room, single or double occupancy or **US$155** per night for a suite, single or double occupancy. Amenities include complimentary daily newspaper, complimentary high-speed Wi-Fi, fitness center, indoor heated pool, on-site restaurant, *Dover*

Restaurant and Bar, complimentary parking, and business center. This property is located approximately 4 miles from 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 a reduced rate is **October 6, 2016**.

Hilton Minneapolis, 1001 Marquette Avenue, Minneapolis, MN, 55403; 612-376-1000; www3.hilton.com/en/hotels/minnesota/hilton-minneapolis-MSPMHHH/index.html Rates are **US$129** per night for a single or double occupancy room, **US$149** for a triple occupancy room, and **US$169** for a quad occupancy room. Amenities include complimentary in-room high-speed Wi-Fi; on-site restaurant, *Skywater Cuisine and Cocktails;* fitness center; indoor pool and sauna; and business center. This property is located approximately .4 miles from 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 **September 27, 2016.**

The Hotel Minneapolis, 215 4th Street South, Minneapolis, MN, 55401; 612-340-2000; www.marriott.com/hotels/travel/mspak-the-hotel-minneapolis-autograph-collection/?scid=bb1a189a-fec3-4d19-a255-54ba596febe2 Rates are **US$89** per night for a king room with single occupancy or **US$129** per night for a room with two queen beds with single occupancy. Amenities include on-site restaurant, *Restaurant Max*, fitness center, lounge, and 24-hour room service. This property is located approximately .5 miles from 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 **October 7, 2016.**

The Marquette Hotel, 710 Marquette Avenue, Minneapolis, MN, 55402; 612-333-4545; www3.hilton.com/en/hotels/minnesota/the-marquette-hotel-MSPVIHH/index.html Rates are **US$139** per night for a room with two double beds or for a room with one king bed, this rate is applicable for single or double occupancy. Amenities include fitness room, on-site restaurant *Basil's*, on-site lounge *MARQ VII Lounge,* and business center. This property is located approximately .5 miles from 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 **October 3, 2016.**

Radison Blu, 35 South 7th St. Minneapolis, MN 55402; 612-339-4900; https://www.radissonblu.com/en/hotel-minneapolis Rates are **US$159** per night for a room with single or double occupancy. Amenities include, complimentary high-speed Wi-Fi, in-room refrigerator, fitness room, on-site restaurant, *FireLake Grill House and Cocktail Bar*, and business center. This property is located approximately .5 miles from 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 **September 28, 2016.**

Dining

The University of St. Thomas is located in the heart of Minneapolis, and there are many restaurants nearby. A few of the closer options are listed here.

Coffee

Angel Food Bakery & Coffee Bar, 86 S. 9th St, 612-238-1425; coffee bar and bakery.

Starbucks, 1101 Lasalle Avenue, 612-492-2230, starbucks.com.

Sandwiches

*Cosi, 8*0 S 8th St. #150, 612-332-5700, getcosi.com; Sandwiches and pizza made with flatbread.

D Brian's Deli, 800 Nicollet Mall #210, 612 455-1600, dbrians.com, deli, soup and salad.

Panera Bread, 809 Nicollet Mall, 612-338-9850, panerabread.com; bakery, sandwiches, Wi-Fi.

Potbelly Sandwich Shop, 80 S. 8th St., 612-332-1144, potbelly.com; counter-serve, made-to-order toasted sandwiches, salads.

Subway, 121 S. 8th St. #242, 612-333-1956, subway.com.

Which Wich Superior Sandwiches, 800 Nicollet Mall, 612-284-5325, whichwich.com; design-your-own sandwiches.

American

8th Street Grill, 800 S. Marquette Ave #107, 612-349-5717, 8thstreetgrillmn.com.

American Burger Bar, 825 Hennepin Ave., 612-345-4487, americanburgerbar.com; burgers, craft beers.

CRAVE Restaurant, 825 Hennepin Ave., 612-332-1133, craveminneapolis.com; modern chain; an eclectic mix of American fare & sushi.

Dakota Jazz Club & Restaurant, 1010 Nicollet Mall, 612-332-1010, dakotacooks.com; fine dining American, music nightly.

Dave's Downtown Restaurant, 900 2nd Ave. S., 612-339-8787, davesdowntown.com; local breakfast and lunch spot.

Devil's Advocate, 89 S. 10th St., 612-843-2260, Devilsadvocatebar.com; upscale pub food.

Hell's Kitchen, 80 S. 9th St., 612-332-4700, hellskitcheninc.com; quirky American restaurant with frequent live music.

Keys at the Foshay, 114 S. 9th St., 612-339-6399, keysfoshay.com; big plates of comfort food, breakfast, bakery.

Marin Restaurant & Bar, 901 Hennepin Ave., 612-252-7000, marinrestaurant.com; elegant California/New American cuisine (duck breast/flatbreads).

Mission American Kitchen & Bar, 77 7th St. S., 612-339-1000, missionamerican.com; American upscale comfort food.

The News Room, 990 Nicollet Mall, 612-343-0073, thenewsroommpls.com; eclectic American, sports TV.

Rock Bottom Restaurant & Brewery, 825 Hennepin Ave., 612-332-2739, rockbottom.com; house beers and American pub fare.

UNION Restaurant, 731 Hennepin Ave., 612-455-6690, unionmpls.com; seafood, New American; opens at 3:00 pm.

Asian

Ling & Louie's Asian Bar and Grill, 921 Nicollet Mall, 612-351-1234, lingandlouies.com; casual Asian restaurant.

Leeann Chin, 700 Nicollet Mall, 612-375-2763, leeannchin.com; fast food, Chinese.

Irish/English

Brit's Pub, 1110 Nicollet Mall, 612-332-8011, britspub.com; English pub fare, fireplace.

The Local, 931 Nicollet Mall, 612-904-1000, the-local.com; traditional Irish.

Indian

Bombay Bistro, 820 S. Marquette Ave, 612-312-2800, bombaybistromn.com; South Indian cuisine, with vegetarian options & a daily lunch buffet.

Italian

Bucca di Beppo, 1204 Harmon Pl., 612-288-0138, bucadibeppo.com; Italian chain restaurant.

Zelo, 831 Nicollet Mall, 612-333-7000, zelomn.com; contemporary Italian.

Mexican

Chipotle Mexican Grill, 1040 Nicollet Mall, 612-659-7955, chipotle.com; fast food Mexican.

Qdoba Mexican Grill, 50 S. 10th St., 612-339-5136, qdoba.com; fast food Mexican.

Miscellaneous

Hen House Eatery, 114 S. 8th St., 612-345-4664, henhouseeatery.com; American breakfast and lunch café, plus tapas.

The Melting Pot Minneapolis, 80 S. 9th St., 612-338-9900, meltingpot.com; fondue.

Steakhouse

Manny's Steakhouse, 825 S Marquette Ave., 612-339-9900; mannyssteakhouse.com.

McCormick & Schmick's Seafood & Steaks, 800 Nicollet Mall, 612-338-3300, mccormickandschmicks.com.

Ruth's Chris Steak House, 920 2nd Ave. S., 612-672-9000, ruthschris.com. Opens at 5:00 pm.

Registration and Meeting Information

Advanced Registration: Advanced registration for this meeting opens on **August 1st.** Advanced registration fees will be US$59 for AMS members, US$85 for nonmembers, and US$10 for students, unemployed mathematicians, and emeritus members.

On-site Information and Registration: The registration desk and AMS book sale and coffee service will be located in Opus Hall (MOH) nearby to Room 201. The Invited Addresses will be held in Murphy Hall (TMH). Special Sessions and Contributed Paper Sessions will take place in Opus Hall (MOH) and Murphy Hall (TMH). Please look for additional information about specific room locations on the web and in the printed program. For further information on building locations, campus maps are available at https://www.stthomas.edu/campusmaps/minneapoliscampus/.

The registration desk will be open on Friday, October 28, 1:30pm–5:00 pm and Saturday, September 29, 7:30 am–4:30 pm. The same fees apply for on-site registration, as for advanced registration. Fees are payable on-site via cash, check, or credit card.

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.

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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.

Reception: The University of St. Thomas will graciously host a reception on **Saturday evening** in the School of Law (MSL), in the first floor atrium and second floor balcony, between 5:30 pm and 6:30 pm.

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 e-mail 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 campus of the University of St. Thomas in Minneapolis, MN. Maps for the Minneapolis campus can be found at www.stthomas.edu/campusmaps/minneapoliscampus/. Information about the Mathematics Department at the University of St. Thomas can be found at www.stthomas.edu/mathematics/. Visit the University of St. Thomas website at www.stthomas.edu/ for additional information.

Please watch the AMS website at www.ams.org/meetings/sectional/sectional.html for updated information on this meeting.

Parking

There is public parking available at the City of Minneapolis parking garage at 11th Street and Harmon Place, see www.stthomas.edu/media/campusmaps/mpls2Dmap.pdf. The entrance to the garage is on 11th Street. The garage has an electronic pay-as-you-leave system. Payments can be made by cash or credit card. The rates are currently US$2.50 for one hour, US$4.00 for two hours, etc., up to US$10.50 for 24 hours. See www.parkme.com/lot/18264/11th-harmon-ramp-minneapolis-mn. Several other public parking garages are identified on the interactive map at webapp.stthomas.edu/campusmaps/?campus=mpls&lng=-93.27783644199371&lat=44.973879908537015&maptype=UST&zoomlevel=17.

Travel

This meeting will take place on the Minneapolis campus of the University of St. Thomas. The address is 1000 LaSalle Avenue, Minneapolis, MN 55403.

By Air: The Minneapolis–St. Paul International Airport (MSP) is served by thirteen commercial passenger airlines. There are two terminals accessed by different roads: Terminal 1-Lindbergh and Terminal 2-Humphrey. For the list of airlines using each terminal, see www.mspairport.com/airlines.aspx. Terminal 1 is located at 4300 Glumack Drive, St. Paul, MN 55111, and Terminal 2 is at 7150 Humphrey Drive, Minneapolis, MN 55450. The home page of the airport's website is at www.mspairport.com.

There are several options available for transportation to/from the airport. Please see https://www.mspairport.com/GroundTransportation.aspx.

Public Transportation: Public transportation is available through Metro Transit (www.metrotransit.org), which provides Light Rail transit and public bus service throughout the Minneapolis–St. Paul metropolitan area.

At Terminal 1, the Light Rail station (LRT) is located below the Transit Center, between the Blue and Red Parking ramps. From the Tram Level (Level T, one level below baggage claim), take the tram to the Transit Center. After exiting the tram, follow the signs to the LRT, which is located 70 feet underground.

At Terminal 2, the LRT is located on the north side of the Orange Parking ramp. From Level 1, take the elevator or escalator up to the Orange Ramp skyway and follow the signs to the station.

The LRT Blue Line map is here: www.metrotransit.org/blue-line-map. The Blue Line, which has stops at both airport terminals, goes directly to Nicollet Mall at 5th Street, about half a mile from the campus. The campus lies between 9th and 12th Streets, along LaSalle Avenue, which is roughly parallel to Nicollet Mall. The fare is US$2.25 during rush hours and US$1.75 at other times. Trains run every 10 minutes during peak hours and every 15 minutes at other times of the day. The Light Rail takes approximately half an hour to reach downtown Minneapolis from the airport. Please check the full schedule at www.metrotransit.org if you plan to utilize this service. If you are staying at a nearby hotel, ascertain whether public transport will be convenient.

City bus service is provided through Metro Transit to Terminal 1 only. Route 54 goes to the airport. For fares and other information, please contact Metro Transit at (612) 373-3333. 24-hour automated bus information: (612) 341-4287.

Shuttle: SuperShuttle, Call (800) BLUE VAN (258-3826), or book online at www.supershuttle.com/Locations/MinneapolisStPaulMSP. At Terminal 1, there is a SuperShuttle counter in the Transit Center atrium, and in Terminal 2, there is a SuperShuttle kiosk in the Ground Transport Center, located on Level 1 of the Purple parking ramp across from the terminal building. A one way trip to the downtown area near Nicollet Mall is currently US$16.00.

Taxi: Taxi service is available from both terminals. At Terminal 1, taxi service is available from the Tram Level (T). Signs will direct you one level up to the taxi starter booth. At Terminal 2, taxi service is available from the Ground Transport Center, located on the ground level of the Purple parking ramp directly across from the terminal building. Downtown Minneapolis is approximately 12 miles from the airport, with fares averaging US$39–$49. A US$6.75 fare will be displayed on the Taxicab meter at the onset of your trip. This fee includes a US$2.50 flag drop and a US$4.25 airport access fee.

Car Rental: Most major rental car agencies have offices at the Minneapolis–St. Paul International Airport. At Terminal 1-Lindbergh, these are located on the second and third levels between the Blue and Red parking ramps. Take the underground tram to the parking ramps, and then take an elevator to the second or third level. At Terminal 2-Humphrey, the rental car agencies are located in the Ground Transport Center on the ground level of the Purple parking ramp, directly across from the terminal building.

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.

Driving Directions

It is best to use your favorite travel website for driving to campus, however, the following directions are provided for your reference.

Directions from Terminal 1-Lindbergh: Head southwest on Glumack Drive and keep left at the fork. Merge onto MN-5 East toward St. Paul/Minneapolis. Stay on the right to take the exit for MN-55/MN-55W/MN-5W toward Minneapolis/Fort Snelling. In about 3/4 of a mile, merge onto MN-55W, staying left at the fork. Continue on to MN-62 W. Use the right two lanes to take the exit onto I-35W N. Keep left at the fork, and follow the signs for

Downtown I-94W. Use the right lane to continue on to MN-65. Take the downtown 11th Street/E. Grant Street exit and continue onto S. 11th Street to LaSalle Avenue. The campus will be on your right.

Terminal 2-Humphrey: Head southwest on Humphrey Drive, which will become E. 72nd Street. Follow the signs for I-494/MN-5. Take a right onto 34th Avenue S., and right again to merge onto I-494 W/MN-5W. Take exit 2B to MN-77N, and take the exit onto MN-62 W. Use the right two lanes to take the exit onto I-35W N. Keep left at the fork, and follow the signs for Downtown I-94W. Use the right lane to continue on to MN-65. Take the downtown 11th Street/E. Grant Street exit and continue onto S. 11th Street to LaSalle Avenue. The campus will be on your right.

The University of St. Thomas lists general directions to the campus on their website here: www.stthomas.edu/media/campusmaps/mplsdirections.pdf. They are reproduced below for your convenience.

From Points West:

Option One: I-394 east to the I-394 downtown exit to 12th Street North (Exit 9A) to LaSalle Avenue. Turn left on LaSalle Avenue to 11th Street. Turn left on 11th Street. The campus will be on your right.

Option Two: I-94 east to the downtown exit to Fourth Street. Take Fourth Street to First Avenue. Turn right on First Avenue to 10th Street. Turn left on 10th Street to LaSalle Avenue. Turn right on LaSalle Avenue to 11th Street. Turn right on 11th Street. The campus will be on your right.

From Points East: I-94 west to the 11th Street exit (Exit 233A) and turn left. Go west on 11th Street to LaSalle Avenue (one block past Nicollet Mall). The campus will be on your right.

From Points North: I-35W south to west I-94. Travel west on I-94 to the 11th Street exit (Exit 233A) and turn left. Go west on 11th Street to LaSalle Avenue (one block past Nicollet Mall). Cross LaSalle Avenue. The campus will be on your right.

From Points South: I-35W north to the downtown exits to the 11th Street/E. Grant Street exit (Exit 16A), and turn left. Go west on 11th Street to LaSalle Avenue (one block past Nicollet Mall). Cross LaSalle Avenue. The campus will be on your right.

Weather:

The average high temperature for October is approximately 52 degrees Fahrenheit and the average low is 35 degrees Fahrenheit. Visitors should check the weather forecast before they begin their travel.

Social Networking:

Attendees and speakers are encouraged to tweet about the meeting using the hashtag #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.

Raleigh, North Carolina

North Carolina State University

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: September 22, 2016

Issue of *Abstracts*: Volume 37, Issue 4

Deadlines

For organizers: Expired
For abstracts: September 13, 2016
The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Ricardo Cortez, Tulane University, *Title to be announced.*

Gaven J. Martin, Massey University, *Title to be announced.*

Jason Metcalfe, University of North Carolina at Chapel Hill, *Local Energy Decay for the Wave Equation.*

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.

Advances in Numerical Methods for Partial Differential Equations (Code: SS 7A), **Andreas Aristotelous**, West Chester University, and **Thomas Lewis**, The University of North Carolina at Greensboro.

Algebraic Structures Motivated by and Applied to Knot Theory (Code: SS 6A), **Jozef H. Przytycki**, The George Washington University, and **Radmila Sazdanovic**, North Carolina State University.

Applied Algebraic Geometry (Code: SS 15A), **Seth Sullivant** and **Agnes Szanto**, North Carolina State University.

Commutative Ring Theory (in honor of Jay Shapiro's retirement) (Code: SS 21A), **Neil Epstein**, George Mason University, and **Alan Loper**, Ohio State University.

Contemporary Geometric Methods in Mechanics and Control (Code: SS 16A), **Vakhtang Putkaradze**, University of Alberta, and **Dmitry Zenkov**, North Carolina State University.

Control, Optimization, and Differential Games (Code: SS 12A), **Lorena Bociu**, North Carolina State University, and **Tien Khai Nguyen**, Penn State University.

Difference Equations and Applications (Code: SS 2A), **Michael A. Radin**, Rochester Institute of Technology, and **Youssef Raffoul**, University of Dayton.

Geometry and Topology in Image and Shape Analysis (Code: SS 13A), **Irina Kogan**, North Carolina State University, and **Facundo Mémoli**, The Ohio State University.

Graphs, Hypergraphs, and Set Systems (Code: SS 22A), **David Galvin**, University of Notre Dame, and **Clifford Smyth**, University of North Carolina, Greensboro.

Harmonic Analysis and Dispersive PDE (Code: SS 18A), **Robert Booth**, **Jason Metcalfe**, and **Katrina Morgan**, University of North Carolina.

Homological Methods in Commutative Algebra (Code: SS 1A), **Alina Iacob** and **Saeed Nasseh**, Georgia Southern University.

Low-dimensional Topology (Code: SS 9A), **Caitlin Leverson**, Georgia Tech, **Tye Lidman**, North Carolina State University, and **Leonard Ng**, Duke University.

Mathematical Modeling of Infectious Disease and Immunity (Code: SS 11A), **Lauren Childs**, Virginia Tech and Harvard Chan School of Public Health, and **Stanca Ciupe**, Virginia Tech.

Mathematical String Theory (Code: SS 3A), **Paul Aspinwall**, Duke University, **Ilarion Melnikov**, James Madison University, and **Eric Sharpe**, Virginia Tech.

Metric and Topological Oriented Fixed Point Theorems (Code: SS 5A), **Clement Boateng Ampadu**, Boston, MA, **Sartaj Ali**, National College of Business Administration and Economics, Lahore, Pakistan, **Xiaorong Liu**, University of Colorado at Boulder, and **Xavier Alexius Udo-Utun**, University of Uyo, Uyo, Nigeria.

Nonlinear Boundary Value Problems (Code: SS 10A), **Maya Chhetri**, UNC Greensboro, and **Stephen Robinson**, Wake Forest University.

Recent Advances in Stochastic Processes and Stochastic Computation (Code: SS 20A), **Jianfeng Lu** and **James Nolen**, Duke University, and **Kostas Spiliopoulous**, Boston University.

Representations of Lie Algebras, Quantum Groups and Related Topics (Code: SS 8A), **Naihuan Jing** and **Kailash C. Misra**, North Carolina State University.

Set Theoretic Topology (Code: SS 14A), **Alan Dow**, UNC-Charlotte, and **Jerry Vaughan**, UNC—Greensboro.

Structural and Computational Graph Theory (Code: SS 19A), **Stephen Harte**, University of Colorado Denver, and **Bernard Lidický**, Iowa State University.

The Analysis of Inverse Problems and their Applications (Code: SS 17A), **Shitao Liu**, Clemson University, and **Loc Nguyen**, University of North Carolina.

Varieties, Their Fibrations and Automorphisms in Mathematical Physics and Arithmetic Geometry (Code: SS 4A), **Jimmy Dillies** and **Enka Lakuriqi**, Georgia Southern University, and **Tony Shaska**, Oakland 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, 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: Expired
For abstracts: September 20, 2016

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

Joint Invited Addresses

Ingrid Daubechies, Duke University, *Title to be announced* (MAA-AMS-SIAM Gerald and Judith Porter Public Lecture).

Lisa Jeffrey, University of Toronto, *Title to be announced* (AWM-AMS Noether Lecture).

Donald Richards, Pennsylvania State University, *Title to be announced* (AMS-MAA Invited Address).

Alice Silverberg, University of California, Irvine, *Title to be announced* (AMS-MAA Invited Address).

AMS Invited Addresses

Tobias Colding, Massachusetts Institute of Technology, *Title to be announced*.

Carlos E. Kenig, University of Chicago, *Title to be announced* (AMS Colloquium Lectures: Lecture I).

Carlos E. Kenig, University of Chicago, *Title to be announced* (AMS Colloquium Lectures: Lecture II).

Carlos E. Kenig, University of Chicago, *Title to be announced* (AMS Colloquium Lectures: Lecture III).

John Preskill, California Institute of Technology, *Title to be announced* (AMS Josiah Willard Gibbs Lecture).

Barry Simon, California Institute of Technology, *Title to be announced*.

Gigliola Staffilani, Massachusetts Institute of Technology, *Title to be announced*.

Richard Taylor, Institute for Advanced Study, *Title to be announced*.

Anna Wienhard, Heidelberg University, *Title to be announced*.

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 jointmathematicsmeetings.org/meetings/abstracts/abstract.pl?type=jmm.

Some sessions are cosponsored with other organizations. These are noted within the parenthesis at the end of each listing, where applicable.

Advanced Mathematical Programming and Applications (Code: SS 67A), **Ram N. Mohapatra**, University of Central Florida, **Ram U. Verma**, University of North Texas, and **Gayatri Pani**, Indian Institute of Technology.

Advances in Mathematics of Ecology, Epidemiology and Immunology of Infectious Diseases (Code: SS 49A), **Abba Gumel**, Arizona State University.

Advances in Numerical Analysis for Partial Differential Equations (Code: SS 57A), **Thomas Lewis**, University of North Carolina at Greensboro, and **Amanda Diegel**, Louisiana State University.

Advances in Operator Algebras (Code: SS 50A), **Michael Hartglass**, University of California, Riverside, **David Penneys**, University of California, Los Angeles, and **Elizabeth Gillaspy**, University of Colorado, Boulder.

Algebraic Statistics (a Mathematics Research Communities Session) (Code: SS 15A), **TBA**.

An Amicable Combination of Algebra and Number Theory (Dedicated to Dr. Helen G. Grundman) (Code: SS 48A), **Eva Goedhart**, Lebanon Valley College, **Pamela E. Harris**, Williams College, **Daniel P. Wisniewski**, DeSales University, and **Alejandra Alvarado**, Eastern Illinois University.

Analysis of Fractional, Stochastic, and Hybrid Dynamic Systems and their Applications (Code: SS 6A), **Aghalaya S. Vatsala**, University of Louisiana, **Gangaram S. Ladde**, University of South Florida, and **John R. Graef**, University of Tennessee at Chattanooga.

Analytic Number Theory and Arithmetic (Code: SS 71A), **Robert Lemke Oliver**, Tufts University, **Paul Pollack**, University of Georgia, and **Frank Thorne**, University of South Carolina.

Analytical and Computational Studies in Mathematical Biology (Code: SS 30A), **Yanyu Xiao**, University of Cincinnati, and **Xiang-Sheng Wang**, Southeast Missouri State University.

ApREUF: Applied Research Experience for Undergraduate Faculty (Code: SS 59A), **Shenglan Yuan**, LaGuardia Community College, CUNY, **Jason Callahan**, St. Edwards University, **Eva Strawbridge**, James Madison University, and **Ami Radunskaya**, Pomona College.

Applications of Partially Ordered Sets in Algebraic, Topological, and Enumerative Combinatorics (Code: SS 74A), **Rafael S. González D'León**, University of Kentucky, and **Joshua Hallam**, Wake Forest University.

Arithmetic Properties of Sequences from Number Theory and Combinatorics (Code: SS 42A), **Eric Rowland**, Hofstra University, and **Armin Straub**, University of South Alabama.

Automorphic Forms and Arithmetic (Code: SS 81A), **Frank Calegari**, University of Chicago, **Ana Caraiani**, Princeton University, and **Richard Taylor**, Institute for Advanced Study.

Bases in Function Spaces: Sampling, Interpolation, Expansions and Approximations (Code: SS 35A), **Shahaf Nitzan** and **Christopher Heil**, Georgia Institute of Technology, and **Alexander V. Powell**, Vanderbilt University.

Character Varieties: Experiments and New Frontiers (a Mathematics Research Communities Session) (Code: SS 14A), **TBA**.

Coding Theory for Modern Applications (Code: SS 54A), **Christine A. Kelley**, University of Nebraska-Lincoln, **Iwan M. Duursma**, University of Illinois Urbana-Champaign, and **Gretchen L. Matthews**, Clemson University.

Combinatorial and Cohomological Invariants of Flag Manifolds and Related Varieties (Code: SS 18A), **Martha Precup**, Northwestern University, and **Rebecca Goldin**, George Mason University.

Commutative Algebra: Research for Undergraduate and Early Graduate Students (Code: SS 8A), **Nicholas Baeth**,

University of Central Missouri, and **Courtney Gibbons**, Hamilton College.

Complex Analysis and Special Functions (Code: SS 40A), **Brock Williams**, Texas Tech University, **Kendall Richards**, Southwestern University, and **Alex Solynin**, Texas Tech University.

Continued Fractions (Code: SS 38A), **James McLaughlin**, West Chester University, **Geremías Polanco**, Hampshire College, and **Nancy J. Wyshinski**, Trinity College.

Control and Long Time Behavior of Evolutionary PDEs (Code: SS 28A), **Louis Tebou**, Florida International University, and **Luz de Teresa**, Instituto de Matemáticas, UNAM.

Discrete Geometry and Convexity (Dedicated to András Bezdek on the occasion of his 60th birthday) (Code: SS 34A), **Krystyna Kuperberg**, Auburn University, **Gergely Ambrus**, Renyi Institute of Mathematics, **Braxton Carrigan**, Southern Connecticut State University, and **Ferenc Fodor**, University of Szeged.

Discrete Structures in Number Theory (Code: SS 29A), **Anna Haensch**, Duquesne University, and **Adriana Salerno**, Bates College.

Dynamical Systems (Code: SS 5A), **Jim Wiseman**, Agnes Scott College, and **Aimee Johnson**, Swarthmore College.

Dynamics of Fluids and Nonlinear Waves (Code: SS 66A), **Zhiwu Lin**, **Jiayin Jin**, and **Chongchun Zeng**, Georgia Institute of Technology.

Ergodic Theory and Dynamical Systems (Code: SS 23A), **Mrinal Kanti Roychowdhury**, University of Texas Rio Grande Valley, and **Tamara Kucherenko**, City College of New York.

Fusion Categories and Quantum Symmetries (Code: SS 65A), **Julia Plavnik**, Texas A&M University, **Paul Bruillard**, Pacific Northwest National Laboratory, and **Eric Rowell**, Texas A&M University.

Gaussian Graphical Models and Combinatorial Algebraic Geometry (Code: SS 37A), **Rainer Sinn**, Georgia Institute of Technology, **Seth Sullivant**, North Carolina State University, and **Josephine Yu**, Georgia Institute of Technology.

Graphs and Matrices (Code: SS 53A), **Sudipta Mallik**, Northern Arizona University, **Keivan Hassani Monfared**, University of Calgary, and **Bryan Shader**, University of Wyoming.

Group Actions and Geometric Structures (Code: SS 80A), **Anna Wienhard**, Universität Heidelberg, and **Jeffrey Danciger**, University of Texas at Austin.

Group Representations and Cohomology (Code: SS 52A), **Hung Nguyen**, The University of Akron, **Nham Ngo**, The University of Arizona, **Andrei Pavelescu**, University of South Alabama, and **Paul Sobaje**, University of Georgia.

Harmonic Analysis (In Honor of Gestur Olafsson's 65th Birthday) (Code: SS 55A), **Jens Christensen**, Colgate University, and **Susanna Dann**, Technische Universität Wien-Vienna, Austria.

History of Mathematics (Code: SS 25A), **Adrian Rice**, Randolph-Macon College, **Sloan Despeaux**, Western Carolina University, and **Daniel Otero**, Xavier University (AMS-MAA-ICHM).

Hopf algebras and their actions (Code: SS 47A), **Henry Tucker**, University of California, San Diego, **Susan Montgomery**, University of Southern California - Los Angeles, and **Siu-Hung Ng**, Louisiana State University.

Inverse Problems and Applications (Code: SS 45A), **Vu Kim Tuan** and **Amin Boumenir**, University of West Georgia.

Inverse Problems and Multivariate Signal Analysis (Code: SS 79A), **M. Zuhair Nashed**, University of Central Florida, **Willi Freeden**, University of Kaiserslautern, and **Otmar Scherzer**, University of Vienna.

Lie Group Representations, Discretization, and Gelfand Pairs (a Mathematics Research Communities Session) (Code: SS 13A), **TBA**.

Mapping Class Groups and their Subgroups (Code: SS 22A), **James W. Anderson**, University of Southampton, UK, and **Aaron Wootton**, University of Portland.

Mathematics and Music (Code: SS 9A), **Mariana Montiel**, Georgia State University, and **Robert Peck**, Louisiana State University.

Mathematics in Physiology and Medicine (a Mathematics Research Communities Session) (Code: SS 16A), **TBA**.

Mathematics of Cryptography (Code: SS 11A), **Nathan Kaplan** and **Alice Silverberg**, University of California, Irvine (AMS-MAA).

Mathematics of Signal Processing and Information (Code: SS 41A), **Rayan Saab**, University of California, San Diego, and **Mark Iwen**, Michigan State University.

Measure and Measurable Dynamics (In Memory of Dorothy Maharam, 1917-2014) (Code: SS 72A), **Cesar Silva**, Williams College.

Minimal Integral Models of Algebraic Curves (Code: SS 33A), **Tony Shaska**, Oakland University.

NSFD Discretizations: Recent Advances, Applications, and Unresolved Issues (Code: SS 51A), **Talitha M. Washington**, Howard University, and **Ronald E. Mickens**, Clark Atlanta University.

New Developments in Noncommutative Algebra & Representation Theory (Code: SS 46A), **Ellen Kirkman**, Wake Forest University, and **Chelsea Walton**, Temple University.

Nonlinear Systems and Applications (Code: SS 20A), **Wenrui Hao**, Ohio State University.

Open & Accessible Problems for Undergraduate Research (Code: SS 4A), **Allison Henrich**, Seattle University, **Michael Dorff**, Brigham Young University, and **Nicholas Scoville**, Ursinus College.

Operator Theory, Function Theory, and Models (Code: SS 7A), **William Ross**, Florida Gulf Coast University, and **Alberto Condori**, University of Richmond.

Orthogonal Polynomials (Code: SS 17A), **Doron Lubinsky** and **Jeff Geronimo**, Georgia Institute of Technology.

PDE Analysis on Fluid Flows (Code: SS 39A), **Xiang Xu**, Old Dominion University, and **Geng Chen** and **Ronghua Pan**, Georgia Institute of Technology.

PDEs for Fluid flow: Analysis and Computation (Code: SS 60A), **Thinh Kieu**, University of North Georgia, **Emine Celik**, Texas Tech University, and **Hashim Saber**, University of North Georgia.

Partition Theory and Related Topics (Code: SS 78A), **Amita Malik**, University of Illinois at Urbana-Champaign, **Dennis Eichhorn**, University of California, Irvine, and **Tim Huber**, University of Texas-Rio Grande Valley.

Problems in Partial Differential Equations (Code: SS 44A), **Alex Himonas**, University of Notre Dame, and **Dionyssios Mantzavinos**, State University of New York at Buffalo.

Public School Districts and Higher Education Mathematics Partnerships (Code: SS 21A), **Virgil U. Pierce** and **Aaron Wilson**, University of Texas Rio Grande Valley.

Pure and Applied Talks by Women Math Warriors Presented by EDGE (Enhancing Diversity in Graduate Education) (Code: SS 77A), **Candice Price**, University of San Diego, and **Amy Buchman**, Tulane University.

Quantum Groups (Code: SS 76A), **Shuzhou Wang** and **Angshuman Bhattacharya**, University of Georgia.

Quaternions (Code: SS 31A), **Johannes Familton**, Borough of Manhattan Community College, **Terrence Blackman**, Medgar Evers College, and **Chris McCarthy**, Borough of Manhattan Community College.

RE(UF)search on Graphs and Matrices (Code: SS 58A), **Cheryl Grood**, Swarthmore College, **Daniela Ferrero**, Texas State University, and **Mary Flagg**, University of St. Thomas.

Random Matrices, Random Percolation and Random Sequence Alignments (Code: SS 19A), **Ruoting Gong**, Illinois Institute of Technology, and **Michael Damron**, Georgia Institute of Technology.

Real Discrete Dynamical Systems with Applications (Code: SS 32A), **M. R. S. Kulenovic**, University of Rhode Island, and **Abdul-Aziz Yakubu**, Howard University.

Recent Advances in Mathematical Biology (Code: SS 63A), **Zhisheng Shuai**, University of Central Florida, **Guihong Fan**, Columbus State University, **Andrew Nevai**, University of Central Florida, and **Eric Numfor**, Augusta University.

Recent Progress on Nonlinear Dispersive and Wave Equations (Code: SS 10A), **Dana Mendelson**, **Carlos Kenig**, and **Hao Jia**, University of Chicago, **Andrew Lawrie**, University of California, Berkeley, **Gigliola Staffilani**, Massachusetts Institute of Technology, and **Magdalena Czubak**, University of Colorado Boulder.

Representations and Related Geometry in Lie Theory (Code: SS 68A), **Laura Rider**, Massachusetts Institute of Technology, and **Amber Russell**, Butler University.

Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs (Code: SS 1A), **Darren A. Narayan**, Rochester Institute of Technology, **Tamas Forgacs**, California State University, Fresno, and **Ugur Abdulla**, Florida Institute of Technology (AMS-MAA-SIAM).

Sheaves in Topological Data Analysis (Code: SS 69A), **Mikael Vejdemo-Johansson**, CUNY College of Staten Island, **Elizabeth Munch**, University at Albany, SUNY, and **Martina Scolamiero**, École polytechnique fédérale de Lausanne.

Spectral Calculus & Quasilinear Partial Differential Equations (Code: SS 3A), **Shijun Zheng**, Georgia Southern University, **Marius Beceanu**, State University of New York - Albany, and **Tuoc Van Phan**, University of Tennessee, Knoxville.

Spin Glasses and Disordered Media (Code: SS 36A), **Antonio Auffinger**, Northwestern University, **Aukosh Jagannath**, New York University, and **Dmitry Panchenko**, University of Toronto.

Statistical Methods in Computational Topology and Applications (Code: SS 73A), **Yu-Min Chung** and **Sarah Day**, College of William & Mary.

Stochastic Matrices and Their Applications (Code: SS 56A), **Selcuk Koyuncu**, University of North Georgia, and **Lei Cao**, Georgian Court University.

Stochastic Processes and Modelling (Code: SS 26A), **Erkan Nane**, Auburn University, and **Jebessa B. Mijena**, Georgia College and State University.

Symmetries, Integrability, and Beyond (Code: SS 61A), **Maria Clara Nucci**, Università di Perugia, ITALY, and **Sarah Post**, University of Hawaií at Manoa.

Symplectic Geometry, Moment Maps and Morse Theory (Code: SS 64A), **Lisa Jeffrey**, University of Toronto, and **Tara Holm**, Cornell University (AMS-AWM).

Teaching Assistant Development Programs: Why and How? (Code: SS 12A), **Solomon Friedberg**, Boston College, **Jessica Deshler**, West Virginia University, **Jeffrey Remmel**, University of California, San Diego, and **Lisa Townsley**, University Of Georgia.

The Mathematics of the Atlanta University Center (Code: SS 70A), **Talitha M. Washington**, Howard University, **Monica Jackson**, American University, and **Colm Mulcahy**, Spelman College (AMS-NAM).

The Modeling First Approach to Teaching Differential Equations (Code: SS 24A), **Chris McCarthy**, City University of New York, and **Brian Winkel**, US Military Academy, West Point.

Theory and Applications of Numerical Algebraic Geometry (Code: SS 62A), **Daniel Brake**, University of Notre Dame, **Robert Krone**, Queen's University, and **Jose Israel Rodriguez**, University of Chicago.

Topics in Graph Theory (Code: SS 27A), **Songling Shan**, Vanderbilt University, and **Xiaofeng Gu**, University of West Georgia.

Topology, Representation Theory, and Operator Algebras (A Tribute to Paul Baum) (Code: SS 2A), **Efton Park** and **Jose Carrion**, Texas Christian University.

Women in Analysis (In Honor of Cora Sadosky) (Code: SS 75A), **Alexander Reznikov**, Vanderbilt University, **Oleksandra Beznosova** and **Hyun-Kyoung Kwon**, University of Alabama, and **Katharine Ott**, Bates College.

Women in Topology (Code: SS 43A), **Jocelyn Bell**, Hobart and William Smith Colleges, **Eleanor Ollhoff**, University of Tennessee, **Candice Price**, University of San Diego, and **Arunima Ray**, Brandeis University.

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
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 10, 2016
For abstracts: January 17, 2017

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

Invited Addresses

Pramod N. Achar, Louisiana State University, *Title to be announced.*

Hubert Bray, Duke University, *Title to be announced.*

Alina Chertock, 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.

Commutative Algebra (Code: SS 1A), **Bethany Kubik**, University of Minnesota Duluth, **Saeed Nasseh**, Georgia Southern University, and **Sean Sather-Wagstaff**, Clemson University.

Data Analytics and Applications (Code: SS 2A), **Scott C. Batson**, **Lucas A. Overbuy**, and **Bryan Williams**, Space and Naval Warfare Systems Center Atlantic.

Graph Theory (Code: SS 5A), **Colton Magnant**, Georgia Southern University, and **Zixia Song**, University of Central Florida.

Knot Theory and its Applications (Code: SS 3A), **Elizabeth Denne**, Washington & Lee University, and **Jason Parsley**, Wake Forest University.

Rigidity Theory and Inversive Distance Circle Packings (Code: SS 4A), **John C. Bowers**, James Madison University, and **Philip L. Bowers**, The Florida State University.

Bloomington, Indiana

Indiana University

April 1–2, 2017

Saturday – Sunday

Meeting #1127

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: February 2017
Program first available on AMS website: February 23, 2017
Issue of *Abstracts*: Volume 38, Issue 2

Deadlines

For organizers: September 1, 2016
For abstracts: February 7, 2017

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

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 Enumerative Combinatorics with Applications (Code: SS 6A), **Saúl A. Blanco**, Indiana University, and **Kyle Peterson**, DePaul University.

Automorphic Forms and Algebraic Number Theory (Code: SS 2A), **Patrick B. Allen**, University of Illinois at Urbana-Champaign, and **Matthias Strauch**, Indiana University Bloomington.

Computability and Inductive Definability over Structures (Code: SS 3A), **Siddharth Bhaskar**, **Lawrence Valby**, and **Alex Kruckman**, Indiana University.

Discrete Structures in Conformal Dynamics and Geometry (Code: SS 5A), **Sarah Koch**, University of Michigan, and **Kevin Pilgrim** and **Dylan Thurston**, Indiana University.

Randomness in Complex Geometry (Code: SS 1A), **Turgay Bayraktar**, Syracuse University, and **Norman Levenberg**, Indiana University.

Spectrum of the Laplacian on Domains and Manifolds (Code: SS 4A), **Chris Judge** and **Sugata Mondal**, Indiana University.

Pullman, Washington

Washington State University

April 22–23, 2017

Saturday – Sunday

Meeting #1128

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: February 2017
Program first available on AMS website: March 9, 2017
Issue of *Abstracts*: Volume 38, Issue 2

Deadlines

For organizers: September 22, 2016
For abstracts: February 28, 2017

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

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.

Fixed Point Methods in Differential and Integral Equations (Code: SS 1A), **Theodore A. Burton**, Southern Illinois University in Carbondale.

Inverse Problems (Code: SS 2A), **Hanna Makaruk**, Los Alamos National Laboratory (LANL), and **Robert Owczarek**, University of New Mexico, Albuquerque & Los Alamos.

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*: March 2017
Program first available on AMS website: March 22, 2017
Issue of *Abstracts*: Volume 38, Issue 2

Deadlines

For organizers: October 6, 2016
For abstracts: March 14, 2017

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

Invited Addresses

Jeremy Kahn, City University of New York, *Title to be announced.*

Fernando Coda Marques, Princeton University, *Title to be announced.*

James Maynard, Magdalen College, University of Oxford, *Title to be announced* (Erdős Memorial Lecture).

Kavita Ramanan, Brown 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.

Commutative Algebra (Code: SS 1A), **Laura Ghezzi**, New York City College of Technology-CUNY, and **Jooyoun Hong**, Southern Connecticut State University.

Cryptography (Code: SS 3A), **Xiaowen Zhang**, College of Staten Island and Graduate Center-CUNY.

Current Trends in Function Spaces and Nonlinear Analysis (Code: SS 2A), **David Cruz-Uribe**, University of Alabama, **Jan Lang**, The Ohio State University, and **Osvaldo Mendez**, University of Texas at El Paso.

Geometry and Topology of Ball Quotients and Related Topics (Code: SS 5A), **Luca F. Di Cerbo**, Max Planck Institute, Bonn, and **Matthew Stover**, Temple University.

Infinite Permutation Groups, Totally Disconnected Locally Compact Groups, and Geometric Group Theory (Code: SS 4A), **Delaram Kahrobaei**, New York City College of Technology and Graduate Center-CUNY, and **Simon Smith**, New York City College of Technology-CUNY.

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
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 31, 2016
For abstracts: To be announced

Denton, Texas

University of North Texas

September 9–10, 2017

Saturday – Sunday

Meeting #1131

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: June 2017
Program first available on AMS website: July 27, 2017
Issue of *Abstracts*: Volume 38, Issue 3

Deadlines

For organizers: February 2, 2017
For abstracts: July 18, 2017

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

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.

Dynamics, Geometry and Number Theory (Code: SS 1A), **Lior Fishman** and **Mariusz Urbanski**, University of North Texas.

Real-Analytic Automorphic Forms (Code: SS 2A), **Olav K Richter**, University of North Texas, and **Martin Westerholt-Raum**, Chalmers University of Technology.

Buffalo, New York

State University of New York at Buffalo

September 16–17, 2017

Saturday – Sunday

Meeting #1132

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: June 2017
Program first available on AMS website: August 3, 2017
Issue of *Abstracts*: Volume 38, Issue 3

Deadlines

For organizers: February 16, 2017
For abstracts: July 25, 2017

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

Invited Addresses

Inwon Kim, University of California at Los Angeles, *Title to be announced.*

Govind Menon, Brown University, *Title to be announced.*

Bruce Sagan, Michigan State University, *Title to be announced.*

Orlando, Florida

University of Central Florida, Orlando

September 23–24, 2017

Saturday – Sunday

Meeting #1133

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: June 2017
Program first available on AMS website: August 10, 2017
Issue of *Abstracts*: Volume 38, Issue 4

Deadlines

For organizers: February 23, 2017
For abstracts: August 1, 2017

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

Invited Addresses

Christine Heitsch, Georgia Institute of Technology, *Title to be announced.*

Jonathan Kujawa, University of Oklahoma, *Title to be announced.*

Christopher D Sogge, Johns Hopkins 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.

Commutative Algebra: Interactions with Algebraic Geometry and Algebraic Topology (Code: SS 1A), **Joseph Brennan**, University of Central Florida, and **Alina Iacob** and **Saeed Nasseh**, Georgia Southern University.

Riverside, California

University of California, Riverside

November 4–5, 2017

Saturday – Sunday

Meeting #1134

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: September 2017
Program first available on AMS website: September 21, 2017
Issue of *Abstracts*: Volume 38, Issue 4

Deadlines

For organizers: April 14, 2017
For abstracts: September 12, 2017

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 10–13, 2018

Wednesday – Saturday

Meeting #1135

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
Issue of *Abstracts*: To be announced

Deadlines
For organizers: April 1, 2017
For abstracts: To be announced

Columbus, Ohio

Ohio State University

March 24–25, 2018
Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: To be announced
For abstracts: To be announced

Portland, Oregon

Portland State University

April 14–15, 2018
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
Issue of *Abstracts*: To be announced

Deadlines
For organizers: To be announced
For abstracts: To be announced

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

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`.

Inverse Problems (Code: SS 2A), **Hanna Makaruk**, Los Alamos National Laboratory (LANL), and **Robert Owczarek**, University of New Mexico, Albuquerque & Los Alamos.

Pattern Formation in Crowds, Flocks, and Traffic (Code: SS 1A), **J. J. P. Veerman**, Portland State University, **Alethea Barbaro**, Case Western Reserve University, and **Bassam Bamieh**, UC Santa Barbara.

Nashville, Tennessee

Vanderbilt University

April 14–15, 2018
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
Issue of *Abstracts*: To be announced

Deadlines
For organizers: To be announced
For abstracts: To be announced

Boston, Massachusetts

Northeastern University

April 21–22, 2018
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
Issue of *Abstracts*: To be announced

Deadlines
For organizers: September 21, 2017
For abstracts: March 6, 2018

People's Republic of China

Fudan University

June 11–14, 2018
Monday – Thursday
Associate secretary: Carla D. Savage
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: To be announced
For abstracts: To be announced

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: Steven H. Weintraub
Announcement issue of *Notices*: October 2018
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 2, 2018
For abstracts: To be announced

Honolulu, Hawaii

University of Hawaii at Manoa

March 29–31, 2019

Friday – Sunday
Central Section
Associate secretaries: Georgia Benkart and Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

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
Announcement issue of *Notices*: To be announced
Program first available on AMS website: November 1, 2019
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
Announcement issue of *Notices*: October 2020
Program first available on AMS website: November 1, 2020
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2020
For abstracts: To be announced

THE BACK PAGE

"One day I told [Barry Simon] about an old inequality for PDEs, which was new to him.
I asked, 'Do you want to see the proof?'
He responded, 'No, that's OK.'
Then he went to the board and wrote down a flawless proof on the spot."

—Evan Harell, Simonfest 2006, math.caltech.edu

Stats on Barry Simon:

Total publications: 384 *Total citations:* 15,304

Most cited publication:

Reed, Michael; Simon, Barry, Methods of modern mathematical physics. I. Functional analysis. Second edition. Academic Press, Inc. [1664 citations].

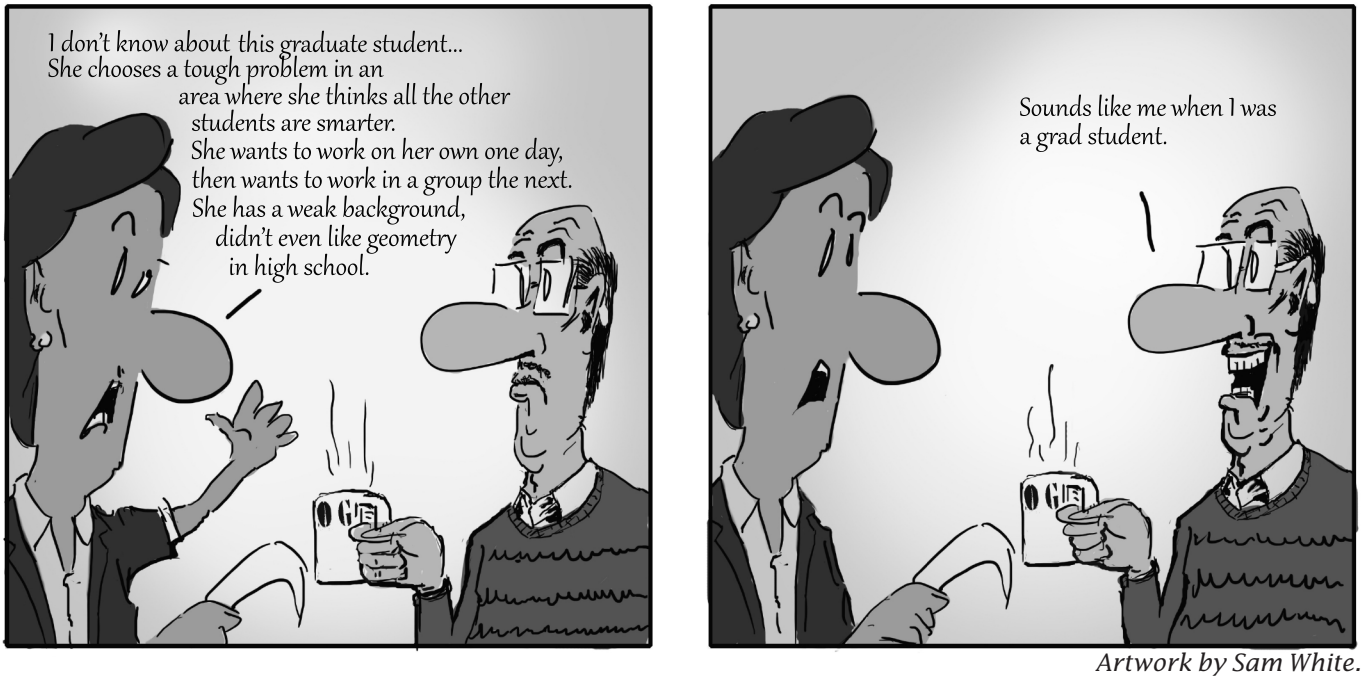
Most cited paper:

Simon, Barry, Schrödinger semigroups. *Bull. Amer. Math. Soc.* 7 (1982), 447–526. (**Source:** MathSciNet®)

Mathematical descendents:

31 students, 120 descendents (**Source:** Mathematics Genealogy Project)

Meanwhile in the Faculty Lounge



Artwork by Sam White.

QUESTIONABLE MATHEMATICS

Mason Porter reports that when he forgot his ID to use with his Caltech Credit Union credit card, the salesman let him define the Fibonacci Sequence instead.

Mason Porter.

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.

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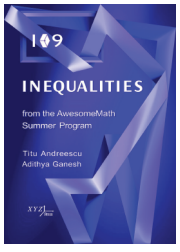
New Books from the AMS



109 Inequalities from the AwesomeMath Summer Program

Titu Andreescu, *University of Texas at Dallas, Richardson, TX*, **and Adithya Ganesh,** *Stanford University, CA*

Explore the theory and techniques involved in proving algebraic inequalities.

A publication of XYZ Press. Distributed in North America by the American Mathematical Society.

XYZ Series, Volume 16; 2015; 203 pages; Hardcover; ISBN: 978-0-9885622-8-8; List US$59.95; AMS members US$47.96; Order code XYZ/16

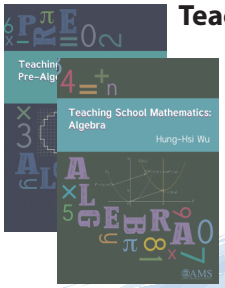
The Case of Academician Nikolai Nikolaevich Luzin

Sergei S. Demidov, *Russian Academy of Sciences, Moscow, Russia* **and Boris V. Lëvshin, Editors**

Translated by Roger Cooke

This book chronicles the 1936 attack on mathematician Nikolai Nikolaevich Luzin during the USSR campaign to "Sovietize" all sciences.

History of Mathematics, Volume 43; 2016; 416 pages; Hardcover; ISBN: 978-1-4704-2608-8; List US$59; AMS members US$47.20; Order code HMATH/43



Teaching School Mathematics: From Pre-Algebra to Algebra

Hung-Hsi Wu, *University of California, Berkeley, CA*

This two-volume set includes a systematic exposition of a major part of the mathematics of grades 5–9 (excluding statistics) written specifically for Common-Core era teachers.

Parts 1 and 2 available for individual sale.

Set: 2016; approximately 667 pages; Hardcover; ISBN: 978-1-4704-3000-9; List US$90; AMS members US$72; Order code MBK/98/99

Gallery of the Infinite

Richard Evan Schwartz, *Brown University, Providence, RI*

This book is a mathematician's unique view of the infinitely many sizes of infinity

2016: 187 pages; Softcover; ISBN: 978-1-4704-2557-9; List US$29; AMS members US$23.20; Order code MBK/97

Socks Are Like Pants, Cats Are Like Dogs

Games, Puzzles & Activities for Choosing, Identifying & Sorting Math!

Malke Rosenfeld and Gordon Hamilton

"Mathematical thinking and calculating are two different things. Of the two, the former skill is far more important to develop than the latter, especially today, when electronic calculators and computers are everywhere. Young children, who may know nothing of calculating, can be remarkably good at mathematical thinking. They do it naturally in their play. The puzzles in this book are meant to be approached playfully, and they help children build upon their natural capacities for mathematical thought."

—Peter Gray, Research Professor, Boston College, and author of "Free to Learn: Why Releasing the Instinct to Play Will Make Our Children Happier, More Self-Reliant, and Better Students for Life"

Explore the mathematics of choosing, identifying, and sorting through a diverse collection of math games, puzzles, and activities.

A publication of Delta Stream Media, an imprint of Natural Math. Distributed in North America by the American Mathematical Society.

Natural Math Series, Volume 4; 2016; 84 pages; Softcover; ISBN: 978-0-9776939-0-0; List US$15; AMS members US$12; Order code NMATH/4

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