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Notices

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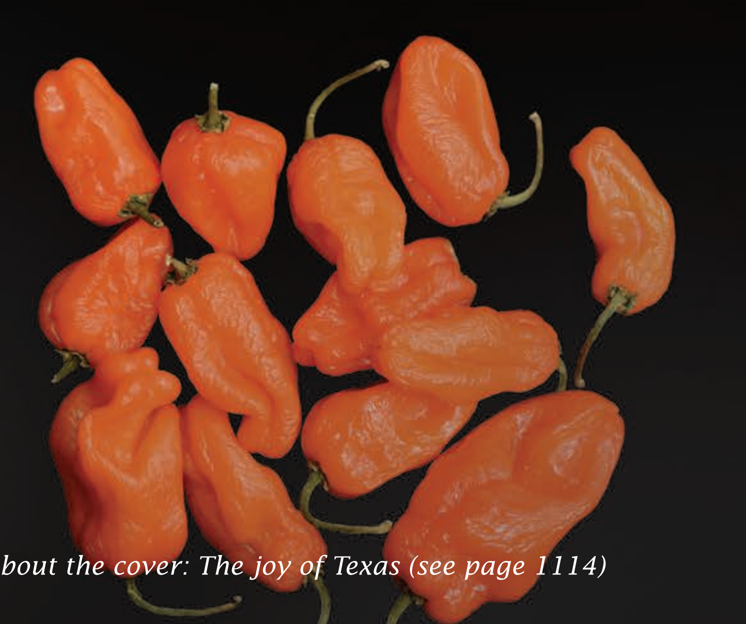

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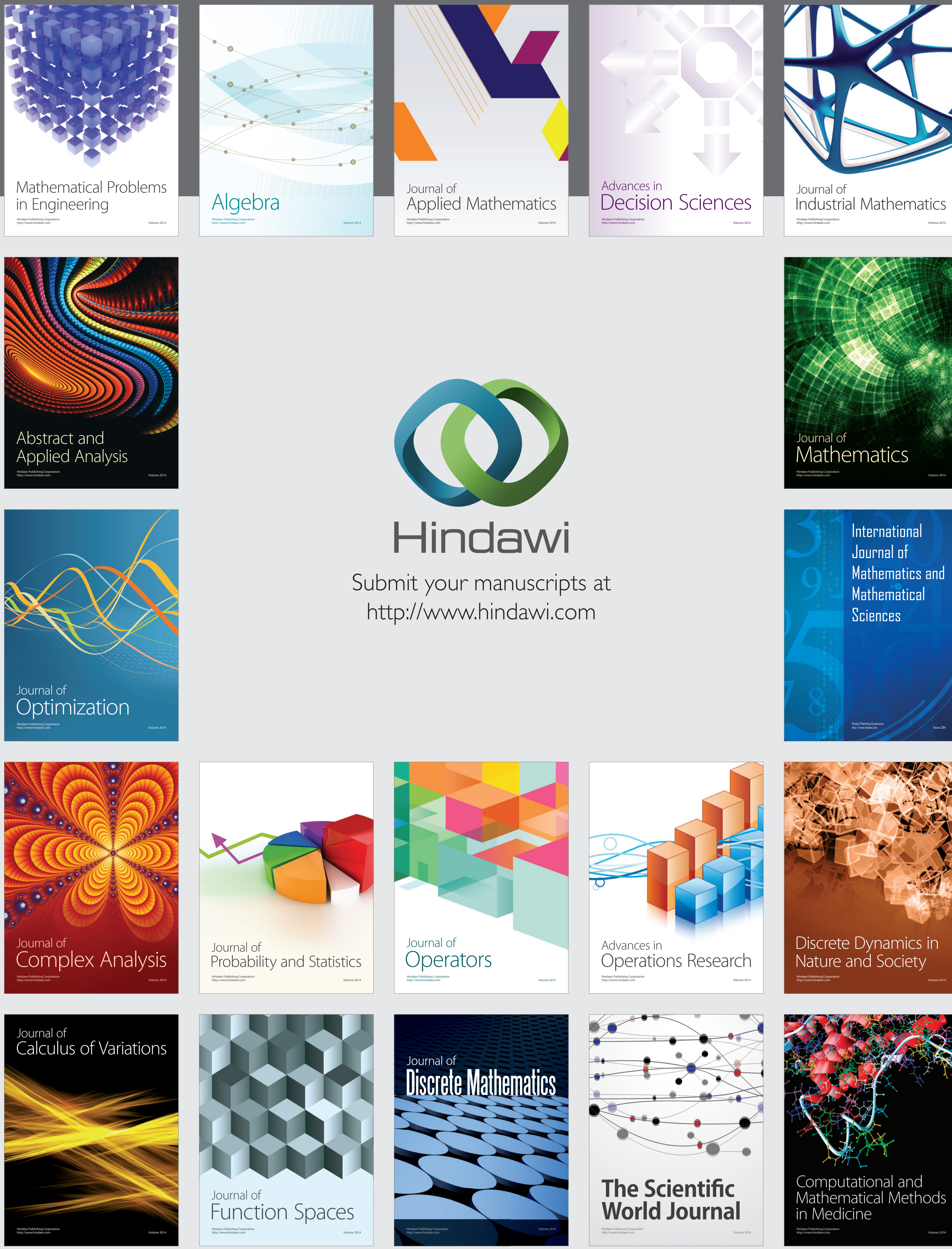
About the cover: The joy of Texas (see page 1114)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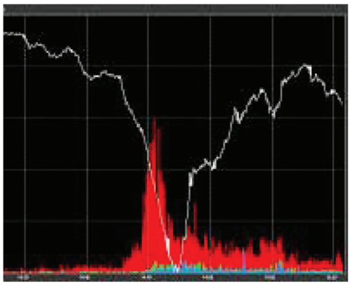

Broad Perspectives and New Directions in Financial Mathematics

March 9 – June 12, 2015

ORGANIZING COMMITTEE: **René Carmona** (Princeton University), **George Papanicolaou** (Stanford University) and Thaleia Zariphopoulou (Univ. of Texas at Austin)

Scientific Overview

The financial crisis of 2007-2008 has dramatically changed research in quantitative finance. The perfect replication paradigm, at the root of the success of the Black and Scholes model, became unsound in light of the dire illiquidity problems that caused several major collapses. As a result, the center of gravity of research in quantitative finance has shifted away from pricing and hedging and from the credit markets. While these problems remain of great importance, new problems are now taking center stage.

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Workshop Schedule

- Financial Mathematics Tutorials. March 10 - 13, 2015.
- Workshop I: Systemic Risk and Financial Networks. March 23 - 27, 2015.
- Workshop II: The Mathematics of High Frequency Financial Markets. April 13 - 17, 2015.
- Workshop III: Commodity Markets and their Financialization. May 4 - 8, 2015.
- Workshop IV: Forensic Analysis of Financial Data. May 18 - 22, 2015.
- Culminating Workshop at Lake Arrowhead Conference Center. June 8 - 12, 2015.

Participation

This long program will involve a community of senior and junior researchers. Full and partial support for participants is available. We are especially interested in applicants who intend to participate in the entire program, but will consider applications for shorter periods. Funding is available for participants at all academic levels, though recent PhDs, graduate students, and researchers in the early stages of their careers are especially encouraged to apply. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications. Applications will be accepted through Tuesday, December 9, 2014 but decisions will be made starting in July. More information and an application are available online.

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Notices

of the American Mathematical Society

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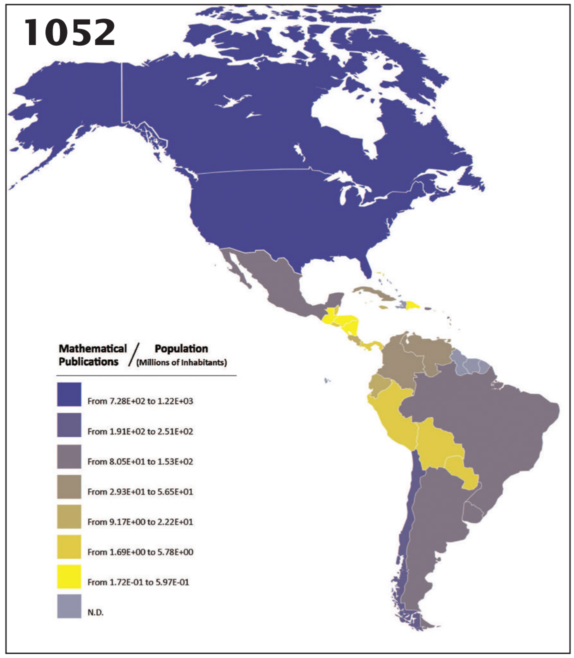
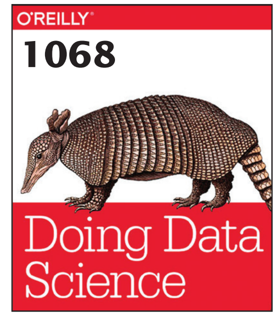
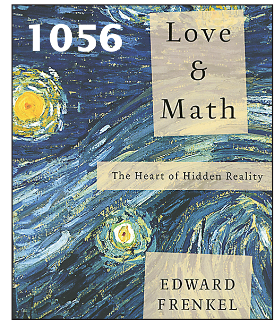
Communications

Commentary







Our October issue offers many pleasures. We have an article arguing the differences between diversity and ability. We have a consideration of mathematics in Latin America. We offer a trip from classical to abstract Fourier analysis. We look at a critique of Hirsch's citation index. And we finish with a study of population stability. Happy reading.

—*Steven G. Krantz, Editor*

Features

Notices

of the American Mathematical Society

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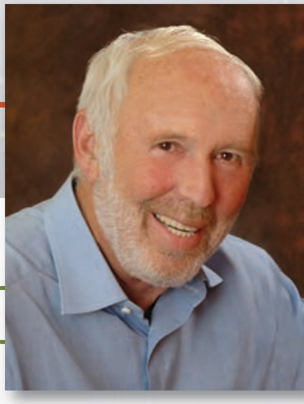
The 2014 AMS Einstein Public Lecture in Mathematics



JAMES H. SIMONS

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Early in his working life, James Simons was demoted from stock boy to floor sweeper. This actually turned out to be a good thing because sweeping gave him more time to think about mathematics. After receiving his PhD in mathematics, chairing a department, and working in cryptanalysis, he founded the financial firm Renaissance Technologies in 1978 and eventually made 100% of the company's investment decisions based on mathematical models, which also turned out to be a good thing as he is one of the 100 richest people in the world. Simons is now a philanthropist who supports basic research through the foundation that he and his wife, Marilyn, created. In this lecture, Simons will ruminate on the three intertwining subjects of his careers: mathematics, finance, and philanthropy.

Courtesy of San Francisco State University

The Einstein Lecture is part of the Fall 2014 AMS Western Sectional Meeting (Oct. 25–26) at SFSU.

FOR MORE INFORMATION:

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Does Diversity Trump Ability?

An Example of the Misuse of Mathematics in the Social Sciences

Abigail Thompson

What Is the Issue and Why Should We Care?

"Diversity" has become an important concept in the modern university, affecting admissions, faculty hiring, and administrative appointments. In the paper "Groups of diverse problem solvers can outperform groups of high-ability problem solvers" [1], L. Hong and S. Page claim to prove that "To put it succinctly, diversity trumps ability." We show that their arguments are fundamentally flawed.

Why should mathematicians care? Mathematicians have a responsibility to ensure that mathematics is not misused. The highly specialized language of mathematics can be used to obscure rather than reveal truth. It is easy to cross the line between analysis and advocacy when strongly held beliefs are in play. Attempts to find a mathematical justification for "diversity" as practiced in universities provide an instructive example of where that line has been crossed.

In this article we examine the arguments of the Hong and Page paper in detail. The paper contains what the authors call a "Mathematical Theorem," ostensibly proving that a group picked on the basis of "diversity" criteria outperforms one picked on the basis of "ability." In contrast to much of the diversity research literature, this paper claims to be based on mathematical reasoning. Its publication in 2004 in the *Proceedings of the National Academy of Sciences* has given it credibility, and it is widely cited. Its conclusions are presented as mathematical truth. Referring to this work in his 2007 book *The Difference* [3] (p. 165), Page says,

> …the veracity of the diversity trumps ability claim is not a matter of dispute. It's true, just as 1 + 1 = 2 is true.

Under careful scrutiny, however, the paper is seen to have essential and irreparable errors.

The mathematical content of [1] is presented in two main sections. In the first of these, "A Computational Experiment," the authors describe a computer simulation involving a collection of algorithms working together to solve a simple optimization problem. In this section the authors find that one collection of algorithms outperforms a second collection. They assign the label "diversity" to the first collection and the label "ability" to the second, and conclude that this is evidence that "diversity trumps ability." In a subsequent section titled "A Mathematical Theorem," the authors indicate that their analysis "…explores the logic behind the simulation results and provides conditions under which diversity trumps ability."

There are multiple problems in each of these sections. We can summarize the content of the theorem as follows: suppose that a group of people is set a task and the entire group's performance is compared to that of just one member of the group working alone on the same task. Assume also that the conditions of the task are such that one person working alone can never complete the task, and that the whole group working together will always complete the task. It is neither surprising nor difficult to see that, in this situation, the group as a whole will outperform the individual. Yet this is the entire content of what Hong and Page call the "Mathematical Theorem," Theorem 1 in [1].

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We also point out several issues with the "Computational Experiment" section of [1]. Here the authors discuss computer simulations intended to illustrate and support the conclusions of Theorem 1. We demonstrate that Theorem 1 is unrelated to the computational experiment and that the experiment offers no support for the social applications proposed by the authors.

A Mathematical Theorem

We first consider the section "A Mathematical Theorem" [1]. Theorem 1 of that section is the basis of the claim that there is a mathematical proof that diversity trumps ability. Once the unnecessary technicalities are removed and basic errors corrected, the theorem is revealed to be little more than a straightforward restatement of its hypotheses. Furthermore, a careful examination of Theorem 1's statement shows that it has no real-world applications.

Statement of the Theorem

Theorem 1 concerns the problem of finding the maximum value of a fixed real-valued function V defined on a finite set X. The function V is assumed to attain its maximum at a unique point x^* in X. Attempting to find this maximum is a finite collection of algorithms, which Hong and Page call "agents," or "problem-solvers." The collection of k agents (algorithms) is denoted by Φ. An agent ϕ is a function from X to X such that $V(\phi(x)) \geq V(x)$. Depending on the initial point x in X, an agent ϕ will sometimes but not always return the point x^* at which V achieves its maximum. Agents can work together in some way on the problem of finding the maximum of V. The authors assume that two copies of a single agent working together operate sequentially using composition of functions, with one taking as input the output of another. Combined with their definition of an agent, this implies that multiple copies of one agent perform identically to a single copy, an assumption required for their proof. We note that this is a strikingly restrictive and artificial condition, precluding an intelligent division of work.

Each agent produces an average value for V, by averaging over all starting points in X with equal weight. Agents can be ordered by these average values, and one agent is said to be *better* than another if its average is larger.

Hong and Page then make the following assumptions.

- Assumption 1: $\forall \phi \in \Phi$, $\exists x \in X$ such that $V(\phi(x)) < V(x^*)$; i.e., for each agent, there is some starting point for which V of its stopping point is not the global maximum.
- Assumption 2: $\forall x \in X$, $x \neq x^*$, $\exists \phi \in \Phi$ such that $\phi(x) \neq x$; i.e., no point of X is fixed under all elements of Φ except x^*.
- Assumption 3: Φ has a unique best element.

Additionally, as part of the definition of an agent, they include:

- Assumption 0: (i) $\forall x \in X, V(\phi(x)) \geq V(x)$. (ii) $\phi(\phi(x)) = \phi(x)$.

Hong and Page offer this interpretation of Assumption 2: "When one agent gets stuck, there is always another agent that can find an improvement" ([1], p. 16387). This interpretation is incorrect without the additional hypothesis that $V(x)$ is a one-to-one function. This error gives rise to a counterexample to the theorem, described in the Appendix. We proceed with the additional assumption that V is one-to-one.

Given this additional hypothesis, together with the additional assumption that agents "work together" by successive composition of functions, Hong and Page's assumptions imply:

(1) An agent working alone will sometimes not return the point x^*.
(2) All agents working together will always return the point x^*.
(3) There is a unique best agent.
(4) Multiple copies of a given agent working together perform identically to a single copy.

From (2) we see that the complete collection of all k agents in Φ, working together, will always return the point where the maximum value of the function V occurs, irrespective of the initial starting point. In contrast, k copies of the best agent in Φ behave identically to a single copy of the best agent (4) and thus do not always return the point where the maximum value of the function V occurs (1). Thus the complete collection of all k agents in Φ, working together, performs better than k copies of the best agent in Φ. Theorem 1 amounts to little more than this simple observation. The following statement of the theorem, as given in ([1], p. 16388), may sound more impressive.

Theorem 0.1 (Theorem 1)**.** *Let Φ be a group of problem solvers that satisfy assumptions 1-3. Let μ be a probability distribution over Φ with full support. Then, with probability one, a sample path will have the following property: there exist positive integers N and N_1, $N \geq N_1$, such that the joint performance of the N_1 independently drawn problem solvers exceeds the joint performance of the N_1 individually best problem solvers among the group of N agents independently drawn from Φ according to μ.*

In Page's book *The Difference* this theorem has been named the "Diversity Trumps Ability" theorem ([3], p. 162), and Page offers this application:

> How do we apply this in the real world? Simple. When picking two hundred employees from a pool of thousands, provided the people are all smart, we should keep the theorem in mind and not necessarily rank people by some crude ability score and pick the best. We should seek out difference.

While it may sound somewhat like Theorem 1, this interpretation is not correct. In reality Theorem 1 has nothing to say about hiring employees. The principal reason it does not apply involves the somewhat mysterious presence in the formal statement of Theorem 1 of the numbers N and N_1. What is not clearly stated is that N and N_1 can, and generally will, be substantially larger than k, the size of the initial pool of agents (or employees). To apply Theorem 1 to pick employees, you must be willing and able to make large numbers of clones of each of your job applicants, and you must be interested in picking from this army of clones a staff of tens of thousands, or the theorem has nothing to say about your hiring process.

We now examine in more detail the authors' arguments as they take a detour through probability. Our goal is to clarify the statement and proof of Theorem 1, and the nature (and relative magnitude) of the unspecified numbers N and N_1.

Idea of the Proof

We illustrate the proof of the corrected theorem with a simple example, using the case $k = 6$. In this case there are six distinct agents in Φ. We can dispense with much of the technical language from probability by associating each of these agents to a face of a standard die, to facilitate picking them at random. (While we confine ourselves to the case $k = 6$ and equal probabilities for purposes of clarity, the arguments apply more generally. For arbitrary finite k we can use any probability distribution with full support on k agents to select agents at random.) Of critical importance, we need to assume there are an unlimited number of copies of each agent, so that, for example, the sentence "Pick fifty agents at random from among the six agents" makes sense. In contrast, in the process of selecting job applicants in the real world, a request to "Pick fifty workers to hire at random from among six job applicants" does not make sense. Suppose that Agent 1 is the unique best agent of our six.

We are ready to understand the essential argument of Theorem 1 in three steps:

Step 1: Throw the die fifty times, and record the results. Call the corresponding collection of fifty agents "Group A." With high probability, Group A contains at least one copy of each of the six agents. Of course Group A probably contains several copies of each agent, but that's okay; we just want to make the size of the group large enough to be reasonably certain that it will contain at least one copy of each.

Step 2: Now throw the die 10,000 times, and record the results. It is extremely likely that each face of the die will show up at least fifty times in the results. In particular, with high probability Agent 1 will show up at least fifty times in the results. Hence if we select the best fifty agents from among the 10,000 with high probability we will select fifty copies of Agent 1. Call this collection of the best fifty agents "Group B."

Step 3: Since with high probability Group A includes a copy of each of our original six agents, Group A will, with high probability, always find the point where the maximum value of V occurs (2). With high probability Group B, however, is fifty copies of Agent 1 and this group of fifty will not always find the point where the maximum value of V occurs ((1) and (4)). Conclude that Group A outperforms Group B.

In this example the numbers N and N_1 have values $N = 10,000$ and $N_1 = 50$. The conclusion, stated in English, would read something like this:

Given six distinct problem-solvers, if fifty are selected at random from among these six, they will, with high probability, collectively outperform the fifty best problem-solvers chosen from 10,000 selected at random from among the six.

This is, as we have shown, an easy consequence. Notice that, when stated this way, it does not sound very sensible. One does not, in general, talk about selecting fifty "problem-solvers" from a group of six. This example highlights a misuse of the word "problem-solvers" in the formal statement of Theorem 1. A "problem-solver" strongly suggests an individual person. However as Hong and Page are using the word, a "problem-solver" is an algorithm. Algorithms, unlike people, can be made to duplicate each other exactly. Set ten copies of a single algorithm to painting a house, and they will paint the same wall ten times over. Ten humans are unlikely to do so.

The problem revealed in the case $k = 6$ does not disappear when using a larger initial set of distinct problem-solvers, or agents. Regardless of the size k of the initial pool of distinct problem-solvers, the argument remains very much the same. There is no information given by the theorem about the performance of any proper subset of the initial pool. The numbers N and N_1 not only may be much larger than k, but indeed must be so for the proof to work. The calculation of appropriate values of N and N_1 is an instance of the classic "coupon collector's problem" from standard probability theory ([2], p. 32). The passage from "highly likely" to certainty, as claimed in Theorem 1, requires a consideration of what happens in the limit as N_1 and N go to infinity.

What can reasonably be concluded from the outperformance of Group A? Nothing. We should not be even mildly surprised to find that a group which includes the best agent along with a collection of additional agents outperforms a group consisting only of identical copies of the best agent.

Furthermore, there is a curious and crucial discrepancy between the mathematical argument and the "diversity trumps ability" terminology. Somehow Hong and Page have transformed Group A, whose chief advantage is that it contains a copy of every single agent in the pool, into a "diverse" group. They say, "This result relies on the intuition that, as the initial pool of problem solvers becomes large, the best-performing agents necessarily become similar in the space of problem solvers. Their relatively greater ability is more than offset by their lack of problem-solving diversity" ([1], p. 16385). This claim doesn't appear to have any mathematical meaning; the term "diversity" has not been defined in the context of Theorem 1.

Having disposed of the ideas that Theorem 1 either contains substantial mathematical content, or is somehow applicable to real life, we now turn to the section of [1] containing a computational simulation.

A Computational Experiment

We give a description of the "Computational Experiment" described in [1] (p. 16386). Let $X = [1, 2, 3, \ldots, n]$ be the set consisting of the first n integers, and let V be a function from X to the real numbers. The goal posited in the computational model in [1] is to find the maximum value of V on the set X. The function V is assumed to have a unique maximum at x^*.

Fix two integers, l and k, with $1 \le k < l < n$, and define an *agent* to be a list of k distinct integers in $[1, \ldots, l]$. An agent describes a procedure to find a maximum value of V as follows:

The agent $\alpha = (a_1, a_2, a_3, \ldots, a_k)$ starts at some point i of X. It checks the value of V at i and then at $i + a_1$. If $V(i) \ge V(i + a_1)$, α next checks the value of V at $i + a_2$. If $V(i) < V(i + a_1)$, α next checks the value of V at $i + a_1 + a_2$. The search continues for elements of X (mod n) and for successive integers in α (mod k) until α gets stuck for a full k checks. Call this the "stopping point" of α for i, and denote it by $\alpha(i)$. Thus each α is a function from X to X. The value of V at the stopping point i is a *local optimum* for α. It is uniquely determined by α and the starting point i. We note in passing that this is an odd and inefficient way to go about finding the maximum value of a function on a finite set.

An agent α has an *average value* on X, defined by $(1/n)\sum_{i=1}^{n} V(\alpha(i))$. An agent α is said to be *better* than an agent β if α has a higher average value than β.

Hong and Page describe a simulation with $n = 2000$, $l = 20$, and $k = 3$. This gives a pool of $20 \times 19 \times 18 = 6840$ agents. They select ten at random and the ten best from the entire pool, and compare their performance as groups. They are surprised to find that the ten random agents acting together outperform the ten best agents acting together. We note that Theorem 1 offers no insight into this experiment, since the assumptions of the theorem are not met by the set-up of the experiment.

To understand what this simulation is doing, we ran a computer simulation following the description in [1] and were able to reproduce the results (code available by request). To see why the result of this simulation is not surprising, we take a closer look at the data from one run of the program. Since Hong and Page's simulation was based on an unreported random function on 2000 points, we used a function on 2000 points constructed with a random number generator.

For our simulation, we obtained the following list of the ten best agents:

$$[12, 4, 13], [7, 9, 14], [4, 12, 13], [10, 6, 17],$$
$$[17, 10, 6], [10, 9, 6], [17, 9, 13], [14, 17, 10],$$
$$[1, 9, 10], [6, 10, 17]$$

Here is a sample collection of ten random agents, one of a set of twenty randomly generated ten-agent collections:

$$[19, 18, 7], [11, 14, 8], [13, 10, 15], [12, 13, 5],$$
$$[10, 9, 20], [15, 13, 17], [20, 6, 14], [17, 2, 20],$$
$$[17, 16, 5], [1, 15, 3]$$

Hong and Page introduce "diversity" at this juncture, through an arbitrary definition. Define two ordered triples of integers to have a *diversity rating* lying between 0 and 3, depending on how many of the entries disagree. So $(1, 2, 5)$ and $(1, 4, 5)$ are given a rating of 1, because they disagree in one place, and $(1, 2, 5)$ and $(1, 4, 3)$ get a rating of 2, because they disagree in two places. The second pair of triples is considered "more diverse" than the first. The pair $(1, 2, 3)$ and $(3, 1, 2)$ is even more "diverse," with a diversity rating of the maximal possible 3, since none of the ordered entries match. Adding up the "diversity" of our set of ten random agents over all forty-five possible pairs, we get a total of 131, which is larger than 120, the total "diversity" of our set of ten best agents. With the gentlest of pushes, the *random* group has been recast as the *more diverse* group and the authors make the leap of logic that this group performs better *because* it is more diverse.

This argument has several problems. A misuse of terminology compounds them. First, the authors are apparently unaware of a principle that is widely known in both the theory of probability and the theory of algorithms. This is the idea that randomization can improve algorithms, and often can improve them dramatically. This phenomenon has been studied by mathematicians and computer scientists for forty years. There are many well-known, important algorithms based on this principle, including, for example, primality testing. It is certainly a powerful idea, but not new, and not "diversity."

Second, the authors make the common mistake of confusing correlation with causation. Because the random group had a characteristic to which the authors assigned the name "diversity," they attributed the relative success of the random group to "diversity." However there is no indication that the cause of this random group's success is its "diversity."

Indeed, if its greater "diversity" is really the cause of the group's improved performance, then a group maximizing "diversity" would perform even better than a random group. But our replication of the authors' model shows this is not the case. We ran the simulation with different groups of ten agents that achieved maximal possible "diversity." In all cases, a maximally "diverse" group performed less well than the median performance of 200 random groups of ten agents. In the spirit of [1], we might claim that *randomness trumps diversity*.

This is not unexpected, and it confirms our first point. Not only does randomness help in algorithms, but randomness often does better than any known deterministic procedure. As stated in *Probability and Computing* by Mitzenmacher and Upfal [2], "In…many important applications, randomized algorithms are significantly more efficient than the best known deterministic solutions." The contrived optimization problem in [1] gives an example of a situation where randomly chosen agents perform better than algorithms that choose agents according to deterministic characteristics, whether they are labeled "diversity" or "ability."

Finally, the attempt to assign a standard English meaning to a mathematical phenomenon is fraught with peril. For example, in the "Computational Experiment," instead of giving two ordered triples of integers a diversity rating between zero and three, we could instead assign them a *hostility rating* of between zero and three. Indeed we can do this using precisely the same mathematical definition as before; all we will change is the English word attached to the mathematical definition. One could argue that this is a more natural terminology, since it reflects the extent of disagreement between two triples. Thus we can give $(1,2,5)$ and $(1,4,5)$ a hostility rating of 1, because they disagree in one place, and $(1,2,5)$ and $(1,4,3)$ a hostility rating of 2, because they disagree in two places.

What does the simulation show now? It is still the case that the ten random agents acting together outperform the ten best agents acting together. But strikingly, we can observe, using precisely the same information as before, that the random group is much more hostile than the best group. Using Hong and Page's line of reasoning, we would be driven to the conclusion that *hostility trumps ability*. That is, if you are trying to form a team to maximize performance on a task, you should make your selection to maximize mutual antipathy among members of the team. We don't recommend this approach, but it is as well founded as Hong and Page's diversity recommendations.

Summary of Problems

Any one of the problems listed below would be sufficient to invalidate the claims of the authors.

1. Theorem 1 is incorrect as stated.
2. Once corrected, Theorem 1 is trivial. It is stated in a way which obscures its meaning. It has no mathematical interest and little content.
3. Theorem 1 is unrelated to the "Computational Experiment." Not only are the numbers of agents selected too small for the theorem to come into play, the hypotheses of the theorem are generally not met. See the Appendix for a detailed example.
4. The "Computational Experiment" is a contrived optimization problem in which the restrictions on the algorithms are artificial.
5. The "Computational Experiment" is an illustration of the benefits of randomness, not "diversity."
6. The "Computational Experiment" has a simple optimal algorithm; the best algorithm simply checks the value of the function V at every point. That is the "highest ability" algorithm for the problem, and it clearly works better than any other possible combination of alternative algorithms, unless they collectively also always return x^*.
7. The attempt to equate mathematical quantities with human attributes is inappropriate. For example, to associate two triples of integers $(1,2,3)$ and $(3,1,2)$ with two "problem-solvers" who have a "diverse" approach to problem-solving is not plausible. It is just as reasonable to say they represent two hostile "problem-solvers."

Who Uses this Result?

The "Diversity Trumps Ability" concept is appealing in certain circles. A Google search for "Diversity Trumps Ability" turns up over 70, 000 hits, some referencing [1], and some the book Page wrote on similar themes [3]. Page's work on diversity has been cited by NASA [4], the US Geological Survey [5], and Lawrence Berkeley Labs [6], among many others.

Hong and Page's paper has been used to give a scientific veneer to the diversity field, as it is one of the few research papers that appears to rely on more than qualitative information for its conclusions. Page comments on Theorem 1 in his book *The Difference* [3] (p. 162),

> This theorem is no mere metaphor or cute empirical anecdote that may or may not be true ten years from now. It is a mathematical truth.

This is just wrong. The claim that diversity trumps ability has been given no foundation by Hong and Page's paper.

To summarize, the paper "Groups of diverse problem solvers can outperform groups of high-ability problem solvers" [1] contains a theorem that has neither mathematical content nor real-world applications, and a contrived computer simulation that illustrates the well-known fact that random algorithms are often effective. What the paper emphatically does not contain is information that can be applied to any real-world situation involving actual people.

Acknowledgments

Thanks to Elizabeth Hass for assistance with the computational component of this paper, and for many helpful conversations. I am also grateful to my colleagues who offered helpful advice and comments on drafts of the paper.

Appendix

We provide a counterexample to Theorem 1, and an example to illustrate that the hypotheses of Theorem 1 are not met by the setup of the "Computational Experiment."

For completeness, we restate Theorem 1 as it appears in [1]. We also indicate how to correct the problem demonstrated by the counterexample by adding a hypothesis. Note that Assumption 0 is included in [1] as part of the definition of a "problem-solver."

- Assumption 0: (i) $\forall x \in X, V(\phi(x)) \geq V(x)$. (ii) $\phi(\phi(x)) = \phi(x)$.
- Assumption 1: $\forall \phi \in \Phi, \exists x \in X$ such that $V(\phi(x)) < V(x^*)$; i.e., for each agent, there is some starting point for which V of its stopping point is not the global maximum.
- Assumption 2: $\forall x \in X$, $x \neq x^*$, $\exists \phi \in \Phi$ such that $\phi(x) \neq x$; i.e., no point of X is fixed under all elements of Φ except x^*.
- Assumption 3: Φ has a unique best element.

Theorem 1 of [1]

Let Φ be a group of problem solvers that satisfies assumptions (1)-(3). Let μ be a probability distribution over Φ with full support. Then, with probability one, a sample path will have the following property: there exist positive integers N and N_1, $N \geq N_1$, such that the joint performance of the N_1 independently drawn problem solvers exceeds the joint performance of the N_1 individually best problem solvers among the group of N agents independently drawn from Φ according to μ.

Counter-example to Theorem 1

Let $X = \{a, b, c, d\}$. Define $V(x)$ and three agents ϕ_1, ϕ_2 and ϕ_3 according to the table below:

	a	b	c	d
$V(x)$	1	2	2	3
$\phi_1(x)$	d	b	c	d
$\phi_2(x)$	c	c	c	d
$\phi_3(x)$	b	b	b	d

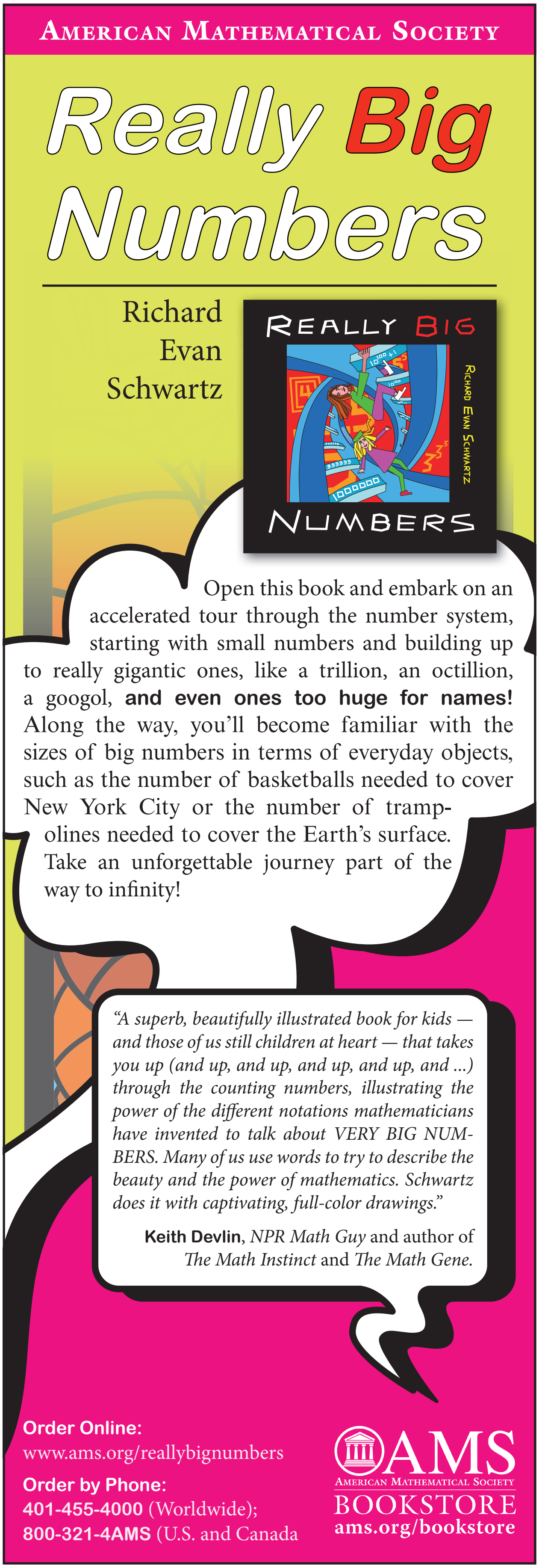
The set of agents $\Phi = \{\phi_1, \phi_2, \phi_3\}$ satisfies all the hypotheses of Theorem 1. The agents ϕ_1, ϕ_2, ϕ_3 have average values $5/2, 9/4, 9/4$ respectively, so ϕ_1 is the "best" agent. Notice that all three agents acting together do not always return the point d, where the maximum of V occurs. Indeed all three agents acting together work only as well as ϕ_1 acting alone. Hence in this case, no group of agents can outperform ϕ_1, or, equivalently, multiple copies of ϕ_1, hence no N and N_1 exist which satisfy the theorem.

The error occurs in Lemma 1 of [1]. It arises because the informal interpretation of Assumption 2 "When one agent gets stuck, there is always another agent that can find an improvement" ([1], p. 16387) is used; however, this informal interpretation is incorrect. For example, ϕ_1 "gets stuck" at b, however neither ϕ_2 nor ϕ_3 "improves" on $V(b)$. However, as required by Assumption 2, $\phi_2(b) \neq b$.

To avoid this problem, one can add the assumption that V is a one-to-one function.

Theorem 1 and the Computational Experiment

The hypotheses of Theorem 1 are not met by the setup of the "Computational Experiment." Even stipulating that V is a one-to-one function does not correct the problems found here, but we will assume it for convenience. We illustrate that it is highly likely under the setup described that there will be points in X where all the agents "get stuck," violating Assumption 2 of Theorem 1. To



see why, consider the case where X consists of the first 2000 integers, and $k = 3$ and $l = 20$, as in the "Computational Experiment." Let x_i be the point where V achieves its maximum. Suppose that x_j is the point where V achieves its next-highest value. Notice that, if $x_i - x_j$ is not between 1 and 20 mod(2000), all agents will get stuck at x_j, violating Assumption 2. Hence it is fairly likely that all agents will get stuck at x_j. This argument can be iterated through the decreasing values of V, making it highly likely that all agents will get stuck at some x for fixed V.

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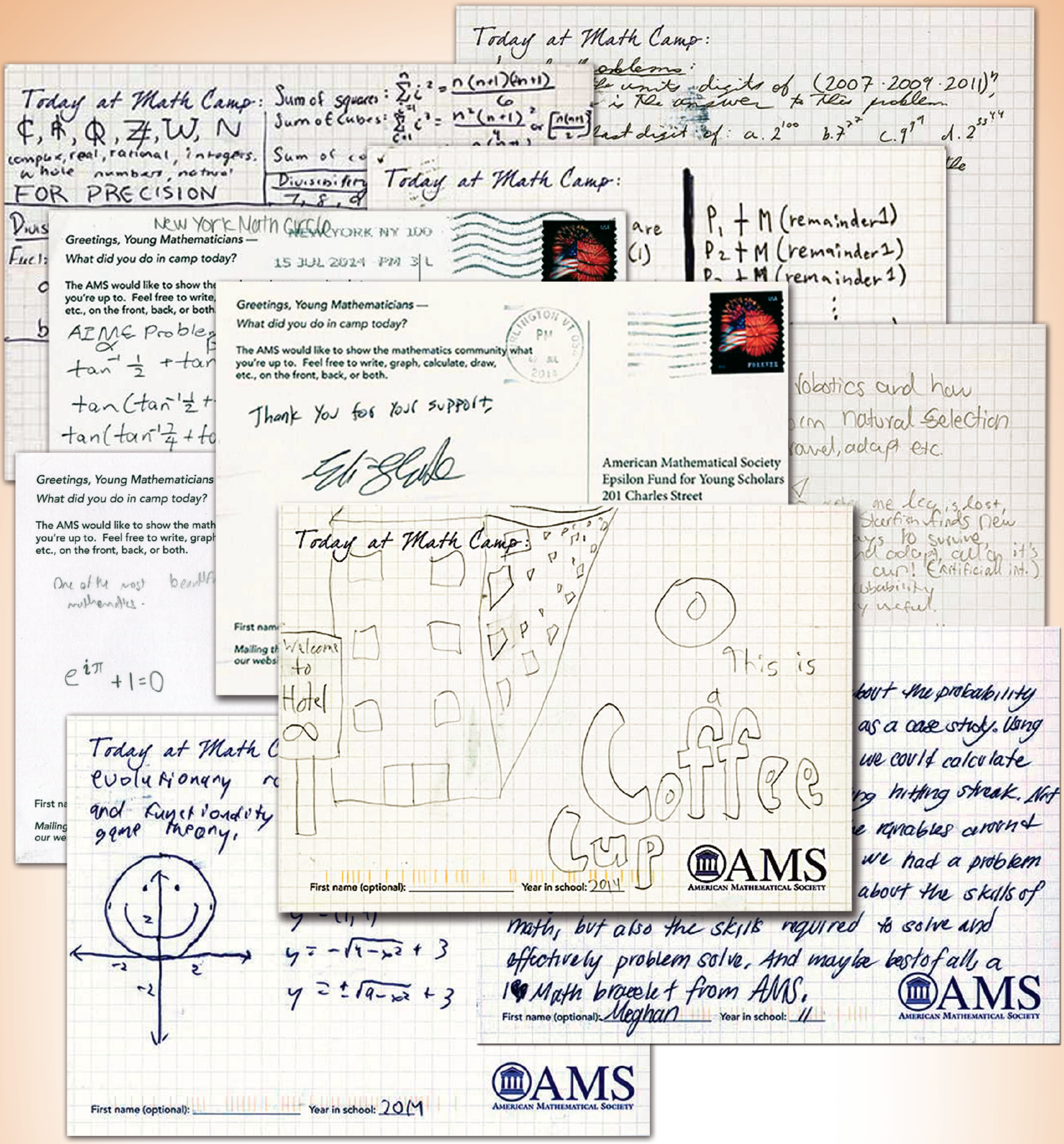

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A Trip from Classical to Abstract Fourier Analysis

Kenneth A. Ross

Classical Fourier analysis began with Fourier series, i.e., the study of periodic functions on the real line $\mathbb{R}$. Because trigonometric functions are involved, we will focus on 2π-periodic functions, which are determined by functions on $[0, 2\pi)$. This is a group under addition modulo 2π, and this group is isomorphic to the circle group $\mathbb{T} = \{z \in \mathbb{C} : |z| = 1\}$ under the map $t \to e^{it}$. Classical results can be viewed as results on the compact abelian group $\mathbb{T}$, and we will do so.

Similarly, Fourier analysis on $\mathbb{R}^n$ can be viewed as analysis on the locally compact[1] abelian (LCA) group $\mathbb{R}^n$.

Our general setting will be a locally compact group G. Every such group has a (left) translation-invariant measure, called Haar measure because Alfred Haar proved this statement in 1932. For $G = \mathbb{R}^n$, this is Lebesgue measure. Haar measure for $G = \mathbb{T}$ is also Lebesgue measure, either on $[0, 2\pi)$ or transferred to the circle group $\mathbb{T}$. Haar measure will always be the underlying measure in our $L^p(G)$ spaces. In particular, $L^1(G)$ is the space of all integrable functions on G. Functions in $L^1(G)$ can be convolved:

$$f * g(x) = \int_G f(x+y)g(-y)\,dy$$

or

$$\int_G f(xy)g(y^{-1})\,dy \quad \text{for} \quad f, g \in L^1(G).$$

Under this convolution, $L^1(G)$ is a Banach algebra.

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[1] *For us, locally compact groups are always Hausdorff.*

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Question. Which functions h in $L^1(G)$ can be written as $f * g$? That is, which h in $L^1(G)$ factors as the convolution of two L^1-functions?

Theorem ([32, Raphaël Salem, 1939]). $L^1(\mathbb{T}) * L^1(\mathbb{T}) = L^1(\mathbb{T})$. *Also* $L^1(\mathbb{T}) * C(\mathbb{T}) = C(\mathbb{T})$, *where* $C(\mathbb{T})$ *is the space of continuous functions on* $\mathbb{T}$. [2]

What year did Salem publish this result? According to Zygmund's book [37] and Salem's published works [33, page 90], this paper was published in 1939. According to Hewitt & Ross [17], this paper was published in 1945. The paper was reviewed in March 1940, so 1939 is surely correct. The story is more complicated than a simple error in [17]. The journal had received papers for that issue in 1939, but no more issues were published until 1945 because of World War II. Unfortunately, Hewitt and I used the publication date on the actual journal.

Who was Salem? He was a very talented banker in France who did mathematics on the side. When World War II broke out, he went to Canada and ended up a professor at M.I.T. Antoni Zygmund gives a brief account of Salem's life in the Preface to Salem's complete works (*Oeuvres Mathèmatiques*) [33]. Edwin Hewitt told me that Salem was a real gentleman who treated graduate students well. Salem died in 1963.[3]

In 1957, Walter Rudin announced[4] that $L^1(\mathbb{R}^n) * L^1(\mathbb{R}^n) = L^1(\mathbb{R}^n)$. This prompted the eminent French mathematician and leading co-author of Nicholas Bourbaki, Jean Dieudonné, to write to

[2] *See the Appendix for more about Salem's theorems.*

[3] *Starting in 1968, the Salem Prize has been awarded almost every year to a young mathematician judged to have done outstanding work in Fourier series, very broadly interpreted. The prize is considered highly prestigious and many recipients have also been awarded the Fields Medal later in their careers.*

[4] Bull. Amer. Math. Soc. *abstract 731t, p. 382.*

Walter Rudin, on December 17, 1957, as follows [30, Chapter 23]:

> Dear Professor Rudin:
>
> In the last issue of the *Bulletin of the AMS*, I see that you announce in abstract 731t, p. 382, that in the algebra $L^1(\mathbb{R}^n)$, any element is the convolution of two elements of that algebra. I am rather amazed at that statement, for a few years ago I had made a simple remark which seemed to me to disprove your theorem [9].[5] I reproduce the proof for your convenience:
>
> Suppose f, g are in L^1 and ≥ 0, and for each n consider the usual "truncated" functions $f_n = \inf(f, n)$ and $g_n = \inf(g, n)$; f (resp. g) is the limit of the increasing sequence (f_n) (resp. (g_n)), hence, by the usual Lebesgue convergence theorem, $h = f * g$ is a.e. the limit of $h_n = f_n * g_n$, which is obviously an increasing sequence. Moreover, f_n and g_n are both in L^2, hence it is well known that h_n can be taken *continuous* and bounded. It follows that h is a.e. equal to a Baire function of the *first class*. However, it is well known that there are integrable functions which *do not* have that property, and therefore they cannot be convolutions.
>
> I am unable to find any flaw in that argument, and if you can do so, I would very much appreciate if you can tell me where I am wrong.
>
> Sincerely yours, J. Dieudonné

As Rudin notes, there are nonnegative L^1-functions that cannot be written as $f * g$ where f, g are nonnegative.[6] Rudin wrote to Dieudonné explaining this subtle error. In fact, in a separate letter to me in 1979, now lost, Rudin commented, "It's a very subtle error, and I would certainly have believed it if I hadn't proved the opposite." Later, in his memoir [30], Rudin wrote, "Needless to say, I was totally amazed. Here was Dieudonné, a world-class mathematician and one of the founders of Bourbaki, not telling me, a young upstart, 'you are wrong, because here is what I proved a few years ago' but asking me, instead, to tell him what he had done wrong! Actually, it took me a while to find the error, and if I had not proved earlier that convolution-factorization is always possible in L^1, I would have accepted his conclusion with no hesitation, not because he was famous, but because his argument was simple and perfectly correct, *as far as it went.*"

[5] *The remark was in a footnote, and the footnote includes the following assertion: "Il suffit pour le montrer de considérer le cas où f et g sont positives;"*

[6] *See the preceding footnote.*

Here is Dieudonné's response of January 17, 1958:

> Dear Professor Rudin:
>
> Thank you for pointing out my error; as it is of a very common type, I suppose I should have been able to detect it myself, but you know how hard it is to see one's own mistakes, when you have once become convinced that some result must be true!!
>
> Your proof is very ingenious; I hope you will be able to generalize that result to arbitrary locally compact abelian groups, but I suppose this would require a somewhat different type of proof.
>
> With my congratulations for your nice result and my best thanks, I am
>
> Sincerely yours, J. Dieudonné

In fact, Rudin proved:

Theorem (Walter Rudin [27, 1957], [28, 1958])**.** *$L^1(G) * L^1(G) = L^1(G)$ for G abelian and locally Euclidean. In particular, this equality holds for $\mathbb{R}$ and $\mathbb{R}^n$.*

I have heard stories that Rudin heard Salem or Zygmund talk about this theorem in Chicago and then ran off and stole the result for himself. But the timing and context are all wrong, and Rudin's proof is quite different from Salem's. When I wrote to Rudin in 1979, I did not of course allude to the stories I'd heard. Nevertheless, his response began:

> First of all, let me say that I regret very much that I never got around to acknowledging Salem's priority in print. I was unaware of his factoring—when I did my stuff, and later there never seemed to be a good opportunity to do anything about it.

The Cohen Factorization Theorem

Walter Rudin did his work at the University of Rochester. His first book, his very successful undergraduate analysis text [26], fondly known as "baby Rudin" or "blue Rudin," was published in 1953 and lists Rudin as at Rochester. However, he wrote this book while at M.I.T. In 1957, Paul Cohen went to the University of Rochester without finishing his Ph.D. at the University of Chicago under Antoni Zygmund. Neither Zygmund nor Cohen were impressed with his thesis, but Rudin and others finally persuaded Cohen to write up his thesis and return to Chicago for his final exam.

About this time, Rudin showed Cohen his work on factorization. Cohen saw Féjer and Riesz kernels and the like and said, "aha, approximate identities." An approximate unit is a sequence or net $\{e_\alpha\}$ such that $x = \lim_\alpha xe_\alpha = \lim_\alpha e_\alpha x$ for all x in the topological algebra. Soon Cohen found an elegant, completely elementary (using only the definitions) short proof of:

Theorem ([5, Paul J. Cohen, 1959]). *If A is a Banach algebra with a bounded approximate unit, then $AA = A$, i.e., each element of A can be factored as a product of two elements in A.*[7]

Paul J. Cohen was a brilliant mathematician who went on to do substantial work in my field, harmonic analysis, for a couple of years. In fact, his other three papers in the subject are the basis for the main results in Chapters 3 and 4 of Rudin's book [29, *Fourier Analysis in Groups*, 1962]. Then in 1961, starting from scratch, he moved into the field of foundations. By 1963 or 1964 he had done the first really fundamental work in foundations since Gödel. [Among many other things, he showed that neither the Axiom of Choice nor the Continuum Hypothesis can be proved in standard Zermelo-Fraenkel set theory.]

In 1968, I presented the Cohen Factorization Theorem in a graduate course I was teaching, probably on the second day, since the proof is self-contained. Bill Paschke, a student in the class, wondered whether the converse might be true and found an example of a Banach algebra A, without a bounded approximate unit, satisfying $AA = A$ [24].

Since every $L^1(G)$ is a Banach algebra with bounded approximate unit, we have the following stunning extension of Rudin's theorem:

Theorem. $L^1(G) * L^1(G) = L^1(G)$ *for all locally compact groups G, including all non-abelian groups.*

Cohen's factorization theorem was the real breakthrough. In fact, he also proved that $L^1(G) * C(G) = C(G)$ for compact G, and module generalizations appeared soon after, created independently by Edwin Hewitt [15] and Philip C. Curtis Jr. and Alessandro Figà-Talamanca [6]. Neither used module language, but Hewitt's axioms were basically module axioms.

Given a Banach algebra A, a left Banach A-module is a Banach space L that the algebra A acts on. We use the notation $(a, x) \to a \bullet x$ for the action of A on L, so that $(a, x) \to a \bullet x$ is a mapping from $A \times L$ into L. In addition, we require the inequality $\| a \bullet x \|_L \leq \| a \|_A \cdot \| x \|_L$ for all $(a, x) \in A \times L$.

The Banach Module Factorization Theorem. ([17, Theorem 32.22]). *If A is a Banach algebra with a bounded approximate unit, and if L is a left Banach A-module, then $A \bullet L$ is a closed linear subspace of L. In particular, if $A \bullet L$ is dense in L (which is usually obvious when true), then $A \bullet L = L$.*

Note. If $A \bullet L = M$, then $A \bullet M = A \bullet (A \bullet L) = (AA) \bullet L = A \bullet L = M$.

[7] *Note that this is obvious if A has a unit.*

Hewitt's main application was:

Theorem ([15, Edwin Hewitt, 1964]). *For $1 \leq p < \infty$, we have $L^1(G) * L^p(G) = L^p(G)$ for any locally compact group G.*

Philip Curtis and Alessandro Figà-Talamanca gave this application and other applications to harmonic analysis and to function algebras. In particular, they proved:

Theorem ([6, 1965, Curtis & Figà-Talamanca, Theorem 3.1]). *For any locally compact group,*

$$L^1(G) * L^\infty(G) = C_{ru}(G) = L^1(G) * C_{ru}(G), \tag{1}$$

where $C_{ru}(G)$ is the space of all bounded right uniformly continuous functions on G. The last equality follows from the Note after the Banach Module Factorization Theorem.

We also have $L^1(G) * C_0(G) = C_0(G)$, where $C_0(G)$ is the space of continuous functions on G that vanish at infinity; see [17, 32.44f].

Rates of Decrease of Fourier Coefficients and Transforms

We now consider an LCA group G. As in the classical setting, Fourier transforms are the key tool. These are functions defined on the character group $\widehat{G}$, which consists of all characters χ on G, i.e., continuous homomorphisms of G into the circle group. Thus

$$\widehat{\mathbb{R}} = \{\chi_y : y \in \mathbb{R}\}, \text{ where } \chi_y(x) = e^{ixy} \text{ for all } x \in \mathbb{R},$$

and

$$\widehat{\mathbb{T}} = \{\chi_n : n \in \mathbb{Z}\}, \text{ where } \chi_n(z) = z^n \text{ for } z \in \mathbb{T}.$$

On $[0, 2\pi)$, χ_n looks like $\chi_n(t) = e^{int}$. It is not an accident that the index sets for $\widehat{\mathbb{R}}$ and $\widehat{\mathbb{T}}$ are familiar groups. It is not obvious in general but, with a suitable topology, $\widehat{G}$ is always an LCA group.

Now, for a function f in $L^1(G)$, its Fourier transform on $\widehat{G}$ is defined by $\hat{f}(\chi) = \int_G f\overline{\chi}$. On $\mathbb{R}$, except for a mildly controversial constant, the Fourier transform is defined by

$$\hat{f}(y) = \int_{-\infty}^{\infty} f(x) e^{-ixy}\, dx.$$

On $\mathbb{T}$, the Fourier transform is defined by

$$\hat{f}(n) = \int_{\mathbb{T}} f(z)\overline{z}^n\, dz \quad \text{or} \quad \frac{1}{2\pi}\int_0^{2\pi} f(t) e^{-int}\, dt.$$

Since $e^{int} = \cos nt + i \sin nt$, there is a simple intimate connection between our Fourier transforms on $\mathbb{T}$ and the classical Fourier coefficients of Fourier series. So it is almost trivial to translate theorems back and forth; you will see that I did this to Salem's theorem if you look at his original paper.

A basic fact is:

Riemann-Lebesgue Lemma. *If f is in $L^1(G)$, then its Fourier transform $\hat{f}$ is in $C_0(\hat{G})$, i.e., $\hat{f}$ is a continuous function on $\hat{G}$ and vanishes at infinity.*

Thus the Fourier transform of any function in $L^1(\mathbb{R})$ vanishes at infinity. Likewise, for f in $L^1(\mathbb{T})$, the sequence $(\hat{f}(n))_{n\in\mathbb{Z}}$ vanishes at infinity, and the same is true for the Fourier coefficients in the Fourier series corresponding to f.

Here is a natural question.

Question. Can $\hat{f}$ vanish at infinity as slowly as we wish?

For the circle group $\mathbb{T}$, the answer is "yes" in the strongest sense. Indeed, if (a_n) is any sequence of nonnegative numbers, on $\mathbb{Z}$, and if $\lim_{|n|\to\infty} a_n = 0$, then there exists f in $L^1(\mathbb{T})$ so that $\hat{f}(n) \geq a_n$ for all $n \in \mathbb{Z}$. This was stated and proved by A. N. Kolmogorov [21, 1923]. This result is true because every sequence (a_n) on $\mathbb{Z}$ that vanishes at $\pm\infty$ is dominated by a symmetric convex sequence (c_n) of positive numbers, and every such sequence is the Fourier transform of a function f in $L^1(\mathbb{T})$. In symbols, $\hat{f}(n) = c_n \geq |a_n|$ for all $n \in \mathbb{Z}$. The last assertion, that such sequences (c_n) are Fourier transforms, goes back to W. H. Young [35, 1913].[8]

Back in 1967 or 1968, when Edwin Hewitt and I were writing our book [17], Ed "assigned" me the task of generalizing these results. I focused on compact abelian groups and got nowhere. Mostly I foolishly worked on the task of generalizing convex functions to more general compact groups. Then I had one of my very rare good ideas. By the Banach-module version of the factorization theorem,

$$\widehat{L^1(G)} \cdot C_0(\hat{G}) = C_0(\hat{G}) \qquad (2)$$

for all LCA groups. Here the module action is $f \bullet \psi = \hat{f}\psi$ for $(f, \psi) \in L^1(G) \times C_0(\hat{G})$.

From (2), the answer to the question is "yes," at least for compact abelian groups. I illustrate the idea on $\mathbb{T}$ using $\widehat{L^1(\mathbb{T})} \cdot c_0(\mathbb{Z}) = c_0(\mathbb{Z})$, where $c_0(\mathbb{Z})$ consists of all sequences on $\mathbb{Z}$ that vanish at $\pm\infty$. Consider a nonnegative sequence (a_n) in $c_0(\mathbb{Z})$. Then there exist g in $L^1(\mathbb{T})$ and (b_n) in $c_0(\mathbb{Z})$ such that $a_n = \hat{g}(n)b_n$ for all $n \in \mathbb{Z}$. Thus $F = \{n \in \mathbb{Z} : |b_n| > 1\}$ is finite and

$$n \notin F \quad \text{implies} \quad |b_n| \leq 1 \quad \text{implies} \quad |\hat{g}(n)| \geq a_n.$$

So g works except possibly on F. But one can always adjust $\hat{g}$ on the finite set F, by adding a suitable trigonometric polynomial to g, to get the desired f.

I was extremely pleased, so I showed this to Ed Hewitt and also to Irving Glicksberg, who was another fine analyst at the University of Washington.[9] They both liked the proof. However, twenty-four hours later Irving returned and pointed out that the result was in Curtis and Figà-Talamanca's paper [6]. I was quite disappointed, because I thought this would be worthy of a short note.

It turns out that an easy adjustment to the argument above proves:

Theorem ([17, Hewitt & Ross, 32.47.b]). *Let G be an LCA group with character group $\hat{G}$. Given a nonnegative function ψ in $C_0(\hat{G})$, there is a function f in $L^1(G)$ such that $\hat{f}(\chi) \geq \psi(\chi)$ for all $\chi \in \hat{G}$.*

We credit the theorem above to Curtis and Figà-Talamanca [6], but I think we were a little too generous. Certainly the equality (2) is clear from their description of $\widehat{L^1(G)} \cdot L^\infty(\hat{G})$, but in looking through the paper more carefully I do not see this equality used to prove the theorem above. Curtis and Figà-Talamanca noted other equalities including $\widehat{L^1(G)} \cdot L^p(\hat{G}) = L^p(\hat{G})$ for $1 \leq p < \infty$. Section 32 in [17] contains many more applications, including N. Th. Varopoulos's theorem that all positive functionals on a Banach $*$-algebra with bounded approximate unit are continuous [17, Theorem 32.27].[10] His proof relied heavily on the following:

Theorem ([17, Theorem 32.23]). *If (a_n) is a sequence in a Banach algebra A and $\lim_n a_n = 0$ in A, then there exists b in A and a sequence (c_n) in A such that $\lim_n c_n = 0$ and $a_n = bc_n$ for all n.*

In 1969, Marc Rieffel found a simple elegant proof of this theorem, as follows. Let $c_0(A)$ be all infinite sequences $(a_1, a_2, \ldots)$ in A where $\lim_n a_n = 0$. Define

$$\| (a_1, a_2, \ldots) \|_{c_0(A)} = \sup\{\| a_n \|_A : n = 1, 2, \ldots\}.$$

Then $c_0(A)$ is a Banach A-module under the module operation $b \bullet (a_1, a_2, \ldots) = (ba_1, ba_2, \ldots)$. So the Banach Module Factorization Theorem gives $A \bullet c_0(A) = c_0(A)$, and this implies the theorem.

Kolmogorov's 1923 theorem, that $\hat{f}$ can vanish infinitely slowly for f in $L^1(\mathbb{T})$, suggests a similar-looking question. Is every sequence (a_n) in $\ell^2(\mathbb{Z})$ dominated by $\hat{f}$ for some f in $C(\mathbb{T})$? Robert E. Edwards, in Australia, and I worked on this in 1972–1973, but without success. An elegant affirmative solution was found in 1977 by Karel de Leeuw,[11] Jean-Pierre Kahane, and Yitzak Katznelson [8]. They state, in passing, that this result holds for all compact abelian groups. A detailed proof of the de Leeuw-Kahane-Katznelson theorem is given in the last chapter of Karl Stromberg's book [34].

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[8] *For more about this, see the Appendix.*

[9] *Hewitt and I worked on* [17] *at the University of Washington, and Glicksberg's office was down the hall.*

[10] *Varopoulos was the first recipient of the Salem Prize.*

[11] *This was de Leeuw's last paper. He was murdered on August 18, 1978, by a disgruntled graduate student at Stanford University. He was 48.*

This result has been generalized in several ways. S. V. Kislyakov [20] showed that, for any nonnegative sequence (a_n) in $\ell^2(\{0,1,2,\ldots\})$, there is a function f in $C(\mathbb{T})$ such that $|\hat{f}(n)| \geq a_n$ for all $n \geq 0$ and $\hat{f}(n) = 0$ for all $n < 0$. Also, the de Leeuw-Kahane-Katznelson theorem was generalized to compact non-abelian groups and to a special class of compact metrizable abelian hypergroups. See Barbara Heiman [14] and the paper [12, Theorem 4.10, Example 2.7], co-authored by John Fournier and me.

Some Other Applications

A representation $\pi : L^1(G) \to B(H)$, where G is a locally compact group and $B(H)$ is the space of bounded operators on a Hilbert space H, is "nondegenerate" if the set $\{\pi(f)\xi : f \in L^1(G), \xi \in H\}$ spans a dense linear subspace of H.[12] See, for example, [7, just before Proposition 6.2.3]. It is worth noting that, in fact, such a set $\{\pi(f)\xi : f \in L^1(G), \xi \in H\}$ must be equal to H. To see this, we use the module operation $(f,\xi) \to f \bullet \xi$ from $L^1(G) \times H \to H$ where $f \bullet \xi = \pi(f)\xi$; then H is a Banach $L^1(G)$-module. Thus, by the Banach Module Factorization Theorem, we have

$$\{\pi(f)\xi : f \in L^1(G), \xi \in H\} = L^1(G) \bullet H = \pi(L^1(G))H = H.$$

This fact was essentially observed by Curtis and Figà-Talamanca [6, Corollary 2.4].

Consider an LCA group G with character group $\hat{G}$. Equation (1) in Curtis and Figà-Talamanca's theorem applies to $\hat{G}$:

$$(3) \quad L^1(\hat{G}) * L^\infty(\hat{G}) = C_{ru}(\hat{G}) = L^1(\hat{G}) * C_{ru}(\hat{G}).$$

$L^1(\hat{G})$ is often called the Fourier algebra of G and written $A(G)$. This object was generalized to all locally compact groups G by Pierre Eymard [11, 1964]. Its dual space is $L^\infty(\hat{G})$ if G is abelian and, in the general case, the dual of $A(G)$ is the von Neumann algebra $VN(G)$. For a suitable generalization of $C_{ru}(\hat{G})$, which he called $UCB(\hat{G})$, Ed Granirer [13, 1974, Proposition 1] showed that

$$(4) \quad A(G) \cdot VN(G) = UCB(\hat{G}) = A(G) \cdot UCB(\hat{G}) \quad \text{for amenable groups } G.$$

He applied the Cohen factorization theorem to the Banach $A(G)$-module $VN(G)$ and Horst Leptin's theorem [23, 1968, Proposition 1] stating that $A(G)$ has a bounded approximate unit if and only if G is amenable. Much later, Tony Lau and Viktor Losert [22, 1993, Proposition 7.1] showed the converse: $UCB(\hat{G}) = A(G) \cdot VN(G)$ implies that G is amenable, so that (4) can be rewritten as an "if and only if" assertion.

[12] *Of course, this definition can be extended to representations of Banach algebras by operators on a Banach space.*

Local Units in Fourier Algebras

Here is another theorem in this arena. It can be found in Rudin [29, Theorem 2.6.8], Hewitt & Ross [17, Theorem 31.37] and Bourbaki [3, Ch. II, §2, Exercise 13(b)].

Theorem. *Let G be an LCA group. Let Φ be a nonempty compact subset of $\hat{G}$ and $\epsilon > 0$. Then there exists f in $L^1(G)$ such that $\hat{f}$ has compact support, $\hat{f} = 1$ on Φ and $\| f \|_1 < 1 + \epsilon$.*

This theorem was easy for G equal to $\mathbb{R}^n$, $\mathbb{Z}^m$ and $\mathbb{T}$, and in fact for all compact (abelian) groups. In the general case, the theorem is still easy except for the norm requirement. It is apparently due to Rudin [29] who proved the highly nontrivial structure theorem for compactly generated LCA groups [29, Theorem 2.4.1] just to be able to prove this useful theorem. Hewitt & Ross and Bourbaki used the same proof.

In the spring of 1971, Gregory Bachelis and Bill Parker, both at Kansas State University at the time, sent me a letter saying that they had a very simple proof of this result for compact abelian groups; in fact, suitably stated for trigonometric polynomials, this result holds for all compact groups. Greg noticed this as a consequence of his study of annihilator algebras. They wanted to know whether I knew of this simple proof for the compact abelian case. I did not know their simple proof, and it took me only a few minutes to adjust their proof to prove the theorem stated above. With help from their colleague Karl Stromberg, Greg and Bill convinced me to be a co-author for such little work. The proof is published as a Shorter Note in the *Proceedings of the American Mathematical Society* [2]. The proof is six lines long, two lines for each author. Incidentally, according to the review of [2], I told the reviewer that Hans Reiter informed me that Horst Leptin also gave a structure-free proof of the theorem.

Here is the simple proof of the theorem as stated. The essence of it is that, if g and h are idempotents in a ring, so is $g + h - gh$. Using the (easy) theorem without the norm requirement, there is a function h in $L^1(G)$ so that $\hat{h}$ has compact support and $\hat{h} = 1$ on Φ. There is an approximate unit for $L^1(G)$ consisting of functions with L^1-norm 1 and with Fourier transforms having compact support. Thus there exists g in $L^1(G)$ such that $\| g \|_1 = 1$ and $\| g * h - h \|_1 < \epsilon$ and such that $\hat{g}$ has compact support. Let $f = g + h - g * h$. Then $\hat{f}$ has compact support, $\| f \|_1 \leq \| g \|_1 + \| h - g * h \|_1 < 1 + \epsilon$, and for a character χ in Φ, we obtain $\hat{f}(\chi) = \hat{g}(\chi) + \hat{h}(\chi) - \hat{g}(\chi)\hat{h}(\chi) = \hat{g}(\chi) + 1 - \hat{g}(\chi) \cdot 1 = 1$.

How did this proof get overlooked? My guess is that Walter Rudin was a classical analyst before writing his book and saw how to prove this result for $\mathbb{R}^n$ and other special cases. Then he used the structure theorem to prove the general result. Hewitt & Ross, and apparently Bourbaki, didn't think to look for such a trivial proof.

There is more to this story. My co-authors asked me to submit this article, so I sent it to the most appropriate editor, Irving Glicksberg. I sent this on a Friday in May 1971, with a note asking him to respond to Greg Bachelis if he had a decision in less than a month, because I was going to be in India for a month. On the next Wednesday, on the way to the airport and India, I dropped by the campus office to check mail, and there was an acceptance! Later, Irving explained that he was teaching out of Rudin [29] when he got my note on that Monday in May, so he immediately recognized that our trivial note was interesting.

The theorem was shown to be valid for LCA hypergroups K for which the set $\hat{K}$ of hypergroup characters is a hypergroup under pointwise operations [4, Theorem 2.9].

The L^p Conjecture

Finally, we discuss the "The L^p Conjecture," which also concerns L^1 and L^p spaces, and which had a similar history in the sense that the conjecture seemed quite difficult until it was finally settled. If G is compact, then Haar measure on G is finite and $L^p(G) \subseteq L^1(G)$. Therefore $L^p(G) * L^p(G) \subseteq L^1(G) * L^p(G) = L^p(G)$. The following possible converse was known as the "L^p conjecture" for some time:

The L^p conjecture

If $p > 1$ and $L^p(G) * L^p(G) \subseteq L^p(G)$, then G is compact.

This was conjectured by M. Rajagopalan in his 1963 Yale thesis, though the conjecture had already been settled in the abelian case by W. Żelazko [36]. Various authors, including Neil Rickert who was also a graduate student at Yale, made progress. They proved this result for various choices of p and various classes of groups such as discrete, totally disconnected, nilpotent, semi-direct product of LCA groups, solvable, and amenable. The project was essentially abandoned in the early 1970s. Then in 1990, Sadahiro Saeki [31, pages 615–620], also at Kansas State University, settled the conjecture for all locally compact groups with a self-contained ingenious proof.

Appendix: A Circle of Ideas

The key to both the factorization theorem and the "rate of decrease theorem" on the circle group $\mathbb{T} = [-\pi, \pi)$ is the fact that positive symmetric sequences (c_n) on $\mathbb{Z}$ that are convex on $\{0, 1, 2, \ldots\}$, and converge monotonically to 0 on $\{0, 1, 2, \ldots\}$, are Fourier transforms of nonnegative functions in $L^1(\mathbb{T})$; this is due to W. H. Young [35, 1913, Theorem, §3]; see also [37, Theorem (1.5), Chapter V] or [10, item 7.3.1].[13] In fact, the Fourier series of the function converges uniformly to the function outside of any neighborhood of 0. Every sequence on $\mathbb{Z}$ converging to 0 is easily shown to be dominated by such a "convex" symmetric sequence; this is noted in [37, just prior to (1.11), Chapter V] and proved in [10, item 7.1.5]. The "rate of decrease theorem" for $\mathbb{T}$ follows from this observation and W. H. Young's theorem. A. N. Kolmogorov [21, 1923] independently stated and proved the "rate of decrease theorem." As we noted earlier, we needed the Banach-module version of Cohen's factorization theorem to generalize this theorem to compact abelian groups and beyond.

A similar result holds for $\mathbb{R}$. In particular, every nonnegative symmetric (i.e., even) function ψ in $C_0(\mathbb{R})$ that is convex on $(0, \infty)$ is the Fourier transform of some function in $L^1(\mathbb{R})$. For $\psi(0) = 1$, this fact is known to probabilists as "Pólya's criterion," which states that any such function is the characteristic function of an absolutely continuous distribution function; see, for example, [19, Theorem 10.5.2]. As noted in Kai Lai Chung's appendix in [1, page 193], this result is "slightly hidden" in Pólya's paper [25, 1918].

The factorization theorem for $L^1(\mathbb{T})$ was established several years later and is universally credited to Raphaël Salem [32]. In fact, his focus was a bit different. He evidently wanted to show that, given f in $L^1(\mathbb{T})$, there is a function g in $L^1(\mathbb{T})$ whose Fourier transform goes to 0 on $\mathbb{Z}$ more slowly than the transform of f. [He showed a similar result for $C(\mathbb{T})$.] Specifically, he essentially showed that, given f in $L^1(\mathbb{T})$, there is a function g in $L^1(\mathbb{T})$ and a positive symmetric sequence (λ_n) on $\mathbb{Z}$ that is concave and increases monotonically to $+\infty$ on $\{0, 1, 2, \ldots\}$ and satisfies $\hat{f}(n) \cdot \lambda_n = \hat{g}(n)$ for all n. Zygmund [37, Notes to Chapter IV, §11] noted that the factorization theorem for $L^1(\mathbb{T})$ is an easy consequence. In fact, it is very easy to check that the sequence of reciprocals $(1/\lambda_n)$ is a convex sequence satisfying the hypotheses of W. H. Young's theorem mentioned above. Thus, for some h in $L^1(\mathbb{T})$, we have $\frac{1}{\lambda_n} = \hat{h}(n)$, so that $\hat{f}(n) = \hat{h}(n)\hat{g}(n)$ for all n. Hence $f = h * g$ by the uniqueness theorem for Fourier transforms. My guess is that this was observed sometime between 1939 and 1959 by Zygmund or by Salem himself. Or both, since "from 1945 to 1959, Zygmund's

[13] *Since the sequence (c_n) is symmetric, the corresponding Fourier series is a cosine series.*

closest friend and collaborator was Salem." [18] They wrote at least ten papers and one book jointly during that period.

Acknowledgments

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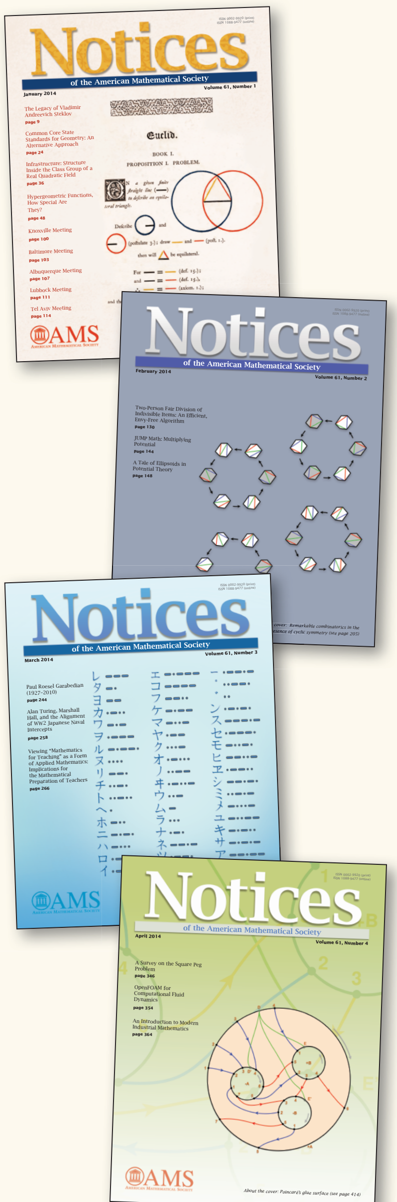

Applications and nominations are invited for the position of Editor of the *Notices of the American Mathematical Society*, to commence with the January 2016 issue. The Society seeks an individual with strong mathematical research experience, broad mathematical interests, and a commitment to communicating mathematics to a diverse audience at a wide range of levels. The applicant must demonstrate excellent written communication skills.

The Editor has editorial responsibility for a major portion of the *Notices* within broad guidelines. The goal of the *Notices* is to serve all mathematicians by providing a lively and informative magazine containing exposition about mathematics and mathematicians, and information about the profession and the Society.

The Editor is assisted by a board of Associate Editors, nominated by the Editor, who help to fashion the contents of the *Notices* and solicit material for publication. Some writing, and all publication support, will be provided by AMS staff in Providence. The Editor will operate from his or her home institution with part-time secretarial support. In order to begin working on the January 2016 issue, some editorial work would begin in early 2015.

Nominations and applications (including curriculum vitae) should be sent to the Executive Director, Donald E. McClure, at exdir@ams.org. Confidential inquiries may also be sent directly to the Executive Director or to any other member of the search committee (Dan Abramovich, Amber Puha, Carla Savage, or David Vogan).

To receive full consideration, nominations and applications should be sent on or before October 1, 2014.

Critique of Hirsch's Citation Index: A Combinatorial Fermi Problem

Alexander Yong

In 2005, physicist J. E. Hirsch [Hi05] proposed the h-index to measure the quality of a researcher's output. This metric is the largest integer n such that the person has n papers with at least n citations each, and all other papers have weakly less than n citations. Although the original focus of Hirsch's index was on physicists, the h-index is now widely popular. For example, *Google Scholar* and the *Web of Science* highlight the h-index, among other metrics such as total citation count, in their profile summaries.

An enticing point made by Hirsch is that the h-index is an easy and useful supplement to a citation count ($N_{\texttt{citations}}$), since the latter metric may be skewed by a small number of highly cited papers or textbooks. In his words:

> "I argue that two individuals with similar h's are comparable in terms of their overall scientific impact, even if their total number of papers or their total number of citations is very different. Conversely, comparing two individuals (of the same scientific age) with a similar number of total papers or of total citation count and very different h values, the one with the higher h is likely to be the more accomplished scientist."

It seems to us that users might tend to eyeball differences of h's and citation counts among individuals during their assessments. Instead, one desires a quantitative baseline for what "comparable," "very different," and "similar" actually mean. Now, while this would appear to be a matter for statisticians, we show how textbook combinatorics sheds some light on the relationship between the h-index and $N_{\texttt{citations}}$. We present a simple model that raises specific concerns about potential misuses of the h-index.

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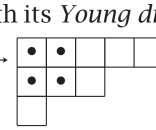
To begin, think of the list of a researcher's citations per paper in decreasing order $\lambda = (\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_{N_{\text{papers}}})$ as a *partition* of size $N_{\texttt{citations}}$. Graphically, λ is identified with its *Young diagram*.

For example, $\lambda = (5, 3, 1, 0) \leftrightarrow$ .

A combinatorialist will recognize that the h-index of λ is the side-length of the **Durfee square** (marked using $\bullet$'s above): this is the largest $h \times h$ square that fits in λ. This simple observation is nothing new, and appears in both the bibliometric and combinatorial literature; see, e.g., [AnHaKi09, FlSe09]. In particular, since the Young diagram of size $N_{\texttt{citations}}$ with maximum h-index is roughly a square, we see graphically that $0 \leq h \leq \lfloor \sqrt{N_{\texttt{citations}}} \rfloor$.

Next, consider the following question:

Given $N_{\texttt{citations}}$, what is the estimated range of h?

Taking only $N_{\texttt{citations}}$ as input hardly seems like sufficient information to obtain a meaningful answer. It is exactly for this reason that we call the question a *combinatorial Fermi problem*, by analogy with usual *Fermi problems*; see the section "Combinatorial Fermi Problems."

Table 1. Confidence intervals for h-index.

$N_{\text{citations}}$	50	100	200	300	400	500	750	1000	1250
Interval for h	[2, 5]	[3, 7]	[5, 9]	[7, 11]	[8, 13]	[9, 14]	[11, 17]	[13, 20]	[15, 22]

1500	1750	2000	2500	3000	3500	4000	4500	5000	5500
[17, 24]	[18, 26]	[20, 28]	[22, 31]	[25, 34]	[27, 36]	[29, 39]	[31, 41]	[34, 43]	[35, 45]

6000	6500	7000	7500	8000	9000	10000
[36, 47]	[37, 49]	[39, 51]	[40, 52]	[42, 54]	[44, 57]	[47, 60]

Table 2. Fields medalists 1998–2010.

Medalist	Award year	$N_{\text{citations}}$	h	Rule of thumb est.	Confidence interval
T. Gowers	1998	1012	15	17.2	[13, 20]
R. Borcherds	1998	1062	14	17.6	[14, 21]
C. McMullen	1998	1738	25	22.5	[18, 26]
M. Kontsevich	1998	2609	23	27.6	[22, 32]
L. Lafforgue	2002	133	5	6.2	[4, 8]
V. Voevodsky	2002	1382	20	20.0	[16, 23]
G. Perelman	2006	362	8	10.0	[7, 12]
W. Werner	2006	1130	19	18.2	[14, 21]
A. Okounkov	2006	1677	24	22.1	[18, 25]
T. Tao	2006	6730	40	44.3	[38, 51]
C. Ngô	2010	228	9	8.2	[5, 10]
E. Lindenstrauss	2010	490	12	12.0	[9, 14]
S. Smirnov	2010	521	12	12.3	[9, 15]
C. Villani	2010	2931	25	29.2	[24, 33]

Since we assume no prior knowledge, we consider each citation profile in an unbiased manner. That is, each partition of $N_{\text{citations}}$ is chosen with equal probability. In fact, there is a beautiful theory concerning the asymptotics of these uniform random partitions. This was largely developed by A. Vershik and his collaborators; see, e.g., the survey [Su10].

Actually, we are interested in "low" (practical) values of $N_{\text{citations}}$ where not all asymptotic results are exactly relevant. Instead, we use generating series and modern desktop computation to calculate the probability that a random λ has Durfee square size h. More specifically, we obtain Table 1 using the **Euler–Gauss identity** for partitions:

$$\prod_{i=1}^{\infty} \frac{1}{1-x^i} = 1 + \sum_{k\geq 1} \frac{x^{k^2}}{\prod_{j=1}^{k}(1-x^j)^2}. \tag{1}$$

The proof of (1) via Durfee squares is regularly taught to undergraduate combinatorics students; it is recapitulated in the section "The Euler–Gauss Identity and its Application to the h-index." The pedagogical aims of this note are elaborated upon in sections "Combinatorial Fermi Problems" and "The Euler–Gauss Identity and its Application to the h-index."

The asymptotic result we use, due to E. R. Canfield–S. Corteel–C. D. Savage [CaCoSa98], gives the mode size of the Durfee square when $N_{\text{citations}} \to \infty$. Since their formula is in line with our computations, even for low $N_{\text{citations}}$, we reinterpret their work as the rule of thumb for h-index:

$$h = \frac{\sqrt{6}\log 2}{\pi}\sqrt{N_{\text{citations}}} \approx 0.54\sqrt{N_{\text{citations}}}.$$

The focus of this paper is on mathematicians. For the vast majority of those tested, the actual h-index computed using *MathSciNet* or *Google Scholar* falls into the confidence intervals. Moreover, we found that the rule of thumb is fairly accurate for pure mathematicians. For example, Table 2 shows this for post-1998 Fields medalists.[1]

[1] *Citations pre-*2000 *in MathSciNet are not complete.* Google scholar *and Thompson Reuters'* Web of Science *also have sources of error. We decided that MathSciNet was our most complete option for analyzing mathematicians. For relatively recent Fields medalists, the effect of lost citations is reduced.*

In [Hi05] it was indicated that the h-index has predictive value for winning the Nobel Prize. However, the relation of the h index to the Fields Medal is, in our opinion, unclear. A number of the medalists' h values above are shared (or exceeded) by noncontenders of similar academic age, or with those who have similar citation counts. Perhaps this reflects a cultural difference between the mathematics and the scientific communities.

In the section "Further Comparisons with Empirical Data," we analyze mathematicians in the National Academy of Sciences, where we show that the correlation between the rule of thumb and actual h-index is $R = 0.94$. After removing book citations, $R = 0.95$. We also discuss Abel Prize winners and associate professors at three research universities.

Ultimately, readers are encouraged to do checks of the estimates themselves.

We discuss three implications/possible applications of our analysis.

Comparing h's when $N_{\mathtt{citations}}$'s Are Very Different

It is understood that the h-index usually grows with $N_{\mathtt{citations}}$. However, when are citation counts so different that comparing h's is uninformative? For example, $h_{\text{Tao}} = 40$ $(6,730$ citations) while $h_{\text{Okounkov}} = 24$ $(1,677$ citations). The model asserts the probability of $h_{\text{Okounkov}} \geq 32$ is less than 1 in 10 million. Note the *Math Genealogy Project* has fewer than $200,000$ mathematicians.

These orders of magnitude predict that no mathematician with $1,677$ citations has an h-index of 32, even though *technically* it can be as high as 40. Similarly, one predicts the rarity of pure mathematicians with these citations having "similar" h-index (in the pedestrian sense). This is relevant when comparing (sub)disciplines with vastly different typical citation counts. We have a theoretical caution about "eyeballing."

The Rule of Thumb and the Highly Cited

The model suggests the theoretical behavior of the h-index for highly cited scholars. The extent to which these predictions hold true is informative. This is true not only for individuals, but for entire fields as well.

Actually, Hirsch defined a proportionality constant a by $N_{\mathtt{citations}} = ah^2$ and remarked, "I find empirically that a ranges between 3 and 5." This asserts h is between $\sqrt{1/5} \approx 0.45$ and $\sqrt{1/3} \approx 0.58$ times $\sqrt{N_{\mathtt{citations}}}$.

One can begin to try to understand the similarity between Hirsch's empirical upper bound and the rule of thumb. A conjecture of E. R. Canfield (private communication, see the section "The Euler–Gauss Identity …") asserts concentration around the mode Durfee square. Thus, *theoretically*, one expects the rule of thumb to be nearly correct for large $N_{\mathtt{citations}}$.

Alas, this is empirically not true, even for pure mathematicians. However, we observe something related: $0.54\sqrt{N_{\mathtt{citations}}}$ is higher than the actual h for almost every very highly cited ($N_{\mathtt{citations}} > 10,000$) scholar in mathematics, physics, computer science and statistics (among others) we considered. On the rare occasion this fails, the estimate is only beat by a small percentage (< 5 percent). The drift in the other direction is often quite large (50 percent or more is not unusual in certain areas of engineering or biology).

Near equality occurs among Abel Prize winners. We also considered all prominent physicists highlighted in [Hi05] (except Cohen and Anderson, due to name conflation in *Web of Science*). The guess is always an upper bound (on average 14–20 percent too high). Near equality is met by D. J. Scalapino $(25,881$ citations; 1.00), C. Vafa $(22,902$ citations; 0.99), J. N. Bahcall $(27,635$ citations; 0.98); we have given the ratio $\frac{\text{true } h}{\text{estimated } h}$.

One reason for highly cited people to have a lower than expected h-index is that they tend to have highly cited textbooks. Also, famous academics often run into the "Matthew effect" (e.g., gratuitous citations of their most well-known articles or books).

Anomalous h-Indices

More generally, our estimates give a way to flag an anomalous h-index for active researchers; i.e., those that are far outside the confidence interval or those for which the rule of thumb is especially inaccurate.

To see what effect book citations have on our estimates, consider the combinatorialist R. P. Stanley. Since Stanley has $6,510$ citations, we estimate his index as 43.6. However, $h_{\text{Stanley}} = 35$, a 20 percent error. Now, $3,362$ of his citations come from textbooks. Subtracting these, one estimates his h-index as 30.3, while his revised h-index is 32, only a 5 percent error. This kind of phenomenon was not uncommon; see Table 5.

For another example, consider T. Tao's *Google Scholar* profile. Since he has $30,053$ citations, the rule of thumb predicts his h-index is 93.6. This is far from his actual h-index of 65. Now, his top five citations (joint with E. Candes on compressed sensing) are applied. Removing the papers on this topic leaves $13,942$ citations. His new estimate is therefore 63.7 and his revised h-index is 61.

In many cases we have looked at, once the "skewing" feature of the scholar's profile is removed, the remainder of their profile agrees with the rule of thumb.

Conclusions and Summary

Whether it be Fields medalists, Abel Prize laureates, job promotion, or grant candidates, clearly, the quality of a researcher cannot be fully measured by numerics. However, in reality, the h-index is used, formally or informally, for comparisons. This paper attempts to provide a theoretical and testable framework to quantitatively understand the limits of such evaluations. For mathematicians, the accuracy of the rule of thumb suggests that the differences of the h-index between two mathematicians is strongly influenced by their respective citation counts.

While discussion of celebrated mathematicians and their statistics makes for fun coffee shop chatter, a serious way that the h-index comes up in faculty meetings concerns relatively junior mathematicians. Consider a scholar A with 100 citations and an h-index of 6 and a scholar B who has 50 citations and an h-index of 4. Such numbers are not atypical of math assistant professors going up for tenure. Our model predicts h_A to be a little bigger than h_B. Can one really discern what portion of $h_A - h_B$ is a signal of quality?

The problem becomes larger when A and B are in different subject areas. Citations for major works in applied areas tend to be more numerous than in pure mathematics. In experimental fields, papers may have many coauthors. Since the h-index does not account for authorship order, this tends to affect our estimates for such subjects.

Pure mathematicians have comparatively fewer coauthors, papers, and citations. It is not uncommon for instance, for solutions to longstanding open problems, to have relatively few citations. Thus an explanatory model for pure mathematicians has basic reasons for being divergent for some other fields. Yet, if this is the case, can the h-index really be used universally? This gives us a theoretical reason to question whether one can make simple comparisons across fields, even after a rescaling, as has been suggested in [IgPe07].

Combinatorial Fermi Problems

Usual Fermi Problems

Fermi problems are so-named after E. Fermi, whose ability to obtain good approximate quantitative answers with little data available is legendary. As an illustration, we use the following example [Co]:

How many McDonald's restaurants operate in the United States?

There are ten McDonald's in Champaign county, which has a population of about 200,000. *Assume the number of McDonald's scales with population.* Since the population of the United States is 300 million, a "back-of-the-envelope" calculation estimates the number of McDonald's at 15,000. The actual answer, as of 2012, is 14,157.

Using a simplified assumption like the italicized one above is a feature of a Fermi problem. Clearly the uniform assumption made is not really correct. However, the focus is on good, fast approximations when more careful answers are either too time consuming to determine, or maybe even impossible to carry out. The approximation can then be used in order to guide further work to determine more accurate/better justified answers.

Now, although the estimate is rather close to the actual number, when the estimate is not good, the result is even more interesting, as it helps identify a truly faulty assumption. For instance, analogous analysis predicts that the number of Whole Foods Markets in the United States is 0. Apparently, the presence of that company does not scale by population.

Fermi problems/back-of-the-envelope calculations are a standard part of a physics or engineering education. They are of theoretical value in the construction of mathematical models, and of "real world" value in professions such as management consulting. However, perhaps because the concept is intrinsically nonrigorous, it is not typically part of a (pure) mathematics curriculum. Specifically, this is true for enumerative combinatorics, even though the subject's purpose is to count the number of certain objects—which in the author's experience, many students hope has nontheoretical applicability.

A Combinatorial Analogue

By analogy we define a **combinatorial Fermi problem**:

> Fix $\epsilon > 0$. Let S be a finite set of combinatorial objects and $\omega : S \to \mathbb{Z}_{\geq 0}$ be a statistic on S. Then, we estimate the value of ω on any element to be the **confidence interval** $[a, b]$ where the *uniform* probability of picking an element of S outside of this range has probability $< \epsilon$.

By definition, the (ordinary) **generating series** for the **combinatorial problem** (S, ω) is defined by $G_{(S,\omega)}(x) = \sum_{s \in S} x^{\omega(s)}$. For any k, $\#\{s \in S : \omega(s) = k\} = [x^k]G_{(S,\omega)}(x)$; i.e., the coefficient of x^k in $G_{(S,\omega)}(x)$. Usually textbook work involves extracting the coefficient using formulae valid in the ring of formal power series. However, what is often not emphasized in class is that this coefficient, and $\#S$ itself, can be rapidly extracted using a computer algebra system, allowing for a quick determination of the range $[a, b]$. Since the computer does the work, this is our analogue of a "back-of-the-envelope" calculation.

Table 3. Abel Prize recipients.

Laureate	Award year	$N_{\texttt{citations}}$	h	rule of thumb est.	Estimated range
J. P. Serre	2003	10119	53	54.3	$[47, 60]$
I. Singer	2004	2982	28	29.5	$[24, 34]$
M. Atiyah	2004	6564	40	43.7	$[37, 49]$
P. Lax	2005	4601	30	36.6	$[31, 42]$
L. Carleson	2006	1980	18	24.0	$[19, 28]$
S. R. S. Varadhan	2007	2894	28	29.0	$[24, 33]$
J. Thompson	2008	789	14	15.2	$[11, 18]$
J. Tits	2008	3463	28	31.8	$[27, 36]$
M. Gromov	2009	7671	41	47.3	$[40, 54]$
J. Tate	2010	2979	30	29.5	$[24, 34]$
J. Milnor	2011	7856	48	47.9	$[41, 54]$
E. Szemerédi	2012	2536	26	27.2	$[22, 31]$
P. Deligne	2013	6567	36	43.8	$[37, 50]$

For "reasonable" values of ϵ (such as $\epsilon = 2$ percent), often the range $[a, b]$ is rather tight. In those cases, there may be a theorem of *asymptotic* concentration near a "typical" object. However, even if such theorems are known, this does not solve the finite problem.

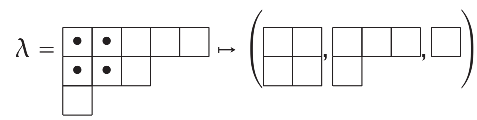
The use of the uniform distribution is a quick way to exactly obtain estimates that can be compared with empirical data. Ultimately, it invites the user to consider other probability distributions and more sophisticated statistical analysis (just as one should with the McDonald's example), using, e.g., Markov Chain Monte Carlo techniques.

We mention another combinatorial Fermi problem we have considered elsewhere: the count of the number of indigenous language families in the Americas [Yo13]. That is a situation where essentially there is no way to know with great certainty the true answer.

The Euler–Gauss Identity and its Application to the h-Index

We apply the perspective of Section 2 to the h-index question, where $S = \mathsf{Par}(n)$ and $\omega : S \to \mathbb{Z}_{\geq 0}$ is the size of a partition's Durfee square. If Par is the set of all partitions and $\sigma : \mathsf{Par} \to \mathbb{Z}_{\geq 0}$ returns the size of a partition, then the generating series for (Par, σ) is $P(x) = \prod_{i=1}^{\infty} \frac{1}{1-x^i}$. That is, $\#\mathsf{Par}(n) = [x^N]P(x)$. A sample textbook reference is [Br10].

Recall the **Euler–Gauss identity** (1) from the introduction. The well-known combinatorial proof is that every Young diagram λ bijectively decomposes into a triple $(D_\lambda, R_\lambda, B_\lambda)$ where D_λ is a $k \times k$ square, R_λ is a Young diagram with at most k rows, and B_λ is a partition with at most k columns. That is, D_λ is the Durfee square, R_λ the shape to the right of the square, and B_λ is the shape below it. For example:



$$= (D_\lambda, R_\lambda, B_\lambda).$$

The generating series for partitions with at most k columns is directly $\prod_{j=1}^{k} \frac{1}{1-x^j}$. Since conjugation (the "transpose") of a shape with at most k rows returns a shape with at most k columns, it follows that the generating series for shapes of the first kind is also $\prod_{j=1}^{k} \frac{1}{1-x^j}$.

From this argument, we see that the generating series for Young diagrams with a Durfee square of size k is $x^{k^2} \prod_{j=1}^{k} (1 - x^j)^{-2}$. We compute, for fixed $h, N_{\texttt{citations}}$:

$$\mathsf{Prob}(\lambda : |\lambda| = N_{\texttt{citations}}, \text{ Durfee square of size } k) = \frac{[x^{N_{\texttt{citations}}}] x^{k^2} \prod_{j=1}^{k} (1 - x^j)^{-2}}{\mathsf{Par}(N_{\texttt{citations}})}.$$

Often textbook analysis ends at the derivation of (1). In a classroom, using a computer to Taylor expand $\sum_{k=a}^{b} x^{k^2} \prod_{j=1}^{k} (1 - x^j)^{-2}$, and comparing the coefficients with the known partition numbers allows the instructor to "physically" demonstrate the identity to the student. Varying a and b shows what range of Durfee square sizes is, e.g., 98 percent likely to occur for partitions of that size. Interpreted in terms of our h-index problem, these same computations are what give us Table 1.[2]

[2] *Actually, our computation of* $\mathsf{Par}(N_{\texttt{citations}})$ *using generating series becomes not so easy on a desktop machine when* $N_{\texttt{citations}}$ *is a few thousand. Instead, one could use the Hardy-Ramanujan approximation* $\mathsf{Par}(N_{\texttt{citations}}) \sim \frac{1}{4N_{\texttt{citations}}\sqrt{3}} e^{\pi\sqrt{\frac{2N_{\texttt{citations}}}{3}}}$. *Even more precisely, one can*

Table 4. Associate professors at three research universities.

	$N_{\mathtt{citations}}$	h	rule of thumb est.	estimated range
Department A				
A1	19	3	2.4	$[1,3]$
A2	80	6	4.8	$[3,6]$
A3	113	6	5.7	$[4,7]$
A4	130	4	6.1	$[4,8]$
A5	202	6	7.7	$[5,10]$
A6	511	11	12.2	$[9,15]$
Department B				
B1	30	3	3.0	$[1,4]$
B2	35	4	3.2	$[2,4]$
B3	56	4	4.0	$[2,5]$
B4	56	5	4.0	$[2,5]$
B5	63	5	4.3	$[3,5]$
B6	63	6	4.3	$[3,5]$
B7	78	3	4.8	$[3,6]$
B8	84	5	4.9	$[3,6]$
B9	88	7	5.1	$[3,6]$
B10	122	8	6.0	$[4,7]$
B11	126	7	6.1	$[4,7]$
B12	133	6	6.2	$[4,8]$
B13	133	7	6.2	$[4,8]$
B14	150	8	6.6	$[4,8]$
B15	163	7	6.9	$[5,8]$
B16	228	10	8.1	$[5,10]$
Department C				
C1	10	2	1.7	$[1,2]$
C2	11	2	1.8	$[1,2]$
C3	25	3	2.7	$[1,3]$
C4	54	4	4.0	$[2,5]$
C5	64	5	4.3	$[3,5]$
C6	64	5	4.3	$[3,5]$
C7	67	6	4.4	$[3,5]$
C8	104	6	5.5	$[4,7]$
C9	144	8	6.5	$[4,8]$
C10	269	5	8.9	$[6,11]$

As we state in the introduction, the work of [CaCoSa98] shows that the model Durfee square size is $\approx 0.54\sqrt{N_{\mathtt{citations}}}$. E. R. Canfield's concentration conjecture states that for each $\epsilon > 0$,

(2)
$$\frac{\#\text{ partitions with } (1-\epsilon)\mu < h < (1+\epsilon)\mu}{\#\mathsf{Par}(N_{\mathtt{citations}})} \to 1,$$

as $N_{\mathtt{citations}} \to \infty$, where $\mu = \frac{\sqrt{6}\log 2}{\pi}\sqrt{N_{\mathtt{citations}}}$. This is consistent with Table 1. Further discussion may appear elsewhere. Also, one would like to examine other distributions on Young diagrams, such as the Plancherel measure, which assigns to the shape λ the probability $(f^\lambda)^2/|\lambda|!$ where f^λ is the number of *standard Young tableaux* of shape λ.

use Wolfram Alpha, which gives the partition numbers for up to a million; this is well beyond our needs.

Further Comparisons with Empirical Data

The National Academy of Sciences

We compared our rule of thumb against all 119 mathematicians of the National Academy of Sciences (see Figures 1 and 2 and the Appendix). The correlation coefficient is $R = 0.93$. After removing books (as identified in *MathSciNet)*, $R = 0.95$. A serious concern is that many pre-2000 citations are not tabulated in *MathSciNet*. Nevertheless, in our opinion, the results are still informative. See the comments in "Further Study".

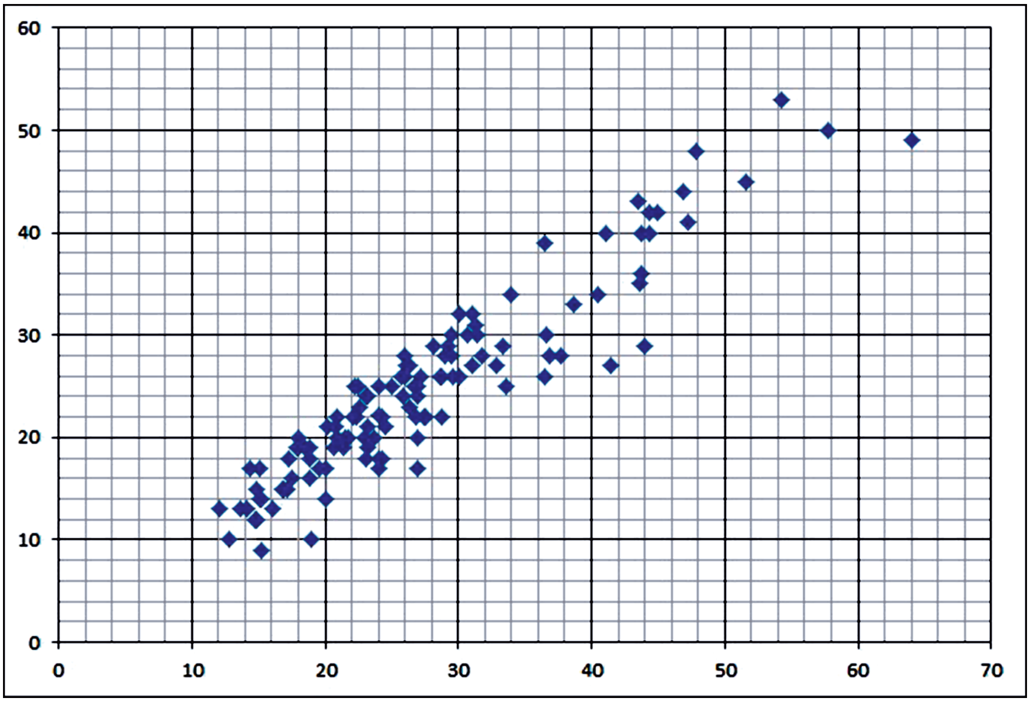


Figure 1. Rule of thumb (x-axis) versus actual h's (y-axis) for mathematics members of the National Academy of Sciences.

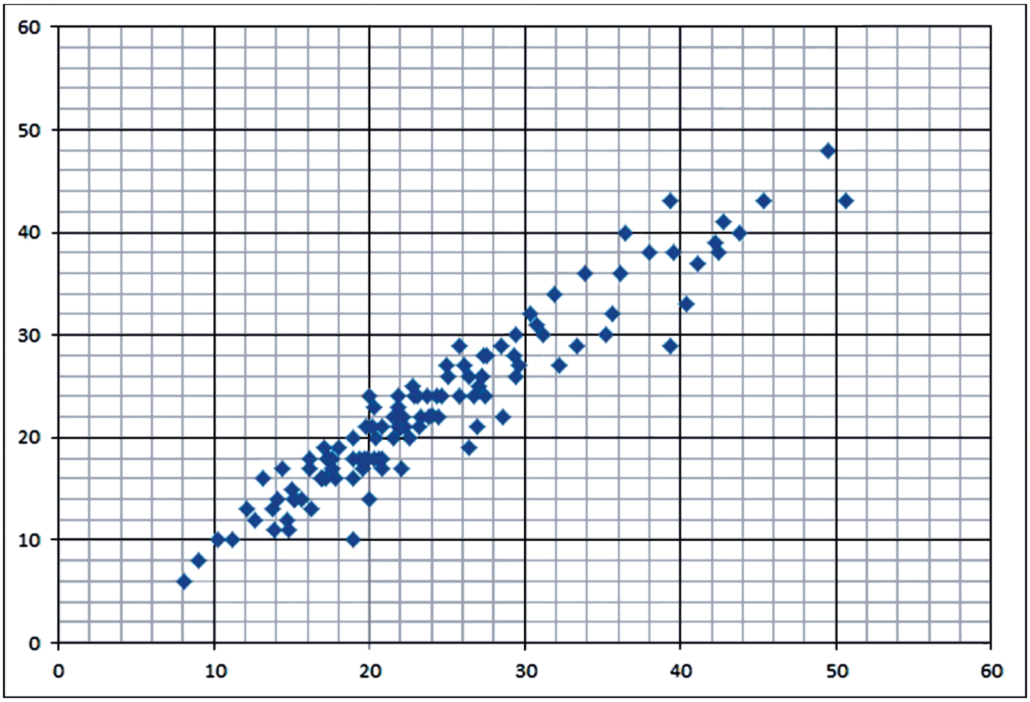


Figure 2. Rule of thumb (x-axis) versus actual h's (y-axis) for mathematics members of the National Academy of Sciences (*with books removed*).

Table 5. Current National Academy of Sciences Members (Mathematics).

Member	$N_{\mathtt{citations}}$	Rule of thumb est.	h	non-books only	revised est.	revised h
G. Andrews	4866	37.7	28	2579	27.4	24
M. Artin	2326	26	26	2097	24.7	24
M. Aschbacher	1386	20	17	911	16.3	13
R. Askey	2480	26.9	17	1235	19.0	16
M. Atiyah	6564	43.7	40	5390	39.6	38
H. Bass	2472	26.8	22	1869	23.3	22
E. Berlekamp	764	14.9	12	363	10.3	10
J. Bernstein	2597	27.5	22	2484	26.9	21
S. Bloch	1497	20.9	20	1363	19.9	18
E. Bombieri	1746	22.6	23	1608	21.7	22
J. Bourgain	6919	44.9	42	6590	43.8	40
H. Brezis	11468	57.8	50	8386	49.5	48
F. Browder	2815	28.7	22	2807	28.6	22
W. Browder	646	13.7	13	547	12.6	12
R. Bryant	1489	20.8	21	1228	18.9	20
L. Caffarelli	6745	44.3	42	6280	42.8	41
E. Calabi	1224	18.9	18	1224	18.9	18
L. Carleson	1980	24	18	1484	20.8	17
S.-Y. Alice Chang	1828	23.1	24	1806	22.9	24
J. Cheeger	3387	31.4	30	3348	31.2	30
D. Christodoulou	783	15.1	17	594	13.2	16
A. Connes	6475	43.5	43	5318	39.4	43
I. Daubechies	4674	36.9	28	3002	29.6	27
P. Deift	3004	29.6	26	2545	27.2	26
P. Deligne	6567	43.8	36	5592	40.4	33
P. Diaconis	3233	30.7	30	2970	29.4	30
S. Donaldson	2712	28.1	29	2277	25.8	29
E. Dynkin	1583	21.5	20	1090	17.8	16
Y. Eliashberg	1628	21.8	20	1460	20.6	18
L. Faddeev	1820	23	20	1285	19.4	18
C. Fefferman	3828	33.4	29	3815	33.4	29
M. Freedman	1207	18.8	16	990	17	16
W. Fulton	5890	41.4	27	1424	20.4	20
H. Furstenberg	2064	24.5	21	1650	21.9	21
D. Gabai	1314	19.6	17	1314	19.6	17
J. Glimm	1826	23.1	18	1419	20.3	18
R. Graham	3881	33.6	25	2280	25.8	24
U. Grenander	895	16.1	13	227	8.1	6
P. Griffiths	4581	36.5	26	1692	22.2	22
M. Gromov	7671	47.3	41	6200	42.5	38
B. Gross	1692	22.2	25	1635	21.8	24

Continued on page 1048

Member	$N_{\texttt{citations}}$	Rule of thumb est.	h	non-books only	revised est.	revised h
V. Guillemin	3710	32.9	27	2035	24.4	22
R. Hamilton	2490	26.9	20	2392	26.4	19
M. Hochster	1727	22.4	22	1657	22	21
H. Hofer	2140	25	25	1928	23.7	24
MJ. Hopkins	714	14.4	17	714	14.4	17
R. Howe	1680	22.1	22	1579	21.5	22
H. Iwaniec	2822	28.7	26	1825	23.1	24
A. Jaffe	794	15.2	9	277	9	8
P. Jones	1112	18	19	1112	18	19
V. Jones	2025	24.3	18	1669	22.1	17
R. Kadison	1922	23.7	20	1042	17.4	18
R. Kalman	558	12.8	10	428	11.2	10
N. Katz	2370	26.3	23	1582	21.5	20
D. Kazhdan	2332	26.1	27	2332	26.1	27
R. Kirby	963	16.8	15	678	14.1	14
S. Klainerman	2324	26	28	2144	25.0	27
J. Kohn	1231	18.9	19	1068	17.6	18
J. Kollár	3100	30.1	26	1947	23.8	22
B. Kostant	2509	27	25	2509	27	25
R. Langlands	1466	20.6	19	773	15.0	15
H.B. Lawson	2576	27.4	22	1846	23.2	21
P. Lax	4601	36.6	30	3560	32.2	27
E. Lieb	5147	38.7	33	4349	35.6	32
T. Liggett	1975	24	17	984	16.9	16
L. Lovasz	5638	40.5	34	4259	35.2	30
G. Lusztig	5786	41.1	40	4945	38.0	38
R. MacPherson	2031	24.3	22	1676	22.1	21
G. Margulis	2267	25.7	26	1788	22.8	25
J. Mather	1399	20.2	21	1399	20.2	21
B. Mazur	2842	28.8	26	2440	26.7	24
D. McDuff	2289	25.8	24	1417	20.3	23
H. McKean	2480	26.9	24	1701	22.3	21
C. McMullen	1738	22.5	25	1368	20.0	24
J. Milnor	7856	47.9	48	4559	36.5	40
J. Morgan	1985	24.1	25	1484	20.8	21
G. Mostow	1180	18.5	19	896	16.2	17
J. Nash	1337	19	10	1337	19	10
E. Nelson	1010	17.2	15	753	14.8	11
L. Nirenberg	9145	51.6	45	8781	50.6	43

Continued on page 1049

Member	$N_{\texttt{citations}}$	Rule of thumb est.	h	non-books only	revised est.	revised h
S. Novikov	2368	26.3	27	1677	22.1	21
A. Okounkov	1677	22.1	24	1677	22.1	24
D. Ornstein	1100	17.9	19	1022	17.3	18
J. Palis	1570	21.4	19	895	16.2	18
P. Rabinowitz	6633	44	29	5316	39.4	29
M. Ratner	506	12.1	13	506	12.1	13
K. Ribet	1022	17.3	18	1021	17.3	18
P. Sarnak	3114	30.1	32	2780	28.5	29
M. Sato	738	14.7	12	738	14.7	12
R. Schoen	3945	33.9	34	3493	31.9	34
J. Serre	10119	54.3	53	4481	36.1	36
C. Seshadri	984	16.9	15	831	15.6	14
Y. Sinai	3357	31.3	31	2547	27.3	28
I. Singer	2982	29.5	28	2951	29.3	28
Y. Siu	1494	20.9	22	1350	19.8	21
S. Smale	4581	36.5	39	3942	33.9	36
R. Solovay	781	15.1	14	781	15.1	14
J. Spencer	758	14.9	15	1334	19.7	18
R. Stanley	6510	43.6	35	3148	30.3	32
H. Stark	678	14.1	13	653	13.8	13
C. Stein	763	14.9	12	658	13.9	11
E. Stein	14049	64	49	5788	41.1	37
R. Steinberg	1850	23.2	19	1068	17.6	17
S. Sternberg	2438	26.7	25	1476	20.8	18
D. Stroock	3299	31.0	27	2028	24.3	24
D. Sullivan	3307	31.1	32	3248	30.8	31
R. Swan	1109	18	20	998	17.1	19
E. Szemerédi	2536	27.2	26	2536	27.2	26
T. Tao	6730	44.3	40	6214	42.3	39
J. Tate	2979	29.5	30	2612	27.6	28
C. Taubes	1866	23.2	24	1626	21.8	23
J. Thompson	789	15.2	14	789	15.2	14
J. Tits	3463	31.8	28	2958	29.4	26
K. Uhlenbeck	1852	23.2	21	1756	22.6	20
S. Varadhan	2894	29	28	2153	25.1	26
D. Voiculescu	2952	29.3	29	2387	26.4	26
A. Wiles	1387	20	14	1387	20	14
S-T. Yau	7536	46.9	44	7066	45.4	43
E. Zelmanov	1055	17.5	16	1020	17.2	16

Abel Prize Winners

Perhaps a closer analogy to the Nobel Prize than the Fields Medal is the Abel Prize, since the latter does not have an age limit. The fit with the estimated intervals remains decent; the concern about pre-2000 citations remains. See Table 3.

Associate Professors

Finally, in Table 4 we considered all mathematics associate professors at three research universities. Of the thirty-two professors, all but five have their h-index in the estimated range, and all are at most one unit outside this range.

Further Study

It seems to us that the simple model presented describes one force governing the h-index. However, other forces/sources of noise are at play, depending on the field or even the fame of the scholar. Future work seeks to better understand this quantitatively, as one works toward more precise models.

The loss of pre-2000 citations in *MathSciNet* is significant to how we interpret the results for the National Academy members/Abel Prize winners. For example, the rough agreement with the rule of thumb might only reflect an "equilibrium state" that arises years after major results have been published. This concern is partly allayed by the similar agreement for recent Fields medalists (Table 2). However, as *MathSciNet* reaches further back in tabulating citations, one would try to quantify these effects. In the meantime, use of *MathSciNet* has practical justification since, in promotion and grant decision cases, recent productivity is important. So for these purposes, post-2000 data is mostly sufficient.

As a further cross-check, we used the rule of thumb for a broad range of fields using *Google Scholar*. For scholars with a moderate number of citations, the agreement is often similarly good. Also the rule is an upper bound for the vast majority of highly cited scholars (but, as we have said earlier, much less accurate in some fields). However, these checks have an obvious bias as they only consider people who have set up a profile, so we do not formally present these results here.

We propose using the rule of thumb and the confidence intervals as a basis for a systematic study. We suggest that the rule of thumb reflects an "ideal scholar." (This terminology is an allusion to "ideal gas" in statistical mechanics. Indeed, a more conventional use of random partitions concerns the study of Boltzmann statistics on a one-dimensional lattice fermion gas.) Divergence from this ideal is a result of "anomalies." For a choice of field, can one statistically distinguish, on quantifiable grounds, scholars who are close to the rule of thumb (in the sense of confidence intervals) from those who are far from it?

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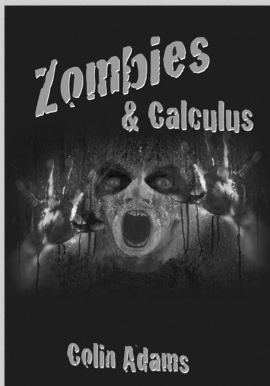

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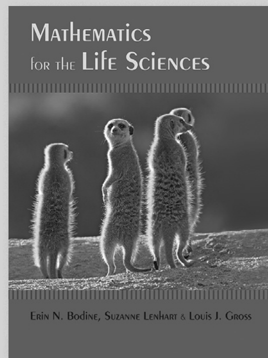

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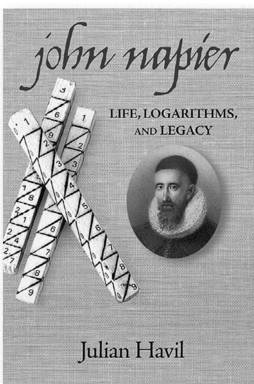

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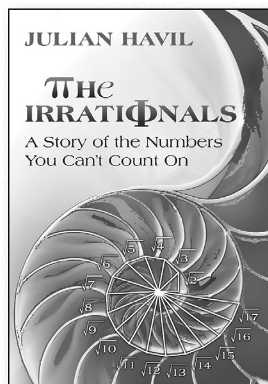

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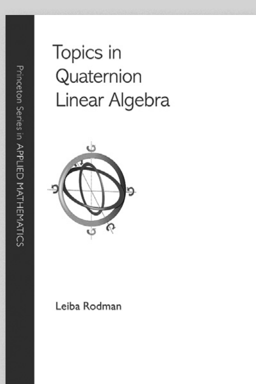

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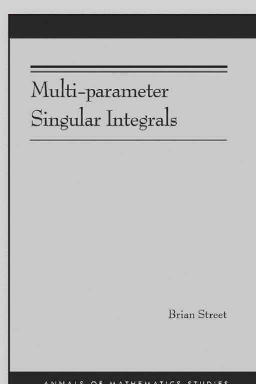

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Mathematics in Latin America and the Caribbean: So Much Happening, So Much to Do

Luis Cáceres, José Antonio de la Peña, Angel R. Pineda, Carlos Di Prisco, and Andrea Solotar

In 2010, prior to the International Congress of Mathematicians (ICM) held in Hyderabad, new authorities of the Commission for Developing Countries (CDC) of the International Mathematical Union (IMU) were elected. In 2011, the CDC met at the new permanent office of the IMU at the Weierstrass Institute in Berlin. Part of the discussion centered on the possibility of organizing a meeting of sponsors of the IMU prior to the next ICM to be held in South Korea in August 2014. One a priori requirement was stressed for the sponsors' meeting: The IMU should know the most urgent needs of the member states and the possibilities for mathematical development. Once this was achieved, resources would be able to be identified and allocated to strategic programs such as volunteer lecturer programs. The mapping of needs and strengths would serve as a guide to what is feasible to do and where to do it. This article presents the highlights of the report on the mathematical development in Latin America and the Caribbean (LAC). The event bringing together sponsors and development projects (MENAO, Mathematics in Emerging Nations: Achievements and Opportunities) was held on August 12, 2014, in conjunction with the NANUM 2014 program in which the Korean ICM hosts invited 1,000 mathematicians from the developing world to attend the ICM. Nanum is a Korean word that means gracious and unconditional sharing.

Language, culture, and even a general approach to life are common to most countries in LAC. Some of the cultural similarities are found in the heaviness of convoluted bureaucracies and the inhomogeneous distribution of wealth, but also in optimism and hope. There are also many differences within and between countries. Here we identify some common patterns of the development of mathematics in this region while recognizing the differences.

LAC suffers from a severe shortage of financial and human resources, excruciating burdens of government incompetence, and a lack of interest in scientific development. Despite these challenges, there are success stories in the region. The average performance in the mathematical olympiads has been improving; there are strong centers of mathematical research; scientific production shows Latin America as the zone of the planet with highest growth; UMALCA, a regional organization of mathematical societies, supports many regional schools every year and promotes collaboration among mathematicians of the region. In short, there are reasons to be optimistic, but the building of a better future requires the concerted action of mathematicians and organizations (regional and global) to develop the full potential of mathematics in this region of the world. The following example illustrates both the challenges and the opportunities.

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Paraguay, a country adjacent to the more developed Argentina and Brazil, until recently had never had a graduate degree program in mathematics. At the engineering department of the National University of Asunción (UNA), UMALCA held the first school in mathematics in September 2005. Organized by a group of mathematicians including a postdoctoral associate at IMPA, the mathematics institute in Rio de Janeiro, and by representatives of the Mathematical Paraguayan Olympics (OMAPA) who coordinated the participation of high school students, the response to the UMALCA call was amazing. Not only did students from several schools participate, school teachers and engineers did also. There were newspaper articles about the event. Today at UNA, there are a Masters program in mathematics and Masters and Ph.D. programs in computer science. The first Ph.D. in the history of Paraguay graduated in 2011. In a few years the number of professional mathematicians in the country has rocketed to fifteen. In addition, there is a demand for scientific progress in the country. This led to the creation, by law of the Paraguayan Congress, of the National Fund for Excellence in Education and Research.

There are many examples, but the essence remains: some action from professional mathematicians is needed to initiate changes in policies and old structures. Our intention in creating this mapping of mathematics in LAC is to identify the most urgent needs from the region and the capacities already in place that may serve to start the action.

Network of Contacts for Mapping Development

Mapping the mathematical development in LAC required creating a network of mathematicians. These contacts were critical in getting information for smaller countries in earlier stages of development where there was no information available online. Mathematicians were identified through their involvement with the mathematical olympiads, previous conference attendance, and personal communications by the authors of this article. The mathematicians who supported this effort filled out a questionnaire which provided information beyond what could be obtained from online sources. This information was included in the summaries for each of the countries and regions in the IMU report. The list of contributors, along with their contact information, was a major product of this report and has already been used to both distribute information about available resources and identify local contacts to coordinate development efforts.

Visualizing Mathematical Development

The complexity of the state of mathematical research in the LAC region cannot be captured by a single number [1]. Our intent with Figure 1 is to visualize rough indicators of the untapped mathematical potential in terms of human capital (mathematical publications per capita). There is a big difference between Canada and the United States and the LAC region.

Under the assumption that mathematical talent is uniformly distributed, Figure 1 visually displays the efficiency of converting that talent into new mathematical knowledge as reflected by publications. We see a large variability in the efficiency across the LAC region. In the extremes, the number of publications per capita of Chile is approximately

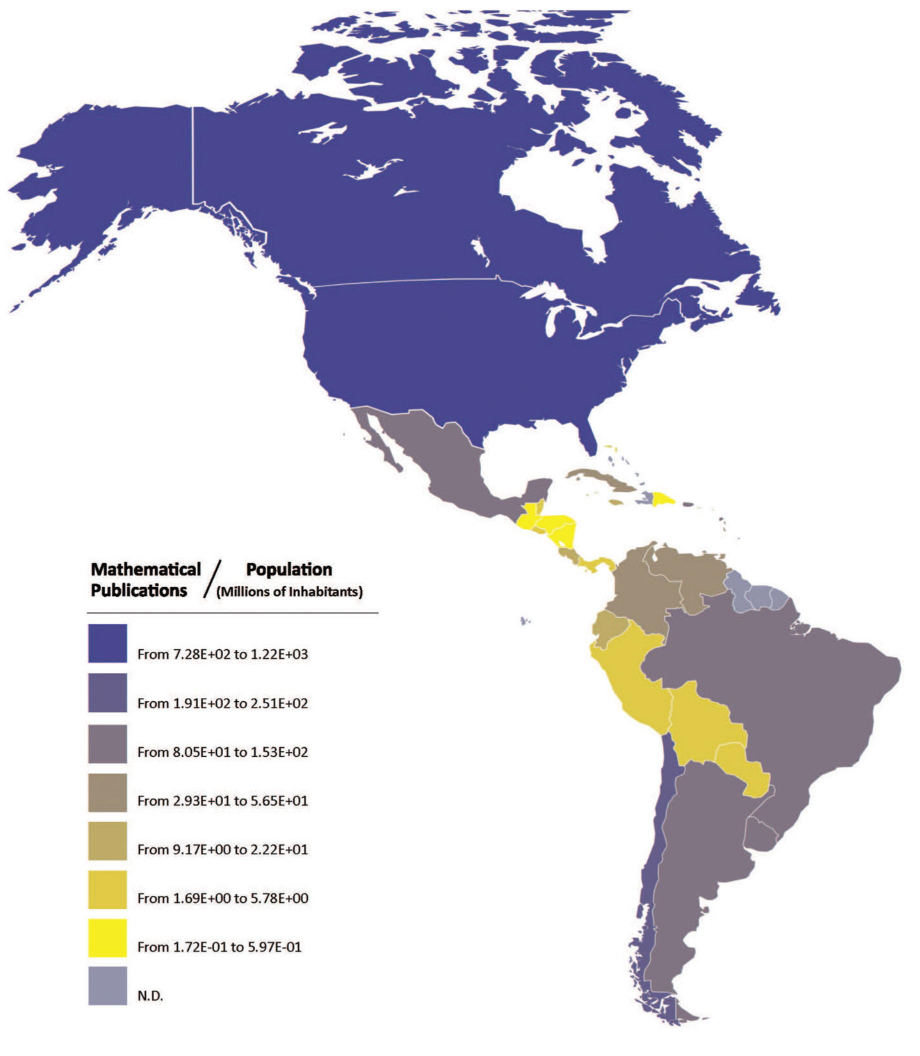

Figure 1. Map showing the per capita mathematical publications in the LAC region.

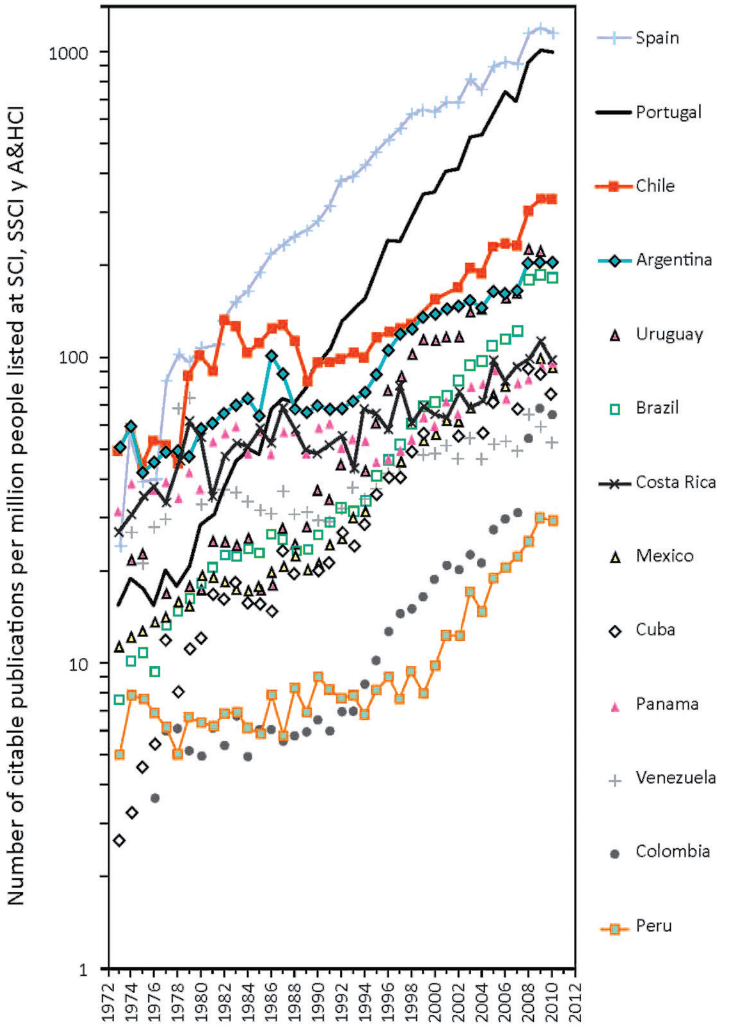

Figure 2. Number of citable publications per million people for the Iberoamerican countries with the largest number of publications.

1,450 times larger than that of Nicaragua. If we consider a country in the top 25 percent (Venezuela), it is approximately 123 times more efficient than a country in the top 75 percent (Honduras). A critical factor which leads to such a discrepancy in scientific output is whether a country has reached a development level where it can sustain a Ph.D. program in mathematics. We should also note that this measure only reflects the number of publications produced and does not account for the quality of the publications or the investment made by the governments in science.

Mexico, Brazil, Argentina, and Chile have large centers of mathematical research but also a large variability in the mathematical level within the countries. They could serve as a resource and model for mathematical development of the region. The situation in Central America is different: a population of more than forty million people has no access to a local Ph.D. program in mathematics. The Caribbean has the largest variability within LAC in terms of language and geography. There is a Ph.D. program in Puerto Rico which could serve as a resource. It is worth noting that communication among the islands has been facilitated by the mathematical olympiads.

Overall Research Growth in the LAC Region

Within the 147 most scientifically productive countries in the world, covering a ten-year plus eight-month period (January 2000–August 31, 2010), the Iberoamerican countries included among the top twenty were Spain (ranked nine) and Brazil (ranked fifteen). Within the same period, Mexico was ranked twenty-eight, Portugal was ranked thirty-four, and Argentina was ranked thirty-five. This is an interesting improvement if we take into account that a similar survey made between 1967 and 1973 had Argentina (ranked twenty-seven), Spain (ranked twenty-nine), Brazil (ranked thirty-two), and Mexico (ranked thirty-four) as the most productive nations of the Iberoamerican and Caribbean region [2]. Nevertheless, the scientific productivity of most of the Latin American countries, between the late 1970s and the late 1980s, remained almost constant. From the mid-1990s, most of the nations of the region began increasing their productivity again. The political and economic changes are reflected in Figure 2. For example, the jump in the productivity in Argentina in 1986 can be explained by political changes starting at the end of 1983 in that country.

Observe that Portugal has the highest growth constant of our sample. Within a period of thirty-eight years, Portugal increased its publications by a factor of seventy-six and its publications per million people by a factor of sixty-four. This dramatic change in the production of Portugal, due in part to political changes (e.g., entering the European Union in 1986), shows that, with the appropriate environment, countries in the LAC region could experience accelerated research productivity. Specifically, the growth of mathematical production in the LAC region has doubled in the span of eight years (1999 to 2007) according to the SCImago [3], [4] database. There is no other region of the world with this amount of growth in this time period.

Mechanisms for Fostering Development

Latin America and the Caribbean have large untapped potential for mathematical talent. With a better use of the region's financial and human resources and the help of more developed countries, some strategic actions could have an important effect on the development of mathematics. Here we identify some specific, relatively low cost activities that may help this development and sustainability. Most of these activities are already in practice in some countries at a good level, but their support and propagation could have a major impact in particular in the less mathematically developed countries. At the heart of these actions is improving the educational level of university faculty and students.

Mathematical schools (EMALCAs) organized by UMALCA and CIMPA have had a large impact on mathematical research in the region. By bringing research mathematicians to developing countries, these schools provide access to mathematical knowledge not available locally. Of a similar nature is the volunteer lecturer program of the IMU. These activities help to create a network which includes mathematicians in countries with a different level of development.

There are resources currently available for mathematicians in developing countries which are underutilized because of lack of information, for example, scholarships for study at major research centers (CIMAT, IMPA, etc.) for students from the region. A major contribution to development would be fostering a network which would help to share information about opportunities.

In several countries of the LAC region, the mathematical olympiads have been a very effective vehicle for promoting mathematics and identifying highly talented students even in remote and low-income areas. The National Mathematical Olympiad in Brazil is an event of impressive magnitude; eighteen million young people are involved, which constitutes ten percent of the country's population. Promoting increased participation in the mathematical olympiads and supporting talented students who are identified through these competitions would have a big effect on both tapping into exceptional mathematical talent in the region and increasing popular enthusiasm about mathematics.

Conclusion

Mathematics education and research are effective tools for international scientific development because, within the context of science, mathematics is inexpensive and ubiquitous. The Latin American context shows fertile ground for supporting current activities which could have a dramatic impact on educational opportunities. The broad variability in publications per capita in Figure 1 and the growth in scientific production in Figure 2 help us to see what exists and what is possible in the region.

Some specific projects that could have a major impact on the development of the region are:

- Master's level schools in less developed regions (e.g., EMALCAs),
- creation of local research networks through long-term research relationships developed through extended scientific exchanges,
- support of local Master's and Ph.D. programs to bring access to advanced education to underserved regions through volunteer lecturer programs and student scholarships,
- creating incentives for students with research education abroad to return to their home countries,
- regional mathematical olympiads.

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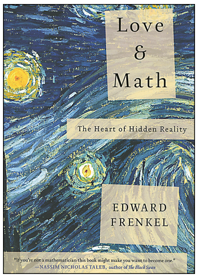

Love and Math: The Heart of Hidden Reality

Reviewed by Anthony W. Knapp

Love and Math: The Heart of Hidden Reality
Edward Frenkel
Basic Books, 2013
292 pages, US$27.99
ISBN-13: 978-0-465-05074-1

Edward Frenkel is professor of mathematics at Berkeley, the 2012 AMS Colloquium Lecturer, and a 1989 émigré from the former Soviet Union. He is also the protagonist Edik in the splendid November 1999 *Notices* article by Mark Saul entitled "Kerosinka: An Episode in the History of Soviet Mathematics." Frenkel's book intends to teach appreciation of portions of mathematics to a general audience, and the unifying theme of his topics is his own mathematical education.

Except for the last of the 18 chapters, a more accurate title for the book would be "Love of Math." The last chapter is more about love than math, and we discuss it separately later in this review.

Raoul Bott once gave a lecture called "Sex and Partial Differential Equations." Come for the sex. Stay for the partial differential equations. The title "Love and Math" is the same idea.

Much of the book is a narrative about Frenkel's own personal experience. If this were all there were to the book, it would be nice, but it might not justify a review in the *Notices*. What sets this book apart is the way in which Frenkel uses his personal story to encourage the reader to see the beauty of some of the mathematics that he has learned. In a seven-page preface, Frenkel says "This book is an invitation to this rich and dazzling world. I wrote it for readers without any background in mathematics." He concludes the preface with this sentence:

> My dream is that all of us will be able to see, appreciate, and marvel at the magic beauty and exquisite harmony of these ideas, formulas, and equations, for this will give so much more meaning to our love for this world and for each other.

Frenkel's Personal Story

Frenkel is a skilled storyteller, and his account of his own experience in the Soviet Union, where he was labeled as of "Jewish nationality" and consequently made to suffer, is gripping. It keeps one's attention and it keeps one wanting to read more. After his failed experience trying to be admitted to Moscow State University, he went to Kerosinka. There he read extensively, learned from first-rate teachers, did mathematics research at a high level, and managed to get some of his work smuggled outside the Soviet Union. The result was that he finished undergraduate work at Kerosinka and was straightway offered a visiting position at Harvard. He tells this story in such an engaging way that one is always rooting for his success. He shows a reverence for various giants who were in the Soviet Union at the time, including I. M. Gelfand and D. B. Fuchs. The account of how he obtained an exit visa is particularly compelling. Once he is in the United States, readers get to see his awe at meeting mathematical giants such as Vladimir Drinfeld and later Edward Witten and Robert Langlands. The reader gets to witness in Chapter 14 the 1990 unmasking of the rector (president) of Moscow University, who had just given a public lecture in Massachusetts and whitewashed that university's discriminatory admissions policies. From there one gets to follow Frenkel's progress through more recent joint work with Witten and up to a collaboration with Langlands and Ngô Bao Châu.

I have to admit that I was dubious when I read the publisher's advertising about the educational aspect of the book. I have seen many lectures and

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books by people with physics backgrounds that contain no mathematics at all—no formulas, no equations, not even any precise statements. Such books tend to suggest that modern physics is really just one great thought experiment, an extension of Einstein's way of thinking about special relativity. *Love and Math* at first sounded to me exactly like that kind of book. I was relieved when I opened *Love and Math* and found that Frenkel was trying not to treat his subject matter this way. He has equations and other mathematical displays, and when his descriptions are more qualitative than that, those descriptions usually are still concrete. The first equation concerns clock arithmetic and appears on page 18, and there are many more equations and mathematical displays starting in Chapter 6. As a kind of compensation for formula-averse readers, he includes a great many pictures and diagrams and tells the reader to "feel free to skip [any formulas] if so desired."

Audience

The equations being as they are, to say that his audience is everyone is an exaggeration. My experience is that the average person in the United States is well below competency at traditional first-year high-school algebra, even though that person may once have had to pass such a course to get a high-school diploma. For one example, I remember a botched discussion on a local television newscast of the meaning of the equation $x^n + y^n = z^n$ after Andrew Wiles announced his breakthrough on Fermat's Last Theorem. As a book that does more than tell Frenkel's own personal story, *Love and Math* is not for someone whose mathematical ability is at the level of those newscasters.

Frenkel really aims at two audiences, one wider than the other. The wider audience consists of people who understand some of the basics of first-year high-school algebra. The narrower audience consists of people with more facility at algebra who are willing to consider a certain amount of abstraction. To write for both audiences at the same time, Frenkel uses the device of lengthy endnotes, encouraging only the interested readers to look at the endnotes. Perhaps he should also have advised the reader that the same zippy pace one might use for reading the narrative parts of the book is not always appropriate for reading the mathematical parts. Anyway, the endnotes occupy 35 pages at the end of the book.

Initial Mathematics

The mathematics begins gently enough with a discussion of symmetry and finite-dimensional representations in Chapter 2. No more mathematics really occurs until Chapter 5, when braid groups are introduced with some degree of detail. Chapter 6 touches on mathematics by alluding to Betti numbers and spectral sequences without really discussing them. It also gives the Fermat equation $x^n + y^n = z^n$ but does not dwell on it.

Chapters 7–9 contain some serious quantitative mathematics, and then there is a break for some narrative. The mathematics resumes in Chapter 14. The topics in Chapters 7–9 quickly advance in level. The mathematical goals of the chapters are respectively to introduce Galois groups and to say something precise yet introductory about the Langlands Program as it was originally conceived [4]. Giving some details but not all, Chapter 7 speaks of number systems—the positive integers, the integers, the rationals, certain algebraic extensions of the rationals, Galois groups, and solutions of polynomial equations by radicals. Frenkel concludes by saying that the Langlands program "ties together the theory of Galois groups and another area of mathematics called harmonic analysis."

Nature of the Langlands Program

It is time in this review to interpolate some remarks about the nature of the Langlands program. The term "Langlands program" had one meaning until roughly 1979 and acquired a much enlarged meaning after that date. The term came into use about the time of A. Borel's Séminaire Bourbaki talk [1] in 1974/75. In the introduction Borel wrote (my translation):

> This lecture tries to give a glimpse of the set of results, problems and conjectures that establish, whether actually or conjecturally, some strong ties between automorphic forms on reductive groups, or representations of such groups, and a general class of Euler products containing many of those that one encounters in number theory and algebraic geometry.
>
> At the present time, several of these conjectures or "questions" appear quite inaccessible in their general form. Rather they define a vast program, elaborated by R. P. Langlands since about 1967, often called the "Langlands philosophy" and already illustrated in a very striking way by the classical or recent results that are behind it, and those that have been obtained since. …
>
> Finally sections 7 and 8 are devoted to the general case. The essential new point is the introduction, by Langlands [in three cited papers] of a group associated to a connected reductive group over a local field, on which are defined *L* factors of representations of *G*; also, following a suggestion of H. Jacquet, we shall call it the *L*-group of *G* and denote it ${}^LG$. …

After 1979 Langlands and others worked on related matters that expanded the scope of the term "Langlands program." More detail about the period before 1979 and the reasons for the investigation appear in Langlands's Web pages, particularly [4].

Nature of Author's Expository Style

Let us return to Frenkel's book. Some detail about Chapter 8, which is where the Langlands program is introduced, may give the reader a feel for the nature of the author's writing style. It needs to be said that the mathematical level of the topics jumps around. For example, the material on Galois groups and polynomial equations in Chapter 7 is followed by half a page at the beginning of Chapter 8 about proofs by contradiction. Then Chapter 8 states Fermat's Last Theorem and explains briefly how a certain conjecture (Shimura-Taniyama-Weil) about cubic two-variable equations implies the theorem. Frenkel does not say what cubics are allowed in the conjecture, but he indicates in the endnotes, without giving a definition, that the allowable ones are those defining "elliptic curves." He soon gets concrete, working with the specific elliptic curve

$$y^2 + y = x^3 - x^2. \tag{1}$$

He introduces prime numbers and the finite field of integers modulo a prime p. Then he counts the number of finite solution pairs (x, y) of (1) modulo p for some small primes p, observing that the number of solution pairs does not seem easily predictable. He defines a_p by the condition that the number of finite solution pairs is $p - a_p$. Thus he has attached a data set $\{a_p\}$ to the elliptic curve, p running over the primes. Then he considers two examples of sequences definable in terms of a generating function. The first, which is included just for practice with generating functions, is the Fibonacci sequence. The second, studied by M. Eichler in 1954, is the sequence $\{b_p\}$ such that b_p is the coefficient of q^p in

$$q(1-q^2)(1-q^{11})^2(1-q^2)^2(1-q^{22})^2(1-q^3)^2 \times (1-q^{33})^2(1-q^4)^2(1-q^{44})^2 \times \cdots .$$

Frenkel states that the sequences $\{a_p\}$ and $\{b_p\}$ match: $a_p = b_p$ for all primes p. Moreover, he says, this is what the Shimura-Taniyama-Weil Conjecture says for the curve (1). There is no indication why this equality holds, nor could there be in a book of this scope. Frenkel's point is to get across the beauty of the result. The seemingly random integers a_p are thus seen to have a manageable pattern that one could not possibly have guessed.

The Shimura-Taniyama-Weil Conjecture is then tied to the Langlands program on pages 91–92, as follows: Without saying much in the text about what modular forms are, Frenkel explains how the Eichler sequence can be interpreted in terms of modular forms of a certain kind. The endnotes come close to explaining this statement completely. In addition, he says also that the statement of the Shimura-Taniyama-Weil Conjecture is that one can find a modular form of this kind for any elliptic curve. He further says that $\{b_p\}$ can be seen to arise from a two-dimensional representation of the Galois group of an extension of the rationals. Although harder mathematics is coming in later chapters, this is the high point of the concrete mathematics in the book.

In trying to summarize the foregoing, the author goes a little astray at this point and asserts that the correspondence of curves to forms such that the data sets $\{a_p\}$ and $\{b_p\}$ match is one-one. This correspondence is not actually one-one, even if we take into account isomorphisms among elliptic curves. In fact, (1) and the curve

$$y^2 + y = x^3 - x^2 - 10x - 20 \tag{2}$$

are nonisomorphic and correspond to the same modular form.[1] This mistake is not fatal to the book, but it takes the reader's focus off the data sets and is a distraction.

L-Functions

Traditionally the data sets are encoded into certain generating functions called L-functions, which are functions of one complex variable. L-functions and the name for them go back at least to Dirichlet in the nineteenth century. Recall that conjectures about L-functions are at the heart of the Langlands program. One might think of L-functions as of two kinds, arithmetic/geometric and analytic/automorphic. Prototypes for them in the arithmetic/geometric case are the Artin L-functions of Galois representations and the Hasse-Weil L-functions of elliptic curves; in the analytic/automorphic case, prototypes are the Dirichlet L-functions and various L-functions of Hecke. Arithmetic/geometric L-functions contain a great deal of algebraic information, much of it hidden, and analytic/automorphic L-functions tend to have nice properties. The key to unlocking the algebraic information is reciprocity laws, such as the Quadratic Reciprocity Law of Gauss and the Artin Reciprocity Law of E. Artin, which say that certain arithmetic/geometric L-functions coincide with analytic/automorphic L-functions.[2] In some further known cases, the above example of elliptic

[1] *The two curves are isogenous but not isomorphic, according to two of the lines under the heading "11" in the table on page 90 of* [2]. *Their data sets* $\{a_p\}$ *match by Theorem 11.67 of* [3], *for example.*

[2] *The principle still holds if the two are equal except for an elementary factor.*

curves being one of them, a similar reciprocity formula holds, and equality reveals some of the hidden algebraic information.

For example, the Hasse-Weil L-function of an elliptic curve is a specific function of a complex variable s built out of the integers a_p and defined for Re $s > \frac{3}{2}$. Because of the Shimura-Taniyama-Weil Conjecture, this L-function, call it $L(s)$, equals a certain kind of L-function of Hecke, and such functions are known to extend analytically to entire functions of s. Thus $L(1)$ is well defined. The Birch and Swinnerton-Dyer Conjecture, a proof or disproof of which is one of the Clay Millennium Prize Problems, is a precise statement of how the behavior of $L(s)$ near $s = 1$ affects the nature of the rational solution pairs for the curve. Toward rational settling the full conjecture, it is already known that there are only finitely many solution pairs if rational $L(1) \neq 0$ and there are infinitely many solution pairs if $L(1) = 0$ and $L'(1) \neq 0$.

A fond unstated hope of the Langlands program is that every algebraic/geometric L-function can be seen to equal an automorphic L-function except possibly for an elementary factor. L-functions do not appear in *Love and Math*.

Weil's Rosetta Stone

Chapter 9 seeks to fit the Langlands program more fully into a framework first advanced by André Weil, and then it looks at what is missing to include the Langlands program in this framework.[3] In a 1940 letter [6] written from prison to his sister, Weil proposed thinking about three areas of mathematics as written on an imaginary Rosetta stone, one column for each area. The varying columns represent what seems to be the same mathematics, but each is written in its own language. The three languages in Frenkel's terms are number fields,[4] curves over finite fields,[5] and Riemann surfaces.[6] Weil understood some of the entries in each column and sometimes knew how to translate part of one column into part of another. Weil sought to create a dictionary to translate each language into the others. Frenkel wants to add versions of the Langlands program to each column.

Representations of Galois groups of number fields fit tidily into the first column, and the Langlands program conjecturally associates suitable automorphic functions to them. Similarly, as Frenkel says, representations of Galois groups of curves over finite fields fit tidily into the second column, and the Langlands program already associates suitable automorphic functions to them. The question is what to do with the third column (the setting of Riemann surfaces). In endnote 21 for Chapter 9, he gives a careful explanation of how the proper analog of the Galois group of a number field is the fundamental group of the Riemann surface. He can speak easily of fundamental groups because of his detailed treatment of braid groups in Chapter 5. He says that, for a proper analog of automorphic functions in the context of Riemann surfaces, functions are inadequate. He proposes "sheaves" as a suitable generalization of functions, and "automorphic sheaves" will be the objects he uses for harmonic analysis in this setting.

He does not introduce sheaves until Chapter 14, after spending several chapters on his further personal history while touching very briefly on mathematical notions like loop groups and Kac-Moody algebras.

Chapters 14–17

Chapters 14–17 contain the remaining substantive comments on mathematics. They are tough slogging, and they are short on details. Chapter 14 is about sheaves. Some intuition is included, but there is no definition in the text or the endnotes. Nor did I find a single example.

However, the endnotes for Chapter 14 contain a nice discussion of algebraic extensions of finite fields and the Frobenius element of the Galois group of the algebraic closure, and the endnotes go on to illustrate how to compute with the Frobenius element. Chapter 15 is about his and Drinfeld's efforts to merge Frenkel's earlier work on Kac-Moody algebras, which is not actually detailed in the book, with the theory of sheaves. The reader may suppose that this merger can take place and that the result completes the enlargement of Weil's Rosetta stone.

More than half of Chapter 15 is occupied with the screenplay of a conversation between Drinfeld and Frenkel. Part of the screenplay reads as follows:

> DRINFELD writes the symbol ${}^LG$ on the blackboard.
>
> EDWARD
>
> Is the L for Langlands?
>
> DRINFELD
>
> (hint of a smile)
>
> Well, Langlands' original motivation was to understand something called L-functions, so he called this group an L-group …

[3] *Weil's framework predates the Langlands program.*

[4] *Finite extensions of the rationals.*

[5] *Finite algebraic extensions of fields F(x), where F is a finite field.*

[6] *Finite extensions of* $\mathbb{C}(x)$.

The snide inclusion of this exchange is completely uncalled for. We have seen that the term L-function goes back to Dirichlet or earlier and that the name L-group and the notation ${}^LG$ were introduced by Jacquet, not Langlands. Langlands himself had initially used the notation $\hat{G}$ to indicate what is now known as the L-group.

Chapters 16 and 17 are about quantum duality, string theory, and superstring theory—all in an effort to put them into the context of the Langlands program. In a sense this is ongoing research. To an extent it is also theoretical physics, which has to mesh eventually with the real universe in order to be acceptable. Langlands put comments about this research on his website at [5] on April 6, 2014. He said of Frenkel's articles in this direction,

> These articles are impressive achievements but often freewheeling, so that, although I have studied them with considerable care and learned a great deal from them that I might never have learned from other sources, I find them in a number of respects incomplete or unsatisfactory. …
>
> It [a certain duality that is involved] has to be judged by different criteria. One is whether it is physically relevant. There is, I believe a good deal of scepticism, which, if I am to believe my informants, is experimentally well founded. Although the notions of functoriality and reciprocity have, on the whole, been well received by mathematicians, they have had to surmount some entrenched resistance, perhaps still latent. So I, at least, am uneasy about associating them with vulnerable physical notions. …

Chapter 18

Chapter 18, the last chapter, is completely different from the others. It is unrelated to the theme of the book and simply does not fit. The most charitable explanation that comes to mind for what happened is that inclusion of the chapter was a marketing decision. In any case, including it was a mistake, and I choose to disregard this chapter.

Summary

Thus much of the book is a personal history about the author. This portion is well written and entertaining. Chapters 7–9 present some mathematics that is at once deep and beautiful, and they do so in a way that largely can be appreciated by many readers. The later chapters have nuggets of mathematics that are well done, but not enough to keep the attention of most readers. Most of those later chapters come dangerously close to the content-empty popular physics books that I find merely irritating. Nevertheless, Frenkel's book is a valiant effort at promoting widespread love of mathematics in a wide audience. It could well be that it is actually impossible to write a book of the scope envisioned by Frenkel that achieves this goal fully. If he had not been so ambitious, the result might have been better. For example, stopping after Chapter 9 and including a little more detail might have enabled him to come closer to achieving what he wanted.

Three stars out of five.

Acknowledgment

I am grateful for helpful conversations with Robert Langlands and Martin Krieger.

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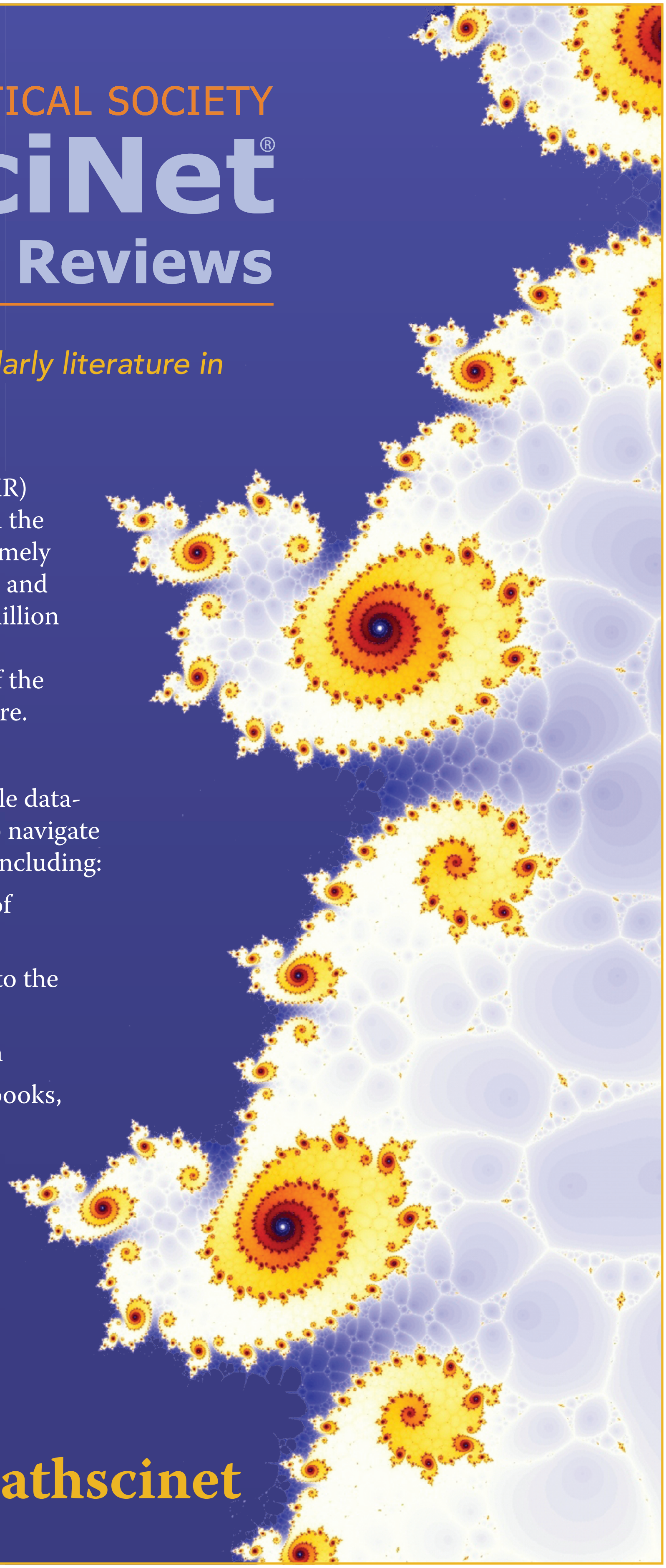

Population Stability and Momentum

Arni S. R. Srinivasa Rao

One commonly prescribed approach for understanding the stability of a system of dependent variables is that of Lyapunov. In a possible alternative approach: when variables in the system have momentum, then that can trigger additional dynamics within the system causing the system to become unstable. In this study, stability of population is defined in terms of elements in the set of births and elements in the set of deaths. Even though the cardinality of the former set has become equal to the cardinality of the latter set, the momentum with which this equality has occurred determines the status of the population to remain *stable.* Such arguments also work for other population ecology problems.

Population Stability Theory

Suppose $|P_N(t_0)|$ to be the cardinality of the set of people, $P_N(t_0)$, representing population at the global level at time t_0, where $P_N(t_0) = \{u_1, u_2, \cdots, u_N\}$, the elements $u_1, u_2, \cdots, u_N$ representing individuals in the population. Broadly speaking, the Lyapunov stability principles (see [VLL]) suggest that, $|P_N(t_0)|$ is asymptotically stable at population size U if $||P_N(T)| - U| < \epsilon$ $(\epsilon > 0)$ at all T whenever $T > t_0$. In some sense, $|P_N(t_0)|$ attains the value U over the indicated period of time. Lotka-Volterra's predator and prey population models provide one of the classical and earliest stability analyses of population biology (see for example, [JDM]) and Lyapunov stability principles often assist in the analysis of such models. These models have equations that describe the dynamics of at least two interacting populations with parameters describing interactions and natural growth. Outside human population models and ecology models, stability also plays a very important role in understanding epidemic spread [AR]. In this paper, we are interested in factors that cause dynamics in P_N and relate these factors with the status of stability. A set of people $P_M(t_0) = \{u_{m_1}, u_{m_2}, \cdots, u_{m_M}\}$, where $P_M(t_0) \subset P_N(t_0)$, are responsible for increasing the population (reproduction) during the period (t_0, s) and contribute to $P_N(s)$, the set of people at s (if they survive until the time s). The set $Q_{M_1}(s - t_0) = \left\{v_{M_{11}}, v_{M_{12}}, \cdots, v_{M_{1M_1}}\right\}$ represents removals (due to deaths) from $P_N(t_0)$ during the time interval (t_0, s). If $\mathrm{R}_\phi(s - t_0)$ is the period reproductive rate (net) applied on $P_M(t_0)$ for the period (t_0, s); then the number of new population added during (t_0, s) is $\mathrm{R}_\phi(s - t_0)\,|P_M(t_0)|$. Net reproduction rate at time t_0 (or in a year t_0) is the average number of female children that would be born to a single woman if she passes through age-specific fertility rates and age-specific mortality rates that are observed at t_0 (for the year t_0). Since net reproductive rates are futuristic measures, we use period (annual) reproductive rates for computing period (annual) increases in population. Let $\mathrm{C}_{N_1}(s - t_0) = \{w_1, w_2, \cdots, w_{N_1}\}$ be the set of newly added population during (t_0, s) to the set $P_N(t_0)$. After allowing the dynamics during (t_0, s), the population at s will be

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To commemorate MPE2013+ launched by the International Mathematics Union, the author dedicates this work to Alfred J. Lotka.

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$$P_N(t_0) \cup C_{N_1}(s-t_0) - Q_{M_1}(s-t_0)$$
$$= \left\{ \begin{array}{c} u : u \in P_N(t_0) \cup C_{N_1}(s-t_0) \\ \text{and } u \notin Q_{M_1}(s-t_0) \end{array} \right\}$$
$$= \{u_1, u_2, \cdots, u_{N+N_1-M_1}\}. \quad (1)$$

Note that $Q_{M_1}(s-t_0) \subset P_N(t_0) \cup C_{N_1}(s-t_0)$ because the set of elements $\left\{v_{M_1}, v_{M_{12}}, \ldots, v_{M_{1M_1}}\right\}$ eliminated during the time period (t_0, s) are part of the set of elements

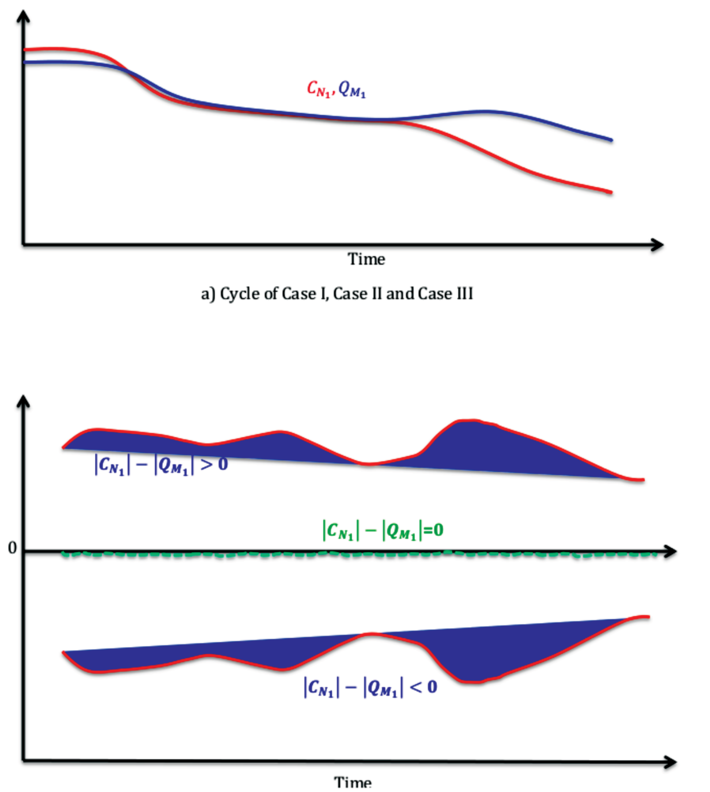
$$\{u_1, u_2, \cdots, u_N, w_1, w_2, \cdots, w_{N_1}\}$$

and the resulting elements surviving by the time s are represented in equation (1). The element u_1 in the set (1) may not be the same individual in the set $P_N(t_0)$. Since we wanted to retain the notation that represents people living at each time point, for ordering purposes, we have used the symbol u_1 in the set (1).

Using the Cantor–Bernstein–Schroeder theorem [PS], $\left|\mathrm{C}_{N_1}(s-t_0)\right| = \left|Q_{M_1}(s-t_0)\right|$ if $\left|\mathrm{C}_{N_1}(s-t_0)\right| \leq \left|Q_{M_1}(s-t_0)\right|$ and $\left|\mathrm{C}_{N_1}(s-t_0)\right| \geq \left|Q_{M_1}(s-t_0)\right|$. If $\left|\mathrm{C}_{N_1}(s-t_0)\right| = \left|Q_{M_1}(s-t_0)\right|$, then the natural growth of the population (in a closed situation) is zero, and if this situation continues further over the time period, then the population could be termed as stationary. Assuming these two quantities are not the same at t_0, the process of two quantities $\left|\mathrm{C}_{N_1}\right|$ and $\left|Q_{M_1}\right|$ becoming equal could eventually happen due to several sub-processes.

Case I: $\left|\mathrm{C}_{N_1}\right| > \left|Q_{M_1}\right|$ at time t_0. We are interested in studying the conditions for the process $\left|\mathrm{C}_{N_1}\right| \to \left|Q_{M_1}\right|$ for some $s > t_0$. Two factors play a major role in determining the speed of this process. They are: compositions of the family of sets $[\{P_M(s)\} : \forall s > t_0]$ and $\left[\left\{\mathrm{R}_\phi(s)\right\} : \forall s > t_0\right]$. Suppose $|P_M(s_1)| > |P_M(s_2)| > \cdots > |P_M(s_T)|$, but the family of $\left\{\left|\mathrm{R}_\phi(s)\right|\right\}$ does not follow any decreasing pattern for some $t_0 < s_1 < s_2 < \cdots < s_T < s$, then $\left|\mathrm{C}_{N_1}\right| \nrightarrow \left|Q_{M_1}\right|$ by the time s_T. If $\mathrm{R}_\phi(s_1) > \mathrm{R}_\phi(s_2) > \cdots > \mathrm{R}_\phi(s_T)$ for $t_0 < s_1 < s_2 < \cdots < s_T < s$ such that $\left|\mathrm{R}_\phi(s_T - s_{T-1})\right| \left|P_M(s_{T-1})\right| - \left|Q_{M_1}(s_T - s_{T-1})\right| \to 0$ for some sufficiently large $T > t_0$ and sufficiently small $\left|\mathrm{R}_\phi(s_T - s_{T-1})\right|$, then $\left|\mathrm{C}_{N_1}\right| \to \left|Q_{M_1}\right|$ by the time s_T. Note that in an ideal demographic transition situation, both these quantities should decline over the period and the rate of decline of $\left|Q_{M_1}\right|$ is slower than the rate of decline in $\left|\mathrm{C}_{N_1}\right|$ because $\left|\mathrm{C}_{N_1}\right| > \left|Q_{M_1}\right|$ at time t_0. Demographic transition theory, in simple terms, is all about determinants, consequences and speed of declining high rates of fertility and mortality to low levels of fertility and mortality rates. For an introduction of this concept, see [KD] and for an update of recent works, see [JC]. The above trend of $|P_M(s_1)| > |P_M(s_2)| > \cdots > |P_M(s_T)|$ (i.e., decline in people of reproductive ages over the time after t_0) happens when births continuously decrease for several years. Following the trend $\mathrm{R}_\phi(s_1) > \mathrm{R}_\phi(s_2) > \cdots > \mathrm{R}_\phi(s_T)$ will lead to decline in newborn babies and this will indirectly result in decline in rate of growth of people who have reproductive potential. However, the decline in $\left|\mathrm{R}_\phi(s)\right|$ for $s > t_0$ is well explained by social and biological factors, which need not follow any pre-determined mathematical model. However the trend in $\left|\mathrm{R}_\phi(t)\right|$ for $t < t_0$ can be explained using models by fitting parameters obtained from data. During the entire process the value of $\left|Q_{M_1}\right|$ after time t_0 is assumed to be dynamic and decreases further. If a population continues to remain at this stage of replacement, we call it a *stable population*. The cycle of births, population aging, and deaths is a *continuous process* with *discretely quantifiable factors*. Due to improvement in medical sciences there could be some delay in deaths, but eventually the aged population has to be moved out of $\{P_N\}$, and consequently, population stability status can be broken with a continuous decline in $\left\{\left|C_{N_1}\right|\right\}$.

Case II: $\left|\mathrm{C}_{N_1}\right| = \left|Q_{M_1}\right|$ at time t_0. It is important to ascertain whether this situation was immediately proceeded by Case I or Case II before determining the stability process. Suppose case II is immediately preceded by case I, then the rapidity and magnitude at which the difference between $\left|\mathrm{C}_{N_1}\right|$ and $\left|Q_{M_1}\right|$ was shrunk prior to t_0 need to be quantified. Let us understand the contributing factors for the set Q_M. At each t, there is a possibility that the elements from the sets $C_{N_1}, P_N - C_{N_1} - P_M, P_M$ are contributing to the set Q_M. Due to high infant mortality rates, the contribution of C_{N_1} into Q_M is considered to be high, deaths of adults of reproductive ages, P_M, and all other individuals (including the aged), $P_N - C_{N_1} - P_M$, will be contributing to the set Q_M. Case II could occur when $\left|\mathrm{C}_{N_1}\right|$ and $\left|Q_{M_1}\right|$ are at higher values or at lower values. Equality at higher values possibly indicates that the number of deaths due to the three factors mentioned here are high (including high old age deaths) and these are replaced by an equally high number of births, i.e., $\left|R_\phi\right|$ and $|P_M|$ are usually high to reproduce high birth numbers. If equality at lower values of $\left|\mathrm{C}_{N_1}\right|$ and $\left|Q_{M_1}\right|$ occurs after phase of Case I, then the chance of P_N remaining in stable position is higher. Suppose elements of P_N are arbitrarily divided into k-independent and nonempty subsets, $A(1), A(2), \cdots, A(k)$ such that $|P_N| = \int_1^k |A(s)|\, ds$. Let F be the family of all the sets $A(s)$ such that $\cup(A(s)) = P_N$. Members of F are disjoint. Suppose $\left(\begin{array}{c} F \\ k^* \end{array}\right)$ is an arbitrary size of k^* of the subset of F



a) Cycle of Case I, Case II and Case III

b) Possibility of global stability even though some sub-populations satisfy $|C_{N_1}| - |Q_{M_1}| = 0$

(a) The cycle of all the cases could follow one after another and the quantity at which equality of C_{N_1} and Q_{M_1} occurs determines the duration of Case II. (b) Some of the sub-populations are not satisfying the equality of C_{N_1} and Q_{M_1}. This is compensated by the other sub-populations which are satisfying either $C_{N_1} > Q_{M_1}$ or $C_{N_1} < Q_{M_1}$.

satisfying Case II and $F - \begin{pmatrix} F \\ k^* \end{pmatrix}$ is not satisfying the case at time t_0 and $t > t_0$, then we are not sure if the total population also attains stability by Theorem 1.

Theorem 1. *Suppose each member of* $\begin{pmatrix} F \\ k^* \end{pmatrix}$ *satisfies the condition* $|C_{N_1}| = |Q_{M_1}|$ *and* $F - \begin{pmatrix} F \\ k^* \end{pmatrix}$ *is not satisfying the condition* $|C_{N_1}| = |Q_{M_1}|$ *at time* $t \geq t_0$*. Then this does not always lead* P_N *to stability.*

Proof. Note that F has a collection of k-sets. Suppose a collection C divides C_{N_1} into k-component of subpopulations $\{C_{N_1}(1), C_{N_1}(2), \ldots, C_{N_1}(k)\}$ such that $|C_{N_1}| = \int_1^k |C_{N_1}(s)|\, ds$, where $C_{N_1}(s)$ is the sth subset in C and a collection Q divides Q_{M_1} into k-component of subpopulations $\{Q_{M_1}(1), Q_{M_1}(2), \ldots, Q_{M_1}(k)\}$ such that $|Q_{M_1}| = \int_1^k |C_{M_1}(s)|\, ds$, where $Q_{M_1}(s)$ is the sth-subset in Q.

By hypothesis, $|C_{N_1}(s^*)| = |Q_{M_1}(s^*)|$ for $s^* \in \{1^*, 2^*, \cdots, k^*\}$ at each time $t \geq t_0$ until, say, t_T. The order between k^* and k-k^* could be one of the following: $2k^* < k$, $2k^* > k$, $k^* = \frac{k}{2}$. Suppose that $C_{N_1} \subset C$ and $Q_{M_1} \subset Q$ with

$$C_{N_1}^* = \left\{C_{N_1}^*(1), C_{N_1}^*(2), \cdots, C_{N_1}^*(k)\right\}$$
$$Q_{M_1} = \left\{Q_{M_1}^*(1), Q_{M_1}^*(2), \cdots, Q_{M_1}^*(k)\right\}$$

for the same arbitrary combination of k^* components and the rest of the k-k^* component satisfying $\left|C_{N_1}^{**}(s^{**})\right| - \left|Q_{M_1}^{**}(s^{**})\right| \neq 0$ for all $s^{**} = 1, 2, \cdots, k$-k^*. We obtain an unstable integral over all k-k^* component to ascertain the magnitude of unstability:

$$(2) \quad \int_1^{k-k^*} \left[\left|C_{N_1}^{**}(s^{**})\right| - \left|Q_{M_1}^{**}(s^{**})\right|\right] ds^{**}.$$

The stable integral for this situation is

$$(3) \quad \int_1^{k^*} \left[\left|C_{N_1}^{*}(s^{*})\right| - \left|Q_{M_1}^{*}(s^{*})\right|\right] ds^{*}.$$

To check the unstable and stable points over the time period (t_0, t_T), one can compute following integrals:

$$(4) \quad \int_{t_0}^{t_T} \int_1^{k-k^*} \left[\left|C_{N_1}^{**}(s^{**})\right| - \left|Q_{M_1}^{**}(s^{**})\right|\right] ds^{**} du$$

$$(5) \quad \int_{t_0}^{t_T} \int_1^{k^*} \left[\left|C_{N_1}^{*}(s^{*})\right| - \left|Q_{M_1}^{*}(s^{*})\right|\right] ds^{*} du.$$

For each of the $k - k^*$ component, the values of $\left|C_{N_1}^{**}(s^{**})\right| - \left|Q_{M_1}^{**}(s^{**})\right|$ can be either positive or negative. If, at time t_0, for all $s^{**} = 1, 2, \cdots, k$-k^*, the values of $\left|C_{N_1}^{**}(s^{**})\right| - \left|Q_{M_1}^{**}(s^{**})\right|$ are positive (or negative), then (2) will take a positive (or negative) quantity and the population at time t_0 is not stable. If such a situation continues for all $t_T \geq t_0$, then the integral in (4) would never become zero, and the population remains unstable in the entire period (t_0, t_T). However, for some of the s^{**}, if the quantity $\left|C_{N_1}^{**}(s^{**})\right| - \left|Q_{M_1}^{**}(s^{**})\right|$ is positive and for other s^{**}, if the quantity $\left|C_{N_1}^{**}(s^{**})\right| - \left|Q_{M_1}^{**}(s^{**})\right|$ is negative, such that (2) is zero at each of the time points for the period (t_0, t_T), then the population remains stable during this period (because by hypothesis the (5) is zero). □

Case III. $|C_{N_1}| < |Q_{M_1}|$ at time t_0. Global occurrence of this case at lower values of $|C_{N_1}|$ and $|Q_{M_1}|$ indicates that the P_N is declining and also is in unstable mode. R_ϕ has been very low consistently for the period $t < t_0$ and the supply to the set P_M has diminished over a period in the past. All the subsets of C_{N_1} and Q_{M_1} might not be stable in case III, but by arguments similar to those in Theorem 1, global population behavior nullifies some of the local population and case III is still satisfied globally.

All three cases would be repeated one following another. Most countries are currently facing case I with varying distance between $|C_{N_1}|$ and $|Q_{M_1}|$.

Replacement Metric

We introduce a metric, d_M, which we call *a replacement metric,* with a space, M_r as follows:

Definition 2. *(Replacement Metric).*

Let $A_1 = \min\{||C_{N_1}(s)| - |Q_{M_1}(s)|| : s > t_0\}$ *and*

$A_2 = \max\{||C_{N_1}(s)| - |Q_{M_1}(s)|| : s > t_0\}$. *Let* $M_r = [A_1, A_2] \subset \mathbb{R}^+$ *and* $M = \{||C_{N_1}(s)| - |Q_{M_1}(s)|| : s > t_0\}$ *with the metric* $d_M(x, y) = \frac{|x-y|}{2}$. *We can verify that* (M, d_M) *is a metric space with* $d_M : (M \times M) \to M_r$ *and nonempty set* M.

The metric on M, in the Definition 2, is bounded, because $d_M(x, y) < k$ for $k > 0$.

Definition 3. *Suppose* $||C_{N_1}(s_1)| - |Q_{M_1}(s_1)|| = f_1$, $||C_{N_1}(s_2)| - |Q_{M_2}(s_2)|| = f_2$ *and so on for* $s_1 < s_2 < \ldots$. *Then we say the population is stable if* $f_{s_T} \to 0$ *for sufficiently large* T *and* $\frac{d}{ds_T}|C_{N_1}(s_T)| = \frac{d}{ds_T}|C_{N_1}(s_T)| = 0$.

Conclusions

We can prove that the value at which the population remains stable is variable, i.e., the value at which the population becomes unstable by deviating from Case II could be different from the value (at a future point in time) at which the population becomes stable when it converges to case II. *Replacement metrics*(see Definition 2) are helpful in seeing this argument and such analysis is not possible by Lotka-Volterra or Lyapunov methods. Due to population momentum, there will be an increase in the population even though the reproduction rate of the population falls below the replacement level. Population stability will always attain a local stable point before diverging and again converge at a local stable point. The duration of a local stable point depends on the density of the population and resources available for the population.

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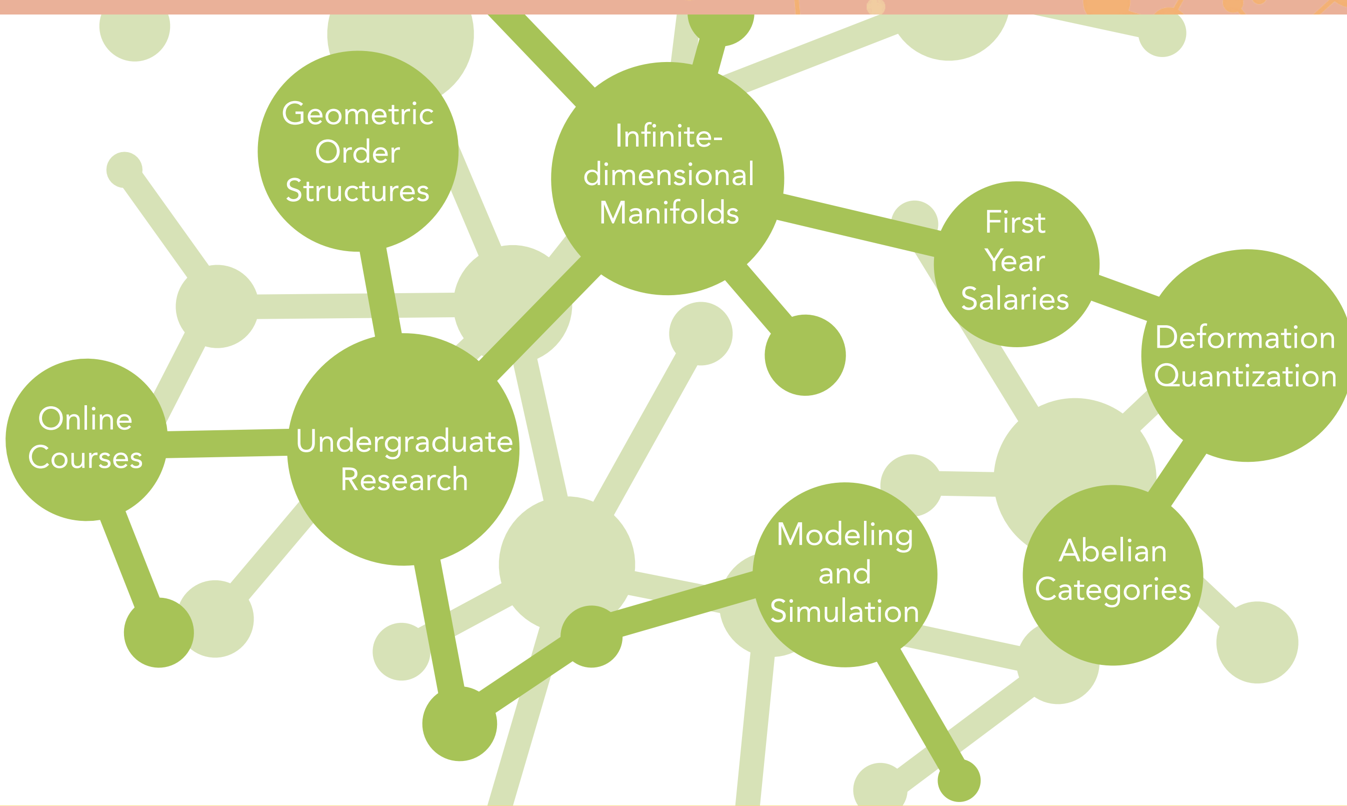

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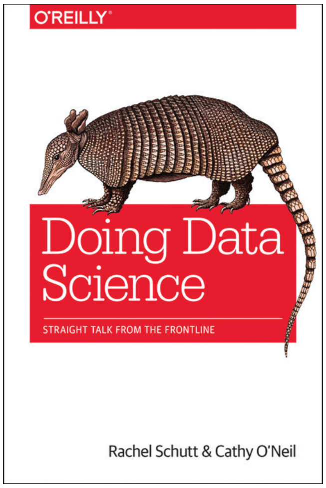


Doing Data Science

Reviewed by Brian Hayes

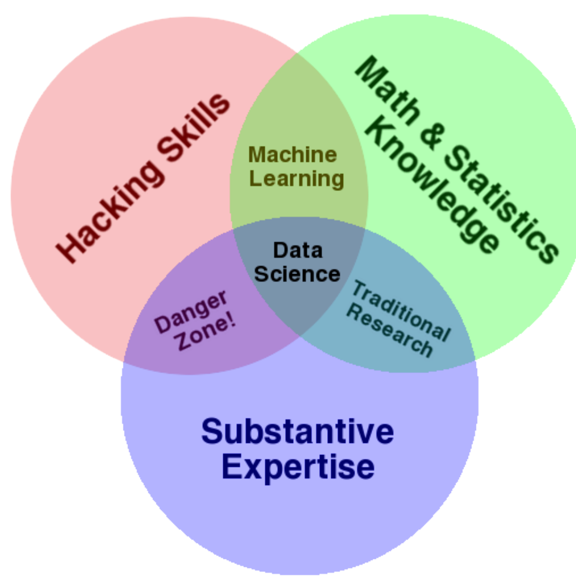
Doing Data Science
Rachel Schutt and Cathy O'Neil
O'Reilly Media, 2014
US$39.99, 375 pages
ISBN 978-1-449-35865-5

"Data Scientist: The Sexiest Job of the 21st Century"—that was the title of a 2012 article in *Harvard Business Review*. Many of us, I suspect, have never met a data scientist, and perhaps never heard of one. Although there's mild controversy about the provenance of the term, it seems the first business cards bearing that job title were printed in 2008. By 2011, Michael Rappa of North Carolina State University counted 394 individuals identifying themselves as data scientists. He came up with this number by doing a little data science of his own: He searched the LinkedIn social network, counting professional profiles with "data scientist" as part of a present or previous job title. In May of 2014 I repeated that experiment and found the population of data scientists on LinkedIn had grown to 4,696.

So what is this sexy new science of data? In *Doing Data Science* Rachel Schutt and Cathy O'Neil take up this question at the start of the first chapter, and it remains open for discussion in the final chapter. Here is one proposed definition:

> [A] data scientist is someone who knows how to extract meaning from and interpret data, which requires …tools and methods from statistics and machine learning, as well as being human.

Another attempt at a definition takes the form of a Venn diagram (created by Drew Conway), suggesting that data science lies at the three-way intersection of mathematical statistics, computing, and expertise in some particular subject domain.



(Why is the intersection of hacking skills and substantive expertise labeled a danger zone? Because those without grounding in mathematics and statistics risk producing results they don't understand.)

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A third definition is attributed to Josh Wills, Director of Data Science at Cloudera:

> Data scientist (noun): Person who is better at statistics than any software engineer and better at software engineering than any statistician.

If none of those definitions gives you a clear sense of just what it is that data scientists do, maybe a few examples will prove more illuminating:

Recommendation engines. When you buy a book from an online merchant, the website presents a list of other items that might tempt you. Where do those suggestions come from? If you were shopping at a neighborhood bookshop (supposing that your neighborhood still has such quaint institutions), recommendations might come from a well-read clerk, relying on personal knowledge of both customers and literature. But such individualized services are not feasible for an online retailer with millions of customers and millions of items for sale. The solution is a "recommendation engine," which Schutt and O'Neil call "the quintessential data-science product." The main source of data to fuel the engine is the huge bipartite graph linking customers with the products they have bought. When you order a copy of *Doing Data Science*, the engine can consult the graph to find other customers who bought the same book (or browsed in it, or reviewed it), then look for other titles that also interested those people.

Fraud detection. Credit-card transactions stream into a bank processing center at a rate of hundreds per second. Some small fraction of the transactions are fraudulent: The purchaser is presenting a stolen or counterfeited card, or perhaps the merchant is making an unauthorized charge to a customer's account. The data scientist's job is to identify these rogue transactions, using algorithms that have access to historical data for both the buyer and the seller. What features of individual transactions will most clearly discriminate between the illicit and the legitimate ones?

Social network analysis. A social network—such as the LinkedIn service mentioned above—can be represented as a mathematical graph: The people are vertices, and the connections between them are edges. Social graphs have a distinctive statistical structure. They are sparse graphs, with relatively few edges overall, and yet almost any two vertices are connected by a short path, traversing no more than a few edges. In other words, in these "small world" graphs, friend-of-a-friend links tie everyone together. Part of what makes the networks so cohesive is the presence of a few individuals with a very large number of contacts, and others who act as bridges between communities that would otherwise be isolated. Identifying these key individuals and the communities they influence is another job for a data scientist.

Masters of the Data Universe

What is it about tasks like these that accounts for the sex appeal of data science? Part of the thrill may be a simple matter of scale. The data scientist claims dominion over a planet-girdling empire of digital commerce and online life. For example, the largest social networks, such as Facebook, now have 10^9 nodes, approaching the size of the entire human population. The masters of this data universe, striding their realm with youthful swagger, are not always gentle as they sweep away the outworn ideas of earlier generations. One advocate of data-driven machine inference remarks: "Your decades of specialist knowledge are not only useless, they're actually unhelpful." In other words, get out of the way and let the algorithms do their work.

Most of the software tools and computational infrastructure built to deal with these huge data sets might properly be described as data engineering rather than data science. Yet there are issues of genuine scientific and mathematical interest underlying such activities. For example, the problem of extracting meaning from large, high-dimensional data arrays is not just a matter of data processing, to be solved by installing a bigger computer. Many of the inference and prediction procedures in data science rely on clustering algorithms, which partition data into subsets of values that are all near one another according to some metric. Those algorithms run up against an impossibility theorem for clustering, formulated by Jon Kleinberg of Cornell and reminiscent of the Arrow impossibility theorem for elections. Kleinberg lists three desirable criteria for a clustering function, which he calls scale invariance, richness, and consistency, and he shows that no algorithm can satisfy all three. Kleinberg's theorem is not mentioned in *Doing Data Science*, but other limitations of algorithms for clustering, classification, and ranking are discussed with some care. (Admittedly, such cautions may not dampen the boisterous enthusiasms of young people impatient to go out and change the world. Perhaps that's for the best.)

The two authors of *Doing Data Science* partake of the enthusiasms, but they also bring a measure of maturity and experience to the subject. Schutt is a mathematician and statistician, an adjunct professor at Columbia University; since the book was published she has become Vice President of Data Science at News Corp. O'Neil is a mathematician who left the academic world to work in finance, then turned away from that career as well, becoming active in the Occupy Wall Street movement; she is now a Data Science Consultant at Johnson Research Labs in New York. She also writes a blog called `mathbabe.org`. In 2012 Schutt undertook to teach an introductory data science course at Columbia. O'Neil audited the course and reported on the experience in her `mathbabe` blog. The two authors then drew together the blog posts and other material to create the book.

Doing Data Science is not a tutorial or a textbook. It introduces lots of basic principles and techniques—probability distributions, linear regression, Bayes's theorem, various algorithms for machine learning—but none of these ideas are presented in great depth or detail. Most of the chapters are based on talks by guest lecturers, who chat about their tools, their tastes, and their habits of thought, then present one of their projects, perhaps illustrated with a few equations or snippets of code. It's like a television cooking show where every week a different celebrity chef comes to prepare a signature dish. Seeing the masters at work is entertaining and even inspiring, but when you go into the kitchen, you may realize you didn't learn quite enough to make that *vol-au-vent* on your own.

The King-of-the-Mountain Metric

Data science has its detractors. One of them is Cosma Shalizi, a statistician at Carnegie Mellon University. Schutt and O'Neil paraphrase his position as follows:

> Cosma basically argues that any statistics department worth its salt does all the stuff in the descriptions of data science that he sees, and therefore data science is just a rebranding and unwelcome takeover of statistics.

Shalizi may be right, but one could also argue that the problem with data science is that there are parts of statistics it has *not* yet assimilated. Some of the parts left out are really good parts.

Let us go back to the beginning of data science—or maybe it was before the beginning. In 2006 the movie rental company Netflix announced a contest: They would pay a million-dollar prize to anyone who could improve the accuracy of their recommendation engine by 10 percent or more. Some 20,000 teams registered for the competition. Contestants were given data showing how 500,000 viewers rated various subsets of 17,000 films; in all, there were about 100 million ratings in this training set. The challenge was to predict an additional three million ratings. A team from BellCore won a preliminary round of the contest. Their strategy was to apply a wide variety of algorithms to the training set—eventually they had 107 of them—then take a weighted sum of the predictions; the weights were tuned to maximize the score. In 2009 the BellCore team merged with two others, each of which added still more methods to the mix, and this consortium won the grand prize.

Elements of the Netflix contest seem to have become permanent fixtures of the data science scene. In particular, competitions remain a popular way of stimulating work on a problem and evaluating progress toward a solution. A company called Kaggle has made a business of conducting such contests. Moreover, many of the contest winners still favor a scattershot strategy, in which multiple algorithms are flung at the problem, with the final result being some weighted combination of their outputs. "Overfitting" is a constant hazard: When you work too hard at optimizing the weights, you may find you have tuned the model to mere noise in the training set, impairing performance on real-world data.

The continuing success of multi-algorithm mashups in open competition is undeniably an argument for their soundness. Nevertheless, I am disappointed to learn that we can't measure the performance of an optimization technique in a more meaningful way than to say that nobody has been able to beat it so far. This king-of-the-mountain metric tells us almost nothing about any fundamental bounds on accuracy or efficiency. You can know where you stand with respect to other contestants, but not how closely you might be approaching a true limit on predictive ability. And a program that combines outputs from more than 100 algorithms makes it hard to discern which techniques work best, or how to formulate more general procedures that can be applied to a wider variety of problems.

In statistics, by contrast, it's not the usual practice to choose a data model or estimator by holding a prize competition. There's a body of systematic knowledge that guides such decisions, generally leading to a single solution or a small set of alternatives, and quantifying the error and uncertainty in the results. Data science, as far as I can tell, has yet to develop its central limit theorem. Of course it is still very young.

So far, data science has evolved mainly outside the academic world, at Google and Facebook and a host of smaller startup companies. But if this new suite of ideas and techniques is to sustain itself, it will have to find a place in the university as well. A century ago, when statistics was emerging as a distinct academic discipline, there was some doubt about where it should make its intellectual and institutional home. The underlying ideas were clearly mathematical, but the new field also had strong affinities with social, political, and biological sciences. In the end, statistics did not become just another branch of mathematics, on the same level as number theory or combinatorics. Statisticians stand at a slightly greater remove; to borrow a metaphor from politics, they are independents who caucus with the mathematicians.

Questions about intellectual and institutional affiliations arose again when computer science was born in the 1960s and 1970s. The outcome in that case was even greater autonomy, although the computing professions still have strong ties to mathematics on the one side and engineering on the other.

We may now be witnessing the birth of another new discipline. Will the community of data scientists be captured by either statistics or computer science? Or will it develop its own institutions—membership societies, journals, annual meetings, university departments?

The Students' View

Schutt and O'Neil allow the younger generation to have the last word in their book. In the final chapter the students in Schutt's course report their reactions to the curriculum and reflect on the careers they are about to launch. Interestingly, it is the students who most directly confront ethical issues and the broader role of data and data science in peoples' lives. They cite a comment from Jeff Hammerbacher, who was one of the two pioneers who first called themselves data scientists:

> The best minds of my generation are thinking about how to make people click ads…That sucks.

It's a sobering thought, and the students express determination to put their skills to better use. One naturally hopes that the brightest minds will be drawn to the deepest and most important questions. But sexy jobs also matter.

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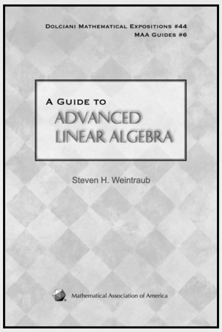

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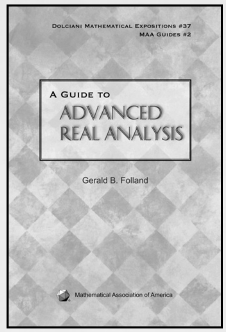

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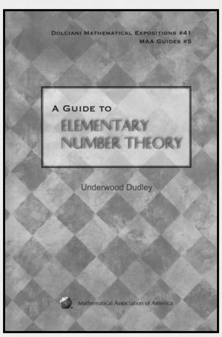

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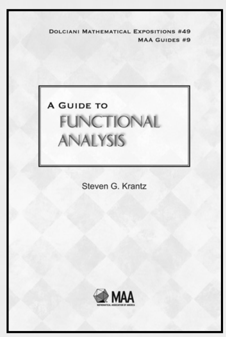

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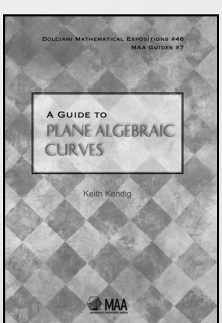

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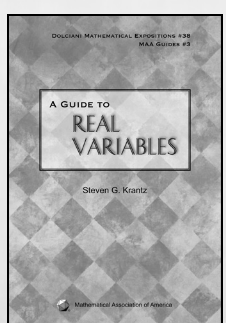

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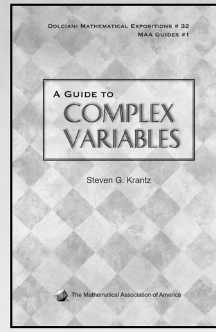

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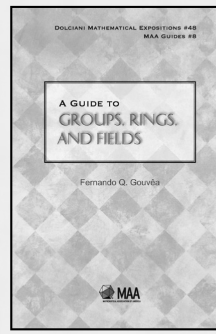

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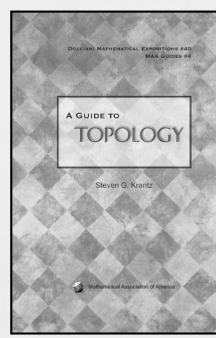

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2014 Fields Medals

On August 13, 2014, the 2014 Fields Medals were awarded at the opening ceremony of the International Congress of Mathematicians in Seoul, South Korea. The following news releases, issued by the International Mathematical Union (IMU), provide descriptions of the medalists' work. A future issue of the *Notices* will carry the news releases about other IMU awards given at the Congress.

—Allyn Jackson

The Work of Artur Avila


Courtesy of IMU.

Artur Avila

Artur Avila has made outstanding contributions to dynamical systems, analysis, and other areas, in many cases proving decisive results that solved long-standing open problems. A native of Brazil who spends part of his time there and part in France, he combines the strong mathematical cultures and traditions of both countries. Nearly all his work has been done through collaborations with some thirty mathematicians around the world. To these collaborations Avila brings formidable technical power, the ingenuity and tenacity of a master problem-solver, and an unerring sense for deep and significant questions.

Avila's achievements are many and span a broad range of topics; here we focus on only a few highlights. One of his early significant results closes a chapter on a long story that started in the 1970s. At that time, physicists, most notably Mitchell Feigenbaum, began trying to understand how chaos can arise out of very simple systems. Some of the systems they looked at were based on iterating a mathematical rule such as $3x(1-x)$. Starting with a given point, one can watch the trajectory of the point under repeated applications of the rule; one can think of the rule as moving the starting point around over time. For some maps, the trajectories eventually settle into stable orbits, while for other maps the trajectories become chaotic.

Out of the drive to understand such phenomena grew the subject of discrete dynamical systems, to which scores of mathematicians contributed in the ensuing decades. Among the central aims was to develop ways to predict longtime behavior. For a trajectory that settles into a stable orbit, predicting where a point will travel is straightforward. But not for a chaotic trajectory: Trying to predict exactly where an initial point goes after a long time is akin to trying to predict, after a million tosses of a coin, whether the million-and-first toss will be a head or a tail. But one can model coin-tossing probabilistically, using *stochastic* tools, and one can try to do the same for trajectories. Mathematicians noticed that many of the maps that they studied fell into one of two categories: "regular," meaning that the trajectories eventually become stable, or "stochastic," meaning that the trajectories exhibit chaotic behavior that can be modeled stochastically. This dichotomy of regular vs. stochastic was proved in many special cases, and the hope was that eventually a more complete understanding would emerge. This hope was realized in a 2003 paper by Avila, Welington de Melo, and Mikhail Lyubich, which brought to a close this long line of research. Avila and his co-authors considered a wide class of dynamical systems—namely, those arising from maps with a parabolic shape, known as unimodal maps—and proved that, if one chooses such a map at random, the map will be either regular or stochastic. Their work provides a unified, comprehensive picture of the behavior of these systems.

Another outstanding result of Avila is his work, with Giovanni Forni, on *weak mixing*. If one attempts to shuffle a deck of cards by only cutting the deck—that is, taking a small stack off the top of the deck and putting the stack on the bottom—then the deck will not be truly mixed. The cards are simply moved around in a cyclic pattern. But if one shuffles the cards in the usual way, by interleaving them—so that, for example, the first card now comes after the third card, the second card after the fifth, and so on—then the deck will be truly mixed. This is the essential idea

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of the abstract notion of mixing that Avila and Forni considered. The system they worked with was not a deck of cards, but rather a closed interval that is cut into several subintervals. For example, the interval could be cut into four pieces, ABCD, and then one defines a map on the interval by exchanging the positions of the subintervals so that, say, ABCD goes to DCBA. By iterating the map, one obtains a dynamical system called an "interval exchange transformation."

Considering the parallel with cutting or shuffling a deck of cards, one can ask whether an interval exchange transformation can truly mix the subintervals. It has long been known that this is impossible. However, there are ways of quantifying the degree of mixing that lead to the notion of "weak mixing," which describes a system that just barely fails to be truly mixing. What Avila and Forni showed is that almost every interval exchange transformation is weakly mixing; in other words, if one chooses at random an interval exchange transformation, the overwhelming likelihood is that, when iterated, it will produce a dynamical system that is weakly mixing. This work is connected to more recent work by Avila and Vincent Delecroix, which investigates mixing in regular polygonal billiard systems. Billiard systems are used in statistical physics as models of particle motion. Avila and Delecroix found that almost all dynamical systems arising in this context are weakly mixing.

In the two lines of work mentioned above, Avila brought his deep knowledge of the area of analysis to bear on questions in dynamical systems. He has also sometimes done the reverse, applying dynamical systems approaches to questions in analysis. One example is his work on quasi-periodic Schrödinger operators. These are mathematical equations for modeling quantum mechanical systems. One of the emblematic pictures from this area is the Hofstadter butterfly, a fractal pattern named after Douglas Hofstadter, who first came upon it in 1976. The Hofstadter butterfly represents the energy spectrum of an electron moving under an extreme magnetic field. Physicists were stunned when they noticed that, for certain parameter values in the Schrödinger equation, this energy spectrum appeared to be the Cantor set, which is a remarkable mathematical object that embodies seemingly incompatible properties of density and sparsity. In the 1980s, mathematician Barry Simon popularized the "Ten Martini Problem" (so named by Mark Kac, who offered to buy ten martinis for anyone who could solve it). This problem asked whether the spectrum of one specific Schrödinger operator, known as the almost-Mathieu operator, is in fact the Cantor set. Together with Svetlana Jitomirskaya, Avila solved this problem.

As spectacular as that solution was, it represents only the tip of the iceberg of Avila's work on Schrödinger operators. Starting in 2004, he spent many years developing a general theory that culminated in two preprints in 2009. This work establishes that, unlike the special case of the almost-Mathieu operator, general Schrödinger operators do not exhibit critical behavior in the transition between different potential regimes. Avila used approaches from dynamical systems theory in this work, including renormalization techniques.

A final example of Avila's work is a very recent result that grew out of his proof of a regularization theorem for volume-preserving maps. This proof resolved a conjecture that had been open for thirty years; mathematicians hoped that the conjecture was true but could not prove it. Avila's proof has unblocked a whole direction of research in smooth dynamical systems and has already borne fruit. In particular, the regularization theorem is a key element in an important recent advance by Avila, Sylvain Crovisier, and Amie Wilkinson. Their work, which is still in preparation, shows that a generic volume-preserving diffeomorphism with positive metric entropy is an ergodic dynamical system.

With his signature combination of tremendous analytical power and deep intuition about dynamical systems, Artur Avila will surely remain a mathematical leader for many years to come.

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Biography

Born in Brazil in 1979, Artur Avila is also a naturalized French citizen. He received his Ph.D. in 2001 from the Instituto Nacional de Matemática Pura e Aplicada (IMPA) in Rio de Janeiro, where his advisor was Welington de Melo. Since 2003 Avila has been a researcher in the Centre National de la Recherche Scientifique and he became a directeur de recherche in 2008; he is attached to the Institut de Mathématiques de Jussieu-Paris Rive Gauche. Also, since 2009 he has been a researcher at IMPA. Among his previous honors are the Salem Prize (2006), the European Mathematical Society Prize (2008), the Grand Prix Jacques Herbrand of the French Academy of Sciences (2009), the Michael Brin Prize (2011), the Prêmio of the Sociedade Brasileira de Matemática (2013), and the TWAS Prize in Mathematics (2013) of the World Academy of Sciences.

The Work of Manjul Bhargava

Courtesy of IMU.

Manjul Bhargava

Manjul Bhargava's work in number theory has had a profound influence on the field. A mathematician of extraordinary creativity, he has a taste for simple problems of timeless beauty, which he has solved by developing elegant and powerful new methods that offer deep insights.

When he was a graduate student, Bhargava read the monumental *Disquisitiones Arithmeticae*, a book about number theory by Carl Friedrich Gauss (1777–1855). All mathematicians know of the *Disquisitiones*, but few have actually read it, as its notation and computational nature make it difficult for modern readers to follow. Bhargava nevertheless found the book to be a wellspring of inspiration. Gauss was interested in *binary quadratic forms*, which are polynomials $ax^2 + bxy + cy^2$, where a, b, and c are integers. In the *Disquisitiones*, Gauss developed his ingenious *composition law*, which gives a method for composing two binary quadratic forms to obtain a third one. This law became, and remains, a central tool in algebraic number theory. After wading through the twenty pages of Gauss's calculations culminating in the composition law, Bhargava knew there had to be a better way.

Then one day, while playing with a Rubik's cube, he found it. Bhargava thought about labeling each corner of a cube with a number and then slicing the cube to obtain two sets of four numbers. Each 4-number set naturally forms a matrix. A simple calculation with these matrices resulted in a binary quadratic form. From the three ways of slicing the cube, three binary quadratic forms emerged. Bhargava then calculated the discriminants of these three forms. (The discriminant, familiar to some as the expression "under the square root sign" in the quadratic formula, is a fundamental quantity associated with a polynomial.) When he found the discriminants were all the same, as they are in Gauss's composition law, Bhargava realized he had found a simple, visual way to obtain the law.

He also realized that he could expand his cube-labeling technique to other polynomials of higher degree (the degree is the highest power appearing in the polynomial; for example, $x^3 - x + 1$ has degree 3). He then discovered thirteen new composition laws for higher-degree polynomials. Up until this time, mathematicians had looked upon Gauss's composition law as a curiosity that happened only with binary quadratic forms. Until Bhargava's work, no one realized that other composition laws existed for polynomials of higher degree.

One of the reasons Gauss's composition law is so important is that it provides information about quadratic *number fields*. A number field is built by extending the rational numbers to include nonrational roots of a polynomial; if the polynomial is quadratic, then one obtains a quadratic number field. The degree of the polynomial and its discriminant are two basic quantities associated with the number field. Although number fields are fundamental objects in algebraic number theory, some basic facts are unknown, such as how many number fields there are for a fixed degree and fixed discriminant. With his new composition laws in hand, Bhargava set about using them to investigate number fields.

Implicit in Gauss's work is a technique called the "geometry of numbers"; the technique was more fully developed in a landmark 1896 work of Hermann Minkowski (1864–1909). In the geometry of numbers, one imagines the plane, or 3-dimensional space, as populated by a lattice that highlights points with integer coordinates. If one has a quadratic polynomial, counting the number of integer lattice points in a certain region of 3-dimensional space provides information about the associated quadratic number field. In particular, one can use the geometry of numbers to show that, for discriminant with absolute value less than X, there are approximately X quadratic number fields. In the 1960s, a more refined geometry of numbers approach by Harold Davenport (1907–1969) and Hans Heilbronn (1908–1975) resolved the case of degree 3 number fields. And then progress stopped. So a great deal of excitement greeted Bhargava's work in which he counted the number of degree 4 and degree 5 number fields having bounded discriminant. These results use his new composition laws, together with his systematic development of the geometry of numbers, which greatly extended the reach and power of this technique. The cases of degree bigger than 5 remain open, and Bhargava's composition laws will not resolve those. However, it is possible that those cases could be attacked using analogues of his composition laws.

Recently, Bhargava and his collaborators have used his expansion of the geometry of numbers to produce striking results about *hyperelliptic curves*. At the heart of this area of research is the ancient question of when an arithmetic calculation yields a square number. One answer Bhargava found is strikingly simple to state: A typical polynomial of degree at least 5 with rational coefficients never takes a square value. A hyperelliptic curve is the graph of an equation of the form y^2 = a polynomial with rational coefficients. In the case where the polynomial has degree 3, the graph is called an *elliptic curve*. Elliptic curves have especially appealing properties and have been the subject of a great deal of research; they also played a prominent role in Andrew Wiles's celebrated proof of Fermat's Last Theorem.

A key question about a hyperelliptic curve is how one can count the number of points that have rational coordinates and that lie on the curve. It turns out that the number of rational points is closely related to the degree of the curve. For curves of degree 1 and 2, there is an effective way of finding all the rational points. For degree 5 and higher, a theorem of Gerd Faltings (a 1986 Fields Medalist) says that there are only finitely many rational points. The most mysterious cases are those of degree 3—namely, the case of elliptic curves—and of degree 4. There is not even any algorithm known for deciding whether a given curve of degree 3 or 4 has finitely many or infinitely many rational points.

Such algorithms seem out of reach. Bhargava took a different tack and asked, what can be said about the rational points on a *typical* curve? In joint work with Arul Shankar and also with Christopher Skinner, Bhargava came to the surprising conclusion that a positive proportion of elliptic curves have only one rational point and a positive proportion have infinitely many. Analogously, in the case of hyperelliptic curves of degree 4, Bhargava showed that a positive proportion of such curves have no rational points and a positive proportion have infinitely many rational points. These works necessitated counting lattice points in unbounded regions of high-dimensional space, in which the regions spiral outward in complicated "tentacles." This counting could not have been done without Bhargava's expansion of the geometry of numbers technique.

Bhargava also used his expansion of the geometry of numbers to look at the more general case of higher degree hyperelliptic curves. As noted above, Faltings's theorem tells us that for curves of degree 5 or higher, the number of rational points is finite, but the theorem does not give any way of finding the rational points or saying exactly how many there are. Once again, Bhargava examined the question of what happens for a "typical" curve. When the degree is even, he found that the typical hyperelliptic curve has no rational points at all. Joint work with Benedict Gross, together with follow-up work of Bjorn Poonen and Michael Stoll, established the same result for the case of odd degree. These works also offer quite precise estimates of how quickly the number of curves having rational points decreases as the degree increases. For example, Bhargava's work shows that, for a typical degree 10 polynomial, there is a greater than 99 percent chance that the curve has no rational points.

A final example of Bhargava's achievements is his work with Jonathan Hanke on the so-called "290-Theorem." This theorem concerns a question that goes back to the time of Pierre de Fermat (1601-1665), namely, which quadratic forms represent all integers? For example, not all integers are the sum of two squares, so $x^2 + y^2$ does not represent all integers. Neither does the sum of three squares, $x^2 + y^2 + z^2$. But, as Joseph-Louis Lagrange (1736–1813) famously established, the sum of four squares, $x^2 + y^2 + z^2 + w^2$, *does* represent all integers. In 1916, Srinivasa Ramanujan (1887–1920) gave fifty-four more examples of such forms in four variables that represent all integers. What other such "universal" forms could be out there? In the early 1990s, John H. Conway and his students, particularly William Schneeberger and Christopher Simons, looked at this question a different way, asking whether there is a number c such that, if a quadratic form represents integers less than c, it represents all integers. Through extensive computations, they conjectured that c could perhaps be taken as small as 290. They made remarkable progress, but it was not until Bhargava and Hanke took up the question that it was fully resolved. They found a set of twenty-nine integers, up to and including 290, such that, if a quadratic form (in any number of variables) represents these twenty-nine integers, then it represents all integers. The proof is a feat of ingenuity combined with extensive computer programming.

In addition to being one of the world's leading mathematicians, Bhargava is an accomplished musician; he plays the Indian instrument known as the tabla at a professional level. An outstanding communicator, he has won several teaching awards, and his lucid and elegant writing has garnered a prize for exposition.

Bhargava has a keen intuition that leads him unerringly to deep and beautiful mathematical questions. With his immense insight and great technical mastery, he seems to bring a "Midas touch" to everything he works on. He surely will bring more delights and surprises to mathematics in the years to come.

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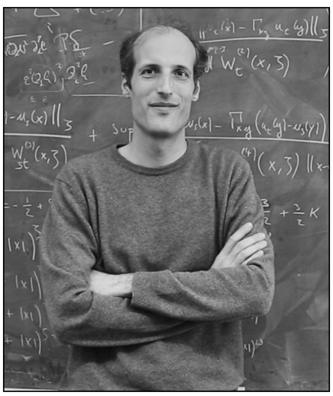
Biography

Born in 1974 in Canada, Manjul Bhargava grew up primarily in the USA and also spent much time in India. He received his Ph.D. in 2001 from Princeton University, under the direction of Andrew Wiles. Bhargava became a professor at Princeton in 2003. His honors include the Merten M. Hasse Prize of the Mathematical Association of America (2003), the Blumenthal Award for the Advancement of Research in Pure Mathematics (2005), the SASTRA Ramanujan Prize (2005), the Cole Prize in Number Theory of the American Mathematical Society (2008), the Fermat Prize (2011), and the Infosys Prize (2012). He was elected to the U.S. National Academy of Sciences in 2013.

The Work of Martin Hairer



Courtesy of IMU.

Martin Hairer

Martin Hairer has made a major breakthrough in the study of stochastic partial differential equations by creating a new theory that provides tools for attacking problems that up to now had seemed impenetrable.

The subject of differential equations has its roots in the development of calculus by Isaac Newton and Gottfried Leibniz in the seventeenth century. A major motivation at that time was to understand the motion of the planets in the solar system. Newton's laws of motion can be used to formulate a differential equation that describes, for example, the motion of the Earth around the Sun. A *solution* to such an equation is a function that gives the position of the Earth at any time t. In the centuries since, differential equations have become ubiquitous across all areas of science and engineering to describe systems that change over time.

A differential equation describing planetary motion is *deterministic*, meaning that it determines exactly where a planet will be at a given time in the future. Other differential equations are *stochastic*, meaning that they describe systems containing an inherent element of randomness. An example is an equation that describes how a stock price will change over time. Such an equation incorporates a term that represents fluctuations in the stock market price. If one could predict exactly what the fluctuations would be, one could predict the future stock price exactly (and get very rich!). However, the fluctuations, while having some dependence on the initial stock price, are essentially random and unpredictable. The stock-price equation is an example of a *stochastic* differential equation.

In the planetary-motion equation, the system changes with respect to only one variable, namely, time. Such an equation is called an *ordinary* differential equation (ODE). By contrast, *partial* differential equations (PDEs) describe systems that change with respect to more than one variable, for example, time and position. Many PDEs are *nonlinear*, meaning that the terms in it are not simple proportions—for example, they might be raised to an exponential power. Some of the most important natural phenomena are governed by nonlinear PDEs, so understanding these equations is a major goal for mathematics and the sciences. However, nonlinear PDEs are among the most difficult mathematical objects to understand. Hairer's work has caused a great deal of excitement because it develops a general theory that can be applied to a large class of nonlinear stochastic PDEs.

An example of a nonlinear stochastic PDE—and one that played an important role in Hairer's work—is the KPZ equation, which is named for Mehran Kardar, Giorgio Parisi, and Yi-Cheng Zhang, the physicists who proposed the equation in 1986 for the motion of growing interfaces. To gain some insight into the nature of the equation, consider the following simplified model for ballistic deposition. Particles move towards a substrate and stick upon arrival; as a consequence, the substrate height grows linearly in time, at the same time becoming increasingly more rough. In this context the KPZ equation describes the time evolution of the interface between vacuum and accumulated material. The randomness in the arrival positions and times of the particles introduces a space-time white noise into the equation, thus turning KPZ into a stochastic PDE, which describes the evolution over time of the rough, irregular interface between the vacuum above and the material accumulating below. A solution to the KPZ equation would provide, for any time t and any point along the bottom edge of the substrate, the height of the interface above that point.

The challenge the KPZ equation posed is that, although it made sense from the point of view of physics, it did not make sense mathematically. A solution to the KPZ equation should be a mathematical object that represents the rough, irregular nature of the interface. Such an object has no smoothness; in mathematical terms, it is not *differentiable*. And yet two of the terms in the KPZ equation call for the object to be differentiable. There is a way to sidestep this difficulty by using an object called a *distribution*. But then a new problem arises, because the KPZ equation is nonlinear: It contains a square term, and distributions cannot be squared. For these reasons, the KPZ equation was not well defined. Although researchers came up with some technical tricks to ameliorate these difficulties for the special case of the KPZ equation, the fundamental problem of its not being well defined long remained an unresolved issue.

In a spectacular achievement, Hairer overcame these difficulties by describing a new approach to the KPZ equation that allows one to give a mathematically precise meaning to the equation and its solutions. What is more, in subsequent work he used the ideas he developed for the KPZ equation to build a general theory, *the theory of regularity structures*, that can be applied to a broad class of stochastic PDEs. In particular, Hairer's theory can be used in higher dimensions.

The basic idea of Hairer's approach to the KPZ equation is the following. Instead of making the usual assumption that the small random effects occur on an infinitesimally small scale, he adopted the assumption that the random effects occur on a scale that is small in comparison to the scale at which the system is viewed. Removing the infinitesimal assumption, which Hairer calls "regularizing the noise", renders an equation that can be solved. The resulting solution is *not* a solution to KPZ; rather, it can be used as the starting point to construct a sequence of objects that, in the limit, converges to a solution of KPZ. And Hairer proved a crucial fact: the limiting solution is always the same regardless of the kind of noise regularization that is used.

Hairer's general theory addresses other, higher-dimensional stochastic PDEs that are not well defined. For these equations, as with KPZ, the main challenge is that, at very small scales, the behavior of the solutions is very rough and irregular. If the solution were a smooth function, one could carry out a *Taylor expansion*, which is a way of approximating the function by polynomials of increasingly higher degree. But the roughness of the solutions means they are not well approximated by polynomials. What Hairer did instead is to define objects, custom-built for the equation at hand, that approximate the behavior of the solution at small scales. These objects then play a role similar to polynomials in a Taylor expansion. At each point, the solution will look like an infinite superposition of these objects. The ultimate solution is then obtained by gluing together the pointwise superpositions. Hairer established the crucial fact that the ultimate solution does not depend on the approximating objects used to obtain it.

Prior to Hairer's work, researchers had made a good deal of progress in understanding *linear* stochastic PDEs, but there was a fundamental block to addressing nonlinear cases. Hairer's new theory goes a long way towards removing that block. What is more, the class of equations to which the theory applies contains several that are of central interest in mathematics and science. In addition, his work could open the way to understanding the phenomenon of universality. Other equations, when rescaled, converge to the KPZ equation, so there seems to be some universal phenomenon lurking in the background. Hairer's work has the potential to provide rigorous analytical tools to study this universality.

Before developing the theory of regularity structures, Hairer made other outstanding contributions. For example, his joint work with Jonathan Mattingly constitutes a significant advance in understanding a stochastic version of the Navier-Stokes equation, a nonlinear PDE that describes wave motion.

In addition to being one of the world's top mathematicians, Hairer is a very good computer programmer. While still a school student, he created audio editing software that he later developed and successfully marketed as "the Swiss army knife of sound editing." His mathematical work does not depend on computers, but he does find that programming small simulations helps develop intuition.

With his commanding technical mastery and deep intuition about physical systems, Hairer is a leader in the field who will doubtless make many further significant contributions.

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Biography

Born in 1975, Martin Hairer is an Austrian citizen. In 2001, he received his Ph.D. in physics from the University of Geneva, under the direction of Jean-Pierre Eckmann. He is currently Regius Professor of Mathematics at the University of Warwick. His honors include the Whitehead Prize of the London Mathematical Society (2008), the Philip Leverhulme Prize (2008), the Wolfson Research Merit Award of the Royal Society (2009), the Fermat Prize (2013), and the Fröhlich Prize of the London Mathematical Society (2014). He was elected a Fellow of the Royal Society in 2014.

The Work of Maryam Mirzakhani

Maryam Mirzakhani has made striking and highly original contributions to geometry and dynamical systems. Her work on Riemann surfaces and their moduli spaces bridges several mathematical disciplines—hyperbolic geometry, complex analysis, topology, and dynamics—and influences them all in return. She gained widespread recognition for her early results in hyperbolic geometry, and her most recent work constitutes a major advance in dynamical systems.

Courtesy of IMU.

Maryam Mirzakhani

Riemann surfaces are named after the nineteenth century mathematician Bernhard Riemann, who was the first to understand the importance of abstract surfaces, as opposed to surfaces arising concretely in some ambient space. Mathematicians building on Riemann's insights understood more than 100 years ago that such surfaces can be classified topologically, i.e., up to deformation, by a single number, namely, the number of handles. This number is called the *genus* of the surface. The sphere has genus zero, the surface of a coffee cup has genus one, and the surface of a proper pretzel has genus three. Provided that one disregards the precise geometric shape, there is exactly one surface of genus g for every positive integer g.

A surface becomes a Riemann surface when it is endowed with an additional geometric structure. One can think of this geometric structure as a so-called complex structure, which allows one to do complex analysis on the abstract surface. Since the complex numbers involve two real parameters, a surface, which is two-dimensional over the real numbers, has only one complex dimension and is sometimes called a complex curve. The following fact links the theory of Riemann surfaces to algebraic geometry: Every complex curve is an algebraic curve, meaning that the complex curve, although defined abstractly, can be realized as a curve in a standard ambient space, in which it is the zero set of suitably chosen polynomials. Thus, although a Riemann surface is a priori an analytic object defined in terms of complex analysis on abstract surfaces, it turns out to have an algebraic description in terms of polynomial equations.

An alternative but equivalent way of defining a Riemann surface is through the introduction of a geometry that allows one to measure angles, lengths, and areas. The most important such geometry is *hyperbolic geometry*, the original example of a non-Euclidean geometry discovered by Bolyai, Gauss, and Lobachevsky. The equivalence between complex algebraic and hyperbolic structures on surfaces is at the root of the rich theory of Riemann surfaces.

Mirzakhani's early work concerns closed geodesics on a hyperbolic surface. These are closed curves whose length cannot be shortened by deforming them. A now-classic theorem proved more than fifty years ago gives a precise way of estimating the number of closed geodesics whose length is less than some bound L. The number of closed geodesics grows exponentially with L; specifically, it is asymptotic to e^L/L for large L. This theorem is called the "prime number theorem for geodesics," because it is exactly analogous to the usual "prime number theorem" for whole numbers, which estimates the number of primes less than a given size. (In that case the number of primes less than e^L is asymptotic to e^L/L for large L.)

Mirzakhani looked at what happens to the "prime number theorem for geodesics" when one considers only the closed geodesics that are *simple*, meaning that they do not intersect themselves. The behavior is very different in this case: the growth of the number of geodesics of length at most L is no longer exponential in L but is of the order of L^{6g-6}, where g is the genus. Mirzakhani showed that in fact the number is asymptotic to $c \cdot L^{6g-6}$ for large L (going to infinity), where the constant c depends on the hyperbolic structure.

While this is a statement about a single, though arbitrary, hyperbolic structure on a surface, Mirzakhani proved it by considering all such structures simultaneously. The complex structures on a surface of genus g form a continuous, or nondiscrete, space, since they have continuous deformations. While the underlying topological surface remains the same, its geometric shape changes during a deformation. Riemann knew that these deformations depend on $6g-6$ parameters or "moduli", meaning that the "moduli space" of Riemann surfaces of genus g has dimension $6g-6$. However, this says nothing about the global structure of moduli space, which is extremely complicated and still very mysterious. Moduli space has a very intricate geometry of its own, and different ways of looking at Riemann surfaces lead to different insights into its geometry and structure. For example, thinking of Riemann surfaces as algebraic curves leads to the conclusion that moduli space itself is an algebraic object called an algebraic variety.

In Mirzakhani's proof of her counting result for simple closed geodesics, another structure on moduli space enters, a so-called symplectic structure, which, in particular, allows one to measure volumes (though not lengths). Generalizing earlier work of G. McShane, Mirzakhani establishes a link between the volume calculations on moduli space and the counting problem for simple closed geodesics on a single surface. She calculates certain volumes in moduli space and then deduces the counting result for simple closed geodesics from this calculation.

This point of view led Mirzakhani to new insights into other questions about moduli space. One consequence was a new and unexpected proof of a conjecture of Edward Witten (a 1990 Fields Medalist), one of the leading figures in string theory. Moduli space has many special loci inside it that correspond to Riemann surfaces with particular properties, and these loci can intersect. For suitably chosen loci, these intersections have physical interpretations. Based on physical intuition and calculations that were not entirely rigorous, Witten made a conjecture about these intersections that grabbed the attention of mathematicians. Maxim Kontsevich (a 1998 Fields Medalist) proved Witten's conjecture through a direct verification in 1992. Fifteen years later, Mirzakhani's work linked Witten's deep conjecture about moduli space to elementary counting problems of geodesics on individual surfaces.

In recent years, Mirzakhani has explored other aspects of the geometry of moduli space. As mentioned before, the moduli space of Riemann surfaces of genus g is itself a geometric object of $6g-6$ dimensions that has a complex, and, in fact, algebraic structure. In addition, moduli space has a metric whose geodesics are natural to study. Inspired by the work of Margulis, Mirzakhani and her co-workers have proved yet another analogue of the prime number theorem, in which they count closed geodesics in moduli space, rather than on a single surface. She has also studied certain dynamical systems (meaning systems that evolve with time) on moduli space, proving in particular that the system known as the "earthquake flow," which was introduced by William Thurston (a 1982 Fields Medalist), is chaotic.

Most recently, Mirzakhani, together with Alex Eskin and, in part, Amir Mohammadi, made a major breakthrough in understanding another dynamical system on moduli space that is related to the behavior of geodesics in moduli space. Nonclosed geodesics in moduli space are very erratic and even pathological, and it is hard to obtain any understanding of their structure and how they change when perturbed slightly. However, Mirzakhani et al. have proved that *complex* geodesics and their closures in moduli space are in fact surprisingly regular, rather than irregular or fractal. It turns out that, while complex geodesics are transcendental objects defined in terms of analysis and differential geometry, their closures are algebraic objects defined in terms of polynomials and therefore have certain rigidity properties.

This work has garnered accolades among researchers in the area, who are working to extend and build on the new result. One reason the work sparked so much excitement is that the theorem Mirzakhani and Eskin proved is analogous to a celebrated result of Marina Ratner from the 1990s. Ratner established rigidity for dynamical systems on homogeneous spaces—these are spaces in which the neighborhood of any point looks just the same as that of any other point. By contrast, moduli space is totally inhomogeneous: Every part of it looks totally different from every other part. It is astounding to find that the rigidity in homogeneous spaces has an echo in the inhomogeneous world of moduli space.

Because of its complexities and inhomogeneity, moduli space has often seemed impossible to work on directly. But not to Mirzakhani. She has a strong geometric intuition that allows her to grapple directly with the geometry of moduli space. Fluent in a remarkably diverse range of mathematical techniques and disparate mathematical cultures, she embodies a rare combination of superb technical ability, bold ambition, far-reaching vision, and deep curiosity. Moduli space is a world in which many new territories await discovery. Mirzakhani is sure to remain a leader as the explorations continue.

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Biography

Born in 1977 in Tehran, Iran, Maryam Mirzakhani received her Ph.D. in 2004 from Harvard University, where her advisor was Curtis McMullen. From 2004 to 2008 she was a Clay Mathematics Institute Research Fellow and an assistant professor at Princeton University. She is currently a professor at Stanford University. Her honors include the 2009 Blumenthal Award for the Advancement of Research in Pure Mathematics and the 2013 Satter Prize of the American Mathematical Society.

—IMU News Releases

? WHAT IS...

a Perfectoid Space?

Bhargav Bhatt

Perfectoid spaces are a class of algebro-geometric objects living in the realm of p-adic geometry that were introduced by Peter Scholze [Sch12] in his Ph.D. thesis. Their definition is heavily inspired by a classical result in Galois theory (see Theorem 1) due to Fontaine and Wintenberger, and the resulting theory has already had stunning applications.

Motivation

Fix a prime number p, and consider the field $L_0 := \mathbf{Q}_p$ of p-adic numbers, as well as the field $L_0^\flat := \mathbf{F}_p((t))$ of Laurent series over $\mathbf{F}_p$. These fields are formally quite similar: one can represent elements in L_0 as Laurent series in p with integer coefficients, and a similar description applies to $L_0^\flat$ with t replacing p. Of course there is no isomorphism $L_0 \simeq L_0^\flat$ of fields realizing this similarity: L_0 has characteristic 0, while $L_0^\flat$ has characteristic $p > 0$. Nevertheless, it is a fundamental insight of [FW79] that a robust relationship between the two *does* exist, at least after replacing L_0 with the larger field $L := \mathbf{Q}_p[p^{\frac{1}{p^\infty}}] := \cup_n \mathbf{Q}_p(p^{\frac{1}{p^n}})$, and $L_0^\flat$ with its perfection $L^\flat := \cup_n \mathbf{F}_p((t^{\frac{1}{p^n}}))$.

Theorem 1 (FW79). *The (absolute) Galois groups of L and $L^\flat$ are canonically isomorphic.*

Theorem 1 gives a correspondence between finite field extensions of L and $L^\flat$ which, heuristically, is established by replacing p with t. For example, the splitting field of $X^2 - t$ over $L^\flat$ corresponds to the splitting field of $X^2 - p$ over L. This mechanism can be somewhat demystified by noticing that the "integral" subrings $\mathbf{Z}_p[p^{\frac{1}{p^\infty}}] \subset L$ and $\mathbf{F}_p[t^{\frac{1}{p^\infty}}] \subset L^\flat$ are related by an isomorphism of rings

$$\mathbf{Z}_p[p^{\frac{1}{p^\infty}}]/(p) \simeq \mathbf{F}_p[t^{\frac{1}{p^\infty}}]/(t) \tag{1}$$

that carries $p^{\frac{1}{p^n}}$ to $t^{\frac{1}{p^n}}$. Besides its intrinsic beauty, this correspondence allows us to transport Galois-theoretic information between L and $L^\flat$.

Example 1. Certain invariants are very easy to compute for $L^\flat$ on account of the Frobenius automorphism; Theorem 1 can sometimes help transfer this computation to L. For example, using this strategy, one deduces that the $\mathbf{F}_p$-cohomological dimension of the absolute Galois group of L is ≤ 1 because the corresponding assertion for $L^\flat$ is classical (Hilbert).

Recall that fields are zero-dimensional varieties from an algebro-geometric perspective. The goal of the theory of perfectoid spaces is to extend Theorem 1 to higher dimensions, i.e., to relate (certain) algebras over L and $L^\flat$ in a relatively lossless manner.

Perfectoid Spaces

Fix L and $L^\flat$ as in the previous section. To introduce perfectoid spaces over these fields, it will be useful to recall some additional structures on L and $L^\flat$. Specifically, note that both L and $L^\flat$ are equipped with natural norms given by the p-adic and t-adic metrics respectively. As our subsequent constructions involve various limiting operations (such as the extraction of arbitrary p-power roots), it is convenient to cast all constructions in a slightly more analytic framework. We will thus pass from L to its p-adic completion K, and $L^\flat$ to its t-adic

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completion $K^\flat$; the analogue of Theorem 1 holds for K and $K^\flat$ as completions do not change Galois groups. The basic definition is:

Definition 1. A *perfectoid K-algebra A* is a Banach K-algebra such that the subring A° of power-bounded elements is open and bounded, and the Frobenius endomorphism is surjective on A°/p; one similarly defines *perfectoid $K^\flat$-algebras*.

To unravel this definition, let us study some examples. The simplest example of such an algebra is K itself. Indeed, the norm on K endows K with a Banach algebra structure. The subring K° is the p-adic completion $\widehat{\mathbf{Z}_p[p^{\frac{1}{p^\infty}}]}$ and is thus open and bounded in the (p-adic) topology on K; the Frobenius on K°/p is surjective by construction. This example corresponds to a "point" in the world of perfectoid K-spaces. The next simplest example is that of a "line":

Example 2. Consider the p-adically complete K°-algebra $A' := \widehat{K^\circ[X^{\frac{1}{p^\infty}}]}$, and let $A := A'[\frac{1}{p}]$. Then one can endow A with a natural Banach K-algebra structure such that $A^\circ = A'$ is open and bounded. Moreover, as we have already extracted arbitrary p-power roots of X, the Frobenius on A°/p is surjective, so A is a perfectoid K-algebra; this algebra is often denoted $K\langle X^{\frac{1}{p^\infty}}\rangle$. Similarly, $A^\flat := K^\flat\langle X^{\frac{1}{p^\infty}}\rangle$ is a perfectoid $K^\flat$-algebra.

It is also easy to build examples in characteristic p:

Example 3. Let A_0 be any $K^{\flat,\circ}$ algebra. Extracting p-power roots of all elements in A (i.e., passing to the perfection) gives a new $K^{\flat,\circ}$-algebra $A_{0,\mathrm{perf}}$. This leads to the $K^\flat$-algebra $A := \widehat{A_{0,\mathrm{perf}}}[\frac{1}{t}]$ by inverting t in the t-adic completion. One may endow A with a natural Banach $K^\flat$-algebra structure to make it perfectoid. For example, applying this procedure to $A_0 := K^{\flat,\circ}[X]$ produces $A^\flat$ from Example 2.

Recall from algebraic geometry that affine varieties are completely described by their rings of functions, while varieties are built by glueing affine varieties together. The situation with perfectoid K-spaces is analogous: the "affine" objects correspond to perfectoid K-algebras, while perfectoid K-spaces are built by glueing these "affine" objects together. Actually, to retain the analytic flavor of Definition 1, this glueing is carried out in the world of rigid analytic geometry (incarnated through Huber's adic spaces [Hub96]). We will ignore this technical, but absolutely crucial, point here, and assume that the notion of a perfectoid K-space, built by glueing together "spectra" of perfectoid K-algebras, has been defined. The main theorem concerning these objects is:

Theorem 2 (Sch12, Theorems 1.9 and 1.11)**.** *The categories of perfectoid K-spaces and perfectoid $K^\flat$-spaces are canonically identified; this identification preserves the étale topology.*

To describe this equivalence, observe that (1) gives a formula describing $K^\flat$ in terms of K:

$$K^\flat \simeq (\lim K^\circ/p)[\frac{1}{t}], \tag{2}$$

where the limit is along the Frobenius maps on K°/p, and $t \in \lim K^\circ/p$ is the p-power compatible system $(p^{\frac{1}{p^n}})$. The identification in Theorem 2 is given by exactly the same formula (for affines): one sends a perfectoid K-algebra A to the perfectoid $K^\flat$-algebra

$$A^\flat := (\lim A^\circ/p)[\frac{1}{t}].$$

The association $A \mapsto A^\flat$ is called *tilting*, while the inverse is called *untilting*; the nomenclature suggests viewing these operations as carrying us between the two ends of the following picture, resulting from (2):

$$\begin{array}{ccccc} & & K^\circ & \xrightarrow{\text{invert p}} & K \\ & & \downarrow{\scriptstyle\text{kill p}} & & \\ K^{\flat,\circ} & \xrightarrow{\text{kill t}} & K^{\flat,\circ}/t \simeq K^\circ/p & & \\ \downarrow{\scriptstyle\text{invert t}} & & & & \\ K^\flat. & & & & \end{array}$$

We have already encountered some examples of tilting earlier in this note:

Example 4. The field $K^\flat$ is the tilt of K, as explained above, which clarifies the notation. Similarly, in Example 2, the ring $A^\flat$ is the tilt of A.

A more "global" example of tilting is given by:

Example 5. Fix an integer n. Globalizing Example 3 leads to a perfectoid $K^\flat$-space $\mathbf{P}^n_{K^\flat,\mathrm{perf}}$ obtained as the perfection of projective space $\mathbf{P}^n_{K^\flat}$ over $K^\flat$. Its untilt is (roughly) given by $\mathbf{P}^n_{K,\mathrm{perf}} := \lim \mathbf{P}^n_K$, where the transition maps raise all homogeneous coordinates to the p-th power.

The preservation of the étale topology under tilting is a deep result: it is a simultaneous generalization of Theorem 1 and of Faltings's "almost purity theorem," the key ingredient of his fundamental work in p-adic Hodge theory, which began in [Fal88] and allowed him to prove various conjectures of Fontaine.

Theorem 2 leads to the following picture summarizing the relationship of perfectoid spaces to classical algebraic geometry:

$$\begin{array}{ccc}\{\text{algebraic varieties}/K\} & & \{\text{algebraic varieties}/K^\flat\} \\ \Big\downarrow \Psi & & \Big\downarrow \text{perfection} \\ \{\text{perfectoid spaces}/K\} & \underset{\text{untilt}}{\overset{\text{tilt}}{\rightleftarrows}} & \{\text{perfectoid spaces}/K^\flat\}\end{array}$$

Here the horizontal arrows come from Theorem 2, and the right vertical arrow is the globalization of Example 3. The mysterious dotted arrow Ψ is, in fact, nonexistent: there is no natural way to attach a perfectoid K-space to an algebraic K-variety. This apparent asymmetry can be explained by noticing that there is a *canonical* procedure for extracting all p-th roots in characteristic p (namely, taking the perfection), while there is no analogous construction in characteristic 0. Instead, given an algebraic K-variety X, each time one can *somehow* construct a related perfectoid K-space $\Psi(X)$, one learns a wealth of new information about X. We discuss some examples of this phenomenon in the section entitled "Examples and Applications."

Remark 1. In [Sch12], one finds a slightly more general version of the theory sketched here: the field K above is simply an example of a *perfectoid field*. For any such K, there is a tilt $K^\flat$ in characteristic p, and an analogous theory of perfectoid spaces over these fields (including, in particular, Theorem 2). An important example is $K = \mathbf{C}_p$ (the completed algebraic closure of $\mathbf{Q}_p$) whose tilt $K^\flat$ is the completed algebraic closure of $\mathbf{F}_p((t))$.

Examples and Applications

The theory of perfectoid spaces is rather young, but already extremely potent: each class of examples discovered so far has led to powerful and deep theorems in arithmetic geometry. We give a summary of some such examples next, with notation as in the previous section.

• Given a hypersurface $H \subset \mathbf{P}^n_K$, one can construct a perfectoid space U_ϵ which, essentially, is the tubular neighborhood of radius ϵ around the inverse image of H under $\mathbf{P}^n_{K,\text{perf}} \to \mathbf{P}^n_K$, following the notation in Example 5. Using U_ϵ and Theorem 2, Scholze proved Deligne's weight-monodromy conjecture for smooth H in [Sch12] by reducing it to the analogous statement for a smooth hypersurface H' over the characteristic p field $K^\flat$ (as the latter was proven by Deligne en route to the Weil conjectures).

• Given a positive integer g, one may consider the moduli space $\mathcal{A}_g(p^\infty)$ parameterizing abelian varieties A over K equipped with a trivialization $\phi : \mathbf{Z}_p^{\oplus 2g} \simeq T_p(A)$ of their p-adic Tate modules. This space is rather large and pathological from the viewpoint of classical algebraic geometry. Nevertheless, in a recent preprint (titled "On torsion in the cohomology of locally symmetric varieties"), Scholze showed that $\mathcal{A}_g(p^\infty)$ is a well-behaved object: it is naturally a perfectoid K-space. In fact, he deduced a similar statement for any Shimura variety (of Hodge type) with full level structure at p. Using these spaces, he proved the following two results, which outwardly have nothing to do with perfectoid spaces (or even local fields): (a) a cohomological vanishing conjecture of Calegari and Emerton for Shimura varieties over $\mathbf{C}$ is true (much in the spirit of Example 1), and (b) one can attach Galois representations to *torsion* classes in the cohomology of locally symmetric spaces, which builds on recent work of Harris-Lan-Taylor-Thorne, and represents a significant step forward in the Langlands program.

• We end by touching on a theme that was largely skirted in the previous section. Namely, as perfectoid spaces live in the world of analytic geometry, they actually help study classical rigid-analytic spaces, not merely algebraic varieties (as in the previous two examples). In his "p-adic Hodge theory for rigid-analytic varieties" paper, Scholze pursues this idea to extend the foundational results in p-adic Hodge theory, such as Faltings's work mentioned above, to the setting of rigid-analytic spaces over $\mathbf{Q}_p$; such an extension was conjectured many decades ago by Tate in his epoch-making paper "p-divisible groups." The essential ingredient of Scholze's approach is the remarkable observation that *every* classical rigid-analytic space over $\mathbf{Q}_p$ is locally perfectoid, in a suitable sense.

The power of perfectoid spaces is only beginning to be exploited, and more applications will surely arise!

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The Digital Mathematics Library as of 2014

Thierry Bouche

TEX and the Internet appeared in the 1980s. In 1991, Paul Ginsparg started a small HTTP server where people could upload their preprints written in TEX or LATEX rather than circulating them by postal mail. During the 1990s most scientific publishers started their electronic publishing platforms, and digitization programs such as Gallica, JSTOR, and GDZ were launched. Digital publishing at the end of the twentieth century could now be called the digital incunables as since then things have started to look pretty mature, evolving at a much slower pace. The basic layers such as TCP/IP, HTML, PDF, and XML were in place and have since then remained quite stable. At that time, the cliché of the World Wide Web as a universal library where all mankind's knowledge would rapidly be easily retrievable through hypertext links was well established. Ironically, Google itself was started in the context of a project aiming "to develop the enabling technologies for a single, integrated and 'universal' library" [7].

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In 2001 every working mathematician was already supposed to have a personal homepage: The International Mathematical Union (IMU) emitted a "Call to all mathematicians to make their publications electronically available" [5]. This was the first effective, somewhat naive, attempt to create from scratch an open access universal library of the mathematical corpus. The idea was that a mathematician would maintain a webpage with a list of his/her published works, with links to full texts, either typeset (or rekeyed) with TEX or scanned. Supposedly, discovery and access would rely on generic Web crawlers and search engines.

At the same time, the project of digitizing twenty centuries of the published mathematical literature was discussed, first in Washington DC, but the discussion rapidly spread worldwide, filed under the name "The digital mathematical library" (DML) [4], [6]. An incarnation of this idea has been the DML list maintained by Ulf Rehmann [11].

Today, almost fifteen years later, this duality persists between the vision of the digital counterpart to the traditional library and the crowd-sourced constitution of a loose collection of digital content, based on availability rather than selection, with the hope that interlinking and advanced indexing, ranking or semantic computations will help users find the pearls.

Publishing and Library Businesses Differ

In today's glossary, a *digital library* is any collection of digital objects with a management plan. Thus the website of a commercial publisher constitutes a digital library as well as a linked webpage.

However, the functions and skills expected from publishers and librarians are not to be confused. Publishing is a business that aims at delivering new content, which is afterwards exploited over a limited period of time. It is risky because it requires a lot of investment prior to publication, while success is never certain. The library business has evolved a lot over the ages, but it is pretty well understood (as long as we stick to paper) that it involves content selection and acquisition, cataloguing, archiving, and preservation in order to maintain collections accessible to patrons. It is nowadays predominantly a nonprofit activity, typically a service offered by scientific institutions to their members.

It is amazing how many of the grand maneuvers in science, technology, and medicine (STM) publishing have been aimed at reducing the risks of publishing while removing the library functions from universities (see [9], [10]): journal Big Deals, subscriptions to book series, or, more generally, licensing access to bundled resources on the Web are effective methods to take away the selection process from libraries. The acquisition is limited to transferring an amount of money to license content hosted by the publisher. Gold open access publishing is in a sense the ultimate weapon in this direction as the publication costs are covered in advance and there is no longer any risk that an unsatisfied consumer will cancel the subscription.

Being the collection's host, the publisher should therefore take care of preservation and long-term access. Now even the discussions within the library buildings are being privatized through the development of so-called scientific social networks!

I think it is time to stop this trend and to balance the weight of libraries and publishers in the interest of science. Contrary to many colleagues, I don't think we should eliminate publishers. In fact the Internet has facilitated the creation of many publishing venues where publishing skills and professionalism are missing. Publishers should concentrate on producing new quality content and services while the archive should be selected and curated by nonprofit long-lasting institutions.

As a side note, I think it is also important to keep in mind the distinction between the library as a raw reservoir of original works and the encyclopedia as a gateway to highlighted and synthesized parts of that knowledge. An encyclopedia can be a very effective way to enter the library and to single out distinguished entry points to some subject. By design it cannot be neutral and exhaustive. In fact, the library is the infrastructure that stores original results, on top of which as many different gateways can be built as user communities require.

The DML: Vision and Content

The initial DML vision was to digitize all published mathematics since Euclid up to the advent of electronic publishing in order to assemble a reference corpus, highly navigable and freely accessible. The motivation to do this is that verified mathematical results not only do not age but can find unexpected applications at any point in time, so a freely and easily accessible corpus would feed both current mathematical research and further innovation. Also, as mathematical writing is *cumulative* (new results are built upon old ones; they do not replace them), we feel uncomfortable as long as the reference corpus is incomplete. A pragmatic reason for urging in this direction at the end of twentieth century was a certain kind of academic Internet bubble: the belief that any move toward digital science would be heavily funded. But the bubble burst and the envisioned centralized project vanished, leaving us with a name and numerous local (many of them national) DML projects, each one with unique standards and policies.

Today, the portion of the mathematical corpus that exists in digital form is not far from exhaustive (of course the proportion of digital items is steadily approaching 100 percent as each new item is produced digitally, but there are still important references that have not been digitized). The landscape has been changed by the systematic digitization of backfiles by publishers, of entire shelf holdings from some large libraries, as well as a few dedicated projects. But most of this is unreachable to the working mathematician.

The IMU has advocated free access to the mathematical corpus after a reasonable time lag ("moving wall"), but this advice has not been followed beyond some academic circles. Well, it might have been heard in the form of understanding that the archive had value to mathematicians, hence could be sold, which is probably the dominant model currently. The DML content exists, but it is highly fragmented and locked behind a multitude of walls.

Typical barriers encountered by the working mathematician are:

- Digital content has been produced by a commercial provider and is behind a paywall. This also concerns very old content (including public domain).
- Digital content is available somewhere but practically invisible (badly indexed or unstable webpages, nonexistent or inaccurate metadata, no interoperability with those search systems the users are familiar with…).

These barriers move all the time: A Web crawler can suddenly index or forget a page; Elsevier freed access to four-year-old backfiles of fifty-three mathematical journals, which can be reverted whenever they see fit as there is no third party archive; JSTOR decided to provide open access to public domain texts after denying it for years; the *Annals of Mathematics* sought to withdraw the freely available content from its open access era when it reverted to the subscription model, etc.

Recent Developments

For almost ten years the only DML-related activity has been focused on creating and maintaining local DMLs as separate islands. Some consensus conferences have been held sporadically, typically in conjunction with a rumor of possible funding.

In 2008, the DML workshop was created by Petr Sojka as a companion to the Mathematical Knowledge Management (MKM) conference (it is now a track in the CICM series of conferences [3]). The main focus is on computer science research that could impact any aspect of a DML.

The Sloan Foundation supported a symposium on "The Future World Heritage Digital Mathematics Library: Plans and Prospects" held at the National Academy of Sciences, Washington, DC, in 2012, organized by the Committee on Electronic Information and Communication (CEIC) of the IMU. A committee on planning a global library of the mathematical sciences was formed at the National Research Council (NRC) right after and produced a report [8] which is summarized by Jim Pitman and Clifford Lynch in the June/July 2014 issue of the *Notices* ("Planning a 21st century global library for mathematics research," pp. 776–777).

Since 2003, the European Mathematical Society has tried to get some funding to advance the European chapter of the DML. The EuDML[1] project proposal was finally selected by the European Commission and the project started in February 2010 for a duration of three years. I have written a personal summary of the achievements of this project, to which I refer the reader for further details [1]. Earlier this year, the EuDML Initiative was established as the association of the partners taking care of the future of this effort [2].

EuDML was a breakthrough in a number of aspects.

- It was the first project to effectively build a transnational DML, built on local DMLs from eight countries.
- It set up the machinery to harvest and transform metadata from thirteen sources and exploit it on a single user-friendly website. It tried to make much more content visible by upgrading metadata at the article level.
- It defined and deployed a number of machine-oriented services that are probably not yet known to the extent they should be: it is possible to selectively harvest parts of the database content (using OAI-PMH protocol) but also to use it as a metadata hub (matching a citation against the database, then querying all identifiers associated to an EuDML item, etc.)
- Although most of the content is journal articles, all relevant content types are explicitly supported: edited books such as conference proceedings, monographs, dissertations, multivolume works.
- It didn't target simple textual metadata aggregation but experimented with many MKM techniques and results, making the mathematical nature of the content an asset rather than a liability. To name a few: conversion from TEX metadata to MathML, mathematical OCR, formula search.
- It served as a sandbox to try out more experimental features (such as linking content through mathematical content similarity, making mathematical content more accessible to dyslexic or visually impaired users, etc.)

Also, clear policies have been devised to build a reliable, sustainable system with nonvolatile content:

(1) EuDML content is scientifically validated and formally published in final form.
(2) The digital content is physically hosted at one of the partner institutions (local DML).
(3) It is freely accessible after a reasonable moving wall (which typically ranges from zero, or open access, to five years).

Starting from there, it should be relatively straightforward to enlarge the coverage to the point where EuDML becomes a valuable resource to the working mathematician as well as the educated citizen. The first front that will be engaged by the EuDML Initiative is to enlarge the content partnership beyond the project's partners (this already started with Italian and Serbian DMLs joining) and beyond European Union borders.

The benefits of the EuDML are already obvious, even to users unaware of its existence, through the better visibility of many sources in Web search engines. However, it won't be the one-stop shop for all mathematics literature as long as the underlying corpus is restricted to a limited number of benevolent content providers with sufficient resources to make their systems compliant. On

[1] *EuDML: The European Digital Mathematics Library; see* `http://eudml.org`.

this front, my guess is that we can cross a new boundary if every scientific editor of every live journal or book series requires from its publishers cooperation with a local DML to archive its content and arrange a continuous flow for new material. Beware that all *three* conditions in EuDML policy above should be checked or else this could be reversed afterwards! If the publisher refuses, move to a more sympathetic publisher. There are many of them, and they will typically be nearer to the community, thus serving your publication better.

What Next?

One new challenge is the number of non- (or hardly) archivable mathematical contents like Polymath (relying on a combination of a blog and a wiki), personal collected works on professional homepages after leave or retirement of the author, collective books that are indeed a version control repository (like the Univalent Foundations book from Princeton), PlanetMath, MathOverflow, etc. While these are properly indexable and crawlable by Web search engines, it is not at all obvious how they will be preserved and referred to in decades to come, if ever this happens.

Nevertheless, I hope that in the near future we will see clear progress in the following areas:

- The EuDML Initiative will establish a strong organization (Europe-based, but with worldwide scope) which will convince more stakeholders to join and adhere to its goals and methods. The number of items available through the EuDML should reach a million, the point of no return.
- The NRC committee's suggested creation of a linked open mathematical concept network will be implemented by a dedicated team, using freely available digital resources as a testbed.

Then, glueing the bits and pieces together, we can expect to advance the DML vision to the point where doing mathematical research and interacting with the mathematical corpus might be completely different and much more powerful in ten years than what we experience today.

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Mathematics People

Castro Receives the Royal Spanish Mathematical Annual Prize

The current year is a significant year in the history of the Royal Spanish Mathematical Society (RSME), which in 2011 commemorated its one hundredth anniversary, and this year celebrates the tenth edition of its highest award, the Rubio de Francia Prize. The prize honors the memory of renowned Spanish analyst J. L. Rubio de Francia (1949-1988). The RSME awards the prize annually to a mathematician from Spain or residing in Spain who is at most thirty-two years of age, in recognition of research contributions to any area of pure or applied mathematics.

This year the recipient is Angel Castro (born 1982) of the Universidad Autónoma de Madrid and the Institute for Mathematical Sciences (ICMAT). The prize jury emphasized Castro's contributions to partial differential equations and fluid mechanics, in particular the results of Castro and his collaborators on the problem of appearance of singularities, which is essential to understanding turbulence. This work of a high caliber becomes particularly significant in view of the fact that little was known about it prior to the contributions of Castro and his collaborators.

The Rubio de Francia Prize is awarded by an international jury covering a range of mathematical areas. This year the prize committee was chaired by Jesús Bastero (Zaragoza, Spain) and made up of Noga Alon (Tel Aviv, Israel), Álvaro Pelayo (University of California, San Diego, USA), Gilles Pisier (Université Pierre et Marie Curie, France), Marta Sanz-Solé (Universidad de Barcelona, Spain), Cédric Villani (Institut Henri Poincaré, France), and Claire Voisin (École Polytechnique, France). Recent prize winners include Maria Pe (2012), Alberto Enciso (2011), Carlos Beltrán (2010), Álvaro Pelayo (2009), and Francisco Gancedo (2008).

—From a Royal Spanish Mathematical Society (RSME) announcement.

2014 Simons Investigators Named

The Simons Foundation has named sixteen mathematicians, theoretical physicists, and theoretical computer scientists as Simons Investigators for 2014. The Simons Investigators program provides a stable base of support for outstanding scientists, enabling them to undertake long-term study of fundamental questions. The names and institutions of the awardees whose work involves the mathematical sciences and brief excerpts from the prize citations follow.

Alex Eskin of the University of Chicago is a leading geometer with important contributions to geometric group theory, ergodic theory, and number theory. He has applied ideas from dynamical systems to solve counting problems in the theory of Diophantine equations, the theory of the mapping class group, and mathematical billiards on rational polygons.

Larry Guth of the Massachusetts Institute of Technology is a geometer with outstanding contributions to Riemannian geometry, symplectic geometry, and combinatorial geometry. In Riemannian geometry, he solved a long-standing problem concerning sharp estimates for volumes of *k*-cycles. In symplectic geometry, he disproved a conjecture concerning higher-dimensional symplectic invariants by constructing ingenious counterexamples. In combinatorial geometry, he adopted a recent proof of the finite field analog of the Kakeya problem to the Euclidean context. He and Jean Bourgain established the best current bounds to the restriction problem. Extending this work, he and Katz essentially solved one of the most well-known problems in incidence geometry, Erdős's distinct distance problem, which was formulated in the 1940s.

Richard Kenyon of Brown University, whose mathematical contributions are centered in statistical mechanics and geometric probability. He established the first rigorous results on the dimer model, opening the door to recent spectacular advances in the Schramm–Loewner evolution theory. In his most recent work, he introduced new homotopic invariants of random structures on graphs, establishing an unforeseen connection between probability and representation theory.

Andrei Okounkov of Columbia University works in a wide range of topics at the interface of representation theory, algebraic geometry, combinatorics, and mathematical physics. He has made major contributions to enumerative geometry of curves and sheaves, the theory of random surfaces and random matrices. His papers reveal hidden structures and connections between mathematical objects and introduce deep new ideas and techniques of wide applicability.

Moses Charikar of Princeton University is one of the world's leading experts on the design of approximation algorithms. He gave an optimal algorithm for unique games, a central problem in complexity theory. His work sheds light on the strengths and limitations of continuous relaxations for discrete problems. He has uncovered new obstructions to dimension reduction and compression of geometric data. His algorithms for locality-sensitive hash functions are now de facto standard in real-life applications.

Shang-Hua Teng of the University of Southern California is one of the most original theoretical computer scientists in the world, with groundbreaking discoveries in algorithm design, spectral graph theory, operations research, and algorithmic game theory. In joint work with Dan Spielman, Shang-Hua introduced smoothed analysis, a new framework that has served as a basis for advances in optimization, machine learning, and data mining. His work laid foundations for many algorithms central in network analysis, computational economics, and game theory.

Simons investigators are appointed for an initial period of five years with possible renewal for a further five years. Investigators receive research support of US$100,000 per year, with an additional US$10,000 per year provided to the investigator's department.

—From a Simons Foundation announcement

Prizes of the London Mathematical Society

The London Mathematical Society (LMS) has awarded a number of prizes for 2014. The Polya Prize was awarded to Miles Reid of the University of Warwick for his exceptionally creative work on higher-dimensional algebraic geometry; in particular, on canonical singularities, the MacKay correspondence, the explicit study of three-dimensional flips, the structure of Gorenstein rings, and for his inspired expositions. The Fröhlich Prize was awarded to Martin Hairer of the University of Warwick for his work on the interface between probability theory and partial differential equations, a body of work that is widely recognized as revolutionizing an entire field of research. Caroline Series of the University of Warwick was awarded the Senior Anne Bennett Prize in recognition of her leading contributions to hyperbolic geometry and symbolic dynamics, and of the major impact of her numerous initiatives toward the advancement of women in mathematics.

The Senior Berwick Prize was awarded to Daniel Freed (University of Texas at Austin), Michael Hopkins (Harvard University), and Constantin Teleman (University of California, Berkeley) in recognition of their paper "Loop groups and twisted *K*-theory," *Journal of Topology* **4** (2011), 737–799. The paper sets out the foundations of twisted equivariant *K*-theory and prepares the ground for the proof that the twisted equivariant *K*-theory of a compact Lie group is isomorphic to the Verlinde algebra of its loop group.

The Whitehead Prizes are given to mathematicians with less than fifteen years' experience at the postdoctoral level (allowing for career breaks). The Whitehead Prizes were awarded to: Clément Mouhot, University of Cambridge, for fundamental mathematical contributions to the foundations of statistical mechanics and the Boltzmann equation; Ruth Baker, University of Oxford, for her outstanding contributions to the field of mathematical biology; Tom Coats, Imperial College, London, for his influential work on Gromov-Witten theory, the quantum Lefschetz theorem, the crepant resolution conjecture, the quantum cohomology of stacks, the higher genus theory of Calabi-Yau manifolds, and the Fanosearch program; and Daniela Kühn and Deryk Osthus (University of Birmingham), jointly, for their many results in extremal graph theory and related areas. Several of their papers resolve long-standing open problems in the area.

—From an LMS announcement

Ford Foundation Fellowships Awarded

Two young mathematicians have been awarded National Research Council-Ford Foundation fellowships for 2014. Christopher Vincent Rackauckas of the University of California, Irvine, and David McMillon of Princeton University received predoctoral fellowships. Samuel Ivy of North Carolina State University received a dissertation fellowship.

—From a Ford Foundation announcement

NSF Postdoctoral Fellowships Awarded

The Mathematical Sciences Postdoctoral Research Fellowship Program of the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) awards fellowships each year for postdoctoral research in pure mathematics, applied mathematics and operations research, and statistics. Following are the names of the fellowship recipients for 2014, together with their Ph.D. institutions (in parentheses) and the institutions at which they will use their fellowships.

Joshua Ballew (University of Maryland), Carnegie Mellon University; Blake Barker (Indiana University), Brown University; ANNA BARRY (Boston University), University of British Columbia; REBECCA BELLOVIN (Stanford University), University of California, Berkeley; JOHN BERGDALL (Brandeis University), Boston University; WILL BONEY (Carnegie Mellon University), University of Illinois-Chicago; ALEXANDER CLONINGER (University of Maryland), Yale University; KATHLEEN CRAIG (Rutgers University), University of California, Los Angeles; DANIEL CRISTOFARO-GARDINER (University of California, Berkeley), Harvard University; RUTH DAVIDSON (North Carolina State University), University of Texas at Austin; GALYNA DOBROVOLSKA (University of Chicago), Columbia University; TAREK ELGINDI (New York University), Princeton University; ILYA GEKHTMAN (University of Chicago), Yale University; BORIS HANIN (Northwestern University), Massachusetts Institute of Technology; PHILIP ISETT (Princeton University), Massachusetts Institute of Technology; LELAND JEFFERIS (University of Wisconsin-Madison), Stanford University; JEFFREY MEIER (University of Texas at Austin), Indiana University; TOBIAS JOHNSON (University of Washington), University of Southern California; TYLER KELLY (University of Pennsylvania), University of Cambridge; DANIEL KETOVER (Massachusetts Institute of Technology), Princeton University; KAROL KOZIOL (Columbia University), University of Toronto; JOEL LEWIS (Massachusetts Institute of Technology), University of Minnesota; KATHRYN LINDSEY (Cornell University), University of Chicago; TIANKAI LIU (Massachusetts Institute of Technology), University of Utah; ALISON MILLER (Princeton University), Harvard University; JASON MURPHY (University of California, Los Angeles), University of California, Berkeley; ANAND OZA (Massachusetts Institute of Technology), Courant Institute; AARON POLLACK (Princeton University), Stanford University; SAM RASKIN (Harvard University), Massachusetts Institute of Technology; JOSE RODRIGUEZ (University of California, Berkeley), North Carolina State University; DUSTIN ROSS (Colorado State University), University of Michigan; SOBHAN SEYFADDINI (University of California, Berkeley), Massachusetts Institute of Technology; SHRENIK SHAH (Princeton University), Columbia University; AARON SILBERSTEIN (Harvard University), University of Chicago; NIKE SUN (Stanford University), Massachusetts Institute of Technology; HIROAKI TANAKA (Northwestern University), Harvard University; SAMUEL TAYLOR (University of Texas at Austin), Yale University; ALEXANDER VOLFOVSKY (University of Washington), Harvard University; MILES WHEELER (Brown University), Courant Institute; JESSE WOLFSON (University of Chicago), University of Chicago; MARY WOOTERS (University of Michigan), Carnegie Mellon University; BOHUA ZHAN (Princeton University), Massachusetts Institute of Technology; ANDREW ZIMMER (University Michigan), University of Chicago.

—NSF announcement

The University of Kent is one of the UK's most dynamic universities demonstrated by our strong European and international presence, our excellent RAE results which confirmed Kent's position as one of the UK's most research intensive universities, and the quality of our teaching and student experience; Kent was ranked 20th in the *2014 Guardian University Guide* and achieved a 90% satisfaction rate in the 2013 NSS for overall student satisfaction.

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Kent celebrates its 50th anniversary in the 14/15 academic year – can you help shape our future for the next 50 years and beyond?

We require an experienced academic, with significant leadership experience, who is keen to progress their career with a highly successful, inspirational and growing School. The School has over 1,000 undergraduate and postgraduate students, and supporting these students with challenging educational programmes and opportunities is a vital part of the School's mission. The Head of School has the unique opportunity to shape the future of the School at this exciting time, both in terms of student activities and developing the School such that it continues to build on its national and international reputation for all of its research fields.

Informal enquiries can be made to Professor Peter Clarkson on P.A.Clarkson@kent.ac.uk.
For further information on the role and details on how to apply, visit our website – www.kent.ac.uk/jobs

Closing date: 13 October 2014
Interviews: 27 & 28 November 2014

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Mathematics Opportunities

AMS-AAAS Mass Media Summer Fellowships

The American Mathematical Society provides support each year for a graduate student in the mathematical sciences to participate in the American Association for the Advancement of Science (AAAS) Mass Media Science & Engineering Fellows Program. This summer fellowship program pairs graduate students with major media outlets nationwide where they will research, write, and report on science news and use their skills to bring technical subjects to the general public.

The principal goal of the program is to increase the public's understanding of science and technology by strengthening the connection between scientists and journalists to improve coverage of science-related issues in the media. Past AMS-sponsored fellows have held positions at National Public Radio, *WIRED*, *Scientific American*, Voice of America, *The Oregonian*, and the *Milwaukee Journal Sentinel*.

Fellows receive a weekly stipend of US$500, plus travel expenses, to work for ten weeks during the summer as reporters, researchers, and production assistants in newsrooms across the country. They observe and participate in the process by which events and ideas become news, improve their ability to communicate about complex technical subjects in a manner understandable to the public, and increase their understanding of editorial decision making and of how information is effectively disseminated. Each fellow attends an orientation and evaluation session in Washington, D.C., and begins the internship in mid-June. Fellows submit interim and final reports to AAAS. A wrap-up session is held at the end of the summer.

Mathematical sciences faculty are urged to make their graduate students aware of this program. The deadline to apply for fellowships for the summer of 2015 is **January 15, 2015**. Further information about the fellowship program and application procedures is available online at `http://www.aaas.org/program/aaas-mass-media-science-engineering-fellows-program` or applicants may contact Dione Rossiter, Project Director, AAAS Mass Media Science & Engineering Fellows Program, 1200 New York Avenue, NW, Washington, DC 20005; telephone 202-326-6645; email `drossite@aaas.org`. Further information is also available at `http://www.ams.org/programs/ams-fellowships/media-fellow/massmediafellow`.

—AMS Washington Office

Call for Proposals for the 2016 AMS Short Courses

The AMS Short Course Subcommittee invites submissions of preliminary proposals for Short Courses to be given at the 2016 Joint Mathematics Meetings. Members are also invited to submit names of colleagues who they think would conduct an inspiring Short Course. A Short Course consists of a coherent sequence of survey lectures and discussions on a single theme of applied mathematics. A Short Course ordinarily extends over a period of two days immediately preceding the Joint Mathematics Meetings held in January. Preliminary proposals may be as short as one page. After reviewing the preliminary proposals, the subcommittee may ask for more details from some of the proposers. Proposals should be sent via email to `aed-mps@ams.org`. For full consideration for the 2016 Short Courses, proposals should be submitted by Friday, **December 19, 2014**.

—AMS Associate Executive Director

NSF Mathematical Sciences Postdoctoral Research Fellowships

The National Science Foundation (NSF) offers a program known as the Mathematical Sciences Postdoctoral Research Fellowships (MSPRF). The purpose of the program is to support future leaders in mathematics and statistics by facilitating their participation in postdoctoral research environments that will have maximal impact on their future scientific development. There are two options for awardees: Research Fellowship and Research Instructorship. Awards will support research in areas of mathematics and statistics, including applications to other disciplines.

Proposals are due by **October 15, 2014**. For further information, visit the NSF website at http://www.nsf.gov/pubs/2014/nsf14582/nsf14582.htm.

—From an NSF program announcement

NSF Conferences and Workshops in the Mathematical Sciences

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

—From an NSF announcement

NSF Project ADVANCE

The goal of the National Science Foundation's (NSF) ADVANCE program is to increase the representation and advancement of women in academic science and engineering careers, thereby contributing to the development of a more diverse science and engineering workforce. ADVANCE encourages institutions of higher education and the broader science, technology, engineering, and mathematics (STEM) community, including professional societies and other STEM-related not-for-profit organizations, to address various aspects of STEM academic culture and institutional structure that may differentially affect women faculty and academic administrators.

Since 2001, the NSF has invested over US$130 million to support ADVANCE projects at more than one hundred institutions of higher learning and STEM-related not-for-profit organizations in forty-one states, the District of Columbia, and Puerto Rico.

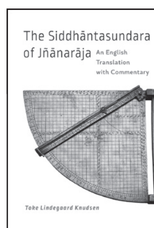
Additional information about ADVANCE programs, as well as application deadlines, can be found at `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383`.

—From an NSF announcement

News from MSRI

MSRI invites applications for 200 Research Members, and thirty semester-long Post-Doctoral Fellows in the following programs: New Challenges in PDE: Deterministic Dynamics and Randomness in High and Infinite Dimensional Systems (August 17–December 18, 2015) and Differential Geometry (January 11–May 20, 2016). Research Memberships are intended for researchers who will be making contributions to a program and who will be in residence for one or more months. Post-Doctoral Fellowships are intended for recent Ph.D.'s. Interested individuals should carefully describe the purpose of their proposed visit, and indicate why a residency at MSRI will advance their research program. To receive full consideration, application must be complete, including all letters of support, by the following deadlines: Research Memberships, December 1, 2014; Post-doctoral Fellowships, December 1, 2014. Application information can be found at `https://www.msri.org/web/msri/scientific/member-application`. It is the policy of MSRI actively to seek to achieve diversity in its programs and workshops. Thus, a strong effort is made to remove barriers that hinder equal opportunity, particularly for those groups that have been historically underrepresented in the mathematical sciences. MSRI is proud to announce a new resource to assist visitors with finding childcare in Berkeley. For more information, please contact Sanjani Varkey at `sanjani@msri.org`. Programs funded by the National Science Foundation.

—From an MSRI announcement



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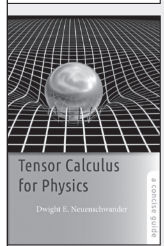

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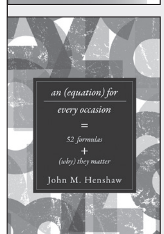

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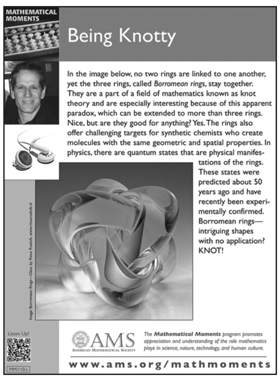
Inside the AMS

From the AMS Public Awareness Office



Mathematical Moments. The latest "Mathematical Moments" were recently mailed to all U.S. mathematics departments. Covering topics from surface tension to scheduling sports leagues, Moments show people that mathematics research is ongoing and demonstrate the applications of that research. See the more than 100 Mathematical Moments and hear podcasts of people talking about their work, for example, Colin Adams (Williams College) talking about knot theory, at www.ams.org/mathmoments/.

—Annette Emerson and Mike Breen
AMS Public Awareness Officers
paoffice@ams.org

For Your Information

New International Women in Mathematics Website

In March 2013 the Executive Committee of the International Mathematical Union (IMU) approved the establishment of an Advisory Group for Women in Mathematics, charged with creating and overseeing a section of the IMU website entitled Women in Mathematics (WiM). Opportunities for women vary widely from country to country and a main aim is to enhance the participation of women in all mathematical communities. The new WiM site will be launched at the International Congress of Women Mathematicians on August 12th just prior to the International Congress of Mathematics, at the address http://www.mathunion.org/wim/.

The site includes information about organizations, people, events, resources, and initiatives of interest to women mathematicians world-wide. In order to maximize the usefulness of this site, we welcome suggestions from the community. Indeed, advice concerning items for inclusion is important to us.

The Advisory Group may be contacted at info-for-wim@mathunion.org. The WiM Advisory Group: Ingrid Daubechies (Chair) (USA), Petra Bonfert-Taylor (USA), Carla Cedarbaum (Germany), Nalini Joshi (Australia), Sunsook Noh (Korea), Marie-Françoise Ouédraogo (Burkina Faso), Dušanka Perišić (Serbia), Claudia Sagastizábal (Brazil), Caroline Series (UK), and Carol Wood (USA).

—WiM Announcement

AMERICAN MATHEMATICAL SOCIETY

Mathematical Reviews/MathSciNet®
Associate Editor

Applications are invited for a full-time position as an Associate Editor of Mathematical Reviews/MathSciNet, to commence as soon as possible in 2015, preferably before August 3, 2015. The Mathematical Reviews (MR) division of the American Mathematical Society (AMS) is located in Ann Arbor, Michigan, in a beautiful, historic building close to the campus of the University of Michigan. The editors are employees of the AMS; they also enjoy many privileges at the university. At present, the AMS employs approximately seventy-five people at Mathematical Reviews, including sixteen mathematical editors. MR's mission is to develop and maintain the MR Database, from which MathSciNet is produced.

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

The successful applicant will have mathematical breadth with an interest in current developments, and will be willing to learn new topics in pure and applied mathematics. In particular, the applicant should have expertise in theoretical computer science, information science, or related areas of mathematics. The ability to write well in English is essential. The applicant should normally have several years of relevant academic (or equivalent) experience beyond the Ph.D. Evidence of written scholarship in mathematics is expected. The twelve-month salary will be commensurate with the experience that the applicant brings to the position.

Applications (including a curriculum vitae; bibliography; and the names, addresses, phone numbers, and email addresses of at least three references) should be sent to:

Dr. Edward Dunne
Executive Editor
Mathematical Reviews
P. O. Box 8604
Ann Arbor, MI 48107-8604

email: egd@ams.org
Tel: (734) 996-5257
Fax: (734) 996-2916
URL: www.ams.org/mr-database

The initial review of the applications will begin on December 17, 2014 and will continue until the position is filled.

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From the AMS Secretary

Report of the Treasurer (2013)

Introduction

One of the most important duties of the treasurer is to lead the Board of Trustees in the oversight of financial activities of the Society. This is done through close contact with the executive staff of the Society, review of internally generated financial reports, review of audited financial statements, and direct contact with the Society's independent auditors. Through these and other means, the Trustees gain an understanding of the finances of the Society and the important issues surrounding its financial reporting. The Report of the Treasurer is presented annually and discusses the financial condition of the Society as of the immediately preceding fiscal year-end and the results of its operations for the year then ended.

When reviewing the financial results of the AMS, it is important to note that the financial support for its membership and professional programs is derived from multiple sources. First, a board-designated endowment fund named the Operations Support Fund (OSF) provided $1,438,000 in operating support to the membership and professional programs in 2013. The OSF is a fund that has grown throughout the years from operating net income as well as investment gains; because the fund is dependent upon market conditions, the amount provided varies from year to year. In addition, the membership and professional programs are supported through dues income and contributions. Finally, the margin from the publication programs supports these services as well. Without the margin from publications and the OSF income, dues and contributions alone would not provide enough support to continue professional programs, such as Mathjobs, scholarships, fellowships, and the *Notices*.

The Society experienced a gain of $1.2 million in net operating income in 2013. While publishing and other revenues were lower than expected, the Society's operating costs were significantly under budget as well, primarily due to a decrease in publishing production. This decrease in costs is related to a drop in the number of books published in 2013. The Society's unrestricted net assets increased by $17.8 million primarily due to a 22.5 percent return on the long-term investments and the $1.2 million in net operating income.

Market Trends and Economic Conditions Affecting the Society

In 2013, the Society experienced a total decrease in printed book sales of $540,771 from 2012. This decline is partially offset by the increase in electronic subscriptions and digitized backlist revenues, which have started to replace the print book sales. However, about $350,000 in this drop in revenues is due to the less-than-budgeted number of books published in 2013. There were sixty-three books published in comparison to the budgeted number of eighty-five. The actual number of books published has shown a steady decline since 2010. Other scientific publishers are experiencing a similar decline.

Another factor affecting the overall revenues and expenses was that the Society unexpectedly took on the management of the MathJax Consortium in March 2013. MathJax is open source software being developed to render mathematics on the Internet. The overall financial effect to the Society is minimal as this project is being supported by many commercial and not-for-profit sponsors and the Society for Industrial and Applied Mathematics (SIAM), as a joint venturer.

Investment markets fared well in 2013. The S&P 500 stock market index experienced a 32 percent return, although the Barclay's US Aggregate bond index experienced a decline of 2 percent. The Society's long-term investments benefitted from the bull market, experiencing a 22.5 percent return overall. The Society's investments in a US total stock market fund experienced a 33 percent return, which was offset by declines in investments in the bond market and low returns in real estate investment trust (REIT) mutual funds. The Society's operating portfolio experienced lackluster returns of 2.5 percent due to the scarcity of short-term investments with attractive returns, such as certificates of deposits, bonds, and money market funds.

Membership numbers at the American Mathematical Society remained constant in 2013, after experiencing a decline for years. However, the number of paying members declined by 5 percent. This is a trend many membership associations have been experiencing across the United States. Within the international institutional membership category, membership increased slightly.

Journal subscriptions to most AMS journals declined in 2013 with an overall decline in paying subscribers of 2.5 percent. In the publishing industry, many scientific journals are experiencing even greater attrition. The subscription attrition was partially offset by a price increase of 4 percent. As shown in Table 1, the majority of the Society's revenues have remained flat for years when adjusted for inflation. For subscription products and dues there has been a steady decline of subscribers and paying members, offset by increasing subscription prices and dues. Mathematical Reviews (MR) revenues from MathSciNet and book program revenues experienced a distinct decline between 2012 and 2013. For MR, the decline is related to the loss in revenues from printed subscriptions of the database (discontinued in 2013), amounting to $260,000. The book revenue decline is due to the decrease in the number of new books published in 2013.

2013 Balance Sheets Highlights

The Society's financial statements, including balance sheets and statements of activities, are shown at the end of this financial review. The Society continues to enjoy healthy balance sheets. Total net assets increased by $21 million, primarily due to investment gains and net operating income of $1.2 million. Total net assets of the organization are $117.6 million, of which $102.5 million are unrestricted. Table 2 shows highlights of the Society's 2013 balance sheets.

2013 Statements of Activities

The Society's 2013 net operating income of $1.2 million was very close to the budgeted net operating income. Total revenues decreased by $436,000 between 2012 and 2013. Publishing revenues decreased by $445,000 in the same period, due mostly to a decline in printed book sales partially offset by electronic backlist and subscription sales. Although the electronic books subscription sales have eroded the sales of printed books, the number of new books published in 2013 is the primary reason for the large drop in sales. There were other factors affecting the Society's revenues to a lesser degree than the publishing revenues. The Society's temporary investment income contributed about $200,000 to the decrease in revenue between 2012 and 2013, which is attributable to the poor results of the bond mutual funds in the operating portfolio and lower short-term interest rates. Partially offsetting these revenue decreases, there was a new revenue source from sponsorships for the MathJax software project, as well as additional travel grant revenues.

The Society has managed its expenses well over the past decades, ensuring a positive net income for twenty-three years as shown in Table 3. Expenses increased between 2012 and 2013 by $807,000 as shown in Table 4. The biggest increase of approximately $320,000 occurred in the contracted services expense in the "All Other Expenses" category due to an effort to digitize the Society's backlist, an increase in digitization/keying services for MathSciNet, and the additional contracted services incurred from assuming the management of the MathJax software project. Although personnel costs did rise between 2012 and 2013, they rose by only 1 percent or $215,000. This small increase was due to a reduction in force that occurred in the second half of 2012, and an actual decrease in health insurance costs associated with changes in the health insurance plan. The largest decrease between 2012 and 2013 was "Outside Printing Binding and Mailing," which was due to the decrease in the number of books published in 2013.

2013 Statements of Invested Funds

The Society's Statements of Invested Funds show a listing of the Society's endowments and quasi-endowments (board-designated funds). In addition, the long-term investments of the Society also contain one new, temporarily restricted fund, the Beal Prize, which at year-end amounted to $1.154 million. The corpus of this fund, $1,000,000, is set aside to fund a prize for solving the Beal Conjecture. The spendable income from the fund will support the Erdős Lecture and other programs. Overall, the 2013 Statements of Invested Funds show a large increase of $21.4 million over 2012 primarily due to returns from the investment markets. This high increase cannot be expected in general.

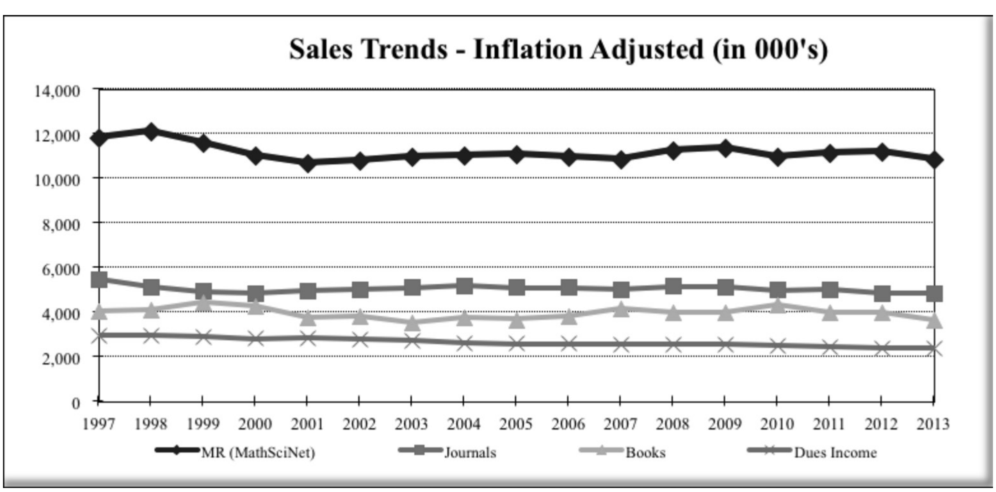

Table 1

Summary Financial Information

The following Statements of Activities and Balance Sheets are from the audited financial statements of the AMS, and the Statement of Invested Funds is from the internal financial records of the AMS. Any member may contact the AMS to request the full audited statements of the Society.

Highlights of Balance Sheets Changes from 2012 to 2013	Commentary
Cash increased by approximately $3,630,000, while short-term investments and certificates of deposits decreased by approximately $2,822,000 and $568,000, respectively.	The increase in cash corresponds to decreases in short-term investments due to the lack of attractive short-term investments in certificates of deposits and money markets. These short-term investments experienced returns less than 1 percent.
Prepaid expense and deposits decreased approximately $401,000.	This decrease was due to lower prepayments and deposits for the 2014 Joint Mathematics Meetings (JMM), which experienced lower costs due to the meeting location. Additionally, prepayments for health insurance were lower due to the timing of the payments.
Long-term investments increased by approximately $21.5 million.	The long-term investments experienced a 22.5 percent return due to the stock market returns in 2013.
Accounts payable and accrued expenses increased by approximately $746,000.	A $935,000 increase to the accrual for paid personal leave (PPL), based on a revision to the Society's policy in 2013, accounted for the majority of the increase. This was offset by a decrease in accounts payable due to timing of payments at year-end.
Deferred revenues decreased by approximately $705,000.	Collections of 2014 subscriptions and membership renewals, the majority of which would have normally occurred in 2013, have carried over into 2014. There was a delay in sending out the 2014 subscription and membership renewals due to the implementation of the association management software, Personify, decreasing the deferred revenues balance.
Post-retirement benefit obligation decreased by approximately $549,000.	This decrease was due to an increase in the assumed discount rate used to actuarially determine the benefit obligation. The discount rate increased from 3.8 percent in 2012 to 4.7 percent in 2013.

Table 2

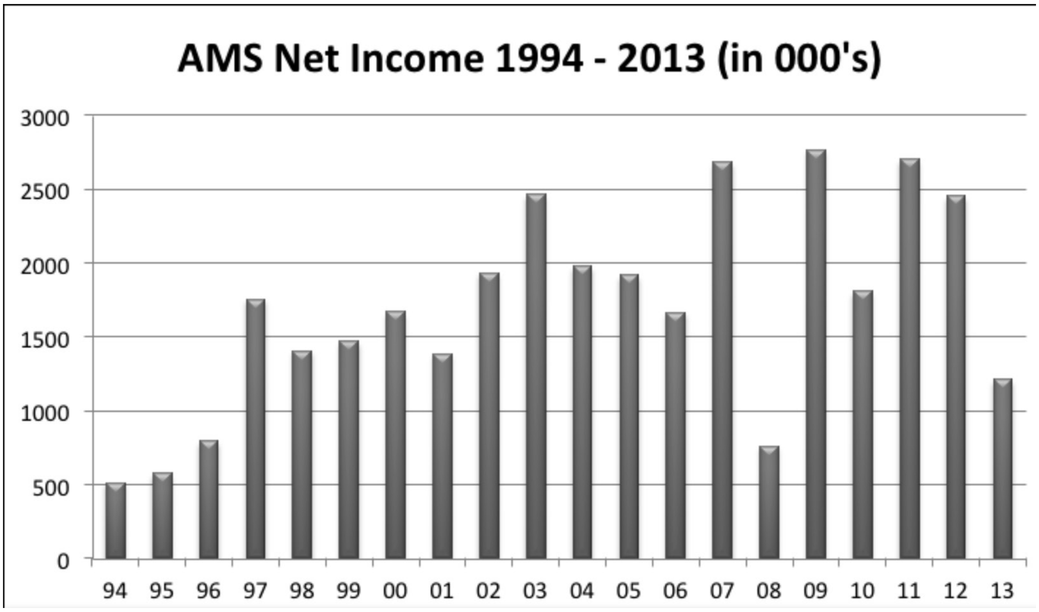

Table 3

Major Expense Categories (in thousands of dollars)

Major Expense Categories (in thousands of dollars)

	2012 Actual		2013 Actual		Variance 12 v. 13 inc(dec)	% chg
Personnel Costs	$18,017	68.5%	$18,232	67.3%	$215	1%
Building and Equipment Related	1,599	6.1%	1,744	6.4%	145	9%
Postage	656	2.5%	591	2.2%	(65)	-10%
Outside Print'g, Bind'g and Mail'g	560	2.1%	351	1.3%	(209)	-37%
Printing paper	335	1.3%	331	1.2%	(4)	-1%
Travel Grant awards	644	2.4%	784	2.9%	140	22%
Travel - Staff, Volunteers	634	2.4%	752	2.8%	118	19%
All Other Expenses	3,842	14.6%	4,309	15.9%	467	12%
	$26,287	100%	$27,094	100%	$ 807	3%

Table 4

AMERICAN MATHEMATICAL SOCIETY

Balance Sheets

	December 31, 2013	December 31, 2012
Assets		
Cash and cash equivalents	$ 4,724,387	$ 1,094,226
Certificates of deposit	951,529	1,520,000
Short-term investments	10,432,357	13,255,356
Accounts receivable, net of allowances of $263,224 and $338,805 in 2013 and 2012, respectively	678,298	912,349
Deferred prepublication costs	555,294	728,923
Completed books	1,282,908	1,384,432
Prepaid expenses and deposits	1,213,201	1,614,823
Land, buildings and equipment, net	5,127,278	5,367,801
Long-term investments	115,196,217	93,748,205
Total assets	**$ 140,161,469**	**$ 119,626,115**
Liabilities and Net Assets		
Liabilities:		
Accounts payable and accrued expenses	$ 4,006,141	$ 3,260,488
Accrued study leave pay	685,363	803,202
Deferred revenue	11,671,731	12,376,468
Postretirement benefit obligation	6,108,330	6,656,993
Total liabilities	**22,471,565**	**23,097,151**
Net assets:		
Unrestricted:		
Undesignated	1,448,012	2,261,743
Designated	101,007,256	82,388,405
	102,455,268	84,650,148
Temporarily restricted	9,968,645	6,782,825
Permanently restricted	5,265,991	5,095,991
Total net assets	**117,689,904**	**96,528,964**
Total liabilities and net assets	**$ 140,161,469**	**$ 119,626,115**

AMERICAN MATHEMATICAL SOCIETY

Statements of Activities

	Years Ended December 31, *2013*	*2012*
Changes in unrestricted net assets:		
Operating revenue, including net assets released from restrictions:		
Mathematical Reviews	$ 10,868,077	$ 11,087,637
Journals	5,062,348	4,829,242
Books	3,623,632	4,023,584
Dues, services, and outreach	3,839,958	3,696,895
Investment returns appropriated for spending	1,459,970	1,772,400
Other publications-related revenue	636,881	419,591
Grants, prizes and awards	1,233,313	1,171,264
Meetings	1,253,181	1,229,138
Short-term investment income	262,762	460,062
Other	67,791	54,202
Total operating revenue	**28,307,913**	**28,744,015**
Operating expenses:		
Mathematical Reviews	7,075,759	7,055,203
Journals	1,415,180	1,426,643
Books	3,220,413	3,421,212
Publications indirect	1,168,463	1,138,659
Customer services, warehousing and distribution	1,567,644	1,227,921
Other publications-related expense	194,186	204,347
Membership, services and outreach	4,016,715	3,727,374
Grants, prizes and awards	1,504,294	1,329,423
Meetings	1,254,622	1,130,959
Governance	553,239	472,553
Member and professional services indirect	740,306	704,489
General and administrative	4,317,500	4,364,657
Other	66,021	83,619
Total operating expenses	**27,094,342**	**26,287,059**
Excess of operating revenue over operating expenses	**1,213,571**	**2,456,956**
Investment returns less investment returns available for spending	16,968,778	9,227,195
Use of board designated Endowment Income Stabilization Funds	(31,112)	
Use of board designated Retrodigitization Funds	(129,481)	
Effect of capitalization of labor for in house software development		667,014
Depreciation of labor for in house software development	(66,701)	
Extraordinary loss - Change in Leave Policy	(935,360)	
Postretirement benefit-related changes other than net periodic cost	785,425	(458,200)
Change in unrestricted net assets	17,805,120	11,892,965

Continued on next page

AMERICAN MATHEMATICAL SOCIETY

Statements of Activities (Continued)

	Years Ended December 31, 2013	*2012*
Changes in temporarily restricted net assets:		
Contributions	$ 1,161,387	$ 79,860
Investment returns less investment returns appropriated for spending	2,631,454	1,562,538
Net assets released from restrictions	(607,021)	(612,858)
Change in temporarily restricted net assets	3,185,820	1,029,540
Change in permanently restricted net assets:		
Contributions	170,000	111,477
Change in permanently restricted net assets	170,000	111,477
Change in net assets	**21,160,940**	**13,033,982**
Net assets, beginning of year	96,528,964	83,494,982
Net assets, end of year	**$ 117,689,904**	**$ 96,528,964**

American Mathematical Society-Statements of Invested Funds

As of Decembers 31, 2013 and 2012

Endowment Funds:	Original Gift	12/31/2013 Total Value	12/31/2012 Total Value
Research Prize Funds			
Steele	145,511	731,899	613,521
Birkhoff	50,132	91,886	77,061
Veblen	58,599	81,317	40,875
Wiener	29,773	48,728	40,875
Bocher	32,557	49,502	41,524
Conant	9,477	48,778	40,917
Cole Number Theory	33,563	50,989	42,320
Cole Algebra	33,563	50,989	42,320
Satter	49,720	80,258	61,151
Doob	45,000	60,303	50,585
Robbins	41,250	56,117	47,073
Eisenbud	40,000	52,556	44,086
Other Prize and Award Funds			
Morgan Prize	25,000	53,082	44,527
Albert Whiteman Prize	93,618	126,892	106,442
Arnold Ross Lectures	70,000	94,483	79,255
Trjitzinsky	196,030	588,060	493,285
C.V. Newsom	100,000	273,651	229,548
Centennial	61,183	145,968	117,697
Menger	97,250	132,953	111,526
Ky Fan (China)	366,757	470,061	394,304
Gross	21,510	26,754	21,100
Epsilon	1,873,067	2,496,505	1,989,005
Einstein Lecture	100,000	136,080	114,148
Exemplary Program	100,000	135,247	113,450
Mathematical Art	20,000	27,050	22,690
Subtotal (Income Restricted)	**3,693,560**	**6,110,110**	**4,979,285**
Endowment	107,530	906,675	754,974
Morita	100,000	161,620	135,667
Henderson	548,223	4,819,435	4,045,510
Schoenfeld/Mitchell	573,447	913,743	767,010
Laha	189,309	306,983	257,687
Ritt	51,347	287,135	241,025
Moore	2,575	27,066	22,720
Subtotal (Income Unrestricted)	**1,572,431**	**7,422,657**	**6,224,593**
Total Endowment Funds	**5,265,992**	**13,532,767**	**11,203,878**
Quasi-Endowment Funds:			
Journal Archive Fund		1,414,581	1,113,204
Young Scholars		812,252	680,247
Economic Stabilization Fund		25,840,754	25,888,951
Backfile Digitization Fund		270,519	400,000
Endowment Income Stabilization Fund		497,710	500,000
Operations Support Fund		72,171,440	53,806,003
Total Quasi-Endowment Funds		**101,007,256**	**82,388,405**
Temporarily Restricted:			
Beal Prize	1,000,000	1,153,924	155,922.00
Total Invested Funds	**$6,265,992**	**$115,693,947**	**$93,748,205**

Statistics on Women Mathematicians Compiled by the AMS

At its August 1985 meeting the Council of the AMS approved a motion to regularly assemble and report in the *Notices* information on the relative numbers of men versus women in at least the following categories: membership in the AMS, invited hour addresses at AMS meetings, speakers at Special Sessions at AMS meetings, percentage of women speakers in AMS Special Sessions by gender of organizers, and members of editorial boards of AMS journals.

It was subsequently decided that this information would be gathered by determining the gender of the individuals in the above categories based on name identification if no other means was available and that additional information on the number of Ph.D.'s granted to women would also be collected using the AMS-ASA-IMS-MAA-SIAM Annual Survey. Since name identification was used, the information for some categories necessitated the use of three classifications:

Male: names that were obviously male

Female: names that were obviously female

Unknown: names that could not be identified as clearly male or female (e.g., only initials given, non-gender-specific names, etc.)

The following is the twenty-eighth reporting of this information. Updated reports will appear annually in the *Notices*.

Invited Hour Address Speakers at AMS Meetings (2004–2013)

Male:	339	81%
Female:	78	19%
Unknown:	0	0%
Total:	417	

Speakers at Special Sessions at AMS Meetings (2009–2013)

Male:	12,668	78%
Female:	3,398	21%
Unknown:	123	1%
Total:	16,189	

Percentage of Women Speakers in AMS Special Sessions by Gender of Organizers (2013)

Special Sessions with at Least One Woman Organizer

Male:	1,065	73%
Female:	393	27%
Unknown:	2	<1%
Total:	1,460	

Special Sessions with No Women Organizers

Male:	1,666	81%
Female:	393	19%
Unknown:	15	1%
Total:	2,064	

2013 Members of the AMS Residing in the U.S.

Male:	13,499	58%
Female:	3,561	15%
Unknown:	6,116	26%
Total:	23,176	

Trustees and Council Members

	2010		2011		2012		2013	
Male:	28	67%	28	67%	26	62%	23	62%
Female:	14	33%	14	33%	16	38%	14	38%
Total:	42		42		42		37	

Members of AMS Editorial Committees

	2004		2005		2006		2007		2008		2009		2010		2011		2012		2013	
Male:	180	84%	184	83%	193	84%	194	84%	168	83%	178	84%	176	82%	176	83%	178	83%	182	82%
Female:	34	16%	38	17%	36	16%	36	16%	35	17%	34	16%	39	18%	37	17%	37	17%	40	18%
Total:	214		222		229		230		203		212		215		213		215		222	

Ph.D.'s Granted to U.S. Citizens

	2004		2005		2006		2007		2008		2009		2010		2011		2012		2013	
Male:	347	68%	355	72%	399	72%	396	69%	431	69%	515	69%	564	71%	574	72%	621	72%	627	73%
Female:	166	32%	141	28%	153	28%	180	31%	191	31%	227	31%	225	28%	228	28%	242	28%	230	27%
Total:	513		496		552		576		622		742		790		802		863		857	

Mathematics Calendar

Please submit conference information for the Mathematics Calendar through the Mathematics Calendar submission form at http://www.ams.org/cgi-bin/mathcal-submit.pl. The most comprehensive and up-to-date Mathematics Calendar information is available on the AMS website at http://www.ams.org/mathcal/.

October 2014

* 3–6 **19th Annual Cum 4th International Conference of Gwalior Academy of Mathematical Sciences (GAMS) on Advances in Mathematical Modeling to Real World Problems**, Department of Applied Mathematics & Humanities, Sardar Vallabhbhai National Institute of Technology, Surat- 395007, Gujarat, India.

Topics to be covered: Mathematical biology, heat and mass transfer, computational fluid dynamics, fluid flow through porous media, population dynamics, air and water pollution, financial mathematics, data mining, neural networks and artificial intelligence, operations research, industrial mathematics, special function, differential equations, numerical analysis, applied analysis, bioinformatics and other allied topics.

Important Dates: Last date of abstract submission: August 5, 2014. Notification of acceptance: August 10, 2014. Last date of registration: September 3, 2014. Full length paper submission: September 3, 2014.

Fees: Registration Fees India and SAARC countries 5000(INR). This includes Rs 500 GAMS delegation fees. Other countries: USD 700. This includes USD 50 GAMS delegation fees. For other details please see website.

Information: http://www.svnitmaths.com.

* 9–10 **Conference on Challenges of Identifying Integer Sequences**, The Center for Discrete Mathematics and Theoretical Computer Science (DIMACS), CoRE Building, Rutgers University, 96 Frelinghuysen Rd., Piscataway, New Jersey.

Description: The conference will honor the contributions to the mathematical sciences of the Online Encyclopedia of Integer Sequences (OEIS) featuring renowned researchers reporting on the latest developments and open conjectures attributed to the OEIS. Conference discussions will highlight the role the database has served in assisting with developing conjectures in number theory, algorithmic and enumerative combinatorics, combinatorial number theory, bifurcative and other nonlinear sequences, sphere packing, and many other mathematical fields as well as the tools necessary for identifying those conjectures. The conference will bring these topics to a large audience, with the express goal of making the ideas accessible to a diverse audience of researchers and students.

Information: http://dimacs.rutgers.edu/Workshops/OEIS/.

December 2014

* 1–5 **BioInfoSummer 2014: Summer Symposium in Bioinformatics**, Monash University (Caulfield), Melbourne, Australia.

Description: Bioinformatics is an exciting, fast-moving area analysing and simulating the structures and processes of biological systems. BioInfoSummer introduces students, researchers, and others working in related areas to the discipline. The program features: An introduction to molecular biosciences and bioinformatics; next-generation DNA sequencing and sequence evolution; high-throughput technology and omics data analysis; methods in bioinformatics and systems biology.

Speakers: Professor Mark Ragan (Institute for Molecular Bioscience), Professor Chris Overall (University of British Columbia), Professor Roger Daly (Monash University), Associate Professor Barbara Holland (University of Tasmania), Dr. Alicia Oshlack, Murdoch Childrens Research Institute.

Information: http://amsi.org.au/BIS.

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

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

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

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

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

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through the AMS website on the World Wide Web. To access the AMS website, use the URL: http://www.ams.org/.

* 8–12 **The 5th International Conference on Scientific Computing and Partial Differential Equations**, Hong Kong Baptist University, Hong Kong, China.
Description: Since 2002, the SCPDE conference series aims to promote research interests in scientific computation. It is our intention to organize a well-respected international conference series on scientific computing in Hong Kong every three years. The past conferences of the series were held in 2002, 2005, and then 2008 and 2011. All conferences in the series were held at the Hong Kong Baptist University, well attended by international experts in respective disciplines and were found highly successful in providing a forum for the exchange of ideas and the latest results within a multi-disciplinary setting. On the occasion of the 60th birthday of Eitan Tadmor, we are organizing this international conference to review recent developments and to explore exciting new directions in scientific computing and partial differential equations for time dependent problems and its interaction with other fields.
Information: `http://www.math.hkbu.edu.hk/SCPDE14/`.

* 18–21 **International Conference on Geometric Function Theory and its Applications (ICGFTA-2014)**, Department of Mathematics, Indian Institute of Technology, Kharagpur, Kharagpur-721302, West Bengal, India.
Objective of the Conference: The conference "International Conference on Geometric Function Theory and its Applications" (ICGFTA-2014) is being organized by the Department of Mathematics, Indian Institute of Technology, Kharagpur. The conference program will cover contemporary topics in complex analysis, including geometric function theory in one complex variable, harmonic univalent mappings, and several complex variables. The goal of this meeting is to bring together researchers from around the globe, working broadly in complex analysis and its most important applications, with an emphasis on informal interactions. Therefore, this kind of meeting will help younger researchers to share valuable thoughts with each other on their respective areas of research. In the process, they will increase the possibility of collaborating among themselves in the days to come. Further, the expertise of the international participants would really inspire the young researchers to go the extra mile in their research.
Information: `http://www.icgfta-2014-iitkgp.in`.

January 2015

* 5–10 **ICMC 2015: The Second International Conference on Mathematics and Computing**, Haldia Institute of Technology Haldia, West Bengal, India.
Description: ICMC 2015 is a forum for the presentation of new advances in the fields of Mathematics, Statistics, and Scientific Computing. The conference will bring together leading academic scientists, experts from the industry, and researchers in mathematics and computing from India and abroad.The conference will be preceded by workshops (5th and 6th) and Tutorials (7th). Key note talks and presentation of research papers will take place from January 8–10, 2015.
Information: `http://hithaldia.co.in/icmc2015/`.

* 6–9 **Winter Meeting on Bruhat-Tits Buildings**, Imperial College London, London, United Kingdom.
Description: The meeting will consist of five lecture series on different aspects of this theory given by leading experts. The five speakers are: Linus Kramer, Bernhard Mühlherr, Anne Parreau, Bertrand Rémy, and Guy Rosseau. We have limited funding available for young researchers.
Deadline: The deadline for applications is October 10, 2014.
Information: `http://www.jschillewaert.wix.com/bruhat-tits`.

* 21–25 **The Ninth International Conference on Nonlinear Analysis and Convex Analysis (NACA2015)**, Rimkok Resort Hotel, Chiang Rai, Thailand.
Description: To hold an international conference on nonlinear analysis and convex analysis jointly is very important for the development of mathematical science and its related areas all over the world. During the last three decades, the study of Nonlinear Analysis has been devoted vigorously and such activity had great influence on other areas of science as much as mathematics. At the same time, Convex Analysis has grown in connection with the study of problems of optimization, equilibrium, control, and stability of linear and nonlinear systems. These two mathematical disciplines have no border and they rather have good effects each other. Based on this idea, we had the following meetings of the International Conference on Nonlinear Analysis and Convex Analysis (NACA): Niigata (1998), Hirosaki (2001), Tokyo (2003), Okinawa (2005), Hsinchu (2007), Tokyo (2009), Busan (2011), Hirosaki (2013) and this time, it reaches the ninth meeting in Chiang Rai, Thailand, on January 21–25, 2015.
Information: `http://www.sci.nu.ac.th/mathematics/math/naca2015/`.

February 2015

* 5–7 **4rd International Conference on Mathematics & Information Science**, Zewail City, Cairo, Egypt.
Description: 4rd International Conference on Mathematics & Information Science (ICMIS 2015), will be held in Zewail City of Science and Technology, February 5–7, 2015, and will feature advances in Mathematical Science, Business, Information Systems Engineering and Technology presented by international researchers. The conference will provide the opportunity to showcase research in mathematics, theoretical physics and information science and technology to engender dialogue and collaboration between Egyptian and international researchers.
Information: `http://icmis5.naturalspublishing.com/`.

* 13–15 **Mathemusical Conversations: Mathematics and Computation in Music Performance and Composition**, Yong Siew Toh Conservatory of Music and Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Mathemusical Conversations is an international workshop bringing together world experts and emerging scholars in and across mathematics and music, with a special focus on mathematical and computational research in music performance and composition that serve as the foundation for understanding and enabling human creativity and for future music technologies. The program, consisting of six thematic sessions and two concerts, is designed for broad appeal not only to researchers in the mathematical music sciences, but also to mathematicians and scientists in general, to musicians interested in the formal models of music knowledge and practice, and the general public. The broad objective of the workshop is to raise awareness of mathematics, music, and the mathematical music fields in Singapore, the region, and beyond.
Information: `http://www2.ims.nus.edu.sg/Programs/015wmusic/index.php`.

March 2015

* 2–5 **Flow(ers) & Friends in Frankfurt (a workshop on Geometric Analysis)**, Goethe Universitaet Frankfurt, Frankfurt am Main, Germany.
Description: Despite the title seems to be targeted at flowers (I mean, Ricci-flowers, etc), the goal is that many other topics of Geometric Analysis will be also well represented "in this garden".
Speakers: Fernando Codá-Marques, Panagiota Daskalopoulos, Camillo De Lellis, Klaus Ecker, Michael Eichmair, Nicola Gigli, Gerhard Huisken, Tom Ilmanen, Dan Knopf, Ernst Kuwert, Tobias Lamm, Rafe Mazzeo, Aaron Naber, André Neves, Frank Pacard, Michael Struwe, Felix Schulze, Peter Topping, Brian White, Burkhard Wilking.
Information: `http://www.math.uni-frankfurt.de/~cabezas/3F_2015/index.html`.

* 18–20 **Critical Issues in Mathematics Education 2015: Developmental Mathematics: For whom? Toward what ends?**, Mathematical Sciences Research Institute, Berkeley, California.
Description: This workshop will address the critical issue of developmental mathematics at two- and four-year colleges and universities and the broader dynamic of mathematics remediation that occurs at all levels. It will engage mathematicians, K-12 teachers, mathematics educators, and administrators in a conversation about the goals of developmental mathematics and the contributions that our different professional communities make to this work.
Information: `http://www.msri.org/workshops/758`.

* 30–April 30 **Sets and Computations**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Two extremely active areas of modern mathematical logic are Computability Theory and Set Theory. These fields are intensively researched in many parts of the USA, Europe, and Asia, including Singapore. One purpose of this programme is to bring leading researchers in these fields to the IMS for collaboration with researchers from Singapore and other parts of Asia. A second purpose is to develop newly-emerging and valuable connections between these fields. The result will be to strengthen cooperation between Singapore and research groups elsewhere, as well as to forge new connections between computability-theorists and set-theorists.
Information: `http://www2.ims.nus.edu.sg/Programs/015set/index.php`.

May 2015

* 4–15 **Workshop on Stochastic Processes in Random Media**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: The aim of the workshop is to bring together researchers from both the physics and probability communities and to promote further interaction between them in areas of common research interest. The central themes of the workshop will include (but are not restricted to): dynamics of reaction-diffusion systems, including biophysical applications of such processes; random polymers and related systems; the Kardar-Parisi-Zhang universality class, and random matrix models. The first week will be a workshop consisting of 25-30 talks. The second week will have fewer talks and more free time and discussion sessions to encourage collaboration.
Information: `http://www2.ims.nus.edu.sg/Programs/015wrandom/index.php`.

* 18–29 **Workshop on New Directions in Stein's Method**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Considering the diversity and the new exciting directions of recent advances, we believe now is the right time to organise a comprehensive workshop on Stein's method and its applications. We plan to bring together not only active researchers directly working in the area, but also those who apply Stein's method in their work in order to stimulate, strengthen, and develop existing interactions between theory and practice. The National University of Singapore has long been a centre of research in Stein's method, having been the base of major programmes and the home to a number of researchers who have been influential in its development. The combination of these many factors makes Singapore a natural place in which to conduct the workshop, with the resulting benefit of fostering collaborations, both locally and internationally.
Information: `http://www2.ims.nus.edu.sg/Programs/015wstein/index.php`.

June 2015

* 1–July 31 **Networks in Biological Sciences**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Activities: Tutorial I: June 3–5, 2015; The Protein Network Workshop: June 8–12, 2015; Tutorial II: July 22–24, 2015; The Phylogenetic Network Workshop: July 27–31, 2015.
Information: `http://www2.ims.nus.edu.sg/Programs/015bio/index.php`.

* 15–19 **MEGA 2015: Effective Methods in Algebraic Geometry**, University of Trento, Povo (Trento), Italy.
Description: MEGA is the acronym for Effective Methods in Algebraic Geometry (and its equivalent in many other languages). This series of biennial international conferences, with a tradition dating back to 1990, is devoted to computational and application aspects of Algebraic Geometry and related topics. The conference will comprise invited talks, regular contributed talks, presentations of computations, and a poster session; the latter three are subject to a competitive submission process.
Invited speakers: Carlos Beltran, Alessandra Bernardi, Petter Brändén, Elisa Gorla, Hans-Christian Graf von Bothmer, Anders Jensen, Michael Joswig, Daniel Lazard (special invited talk on the history of MEGA), Frank Sottile, Caroline Uhler.
Information: `http://mega2015.science.unitn.it/`.

July 2015

* 6–10 **Equadiff 2015**, Université Claude Bernard Lyon 1, Lyon, France.
Description: The Equadiff is a series of international conferences on dynamical systems, ordinary and partial differential equations, and applications, which are held every second year in various countries of Western and Eastern Europe.
Information: `http://equadiff2015.sciencesconf.org/`.

August 2015

* 3–7 **The 3rd Strathmore International Mathematics Conference Theme: Exploring Mathematics and its Applications**, Strathmore University, Nairobi, Kenya.
Description: The goal of this conference is to provide mathematics researchers from around the world, working in various mathematical disciplines, to discuss latest developments and share their research results in contemporary areas of mathematics research and applications. This conference also intends to forge new cross-disciplinary interactions among participants and farther existing partnerships among the international mathematics community and in particular, young researchers in Eastern Africa. The conference provides a unique opportunity for in-depth technical discussions and exchange of ideas in mathematical sciences, as well as explores the potential of their applications in natural and social sciences, engineering and technology and industry and finance.
Information: `http://www.strathmore.edu/carms`.

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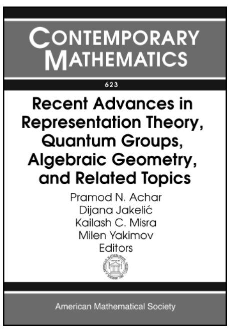
Algebra and Algebraic Geometry



Recent Advances in Representation Theory, Quantum Groups, Algebraic Geometry, and Related Topics

Pramod N. Achar, *Louisiana State University, Baton Rouge, LA*, **Dijana Jakelić**, *University of North Carolina at Wilmington, NC*, **Kailash C. Misra**, *North Carolina University, Raleigh, NC*, and **Milen Yakimov**, *Louisiana State University, Baton Rouge, LA*, Editors

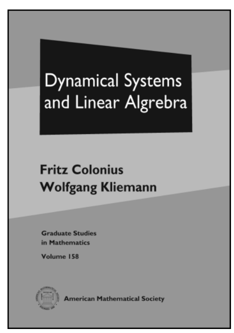
This volume contains the proceedings of two AMS Special Sessions "Geometric and Algebraic Aspects of Representation Theory" and "Quantum Groups and Noncommutative Algebraic Geometry" held October 13–14, 2012, at Tulane University, New Orleans, Louisiana.

Included in this volume are original research and some survey articles on various aspects of representations of algebras including Kac–Moody algebras, Lie superalgebras, quantum groups, toroidal algebras, Leibniz algebras and their connections with other areas of mathematics and mathematical physics.

Contents: D. Adamović, A classification of irreducible Wakimoto modules for the affine Lie algebra $A_1^{(1)}$; **A. M. Armstrong** and **K. C. Misra**, A note on $U_q(D_4^{(3)})$-Demazure crystals; **L. Carbone**, **W. Freyn**, and **K.-H. Lee**, Dimensions of imaginary root spaces of hyperbolic Kac–Moody algebras; **I. Demir**, **K. C. Misra**, and **E. Stitzinger**, On some structures of Leibniz algebras; **S. Doty** and **Y. Li**, A geometric construction of generalized q-Schur algebras; **V. Futorny**, **D. Grantcharov**, and **L. E. Ramirez**, On the classification of irreducible Gelfand–Tsetlin modules of $\mathfrak{sl}(3)$; **I. C.-H. Ip** and **A. M. Zeitlin**, Supersymmetry and the modular double; **D. Jakelić** and **A. Moura**, On Weyl modules for quantum and hyper loop algebras; **N. Jing** and **C. Xu**, Toroidal Lie superalgebras and free field representations; **E. Kirkman**, **J. Kuzmanovich**, and **J. J. Zhang**, Invariants of (-1)-skew polynomial rings under permutation representations; **G. Liu** and **S.-H. Ng**, On total Frobenius-Schur indicators; **I. Mirković**, Loop Grassmannians in the framework of local spaces over a curve; **T. Nakashima**, Decorated geometric crystals and polyhedral realization of type D_n; **B. J. Parshall** and **L. L. Scott**, Some Koszul properties of standard and irreducible modules; **A. M. Zeitlin**, On higher order Leibniz identities in TCFT.

Contemporary Mathematics, Volume 623

October 2014, 280 pages, Softcover, ISBN: 978-0-8218-9852-9, LC 2014003372, 2010 *Mathematics Subject Classification:* 14M15, 16T05, 17A32, 17B10, 17B37, 17B67, 17B69, 20G05, 20G43, 81R50, **AMS members US$81.60**, List US$102, Order code CONM/623



Dynamical Systems and Linear Algebra

Fritz Colonius, *Universität Augsburg, Germany*, and **Wolfgang Kliemann**, *Iowa State University, Ames, IA*

This book provides an introduction to the interplay between linear algebra and dynamical systems in continuous time and in discrete time. It first reviews the autonomous case for one matrix A via induced dynamical systems in $\mathbb{R}^d$ and on Grassmannian manifolds. Then the main nonautonomous approaches are presented for which the time dependency of $A(t)$ is given via skew-product flows using periodicity, or topological (chain recurrence) or ergodic properties (invariant measures). The authors develop generalizations of (real parts of) eigenvalues and eigenspaces as a starting point for a linear algebra for classes of time-varying linear systems, namely periodic, random, and perturbed (or controlled) systems.

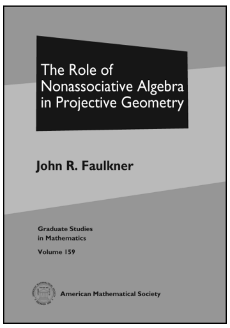
The book presents for the first time in one volume a unified approach via Lyapunov exponents to detailed proofs of Floquet theory, of the properties of the Morse spectrum, and of the multiplicative ergodic theorem for products of random matrices. The main tools, chain recurrence and Morse decompositions, as well as classical ergodic theory are introduced in a way that makes the entire material accessible for beginning graduate students.

This item will also be of interest to those working in differential equations, probability and statistics, and applications.

Contents: *Matrices and linear dynamical systems:* Autonomous linear differential and difference equations; Linear dynamical systems in $\mathbb{R}^d$; Chain transitivity for dynamical systems; Linear systems in projective space; Linear systems on Grassmannians; *Time-varying matrices and linear skew product systems:* Lyapunov exponents and linear skew product systems; Periodic linear and differential and difference equations; Morse decompositions of dynamical systems; Topological linear flows; Tools from ergodic theory; Random linear dynamical systems; Bibliography; Index.

Graduate Studies in Mathematics, Volume 158

November 2014, approximately 291 pages, Hardcover, ISBN: 978-0-8218-8319-8, LC 2014020316, 2010 *Mathematics Subject Classification:* 15-01, 34-01, 37-01, 39-01, 60-01, 93-01, **AMS members US$53.60**, List US$67, Order code GSM/158



The Role of Nonassociative Algebra in Projective Geometry

John R. Faulkner, *University of Virginia, Charlottesville, VA*

There is a particular fascination when two apparently disjoint areas of mathematics turn out to have a meaningful connection to each other. The main goal of this book is to provide a largely self-contained, in-depth account of the linkage between nonassociative algebra and projective planes, with particular emphasis on octonion planes. There are several new results and many, if not most, of the proofs are new. The development should be accessible to most graduate students and should give them introductions to two areas which are often referenced but not often taught.

On the geometric side, the book introduces coordinates in projective planes and relates coordinate properties to transitivity properties of certain automorphisms and to configuration conditions. It also classifies higher-dimensional geometries and determines their automorphisms. The exceptional octonion plane is studied in detail in a geometric context that allows nondivision coordinates. An axiomatic version of that context is also provided. Finally, some connections of nonassociative algebra to other geometries, including buildings, are outlined.

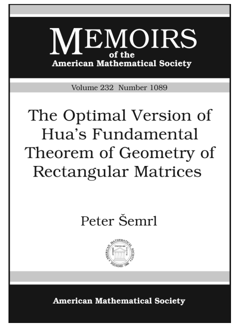
On the algebraic side, basic properties of alternative algebras are derived, including the classification of alternative division rings. As tools for the study of the geometries, an axiomatic development of dimension, the basics of quadratic forms, a treatment of homogeneous maps and their polarizations, and a study of norm forms on hermitian matrices over composition algebras are included.

This item will also be of interest to those working in geometry and topology.

Contents: Affine and projective planes; Central automorphisms of projective planes; Coordinates for projective planes; Alternative rings; Configuration conditions; Dimension theory; Projective geometries; Automorphisms of $G(V)$; Quadratic forms and orthogonal groups; Homogeneous maps; Norms and hermitian matrices; Octonion planes; Projective remoteness planes; Other geometries; Bibliography; Index.

Graduate Studies in Mathematics, Volume 159

November 2014, approximately 233 pages, Hardcover, ISBN: 978-1-4704-1849-6, LC 2014021979, 2010 *Mathematics Subject Classification:* 51A05, 51A20, 51A25, 51A35, 51C05, 17D05, 17C50, **AMS members US$53.60**, List US$67, Order code GSM/159



The Optimal Version of Hua's Fundamental Theorem of Geometry of Rectangular Matrices

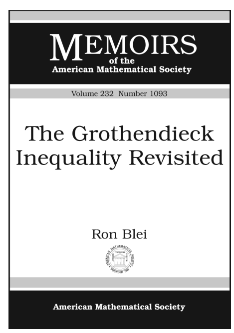
Peter Šemrl, *University of Ljubljana, Slovenia*

Contents: Introduction; Notation and basic definitions; Examples; Statement of main results; Proofs; Bibliography.

Memoirs of the American Mathematical Society, Volume 232, Number 1089

October 2014, 74 pages, Softcover, ISBN: 978-0-8218-9845-1, LC 2014024653, 2010 *Mathematics Subject Classification:* 15A03, 51A50, **Individual member US$39**, List US$65, Institutional member US$52, Order code MEMO/232/1089

Analysis



The Grothendieck Inequality Revisited

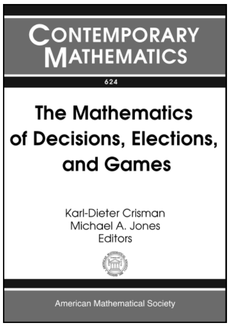
Ron Blei, *University of Connecticut, Storrs, Connecticut*

Contents: Introduction; Integral representations: the case of discrete domains; Integral representations: the case of topological domains; Tools; Proof of Theorem 3.5; Variations on a theme; More about Φ; Integrability; A Parseval-like formula for $\langle \mathbf{x}, \mathbf{y} \rangle$, $\mathbf{x} \in l^p$, $\mathbf{y} \in l^q$; Grothendieck-like theorems in dimensions > 2?; Fractional Cartesian products and multilinear functionals on a Hilbert space; Proof of Theorem 11.11; Some loose ends; Bibliography.

Memoirs of the American Mathematical Society, Volume 232, Number 1093

October 2014, 90 pages, Softcover, ISBN: 978-0-8218-9855-0, LC 2014024660, 2010 *Mathematics Subject Classification:* 46C05, 46E30; 47A30, 42C10, **Individual member US$42.60**, List US$71, Institutional member US$56.80, Order code MEMO/232/1093

Applications



The Mathematics of Decisions, Elections, and Games

Karl-Dieter Crisman, *Gordon College, Wenham, MA*, and **Michael A. Jones**, *Mathematical Reviews, Ann Arbor, MI*, Editors

This volume contains the proceedings of two AMS Special Sessions on The Mathematics of Decisions, Elections, and Games, held January 4, 2012, in Boston, MA, and January 11–12, 2013, in San Diego, CA.

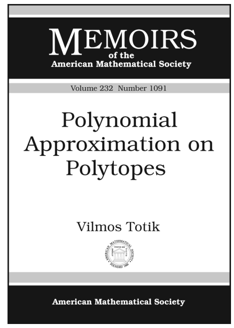
Decision theory, voting theory, and game theory are three intertwined areas of mathematics that involve making optimal decisions under different contexts. Although these areas include their own mathematical results, much of the recent research in these areas involves developing and applying new perspectives from their intersection with other branches of mathematics, such as algebra, representation theory, combinatorics, convex geometry, dynamical systems, etc.

The papers in this volume highlight and exploit the mathematical structure of decisions, elections, and games to model and to analyze problems from the social sciences.

Contents: C. Corcoran and **K. Saxe**, Redistricting and district compactness; **Z. Landau** and **F. E. Su**, Fair division and redistricting; **S. J. Brams** and **D. M. Kilgour**, When does approval voting make the "right choices"?; **K. Nehring** and **M. Pivato**, How indeterminate is sequential majority voting? A judgement aggregation perspective; **C. Stenson**, Weighted voting, threshold functions, and zonotopes; **K.-D. Crisman**, The Borda count, the Kemeny rule and the permutahedron; **M. M. Klawe**, **K. L. Nyman**, **J. N. Scott**, and **F. E. Su**, Double-interval societies; **M. Davis**, **M. E. Orrison**, and **F. E. Su**, Voting for committees in agreeable societies; **T. C. Ratliff**, Selecting diverse committees with candidates from multiple categories; **B. Hopkins**, Expanding the Robinson-Goforth system for 2x2 games; **D. T. Jessie** and **D. G. Saari**, Cooperation in n-player repeated games; **M. A. Jones** and **J. M. Wilson**, The dynamics of consistent bankruptcy rules.

Contemporary Mathematics, Volume 624

October 2014, 229 pages, Softcover, ISBN: 978-0-8218-9866-6, LC 2014003691, 2010 *Mathematics Subject Classification:* 91-06, 91A05, 91A12, 91A20, 91B06, 91B08, 91B12, 91B14, 91B32, 91F10, **AMS members US$72.80**, List US$91, Order code CONM/624



Polynomial Approximation on Polytopes

Vilmos Totik, *Bolyai Institute, University of Szeged, Hungary*

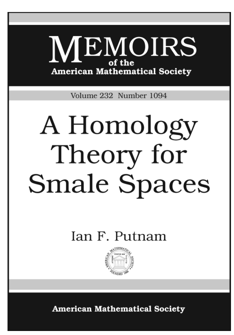
This item will also be of interest to those working in discrete mathematics and combinatorics.

Contents: *Part 1. The continuous case:* The result; Outline of the proof; Fast decreasing polynomials; Approximation on simple polytopes; Polynomial approximants on rhombi; Pyramids and local moduli on them; Local approximation on the sets K_a; Global approximation of $F = F_n$ on $S_{1/32}$ excluding a neighborhood of the apex; Global approximation of f on $S_{1/64}$; Completion of the proof of Theorem 1.1; Approximation in $\mathbf{R}^d$; A K-functional and the equivalence theorem; *Part 2. The L^p-case:* The L^p result; Proof of the L^p result; The dyadic decomposition; Some properties of L^p moduli of smoothness; Local L^p moduli of smoothness; Local approximation; Global L^p approximation excluding a neighborhood of the apex; Strong direct and converse inequalities; The K-functional in L^p and the equivalence theorem; Bibliography.

Memoirs of the American Mathematical Society, Volume 232, Number 1091

October 2014, 110 pages, Softcover, ISBN: 978-1-4704-1666-9, LC 2014024664, 2010 *Mathematics Subject Classification:* 41A10, 41A17, **Individual member US$45**, List US$75, Institutional member US$60, Order code MEMO/232/1091

Differential Equations



A Homology Theory for Smale Spaces

Ian F. Putnam, *University of Victoria, British Columbia, Canada*

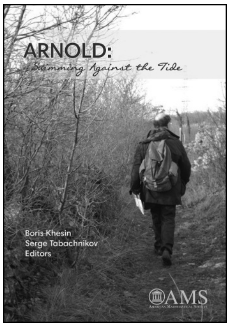
This item will also be of interest to those working in geometry and topology.

Contents: Summary; Dynamics; Dimension groups; The complexes of an s/u-bijective factor map; The double complexes of an s/u-bijective pair; A Lefschetz formula; Examples; Questions; Bibliography.

Memoirs of the American Mathematical Society, Volume 232, Number 1094

October 2014, 122 pages, Softcover, ISBN: 978-1-4704-0909-8, LC 2014024652, 2010 *Mathematics Subject Classification:* 37D20, 37D45, **Individual member US$45.60**, List US$76, Institutional member US$60.80, Order code MEMO/232/1094

General Interest



ARNOLD

Swimming Against the Tide

Boris A. Khesin, *University of Toronto, Ontario, Canada*, and **Serge L. Tabachnikov**, *ICERM, Brown University, Providence, RI, and Pennsylvania State University, State College, PA*, Editors

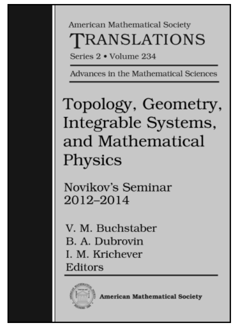
Vladimir Arnold, an eminent mathematician of our time, is known both for his mathematical results, which are many and prominent, and for his strong opinions, often expressed in an uncompromising and provoking manner. His dictum that "Mathematics is a part of physics where experiments are cheap" is well known.

This book consists of two parts: selected articles by and an interview with Vladimir Arnold, and a collection of articles about him written by his friends, colleagues, and students. The book is generously illustrated by a large collection of photographs, some never before published. The book presents many a facet of this extraordinary mathematician and man, from his mathematical discoveries to his daredevil outdoor adventures.

Contents: **B. A. Khesin** and **S. L. Tabachnikov**, Epigraph; *By Arnold:* **V. I. Arnold**, Arnold in his own words; **V. I. Arnold**, From Hilbert's superposition problem to dynamical systems; **J. Moser**, Recollections; **V. I. Arnold**, Polymathematics: Is mathematics a single science or a set of arts?; **V. I. Arnold**, A mathematical trivium; **B. A. Khesin** and **S. L. Tabachnikov**, Comments on "A Mathematical Trivium"; **V. I. Arnold**, About Vladimir Abramovich Rokhlin; *About Arnold:* **A. Givental**, To whom it may concern; **Y. Sinai**, Remembering Vladimir Arnold: Early years; **S. Smale**, Vladimir I. Arnold; **M. Berry**, Memories of Vladimir Arnold; **D. Fuchs**, Dima Arnold in my life; **Y. Ilyashenko**, V. I. Arnold, as I have seen him; **Y. Eliashberg**, My encounters with Vladimir Igorevich Arnold; **B. A. Khesin**, On V. I. Arnold and hydrodynamics; **A. Khovanskii** and **A. Varchenko**, Arnold's seminar, first years; **V. Vassiliev**, Topology in Arnold's work; **H. Hofer**, Arnold and symplectic geometry; **M. Sevryuk**, Some recollections of Vladimir Igorevich; **L. Polterovich**, Remembering V. I. Arnold; **A. Vershik**, Several thoughts about Arnold; **S. Yakovenko**, Vladimir Igorevich Arnold: A view from the rear bench.

November 2014, 173 pages, Softcover, ISBN: 978-1-4704-1699-7, LC 2014021165, 2010 *Mathematics Subject Classification:* 01A65; 01A70, 01A75, **AMS members US$23.20**, List US$29, Order code MBK/86

Geometry and Topology



Topology, Geometry, Integrable Systems, and Mathematical Physics

Novikov's Seminar 2012–2014

V. M. Buchstaber, *Steklov Institute of Mathematics, Moscow, Russia*, **B. A. Dubrovin**, *SISSA, Trieste, Italy*, and **I. M. Krichever**, *Columbia University, New York, NY*, Editors

Articles in this collection are devoted to modern problems of topology, geometry, mathematical physics, and integrable systems, and they are based on talks given at the famous Novikov's seminar at the Steklov Institute of Mathematics in Moscow in 2012–2014. The articles cover many aspects of seemingly unrelated areas of modern mathematics and mathematical physics; they reflect the main scientific interests of the organizer of the seminar, Sergey Petrovich Novikov. The volume is suitable for graduate students and researchers interested in the corresponding areas of mathematics and physics.

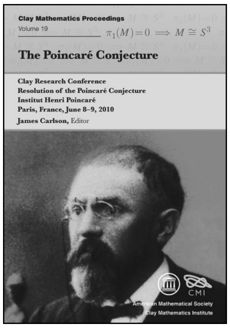
This item will also be of interest to those working in mathematical physics.

Contents: **A. V. Alexeevski** and **S. M. Natanzon**, Algebras of conjugacy classes of partial elements; **I. Beloshapka** and **A. Sergeev**, Harmonic spheres in the Hilbert–Schmidt Grassmannian; **F. Bogomolov** and **C. Böhning**, On uniformly rational varieties; **M. Boiti**, **F. Pempinelli**, and **A. K. Pogrebkov**, IST of KPII equation for perturbed multisoliton solutions; **V. Buchstaber** and **J. Grbić**, Hopf algebras and homology of loop suspension spaces; **L. O. Chekhov** and **M. Mazzocco**, Quantum ordering for quantum geodesic functions of orbifold Riemann surfaces; **V. Dragović**, Pencils of conics and biquadratics, and integrability; **B. Dubrovin**, Gromov–Witten invariants and integrable hierarchies of topological type; **I. Dynnikov** and **A. Skripchenko**, On typical leaves of a measured foliated 2-complex of thin type; **A. A. Gaifullin**, Volume of a simplex as a multivalued algebraic function of the areas of its two-faces; **G. M. Kemp** and **A. P. Veselov**, Discrete analogues of Dirac's magnetic monopole and binary polyhedral groups; **H. M. Khudaverdian** and **Th. Th. Voronov**, Geometric constructions on the algebra of densities; **I. Krichever**, Amoebas, Ronkin function and Monge-Ampère measures of algebraic curves with marked points; **A. Ya. Maltsev**, The averaging of multi-dimensional Poisson brackets for systems having pseudo-phases; **A. E. Mironov**, Periodic and rapid decay rank two self-adjoint commuting differential operators; **O. I. Mokhov**, Commuting ordinary differential operators of arbitrary genus and arbitrary rank with polynomial coefficients; **M. V. Pavlov** and **S. P. Tsarev**, Classical mechanical systems with one-and-a-half degrees of freedom and Vlasov kinetic equation; **O. K. Sheinman**, Lax operator algebras of type G_2.

American Mathematical Society Translations—Series 2 (*Advances in the Mathematical Sciences*), Volume 234

November 2014, approximately 389 pages, Hardcover, ISBN: 978-1-4704-1871-7, 2010 *Mathematics Subject Classification:* 00B25, 51P05, 53-XX, 14-XX, 55-XX, 70-XX, 76-XX, 81-XX, 39-XX, 17B65,

17B80, 14H70, 37J35, 37K15, 70H06, 70H08, **AMS members US$159.20**, List US$199, Order code TRANS2/234



The Poincaré Conjecture

James Carlson, *Clay Mathematics Institute, Cambridge, MA*, Editor

The conference to celebrate the resolution of the Poincaré conjecture, which is one of the Clay Mathematics Institute's seven *Millennium Prize Problems*, was held at the Institut Henri Poincaré in Paris. Several leading mathematicians gave lectures providing an overview of the conjecture—its history, its influence on the development of mathematics, and, finally, its proof.

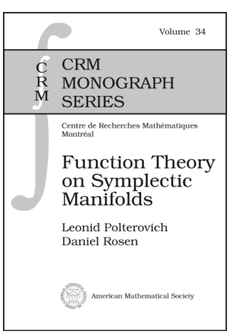
This volume contains papers based on the lectures at that conference. Taken together, they form an extraordinary record of the work that went into the solution of one of the great problems of mathematics.

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

Contents: M. Atiyah, Geometry in 2, 3 and 4 dimensions; **J. Morgan**, 100 Years of Topology: Work Stimulated by Poincaré's Approach to Classifying Manifolds; **C. T. McMullen**, The Evolution of Geometric Structures on 3-Manifolds; **S. K. Donaldson**, Invariants of Manifolds and the Classification Problem; **D. Gabai**, **R. Meyerhoff**, and **P. Milley**, Volumes of Hyperbolic 3-Manifolds; **M. Gromov**, Manifolds: Where do we come from? What are we? Where are we going?; **G. Tian**, Geometric Analysis on 4-Manifolds.

Clay Mathematics Proceedings, Volume 19

November 2014, approximately 181 pages, Softcover, ISBN: 978-0-8218-9865-9, 2010 *Mathematics Subject Classification:* 53-02, 53C44, 53C99, 53D45, 57-02, 57M40, **AMS members US$55.20**, List US$69, Order code CMIP/19



Function Theory on Symplectic Manifolds

Leonid Polterovich and **Daniel Rosen**, *Tel Aviv University, Israel*

This is a book on symplectic topology, a rapidly developing field of mathematics which originated as a geometric tool for problems of classical mechanics. Since the 1980s, powerful methods such as Gromov's pseudo-holomorphic curves and Morse-Floer theory on loop spaces gave rise to the discovery of unexpected symplectic phenomena. The present book focuses on function spaces associated with a symplectic manifold. A number of recent advances show that these spaces exhibit intriguing properties and structures, giving rise to an alternative intuition and new tools in symplectic topology. The book provides an essentially self-contained introduction into these developments along with applications to symplectic topology, algebra and geometry of symplectomorphism groups, Hamiltonian dynamics and quantum mechanics. It will appeal to researchers and students from the graduate level onwards.

I like the spirit of this book. It formulates concepts clearly and explains the relationship between them. The subject matter is important and interesting.

*—**Dusa McDuff, Barnard College, Columbia University***

This is a very important book, coming at the right moment. The book is a remarkable mix of introductory chapters and research topics at the very forefront of actual research. It is full of cross fertilizations of different theories, and will be useful to Ph.D. students and researchers in symplectic geometry as well as to many researchers in other fields (geometric group theory, functional analysis, mathematical quantum mechanics). It is also perfectly suited for a Ph.D.-students seminar.

*—**Felix Schlenk, Université de Neuchâtel***

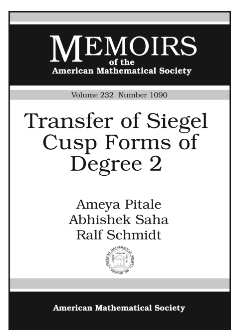
Titles in this series are co-published with the Centre de Recherches Mathématiques.

Contents: Three wonders of symplectic geometry; C^0-rigidity of the Poisson bracket; Quasi-morphisms; Subadditive spectral invariants; Symplectic quasi-states and quasi-measures; Applications of partial symplectic quasi-states; A Poisson bracket invariant of quadruples; Symplectic approximation theory; Geometry of covers and quantum noise; Preliminaries from Morse theory; An overview of Floer theory; Constructing subadditive spectral invariants; Bibliography; Nomenclature; Subject index; Name index.

CRM Monograph Series, Volume 34

October 2014, 203 pages, Hardcover, ISBN: 978-1-4704-1693-5, LC 2014020767, 2010 *Mathematics Subject Classification:* 53Dxx; 57R17, 81S10, 81P15, 22E65, 20F99, 28A10, **AMS members US$72**, List US$90, Order code CRMM/34

Number Theory



Transfer of Siegel Cusp Forms of Degree 2

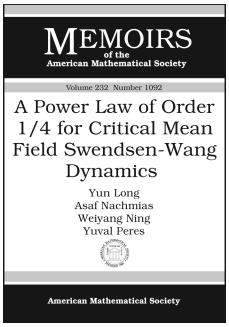
Ameya Pitale, *University of Oklahoma, Norman, Oklahoma*, **Abhishek Saha**, *University of Bristol, United Kingdom*, and **Ralf Schmidt**, *University of Oklahoma, Norman, Oklahoma*

Contents: Introduction; Notation; Distinguished vectors in local representations; Global L-functions for $\mathrm{GSp}_4 \times \mathrm{GL}_2$; The pullback formula; Holomorphy of global L-functions for $\mathrm{GSp}_4 \times \mathrm{GL}_2$; Applications; Bibliography.

Memoirs of the American Mathematical Society, Volume 232, Number 1090

October 2014, 107 pages, Softcover, ISBN: 978-0-8218-9856-7, LC 2014024655, 2010 *Mathematics Subject Classification:* 11F70, 11F46, 11F67, **Individual member US$45**, List US$75, Institutional member US$60, Order code MEMO/232/1090

Probability and Statistics



A Power Law of Order 1/4 for Critical Mean Field Swendsen-Wang Dynamics

Yun Long, *University of California, Berkeley, California*, **Asaf Nachmias**, *University of British Columbia, Vancouver, British Columbia, Canada*, **Weiyang Ning**, *University of Washington, Seattle, Washington*, and **Yuval Peres**, *Microsoft Research, Redmond, Washington*

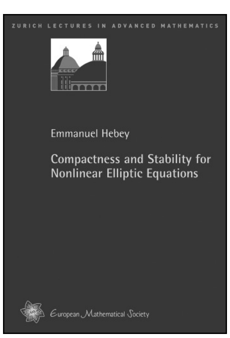
Contents: Introduction; Statement of the results; Mixing time preliminaries; Outline of the proof of Theorem 2.1; Random graph estimates; Supercritical case; Subcritical case; Critical Case; Fast mixing of the Swendsen-Wang process on trees; Acknowledgements; Bibliography.

Memoirs of the American Mathematical Society, Volume 232, Number 1092

October 2014, 84 pages, Softcover, ISBN: 978-1-4704-0910-4, LC 2014024667, 2010 *Mathematics Subject Classification:* 60J10; 82B20, **Individual member US$39**, List US$65, Institutional member US$52, Order code MEMO/232/1092

New AMS-Distributed Publications

Analysis



Compactness and Stability for Nonlinear Elliptic Equations

Emmanuel Hebey, *Université de Cergy-Pontoise, France*

The book offers an expanded version of lectures given at ETH Zürich in the framework of a Nachdiplomvorlesung. Compactness and stability for nonlinear elliptic equations in the inhomogeneous context of closed Riemannian manifolds are investigated. This field is presently undergoing great development. The author describes blow-up phenomena and presents the progress made over the past years on the subject, giving an up-to-date description of the new ideas, concepts, methods, and theories in the field. Special attention is devoted to the nonlinear stationary Schrödinger equation and to its critical formalation.

Intended to be as self-contained as possible, the book is accessible to a broad audience of readers, including graduate students and researchers.

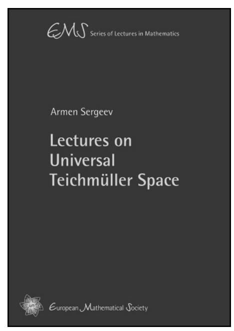
This item will also be of interest to those working in differential equations.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: Some model equations; Basic variational methods; The L^p and H^1-theories for blow-up; Blowing-up solutions in the critical case; An introduction to elliptic stability; Bounded stability; The C^0-theory for blow-up; Analytic stability; Bibliography.

Zurich Lectures in Advanced Mathematics, Volume 20

January 2014, 301 pages, Softcover, ISBN: 978-3-03719-134-7, 2010 *Mathematics Subject Classification:* 58J05, 35J15, **AMS members US$41.60**, List US$52, Order code EMSZLEC/20



Lectures on Universal Teichmüller Space

Armen N. Sergeev, *Steklov Mathematical Institute, Moscow, Russia*

This book is based on a lecture course given by the author at the Educational Center of the Steklov Mathematical Institute in 2011. It is designed for a one-semester course for undergraduate students familiar with basic differential geometry and complex and functional analysis.

The universal Teichmüller space $\mathcal{T}$ is the quotient of the space of quasisymmetric homeomorphisms of the unit circle modulo Möbius transformations. The first part of the book is devoted to the study of geometric and analytic properties of $\mathcal{T}$. It is an infinite-dimensional Kähler manifold which contains all classical Teichmüller spaces of compact Riemann surfaces as complex submanifolds, which explains the name "universal Teichmüller space". Apart from classical Teichmüller spaces, $\mathcal{T}$ contains the space S of diffeomorphisms of the circle modulo Möbius transformations. The latter space plays an important role in the quantization of the theory of smooth strings.

The quantization of $\mathcal{T}$ is presented in the second part of the book. In contrast with the case of diffeomorphism space S, which can be quantized in frames of the conventional Dirac scheme, the quantization of $\mathcal{T}$ requires an absolutely different approach based on the noncommutative geometry methods.

The book concludes with a list of 24 problems and exercises which can used to prepare for examinations.

This item will also be of interest to those working in geometry and topology.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: Quasiconformal maps; Universal Teichmüller space; Subspaces of universal Teichmüller space; Grassmann realization of the universal Teichmüller space; Quantization of space of diffeomorphisms; Quantization of Teichmüller space; Instead of an

About the cover

The joy of Texas

This month's cover reminds us that the 2015 Joint Mathematics Meetings will take place in San Antonio, Texas, January 10–13, 2015.

Entering "Mexican restaurants, San Antonio" into Google brings up nearly half a million hits—and chile peppers are a central ingredient in Mexican food. On the cover, clockwise from the upper left, are these peppers: chile de árbol, guajillo, serrano, habanero, puya, pequin.

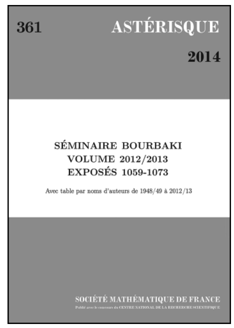
—Bill Casselman
Graphics Editor
(notices-covers@ams.org)

afterword. Universal Teichmüller space and string theory; Problems; Bibliographical comments; Bibliography; Index.

EMS Series of Lectures in Mathematics, Volume 19

August 2014, 111 pages, Softcover, ISBN: 978-3-03719-141-5, 2010 *Mathematics Subject Classification:* 58B20, 58B25, 58B34, 53C55, 53D50, **AMS members US$25.60**, List US$32, Order code EMSSERLEC/19

General Interest



Séminaire Bourbaki: Volume 2012/2013 Exposés 1059–1073

A note to readers: This book is in French.

This 65th volume of the Bourbaki Seminar contains the texts of the fifteen survey lectures presented during 2012/2013 on the following topics: Hodge theory; the structure of certain homeomorphism groups of a Cantor space; differential equations in metric spaces; stochastic partial differential equations; probability theory; laminations and 3-dimensional manifolds; finite groups; the representations of classical groups and on the categorification of those of Lie algebras; the Bloch-Kato conjecture in Galois cohomology; algebraic geometry; ergodic theory; the hyperbolicity of hypersurfaces in projective spaces; the Baum-Connes conjecture.

For the table of contents, go to http://www.ams.org/bookstore.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Astérisque, Number 361

May 2014, 520 pages, Softcover, ISBN: 978-2-85629-785-8, 2010 *Mathematics Subject Classification:* 05E10, 14F10, 14F42, 14J70, 17B37, 11F72, 11R39, 14-02, 14C25, 14D07, 19K35, 20-02, 20B30, 20C15, 20C33, 20D05, 20E32, 20F05, 20F12, 20G15, 20G40, 20H10, 20P05, 22E55, 30F30, 30F40, 30L99, 32G15, 32G20, 32Q45, 32S35, 32S60, 35K05, 37B10, 37B50, 43A07, 43A25, 49J45, 53C21, 57M50, 58A20, 60G70, 60H15, 60J65, 60J80, 82C28, **AMS members US$117.60**, List US$147, Order code AST/361

Classified Advertisements

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

CALIFORNIA

UNIVERSITY OF CALIFORNIA, DAVIS
Arthur J. Krener Assistant Professor Positions in Mathematics

The Department of Mathematics at the University of California, Davis, is soliciting applications for one or more Arthur J. Krener positions starting July 1, 2015.

The department seeks applicants with excellent research potential in areas of faculty interest and effective teaching skills. Applicants are required to have completed their Ph.D. by the time of their appointment, but no earlier than July 1, 2011. The annual salary is $61,100. The teaching load is 3 to 4 quarter-long courses. Krener appointments are renewable for a total of up to three years, upon demonstration of satisfactory performance in research and teaching.

Additional information about the department may be found at `http://math.ucdavis.edu/`.

Applications will be accepted until the position is filled. To guarantee full consideration, the application should be received by November 30, 2014. To apply: submit the AMS Cover Sheet and supporting documentation electronically through `http://www.mathjobs.org/`.

The University of California, Davis, is an Affirmative Action/Equal Opportunity Employer.

000035

UNIVERSITY OF CALIFORNIA, DAVIS
Faculty Position in Mathematics

The Department of Mathematics at the University of California, Davis, invites applications for a tenure-track faculty position starting July 1, 2015.

Outstanding candidates in all areas of mathematics may be considered. Minimum qualifications for the position include a Ph.D. degree or its equivalent in the Mathematical Sciences and excellent potential for performance in teaching and research. Duties include mathematical research, undergraduate and graduate teaching, and departmental, university and professional service.

Additional information about the department may be found at `http://math.ucdavis.edu/`.

Applications will be accepted until the position is filled. For full consideration, completed applications should be received by November 30, 2014. To apply: submit the AMS Cover Sheet and supporting documentation electronically through `http://www.mathjobs.org/`.

The University of California, Davis, is an Affirmative Action/Equal Opportunity Employer.

000036

UNIVERSITY OF CALIFORNIA, DAVIS
Departments of Mathematics and Physics
Four Faculty Positions in Theoretical Physics and Mathematics

The Departments of Mathematics and Physics at the University of California, Davis, invite applications for four full-time faculty positions to launch a new research initiative: The Physics and Mathematics of the Universe. Applications will be considered for appointment at the level of Assistant Professor, Associate Professor, or Professor; appointments will be made either in the Mathematics or Physics Department, or jointly between the two departments, to be determined on a case-by-case basis.

This is an opportunity to build an extraordinary program, and we will exercise flexibility regarding the exact specialties of the faculty we recruit in order to achieve an exciting outcome. We encourage applications from candidates with expertise in areas of theoretical physics and mathematics that aim to increase our understanding of the fundamental physical laws and their underlying mathematical structure.

This program will benefit from synergies with our strong research programs in high energy physics, gravity, cosmology, geometry, topology, and mathematical physics.

Applicants must have a Ph.D. in physics or mathematics and the ability to teach effectively at both undergraduate and graduate levels. Demonstrated success in an active research program in physics or mathematics is essential.

Due to the large number of positions to be filled, applications will be evaluated starting October 10, 2014. To ensure full consideration, applications should be received by this date. The positions will remain open and applications will be accepted until the search is complete. Applications should be submitted online via the job listing PMUFAC2014 on `http://www.mathjobs.org`, and should include a

Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 2014 rate is $3.50 per word with a minimum two-line headline. No discounts for multiple ads or the same ad in consecutive issues. For an additional $10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified ads.

Upcoming deadlines for classified advertising are as follows: November 2014 issue–September 4, 2014; December 2014 issue–September 30, 2014; January 2015 issue–October 29, 2014; February 2015 issue–December 8, 2014; March 2015 issue–January 2, 2015; April 2015 issue–January 29, 2015.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 1373 (vol. 44).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada or 401-455-4084 worldwide for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940; or via fax: 401-331-3842; or send email to `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 20904. Advertisers will be billed upon publication.

cover letter, CV, publication list, research and teaching statements, and letters of recommendation from at least four references.

Inquiries may be addressed to PMU Search Committee Chair, Department of Physics, University of California, One Shields Ave., Davis, CA 95616, or by e-mail to pmusearch@ucdavis.edu. Further information about the departments may be found on our websites at http://www.physics.ucdavis.edu and https://www.math.ucdavis.edu.

UC Davis is an Affirmative Action/Equal Employment Opportunity Employer and is dedicated to recruiting a diverse faculty community. We welcome all qualified applicants to apply, including women, minorities, individuals with disabilities, and veterans.

000034

UNIVERSITY OF CALIFORNIA, IRVINE
Department of Mathematics
Lecturer with Potential Security of Employment Position in Mathematics
Job #02483

Applications are invited for a Lecturer with Potential Security of Employment position (LPSOE). The appointment will be effective July 1, 2015, or later. An excellent record of teaching and outreach activities and the Ph.D. degree are required. The LPSOE is a full-time faculty position designed for individuals who wish to focus their careers on teaching, professional and educational activities, and university and public service. These individuals are not evaluated on their research. LPSOEs are members of the University of California Academic Senate and have all the usual benefits of Senate membership, such as eligibility for UCI's attractive faculty housing programs, medical and retirement benefits. Within eight years (or less), LPSOEs are evaluated for promotion to Lecturer with Security of Employment (LSOE), which has the permanence of a tenured position. Specific duties include the development and implementation of new courses and curricula at the undergraduate level and leadership roles in undergraduate activities and advising, in community outreach activities and in improving instructional resources. It is expected that the Lecturer PSOE will be involved in the submission of grants, attend relevant professional meetings, review programs, submit journal articles, and serve as chair in symposia at professional meetings. Completed applications must be submitted electronically through MathJobs (http://www.mathjobs.org, Position ID: LPSOE. Position Title: UCI - UCI - Lecturer PSOE.) and must contain: (1) AMS cover sheet (2) Curriculum vita (3) Cover letter (4) Teaching Statement (5) Selected reprints and/or preprints (6) Teaching evaluations (7) Three reference letters. Instructions for the electronic application process can be found at http://www.mathjobs.org. Applications are welcome at any time. The review process starts November 1, 2014, and will continue until the positions are filled. The University of California, Irvine is an Equal Opportunity/Affirmative Action Employer advancing inclusive excellence. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, age, protected veteran status, or other protected categories covered by the UC nondiscrimination policy.

000052

UNIVERSITY OF CALIFORNIA SANTA BARBARA
Department of Mathematics
Tenure-Track Position

The Department of Mathematics invites applications for a Tenure-Track Assistant Professor position in Analysis with an emphasis in Partial Differential Equations. UC Santa Barbara offers a unique environment where innovative, interdisciplinary, and foundational research is conducted in a collegial atmosphere. We are looking for candidates who have demonstrated exceptional promise through novel research with strong potential to interact with colleagues in applied analysis, the natural sciences, or engineering. Demonstrated research excellence and potential to become an effective teacher are required. Candidates must possess a Ph.D. by September 2015. Appointments begin July 1, 2015. To apply for this position(s), applicants must submit a curriculum vita, statement of research, statement of teaching philosophy, and the American Mathematical Society cover sheet (available online at http://www.ams.org), and arrange for four letters of reference to be sent (at least one of which is directed towards teaching). Materials should be submitted electronically via http://www.mathjobs.org. Applications received on or before October 15, 2014, will be given full consideration. Questions can be emailed to recruitment@math.ucsb.edu. The department is especially interested in candidates who can contribute to the diversity and excellence of the academic community through research, teaching, and service. The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, or any other characteristic protected by law including protected veterans and individuals with disabilities.

000051

ILLINOIS

UNIVERSITY OF CHICAGO
Department of Mathematics

The University of Chicago Department of Mathematics invites applications for the following positions: 1. L. E. Dickson Instructor: This is open to mathematicians who have recently completed or will soon complete a doctorate in mathematics or a closely related field, and whose work shows remarkable promise in mathematical research. The appointment typically is for two years, with the possibility of renewal for a third year. The teaching obligation is up to four one-quarter courses per year. 2. Assistant Professor: This is open to mathematicians who are further along in their careers, typically two or three years past the doctorate. These positions are intended for mathematicians whose work has been of outstandingly high caliber. Appointees are expected to have the potential to become leading figures in their fields. The appointment is generally for three years, with a teaching obligation of up to three one-quarter courses per year. Applicants will be considered for any of the positions above which seem appropriate. Complete applications consist of (a) a cover letter, (b) a curriculum vitae, (c) three or more letters of reference, at least one of which addresses teaching ability, and (d) a description of previous research and plans for future mathematical research. Applicants are strongly encouraged to include information related to their teaching experience, such as a teaching statement or evaluations from courses previously taught, as well as an AMS cover sheet. If you have applied for an NSF Mathematical Sciences Postdoctoral Fellowship, please include that information in your application, and let us know how you plan to use it if awarded. Applications must be submitted online through http://www.mathjobs.org. Questions may be directed to apptsec@math.uchicago.edu. We will begin screening applications on November 1, 2014. Screening will continue until all available positions are filled. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, age, protected veteran status, or status as an individual with disability. The University of Chicago is an Affirmative Action/Equal Opportunity/Disabled/Veterans Employer.

000050

UNIVERSITY OF CHICAGO
Department of Mathematics

The University of Chicago Department of Mathematics invites applicants for the position of Senior Lecturer, which also carries the departmental title of Co-Director of Undergraduate Studies.

Mathematics is a very popular undergraduate major at Chicago with a large and growing undergraduate program. It is led by a small team consisting of the Director of Undergraduate Studies and the Co-Directors, who are responsible for classroom teaching and leading academic initiatives of the program.

In addition to teaching a talented pool of undergraduates at all levels, Co-Directors advise undergraduates on their coursework and career paths. In collaboration with faculty, they update, revise, and develop curriculum. They hire and train course assistants. In addition, they help maintain a proud tradition at Chicago of training the next generations of mathematicians—especially with regard to their teaching—by training graduate student lecturers as well as mentoring young junior faculty mathematicians in pedagogy. The department also has a strong tradition in outreach, and a portion of the Co-Directors' responsibilities will include involvement in various outreach programming.

Qualified applicants must be mathematicians who are at least several years into their careers beyond the Ph.D. with exceptional competence in teaching, superior academic credentials, and excellent organizational and leadership skills.

The Senior Lecturer appointment would be ongoing with no set end date, but would be subject to reviews at least once every three years. The position is expected to begin July 1, 2015, or soon thereafter.

Applicants must apply through the University's Academic Jobs website (`http://tinyurl.com/qjq4kor`) and upload (a) a cover letter, (b) a curriculum vitae, including a list of publications, and (c) a description of teaching experience, and (d) a description of academic program leadership and any outreach activities or experience. A minimum of 3 reference letters are required. Reference letter submission information will be provided during the application process. Screening of applications will begin November 15, 2014, and continue until the position is filled. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, age, protected veteran status, or status as an individual with disability.

The University of Chicago is an Affirmative Action/Equal Opportunity/Disabled/Veterans Employer.

000046

MARYLAND

JOHNS HOPKINS UNIVERSITY
Department of Mathematics
Tenure-Track Assistant Professor

The Department of Mathematics invites applications for a tenure-track Assistant Professor beginning July 1, 2015. A Ph.D. degree or its equivalent and demonstrated promise in research and commitment to teaching are required. The department is seeking candidates in areas of pure mathematics that fit in with the existing areas of the department. To submit your application, go to `http://www.mathjobs.org/jobs/jhu`. Submit the AMS cover sheet, your curriculum vitae, list of publications, and research and teaching statements, and ensure that at least four letters of recommendation, one of which addresses teaching, are submitted by the reference writers. If you are unable to apply online, you may send application materials to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. If you have questions concerning this position, please write to `cpoole@jhu.edu`. Preference will be given to applications received by October 31, 2014. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply.

000030

JOHNS HOPKINS UNIVERSITY
Department of Mathematics

The Department of Mathematics invites applications for tenured positions at the Associate and Full Professor levels beginning fall 2015 or later. The Department is seeking candidates in areas of pure mathematics that fit in with the existing areas of the department. Preference for the full Professor position will be given to candidates in analysis. Applications may be submitted online at `http://www.mathjobs.org/jobs/jhu` or mailed to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. Submit a curriculum vitae, including a list of publications. The department will assume the responsibility of soliciting letters of evaluation and will provide evaluators with a summary of policies on confidentiality of letters. If you have questions concerning these positions, please write to `cpoole@jhu.edu`. Applications received by October 15, 2014, will be given priority. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply

000031

MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics

The Mathematics Department at MIT is seeking to fill positions in Pure and Applied Mathematics, and Statistics at the level of Instructor, Assistant Professor, or higher beginning September 2015. The department also seeks candidates for the Schramm Postdoctoral Fellowship. Appointments are based primarily on exceptional research qualifications. Appointees will be expected to fulfill teaching duties and to pursue their own research program. Ph.D. required by employment start date.

For more information and to apply, please visit `http://www.mathjobs.org`. To receive full consideration, submit applications by December 1, 2014. MIT is an Equal Opportunity, Affirmative Action Employer.

000044

MINNESOTA

UNIVERSITY OF MINNESOTA
School of Mathematics

The School of Mathematics of the University of Minnesota is seeking outstanding candidates for up to 3 TENURE-TRACK or TENURED faculty positions starting fall semester 2015. Candidates should have a Ph.D. or equivalent degree in mathematics or a closely related field and excellent records in both research and teaching. Applications and all supporting materials must be submitted electronically through: `http://www.mathjobs.org`. No paper submission is needed unless the candidate is unable to submit electronically, in which case letters should be sent to the following address: Peter J. Olver, Professor and Head, School of Mathematics, University of Minnesota, 127 Vincent Hall, 206 Church Street, S.E. Minneapolis, MN 55455. Applicants must include the following: Cover letter, curriculum vitae, at least 4 letters of recommendation, one of which should address teaching ability, and a research and teaching statement. Reference letter writers should be asked to submit their letters online through `http://mathjobs.org`. If they are unable to do so, they may send their letters to the above-mentioned address. In addition to their MathJobs application, the University of Minnesota requires all applicants to register at the University of Minnesota employment website `http://employment.umn.edu`. At this site you should first click on the link "Search Positions", and then enter Requisition Number 19205 for the tenure-track position or 19204 for the tenured position. The review process will start on November 15, 2014, and will continue for as long as positions are available.

Any offer of employment will be contingent on a successful criminal background check. The University of Minnesota is an Equal Opportunity Employer/Educator.

000037

NEW JERSEY

INSTITUTE FOR ADVANCED STUDY
School of Mathematics
Princeton, NJ

The School of Mathematics at the Institute for Advanced Study has a limited number of memberships with financial support for research during the 2015-16 academic year.

The school frequently sponsors special programs. However these programs comprise no more than one-third of the membership so that each year a wide range of mathematics is supported.

Candidates must give evidence of ability in research comparable at least with that expected for the Ph.D. degree, but otherwise can be at any career stage. Successful candidates will be free to devote themselves full time to research.

About half our members will be postdoctoral researchers within 5 years of their Ph.D. We expect to offer some two-year postdoctoral positions.

Up to eight von Neumann Fellowships will be available for each academic year. To be eligible for the von Neumann Fellowship, applicants should be at least five, but no more than fifteen years following the receipt of their Ph.D.

The Veblen Research Instructorship is a three-year position in partnership with the Department of Mathematics at Princeton University. Three-year instructorships will be offered each year to candidates in pure and applied mathematics who have received their Ph.D. within the last three years. Usually the first and third year of the instructorship will be spent at Princeton University and will carry regular teaching responsibilities. The second year is spent at the Institute and dedicated to independent research of the instructor's choice. Candidates interested in a Veblen Instructorship position may apply directly at the IAS website `https://applications.ias.edu` or they may apply through `MathJobs`. If they apply at `MathJobs`, they must also complete the application form at `https://applications.ias.edu` but do not need to submit a second set of reference letters. Those with questions about the application procedure can email `applications@math.ias.edu`.

In addition, there are also two-year postdoctoral positions in computer science and discrete mathematics offered jointly with the following institutions: The Department of Computer Science at Princeton University, `http://www.cs.princeton.edu`, DIMACS at Rutgers, The State University of New Jersey, `http://www.dimacs.rutgers.edu` or the Intractability Center, `http://intractability.princeton.edu`. Candidates must apply to both the IAS and to the other institution indicating their interest in a joint appointment.

School term dates for 2015-16 are: term I, Monday, September 21 to Friday, December 18; term II, Monday, January 11 to Friday, April 8, 2016. Please note that the school's term II begins and ends one week later than the rest of the Institute.

During the 2015-16 academic year, the school will have a special program on Geometric Structures on 3-manifolds, and Ian Agol of the University of California, Berkeley, will be the Distinguished Visiting Professor.

Thurston proposed the classification of geometric structures on n-manifolds. While the spectacular Geometrization Theorem classified the geometric structures on 3-manifolds with compact isotropy group, i.e., locally homogeneous Riemannian metrics, there is a cornucopia of other fascinating structures such as contact structures, foliations, conformally flat metrics and locally homogeneous (pseudo-) Riemannian metrics.

The goal of this program is to investigate these other geometric structures on 3-manifolds and to discover connections between them. Additionally, it is important to forge connections between geometric structures on 3-manifolds and other geometric constructs such as gauge theory, PD (3) groups, minimal surfaces, cube complexes, geometric structures on bundles over 3-manifolds, and strengthened structures such as taut foliations, tight contact structures pA flows, convex projective structures and quasi-geodesic foliations. Many of these do not even have a conjectural classification (in terms of topological restrictions and moduli), and specific examples are still being constructed.

The Institute for Advanced Study is committed to diversity and strongly encourages applications from women and minorities.

Application deadline is December 1.

000033

PRINCETON UNIVERSITY
Program in Applied and Computational Mathematics
Postdoctoral Research Associate

The Program in Applied and Computational Mathematics invites applications for Postdoctoral Research Associates to join in research efforts of interest to its faculty. Domains of interest include nonlinear partial differential equations, computational fluid dynamics and material science, dynamical systems, numerical analysis, stochastic problems and stochastic analysis, graph theory and applications, mathematical biology, financial mathematics and mathematical approaches to signal analysis, information theory, and structural biology and image processing. Appointments are possible for up to three years, renewable yearly, if funding is available and performance is satisfactory. For details on specific faculty members and their research interests, please go to `http://www.pacm.princeton.edu/index.shtml`. Princeton University is an Equal Opportunity Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, or any other characteristic protected by law. Applicants should submit a cover letter, CV, bibliography/publications list, statement of research, and three letters of recommendation. Applicants should have a recently-completed or soon-to-be-completed doctorate. This position is subject to the university background check policy.

000040

NEW YORK

UNIVERSITY OF ROCHESTER
Department of Mathematics

The Department of Mathematics at the University of Rochester invites applications for an opening in pure mathematics, starting on July 1, 2015, or later, at the tenure-track Assistant Professor level; more senior candidates with outstanding research achievements may also be considered. The teaching load for this position is three one-semester courses per year. Applications are encouraged in the general areas currently represented in the department's research profile: algebraic topology, algebra and number theory, analysis and PDE, differential geometry and global analysis, and probability and mathematical physics. Qualifications include a Ph.D. in mathematics, exceptional promise and/or accomplishments in research, and excellence in teaching. Application materials consist of a current C.V.; a statement of current and future research plans; a statement of teaching philosophy and experience; and at least four letters of recommendation, one of which should specifically address teaching. Applications should be submitted electronically through the website `http://www.rochester.edu/fort/mth`. The University of Rochester is a private, Tier I research institution located in western New York State. It consistently ranks among the top 30 institutions, both public and private, in federal funding for research and development. Half of all undergraduates go on to post-graduate or professional education. The university includes the Eastman School of Music, a premiere music conservatory, and the University of Rochester Medical Center, a major medical school, research center, and hospital system. The greater Rochester area is home to approximately one million people, including 80,000 students who attend its 8 colleges and universities, a rich cultural life, and affordable housing in excellent school systems and with easy commutes to the university.

Applications received by Nov. 15, 2014, will receive full consideration, but the search will remain open until the position is closed or filled. The University of Rochester, an Equal Opportunity Employer, has a strong commitment to diversity and actively encourages applications of candidates from groups underrepresented in higher education.

000045

PENNSYLVANIA

PENN STATE
Department of Mathematics

The Department of Mathematics is seeking new or recent Ph.D.'s with exceptional research potential and a commitment to excellence in teaching. These non-tenure-track appointments are for three years. Starting salary is $54,500 for the nine-month academic year. The Chowla program is designed to maximize the professional development of its participants and provides a research stipend. Initial offers will be made in January 2015. Applicants must complete the Penn State application at `http://www.psu.jobs` and must submit an application through (`https://www.mathjobs.org/jobs`) with the following materials in order for the application to be complete: (1) at least three reference letters, one of which should address in detail the candidate's abilities as a teacher, (2) Curriculum Vitae, (3) Publication List, (4) Research Statement, and (5) Teaching Statement. Apply at `https://app2.ohr.psu.edu/Jobs/External/EVMS2_External/currentap1.cfm#52586CAMPUS`.

Security Crime Statistics. For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to `http://www.police.psu.edu/clery/`, which will also provide you with detail on how to request a hard copy of the Annual Security Report. Penn State is an Equal Opportunity, Affirmative Action Employer, and is committed to providing employment opportunities to minorities, women, veterans, disabled individuals, and other protected groups.

000047

PENN STATE
Department of Mathematics

The Department of Mathematics is seeking outstanding applicants for tenure and tenure-track faculty positions in all areas of mathematics. There may be up to three positions in the area of Probability. A Ph.D. is required. Review of applications will begin November 15, 2014, and continue until all positions are filled. Applicants must complete the Penn State application and must submit an application through (`https://www.mathjobs.org/jobs`) with the following materials in order for the application to be complete: (1) at least three reference letters, one of which should address in detail the candidate's abilities as a teacher, (2) Curriculum Vitae, (3) Publication List, (4) Research Statement, and (5) Teaching Statement. These positions are subject to funding availability. Apply at `https://app2.ohr.psu.edu/Jobs/External/EVMS2_External/currentap1.cfm#52585`.

Campus Security Crime Statistics. For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to `http://www.police.psu.edu/clery/`, which will also provide you with detail on how to request a hard copy of the Annual Security Report. Penn State is an Equal Opportunity, Affirmative Action Employer, and is committed to providing employment opportunities to minorities, women, veterans, disabled individuals, and other protected groups.

000048

RHODE ISLAND

BROWN UNIVERSITY
J. D. Tamarkin Assistant Professorships

J. D. Tamarkin Assistant Professorships: These are three-year non-tenured non-renewable appointments, beginning July 1, 2015. The teaching load is one course one semester, and two courses the other semester and consists of courses of more than routine interest. Candidates are required to have received a Ph.D. degree or equivalent by the start of their appointment, and they may have up to three years of prior academic and/or postdoctoral research experience.

Applicants should have strong research potential and a commitment to teaching. Field of research should be consonant with the current research interests of the department.

For full consideration, applicants must submit a curriculum vit, an AMS Standard Cover Sheet, and three letters of recommendation by December 1, 2014. Applicants are encouraged to identify Brown faculty with similar research interests. Please submit all application materials online at `http://www.mathjobs.org`. Email inquiries should be addressed to `juniorsearch@math.brown.edu`. Brown University is committed to fostering a diverse and inclusive academic global community; as an EEO/AA Employer, Brown considers applicants for employment without regard to, and does not discriminate on the basis of, gender, race, protected veteran status, disability, or any other legally protected status.

000042

BROWN UNIVERSITY
Mathematics Department

The Mathematics Department at Brown University invites applications for one position at the level of Associate Professor with tenure to begin July 1, 2015. Exceptionally qualified senior candidates may be considered for appointment as Full Professor. Candidates should have a distinguished research record and a strong commitment to excellence in undergraduate and graduate teaching. Preference will be given to applicants with research interests consonant with those of the present members of the department. For more information see: `http://www.math.brown.edu/faculty/faculty.html`. Qualified individuals are invited to submit a letter of application and a curriculum vitae to: `http://www.mathjobs.org`. Applicants should include the names of five references that would be contacted at the appropriate time by the Search Committee. Applications received by October 15, 2014, will receive full consideration, but the search will remain open until the position is closed or filled. For further information or inquiries, write to `srsearch@math.brown.edu`. Brown University is committed to fostering a diverse and inclusive academic global community; as an EEO/AA Employer, Brown considers applicants for employment without regard to, and does not discriminate on the basis of gender, race, protected veteran status, disability, or any other legally protected status.

000041

SOUTH CAROLINA

UNIVERSITY OF SOUTH CAROLINA
Department of Mathematics
Algebra
Tenure-track Assistant Professor

Applications are invited for a tenure-track Assistant Professor position in the area of algebra. Areas of particular interest include algebraic geometry, commutative algebra, and representation theory.

Candidates must have a Ph.D. in mathematics, an outstanding research program, a commitment to effective teaching at the undergraduate and graduate levels, and a demonstrated potential for excellence in both research and teaching.

Applicants must apply electronically at `http://www.mathjobs.org`. A completed application should contain a cover letter, standard AMS cover sheet, curriculum vitae, description of research plans, statement of teaching philosophy, and four letters of recommendation. One of the letters should appraise the candidate's teaching ability.

The beginning date for the position will be August 16, 2015. Review of applications will begin on December 1, 2014, and continue until the position is filled. To ensure consideration, applications should be received by January 8, 2015. Please address inquiries to vraciu@math.sc.edu.

The Mathematics Department, located in the heart of the historic campus, currently has 36 tenured and tenure-track faculty, 6 instructors, 48 graduate students, over 250 majors, and 40 minors. Faculty research interests include algebra, analysis, applied and computational math, biomath, discrete math, geometry, logic, and number theory.

The University of South Carolina's main campus is located in the state capital, close to the mountains and the coast. The Carnegie Foundation for the Advancement of Teaching has designated the University of South Carolina as one of only 73 public and 35 private academic institutions with "very high research activity" and also lists USC as having strong focus on community engagement. The university has over 31,000 students on the main campus (and over 46,000 students system-wide), more than 350 degree programs, and a nationally-ranked library system that includes one of the nation's largest public film archives. Columbia, the capital of South Carolina, is the center of a greater metropolitan area which has a population over 750,000.

The University of South Carolina is an Affirmative Action, Equal Opportunity Employer. Minorities and women are encouraged to apply. The University of South Carolina does not discriminate in educational or employment opportunities or decisions for qualified persons on the basis of race, color, religion, sex, national origin, age, disability, sexual orientation, or veteran status.

000038

WISCONSIN

UNIVERSITY OF WISCONSIN-MADISON
Department of Mathematics

The Department of Mathematics is accepting applications for an assistant professor (tenure-track) position beginning August 24, 2015, contingent upon budgetary approval. Applications are invited in all areas of mathematics. The minimum requirement is a Ph.D. in mathematics or related field, and faculty members are expected to contribute to the research, teaching, and service missions of the department. Candidates should exhibit evidence of outstanding research potential, normally including significant contributions beyond the doctoral dissertation. The teaching responsibility is three courses per academic year, including both undergraduate- and graduate-level courses, and a strong commitment to excellence in instruction is also expected. Additional departmental information is available at http://www.math.wisc.edu. An application packet should include a completed AMS Standard Cover Sheet, a curriculum vitae that includes a publication list, and brief descriptions of research and teaching. Application packets should be submitted electronically to http://www.mathjobs.org. Applicants should also arrange to have sent to the URL address, three to four letters of recommendation, at least one of which must discuss the applicant's teaching experiences and capabilities and potential. To ensure full consideration, application packets must be received by November 1, 2014. Applications will be accepted until the position is filled. UW-Madison is an Equal Opportunity/Affirmative Action Employer. We promote excellence through diversity and encourage all qualified individuals to apply. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality. A background check will be required prior to employment.

000039

TENNESSEE

VANDERBILT UNIVERSITY
Nashville, Tennessee
Non-Tenure-Track Assistant Professor Positions

We invite applications for several visiting and non-tenure-track assistant professor positions in the research areas of the Mathematics Department beginning fall 2015. These positions will have variable terms and teaching loads but most will be three-year appointments with a 2-2 teaching load. We anticipate that some of these appointments will carry a 1-1 teaching load and provide a stipend to support research.

We are looking for individuals with outstanding research potential and a strong commitment to excellence in teaching. Preference will be given to recent doctorates. Submit your application and supporting materials electronically through the AMS website Mathjobs.org via the link http://www.mathjobs.org/jobs. Alternatively, application materials may be sent to: NTT Appointments Committee, Vanderbilt University, Department of Mathematics, 1326 Stevenson Center, Nashville, TN 37240. These materials should include a letter of application, a curriculum vitae, a publication list, a research statement, a teaching statement, at least four letters of recommendation and the AMS Cover Sheet. One of the letters must discuss the applicant's teaching qualifications. Reference letter writers should be asked to submit their letters online through Mathjobs.org. Evaluation of the applications will commence on December 1, 2014, and continue until the positions are filled. For information about the Department of Mathematics at Vanderbilt University, please consult the Web at http://www.vanderbilt.edu/math/.

Vanderbilt is an Equal Employment Opportunity/Affirmative Action Employer. Women and minorities are especially invited to apply.

000032

AUSTRIA

IST AUSTRIA
Call for Assistant Professors and Professors

IST Austria invites applications for TENURE-TRACK ASSISTANT PROFESSOR and TENURED PROFESSOR positions in all areas of MATHEMATICS.

IST Austria is a recently founded public institution dedicated to basic research and graduate education near Vienna. Currently active fields of research include biology, neuroscience, physics, mathematics, and computer science. IST Austria is committed to becoming a world-class research center with 1,000 scientists and doctoral students by 2026. The institute has an interdisciplinary campus, an international faculty and student body, as well as state-of-the-art-facilities. The working language is English.

Successful candidates will be offered highly competitive research budgets and salaries. Faculty members are expected to apply for external research funds and participate in graduate teaching. Candidates for senior positions must be internationally accomplished scientists in their respective fields.

Deadlines: Open call for Professor applications.

For full consideration, Assistant Professor applications should arrive on or before November 15, 2014.

Application material must be submitted online: http://www.ist.ac.at/professor-applications.

IST Austria values diversity and is committed to Equal Opportunity. Female researchers are especially encouraged to apply.

000043

PUBLICATIONS FOR SALE

FUNDAMENTALS OF STATISTICS AND PROBABILITY THEORY

A Tutorial Approach has significantly raised the ability of students to learn. Details: http://www.StatsTutorialText.com.

000049

Mathematical Sciences Employment Center

Henry B. Gonzalez Convention Center, San Antonio, Texas
January 10–13, 2015

The Employment Center offers a convenient, safe, and practical meeting place for employers and applicants attending the Joint Meetings. The focus of the Employment Center is on Ph.D.-level mathematical scientists and those that seek to hire them from academia, business, and government.

Employment Center Web Services

Employment Center registration information will be accessed through the `MathJobs.org` system. For those who do not have existing `MathJobs.org` accounts, it will be possible to set up special Employment Center accounts on `MathJobs.org`. The website and all information will be available beginning in early September 2014 and will remain accessible through the period of the Employment Center. While some schools may delay appointment-setting until late December, virtually all scheduling will be done before travel takes place, so applicants should expect few or no further appointments after arrival. Registering on site, for applicants, serves no real purpose.

No Admittance Without a JMM Badge

All applicants and employers planning to enter the Employment Center—even just for one interview—must present a 2015 Joint Meetings Registration badge. Meeting badges are obtained by registering for the Joint Mathematics Meetings and paying a meeting registration fee. See the JMM website at: `http://jointmathematicsmeetings.org/jmm` for registration instructions and rates.

Employers: Choose a Table

There are two table types available for employers, based on the number of interviewers who will be present at any one time:

- one or two interviewers per table in the "Quiet Area" (US$320), additional table (US$130).
- three to six interviewers per table in the "Committee Table" area (US$400), additional table (US$145).
- Electricity is available to employers (US$85 per table).

New this year, employers will be able to purchase one-day tables. These tables can only be purchased ON SITE in San Antonio and no Web services or Web forms are included. The table can accommodate up to three interviewers. The fee is (US$190). Electricity will not be available. Please see the employment center staff on site for full details.

All Employment Center forms are now housed on the `MathJobs.org` site. An existing account can be used for accessing Employment Center services and paying appropriate fees, or if no account exists, participants can start an account solely for Employment Center use.

Employers are expected to create their own interview schedules as far in advance as possible, using the assisted-email system in `Mathjobs.org` or using other means of communication.

Please mark appointments as confirmed in your `Mathjobs.org` account which will allow the appointments to display in the applicants' schedules. At the time of the interview, meet the applicant in the waiting area on site and escort him or her to your table.

Employers: How to Register

- Registration runs from early September 2014 through January 10, 2015, at the following website: `www.mathjobs.org`.

2015 Employment Center Schedule:

December 23, 2014–Advance registration deadline for JMM. Meeting badge will be required for admittance. After this date, meeting registration fees go up and meeting registration may only happen on site in San Antonio.

OPEN HOURS (NO access before opening time):

Saturday, January 10, 2015–8:00 a.m.–5:30 p.m.

Sunday, January 11, 2015–8:00 a.m.–5:30 p.m.

Monday, January 12, 2015–8:00 a.m.–5:30 p.m.

Tuesday, January 13, 2015–9:00 a.m.–12:00 noon.

Location: Ballroom A, Street Level, Henry B. Gonzalez Convention Center, 200 East Market Street, San Antonio, Texas.

Do not schedule an interview to begin until 15 minutes after opening.

• Use your existing MathJobs.org account or create a new Employer account at www.mathjobs.org. Once a table is reserved, the ad can be placed at any time (or never) and will run until late January.

• For new users of Mathjobs.org, click the NEW EMPLOYER link on the main page of www.mathjobs.org. Choose your table type and fill out the New Employer Form.

• For existing users of Mathjobs.org, go to www.mathjobs.org. Log into your existing account. Purchase a table by clicking the "EmpCent" logo in the menus along the top tool bar. Use the "buy tables" link. Then post a job using the NewJob link or attach an existing job to your table.

• Each person who will need to enter the Employment Center area must have a meeting badge (obtained by registering for the JMM and paying a meeting registration fee).

To display an ad on site, and use no Employment Center services at all, submit your one-page paper ad on site in San Antonio to the Employment Center staff. There is no fee for this service.

For complete information, visit http://www.ams.org/emp-reg/.

Applicants: Making the Decision to Attend

• The Employment Center offers no guarantees of interviews or jobs. Hiring decisions are not made during or immediately following interviews. In the current job market, the ratio of applicants to employers is about 10:1, and many applicants go completely unnoticed.

• There will ordinarily be no research-oriented postdoctoral positions listed or discussed at the Employment Center.

• Interviews will go to applicants who applied to jobs during the fall and are now being sought out by the institutions for in-person meetings during the JMM.

• There will be no opportunity to speak to employers without a pre-arranged interview, and no walk-up job information tables. Scheduling of interviews is complete prior to the JMM.

In the current job market, the majority of Employment Center employers are academic departments of mathematical sciences seeking to meet a short list of applicants who applied for their open positions during the fall. Each year, a few government or industry employers are present. Often, they are seeking U.S. citizens only due to existing contracts.

All job postings are available on the website in advance, and now that this electronic service is in place, there is no other messaging conducted on paper.

Past attendees have pointed out that all interviews are arranged in advance, and there is no opportunity to make connections on site if it has not happened before the meeting. In a recent survey, fifty percent of applicants responding reported being invited for at least one on-campus visit to an employer they had interviewed with at the Employment Center. Please visit the Employment Center website for further advice, information, and program updates at www.ams.org/emp-reg/.

Applicants: How to Register

• Early registration is vital since most employers will finalize schedules before arriving in San Antonio.

• To register, applicants should log into their Mathjobs.org accounts or create a new account, look for the EmpCent icon across the top tool bar and mark that they will be attending by clicking the link, "click here if you are attending the Employment Center." You can then upload documents and peruse the list of employers attending and the positions available. You do not have the option to request an interview with an employer. However, if you are interested in any position, you can apply to the job. The employer will be aware that you are also attending the event and will contact you directly if interested in setting up an interview.

There are no Employment Center fees for applicants; however, admission to the Employment Center room requires a 2015 JMM badge, obtainable by registering (and paying a fee) for the Joint Mathematics Meetings. To register for the meeting, go to http://jointmathematicsmeetings.org/jmm.

It is possible to attend one or more privately arranged interviews without official Employment Center registration, however, a meeting badge is required to access the interview room.

Applicants should keep track of their interview schedules and note their busy times in their accounts. If invited for an interview at a conflicting time, please ask the employer to offer a new time or suggest one.

For complete information, visit http://www.ams.org/emp-reg/.

Questions about the Employment Center registration and participation can be directed to Steve Ferrucci, AMS Membership and Programs Department, at 800-321-4267, ext. 4113 or by email to emp-info@ams.org.

AMS Short Course in San Antonio, TX

AMS Short Course on Finite Frame Theory: A Complete Introduction to Overcompleteness

This two-day course will take place on Thursday and Friday, January 8 and 9, before the joint meeting actually begins. It is organized by **Kasso A. Okoudjou**, Norbert Wiener Center, Department of Mathematics, University of Maryland, College Park.

Introduction: Hilbert space frames have traditionally been used to decompose, process and reconstruct signals/images. Today frame theory is an exciting, dynamic subject with applications to pure mathematics, applied mathematics, engineering, medicine, computer science, and quantum computing. From a mathematical perspective, frame theory is at the intersection of many fields such as functional and harmonic analysis, numerical analysis, matrix theory, numerical linear algebra, algebraic and differential geometry, probability, statistics, and convex geometry. Problems in frame design arising in applications often present fundamental, completely new challenges never before encountered in mathematics.

The goals of this short course are to: (1) introduce the fundamental tools and examples of frames; (2) describe a number of applications that required the design of specific frames; (3) present the connection of frames to some of the research fields and notions described above; (4) present some recent frame-based developments in compressed sensing and dictionary learning.

Frames and Phaseless Reconstruction

Radu Balan, Department of Mathematics and Center for Scientific Computations and Mathematical Modeling, University of Maryland, College Park

Frame design for phaseless reconstruction is now part of the broader problem of nonlinear reconstruction and is an emerging topic in harmonic analysis. The problem of phaseless reconstruction can be simply stated as follows. Given the magnitudes of the coefficients of an output of a linear redundant system (frame), we want to reconstruct the unknown input. This problem has first occurred in X-ray crystallography starting from the early 20th century. In 1985 the Nobel prize in chemistry was awarded to Herbert Hauptman (a mathematician) for his contributions to the development of X-ray crystallography. The same nonlinear reconstruction problem shows up in speech processing, particularly in speech recognition.

In this lecture we shall cover existing analysis results as well as algorithms for signal recovery including:
(1) Necessary and sufficient conditions for injectivity;
(2) Lipschitz bounds of the nonlinear map and its left inverses;
(3) Stochastic performance bounds;
(4) Convex relaxation algorithms for inversion;
(5) Least-Squares inversion algorithms.

References

[1] R. Balan, P. Casazza, D. Edidin, On signal reconstruction without phase, *Appl. Comput. Harmon. Anal.* **20** (2006), 345–356.

[2] R. Balan, Reconstruction of Signals from Magnitudes of Redundant Representations: The Complex Case, arXiv:1304.1839v1[math.FA] 6, April 2013.

[3] E. Candès, T. Strohmer, V. Voroninski, PhaseLift: Exact and stable signal recovery from magnitude measurements via convex programming, *Comm. Pure and App. Math.* **66**, no. 8, (2013), 1241–1274.

Summary: Construction of Finite Frames with Optimal Ambiguity Function Behavior

John J. Benedetto, Norbert Wiener Center, Department of Mathematics, University of Maryland, College Park.

The $N \times N$ normalized Discrete Fourier Transform (DFT) matrix $D_N = (1/\sqrt{N})(e^{2\pi imn/N})$ gives rise to equal norm tight frames for $\mathbb{C}^d$, where $d \leq N$ and the particular frame is characterized by the specific d columns of D_N which are chosen. In fact, the norm of each frame element is $(d/N)^{1/2}$ and the frame constant is 1. Clearly, this frame is an orthonormal basis for $\mathbb{C}^d$ in the case $d = N$. D_N is a special case of an $N \times N$ complex *Hadamard* matrix $H = H_N = (1/\sqrt{N})(h_{m,n})$, defined by the properties of *constant amplitude*, i.e., each $|h_{m,n}| = 1/\sqrt{N}$, and *orthonormality* (*unitarity*), i.e., $HH^* = \mathbb{I}$, the identity, where H^* is the Hermitian transpose of H.

Let $x\colon \mathbb{Z}/N\mathbb{Z} \longrightarrow \mathbb{C}$, and define the discrete narrow band *ambiguity function*, $A(x)(m,n)$, of x as

$$A(x)(m,n) = \sum_{k=0}^{N-1} x[m+k]\,\overline{x[k]}\,e^{-2\pi ikn/N},$$

and the *autocorrelation* of x on $\mathbb{Z}/N\mathbb{Z}$ as $A(x)(m,0)$. These notions are central to applications such as communications and radar, see, e.g., [3], as well as a host of other applications ranging from pure mathematics to physics to statistics.

Now, let H_x be the circulant matrix with first row, $x = (x[0], x[1], \cdots, x[N-1])$. We shall say that x is a *constant amplitude zero autocorrelation* (CAZAC) sequence if each $|x[n]| = 1/\sqrt{N}$ and if $A(x)(m,0) = 0$ on $\mathbb{Z}/N\mathbb{Z} \setminus \{0\}$. It is elementary to prove that x *is a* CAZAC *sequence if and only if* H_x *is a Hadamard matrix.*

In this context, it is of interest to construct CAZAC sequences, e.g., [2], to construct "CAZAC frames" analogous to DFT frames, and to find optimal ambiguity function bounds associated with CAZAC sequences using classical Welch bound estimates as a guideline. We shall make such constructions and shall see the role played by algebraic number theory, e.g., the Riemann hypothesis for finite fields (see [1]), and algebraic geometry in making such constructions. We shall give a state of the art overview of the subject and list some open problems. We shall also integrate this material into the matter of analyzing finite Gabor frames with CAZAC generating functions. This provides background for a critical comparison of such deterministic frames with the probabilistic frames arising in compressive sensing.

References

[1] John J. Benedetto, Robert L. Benedetto, and Joseph T. Woodworth, Optimal ambiguity functions and Weil's exponential sum bound, *Journal of Fourier Analysis and Applications* **18** (2012), no. 3, 471–487.

[2] John J. Benedetto and Jeffrey J. Donatelli, Ambiguity function and frame theoretic properties of periodic zero autocorrelation waveforms, *IEEE J. Special Topics Signal Processing* **1** (2007), 6–20.

[3] Nadav Levanon and Eli Mozeson, *Radar Signals*, Wiley Interscience, IEE Press, 2004.

An Introduction to Finite Frame Theory

Peter G. Casazza, Frame Research Center, University of Missouri

Hilbert space frames have traditionally been used in signal/image processing. However, today frame theory is an exciting, dynamic subject with applications to pure mathematics, applied mathematics, engineering, medicine, computer science, quantum computing, and more with new applications arising every year. Problems in frame design arising in applications often present fundamental, completely new challenges never before encountered in mathematics.

In this lecture we will introduce the basics of frame theory including:

(1) The definition of a Hilbert space frame and the basics of the subject.

(2) The operators associated with frames including the analysis, synthesis and frame operators, reconstruction Parseval frames and equiangular frames.

(3) A number of examples to illustrate the concepts and the basics of frame construction.

(4) Matrix formulations of these concepts including the Grammian matrix and its properties.

(5) Dual frames and their applications.

(6) Naimark's Theorem classifying Parseval frames.

(7) Equivalence of frames, redundancy and spanning and independence properties of frames.

(8) A brief introduction to some of the significant applications of frame theory.

References

[1] P. G. Casazza, The art of frame theory, *Taiwanese Journal of Math* **4**, No. 2, (2000), 129–201.

[2] P. G. Casazza and G. Kutyniok (eds.), *Finite Frames: Theory and Applications*, Birkhauser, Boston, 2012.

[3] O. Christensen, *An Introduction to Frames and Riesz Bases, Applied and Numerical Harmonic Analysis*, Birkhauser, Boston, 2001.

A Primer on Finite Unit Norm Tight Frames

Dustin G. Mixon, Air Force Institute of Technology

Finite unit norm tight frames (FUNTFs) are one of the most fundamental objects in frame theory. A FUNTF can be efficiently described as the collection of columns of a matrix whose rows are orthogonal with equal norm and whose columns each have unit norm. The purpose of this lecture is to introduce and develop a working understanding of FUNTFs in three different ways:

(i) Describe a variety of applications of FUNTFs.

(ii) Develop an intuition for the frame potential and the "physical" behavior of FUNTFs.

(iii) Introduce the theory of eigensteps to construct all FUNTFs.

References

[1] John J. Benedetto, Matthew Fickus, Finite normalized tight frames, *Adv. Comput. Math.* **18** (2003), 357–385.

[2] Jameson Cahill, Matthew Fickus, Dustin G. Mixon, Miriam J. Poteet, Nate Strawn, Constructing finite frames of a given spectrum and set of lengths, *Appl. Comput. Harmon. Anal.* **35** (2013), 52–73.

[3] Jameson Cahill, Dustin G. Mixon, Nate Strawn, Connectivity and irreducibility of algebraic varieties of finite unit norm tight frames, Available online: arXiv:1311.4748

[4] Matthew Fickus, Dustin G. Mixon, Miriam J. Poteet, Frame completions for optimally robust reconstruction, *Proc. SPIE 8138, Wavelets and Sparsity XIV* (2011), 81380Q.

[5] Matthew Fickus, Dustin G. Mixon, Miriam Poteet, Nate Strawn, Constructing all self-adjoint matrices with prescribed spectrum and diagonal, *Adv. Comput. Math.* **39** (2013), 585–609.

Compressed Sensing and Dictionary Learning

Guangliang Chen, San Jose State University and **Deanna Needell,** Claremont McKenna College

Compressed sensing is a new field that arose as a response to inefficient traditional signal acquisition schemes. Under the assumption that the signal of interest is sparse, one wishes to take a small number of linear samples and later utilize a reconstruction algorithm to accurately recover the compressed signal. Typically, one assumes the signal is sparse itself or with respect to some fixed orthonormal basis. However, in applications one instead more often encounters signals sparse with respect to a tight frame which may be far from orthonormal. In the first part of this lecture, we will introduce the compressed sensing problem as well as recent results extending the theory to the case of sparsity in tight frames.

The second part of the lecture focuses on dictionary learning which is also a new field, but closely related to compressive sensing. Briefly speaking, a dictionary is an overcomplete and redundant system consisting of prototype signals that are used to express other signals. Due to the redundancy, for any given signal, there are many ways to represent it, but normally the sparsest representation is preferred for simplicity and easy interpretability. A good analog is the English language where the dictionary is the collection of all words (prototype signals) and sentences (signals) are short and concise combinations of words. In this lecture, we will introduce the problem of dictionary learning, its origin and applications, and existing solutions.

References

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[3] A. M. Bruckstein, D. L. Donoho, and M. Elad, From sparse solutions of systems of equations to sparse modeling of signals and images, *SIAM Review* **51** (2009), no. 1, 34–81.

[4] J. Mairal, F. Bach, J. Ponce, and G. Sapiro, Online learning for matrix factorization and sparse coding, *Journal of Machine Learning Research* **11** (2010), 19–60.

[5] W. K. Allard, G. Chen, and M. Maggioni, Multiscale geometric methods for data sets II: Geometric multiresolution analysis, *Appl. Comput. Harmon. Anal.* **32** (2012), no. 3, 435–462. http://arxiv.org/pdf/1105.4924v3.pdf.

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Preconditioning Techniques in Frame Theory and Probabilistic Frames

Kasso A. Okoudjou, Norbert Wiener Center, Department of Mathematics, University of Maryland, College Park

The recently developed algebro-geometric methods for constructing FUNTFs are not effective when extra constraints on the FUNTFs are added. It is therefore desirable to have generic methods that would allow one to transform a frame into a tight one. These methods will be analogs of preconditioning methods prevalent in numerical linear algebra. Recently, various techniques have been used to describe a class of frames called scalable frames which have the property that their frame vectors can be rescaled to result in tight frames. In the first part of this lecture, we shall (1) describe the class of scalable frames using some convex geometry tools; (2) provide another geometric formulation of scalable frames based on Fritz John ellipsoid theorem.

Frames are intrinsically defined through their spanning properties. However, in real euclidean spaces, they can also be viewed as distributions of point masses. In this context, the notion of probabilistic frames was introduced as a class of probability measures with finite second moment and whose support spans the entire space. This notion is a special case of continuous frames for Hilbert spaces that has applications in quantum computing. In the second part of the lecture, we shall introduce a probabilistic interpretation of frames, and use this framework to: (1) define probabilistic frames as a generalization of frames and as a subclass of continuous; (2) investigate the minimizers of the frame potential and certain of its generalization in this probabilistic setting.

References

[1] X. Chen, G. Kutyniok, K. A. Okoudjou, F. Philipp, and R. Wang, Measures of scalability, arXiv:1406.2137.

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[4] M. Ehler and K. A. Okoudjou, *Probabilistic frames: An overview*, in: "Finite Frames," Applied and Numerical Harmonic Analysis, (2013), 415–436, Eds: P. Casazza and G. Kutyniok, Birkhaüser. arXiv:1108.2169

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Algebro-Geometric Techniques and Geometric Insights for Finite Frames

Nate Strawn, Duke University

The finite unit norm tight frames (FUNTFs) have a rich geometric structure that can be exploited to carry out dictionary optimization for various applications. Algebraically, FUNTFs are quadratic varieties. Geometrically, the FUNTFs lie in the intersection of a product of spheres and a Stiefel manifold. The interplay between these two perspectives illuminates the structure of the FUNTF spaces.

This goal of this lecture is to answer five important questions about the FUNTF varieties:

(1) What are the singular points?
(2) When is the FUNTF variety a manifold?
(3) What are the tangent spaces at the nonsingular points?
(4) Using elimination theory, can the system of defining quadratic equations be solved explicitly?
(5) Are the FUNTF varieties irreducible?

During the course of this lecture, we'll carry out a series of examples to answers these questions.

References

D. Mixon, J. Cahill,and N. Strawn, Connectivity and irreducibility of algebraic varieties of finite unit norm tight frames. Preprint.

J. Cahill and N. Strawn. Algebraic geometry and finite frames. In *Finite Frame Theory*, P. G. Casazza and G. Kutyniok (eds.), Birkhäuser, Boston, 2012.

N. Strawn, Finite frame varieties: Nonsingular points, tangent spaces, and explicit local parameterizations, *J. Four. Anal. Appl.* **17**(5):821–853, 2011.

Registration

There are separate fees to register for this Short Course. Advance registration fees for members are US$108; nonmembers are US$160; and students/unemployed or emeritus members are US$52. These fees are in effect until December 23, 2014. If you choose to register onsite, the fees for members are US$142; nonmembers are US$190; and students/unemployed or emeritus members are US$77. Advance registration starts on September 2, 2014. Onsite registration will take place on Thursday, January 8, at a location to be announced.

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See `http://www.ams.org/meetings/`. Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL and in an electronic issue of the *Notices* as noted below for each meeting.

Eau Claire, Wisconsin

University of Wisconsin-Eau Claire

September 20–21, 2014

Saturday – Sunday

Meeting #1102

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: June 2014
Program first available on AMS website: August 7, 2014
Program issue of electronic *Notices*: September 2014
Issue of *Abstracts*: Volume 35, Issue 3

Deadlines

For organizers: Expired
For abstracts: Expired

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

Invited Addresses

Matthew Kahle, The Ohio State University, *Recent progress in random topology*.

Markus Keel, University of Minnesota, *To be announced*.

Svitlana Mayboroda, University of Minnesota, *Elliptic PDEs and localization of eigenfunctions in rough media*.

Dylan P. Thurston, Indiana University, Bloomington, *Rubber bands, square tilings, and rational maps*.

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 `http://www.ams.org/cgi-bin/abstracts/abstract.pl`.

Algebraic Combinatorics, **Pavlo Pylyavskyy**, **Victor Reiner**, and **Dennis Stanton**, University of Minnesota.

Algorithms in Arithmetic Geometry, **Adriana Salerno**, Bates College, and **Ursula Whitcher**, University of Wisconsin-Eau Claire.

Analysis and Geometry on Lie Groups, **Chal Benson** and **Gail Ratcliff**, East Carolina University.

Cohomology and Representation Theory of Groups and Related Structures, **Christopher Bendel**, University of Wisconsin-Stout, and **Christopher Drupieski**, De Paul University.

Commutative Ring Theory, **Michael Axtell**, University of St. Thomas, and **Joe Stickles**, Millikin University.

Directions in Commutative Algebra: Past, Present, Future. Dedicated to the memory of H.-B. Foxby, **Joseph P. Brennan**, University of Central Florida, and **Robert M. Fossum**, University of Illinois at Urbana-Champaign.

Graph and Hypergraph Theory, **Sergei Bezrukov**, University of Wisconsin-Superior, **Dalibor Froncek**, University of Minnesota Duluth, and **Xiaofeng Gu**, **Uwe Leck**, and **Steven Rosenberg**, University of Wisconsin-Superior.

Knot Concordance and 4-Manifolds, **Christopher W. Davis**, University of Wisconsin-Eau Claire, **Taylor Martin**, Sam Houston State University, and **Carolyn Otto**, University of Wisconsin-Eau Claire.

Lie Algebras and Representation Theory, **Michael Lau**, Université Laval, **Ian Musson**, University of Wisconsin-Milwaukee, and **Matthew Ondrus**, Weber State University.

New Trends in Toric Varieties, **Christine Berkesch Zamaere**, University of Minnesota, **Daniel Erman**, University of Wisconsin-Madison, and **Hal Schenck**, University of Illinois Urbana-Champaign.

Number Theory, **Colleen Duffy**, University of Wisconsin-Eau Claire, and **Rafe Jones**, Carleton College.

Patterns in Permutations and Words, and Applications, **Manda Riehl**, University of Wisconsin-Eau Claire, and **Alex Woo**, University of Idaho.

Problem Solving in Extremal Combinatorics and Combinatorial Geometry, **Jeremy Alm**, Illinois College, and **Jacob Manske**, Epic.

Random Spaces, **Matthew Kahle**, Ohio State University, and **Dylan Thurston**, Indiana University.

The Mathematical Education of Future K-12 Teachers, **Charles Bingen** and **Ryan Harrison**, University of Wisconsin-Eau Claire.

Wavelets, Frames, and Time-Frequency Analysis, **Patrick Van Fleet**, University of St. Thomas, and **James S. Walker**, University of Wisconsin-Eau Claire.

von Neumann Algebras and Related Fields, **Stephen Avsec** and **Ken Dykema**, Texas A&M University.

Halifax, Canada

Dalhousie University

October 18–19, 2014

Saturday – Sunday

Meeting #1103

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 5, 2014
Program issue of electronic *Notices*: October 2014
Issue of *Abstracts*: Volume 35, Issue 3

Deadlines

For organizers: Expired
For abstracts: Expired

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

Invited Addresses

François Bergeron, Université du Québec à Montréal, *Algebraic combinatorics and finite reflection groups.*

Sourav Chatterjee, Stanford University, *Nonlinear large deviations.*

William M. Goldman, Department of Mathematics, University of Maryland, *Moduli spaces and the classification of geometric structures on manifolds.*

Sujatha Ramdorai, University of British Columbia, *Galois representations and Iwasawa theory.*

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 `http://www.ams.org/cgi-bin/abstracts/abstract.pl`.

Advances in Harmonic Analysis and Partial Differential Equations, **David Cruz-Uribe**, Trinity College, and **Scott Rodney**, Cape Breton University.

Combinatorial Representation Theory, **Cristina Ballantine**, College of the Holy Cross, **Rosa Orellana**, Dartmouth College, and **Mercedes Rosas**, Universidad de Sevilla.

Commutative Algebra and Its Interactions with Algebraic Geometry, **Susan Marie Cooper**, North Dakota State University, **Sara Faridi**, Dalhousie University, and **William Traves**, U.S. Naval Academy.

Differential Geometry and Mathematical Physics, **Virginie Charette**, Université de Sherbrooke, and **Karin Melnick**, University of Maryland.

Experimental Mathematics in Number Theory, Analysis, and Combinatorics, **Marc Chamberland**, Grinnell College, and **Karl Dilcher**, Dalhousie University.

Games on Graphs, **Jason Brown** and **Jeannette Janssen**, Dalhousie University.

General Relativity, **Jack Gegenberg**, University of New Brunswick.

Generalized Catalan Algebraic Combinatorics, **François Bergeron** and **Franco Saliola**, Université du Québec à Montréal, **Hugh Thomas**, University of New Brunswick, and **Nathan Williams**, Université du Québec à Montréal.

Hopf Algebras, **Yuri Bahturin**, Memorial University of New Foundland, **Margaret Beattie**, Mount Allison University, and **Mitja Mastnak**, Saint Mary's University.

New Directions in Category Theory, **Pieter Hofstra**, University of Ottawa, and **Dorette Pronk**, Dalhousie University.

Sampling Theory, **John J. Benedetto**, University of Maryland, **Jean-Pierre Gabardo**, McMaster University, and **Ozgur Yilmaz**, University of British Columbia.

Special Functions and Their Applications., **Mourad E. H. Ismail**, University of Central Florida, and **Nasser Saad**, University of Prince Edward Island.

Symbolic Dynamics and Combinatorics on Words, **Srecko Brlek**, Université du Québec à Montréal, and **Reem Yassawi**, Trent University.

p-adic Methods in Arithmetic, **Henri Darmon**, McGill University, **Adrian Iovita**, Concordia University, and **Sujatha Ramdorai**, University of British Columbia.

San Francisco, California

San Francisco State University

October 25–26, 2014

Saturday – Sunday

Meeting #1104

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 11, 2014
Program issue of electronic *Notices*: October 2014
Issue of *Abstracts*: Volume 35, Issue 4

Deadlines

For organizers: Expired
For abstracts: Expired

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

Invited Addresses

Kai Behrend, University of British Columbia, Vancouver, Canada, *The virtual fundamental class and "derived" symplectic geometry*.

Kiran S. Kedlaya, University of California, San Diego, *A brief history of perfectoid spaces*.

Julia Pevtsova, University of Washington, Seattle, *Applications of geometry to modular representation theory*.

Jim Simons, Euclidean Capital, *Mathematics, common sense, and good luck*.

Burt Totaro, University of California, Los Angeles, *The fundamental group of an algebraic variety, and hyperbolic complex manifolds*.

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 http://www.ams.org/cgi-bin/abstracts/abstract.pl.

Algebraic Geometry, **Renzo Cavalieri**, Colorado State University, **Noah Giansiracusa**, University of California, Berkeley, and **Burt Totaro**, University of California, Los Angeles.

Algebraic Statistics, **Elizabeth Gross**, San Jose State University, and **Kaie Kubjas**, Aalto University.

Applications of Knot Theory to the Entanglement of Biopolymers, **Javier Arsuaga**, San Francisco State University, **Michael Szafron**, University of Saskatchewan, and **Mariel Vazquez**, San Francisco State University.

Categorical Methods in Representation Theory, **Eric Friedlander**, University of Southern California, **Srikanth Iyengar**, University of Utah, and **Julia Pevtsova**, University of Washington.

Combinatorics and Algebraic Geometry, **Madhusudan Manjunath**, University of California, Berkeley, and **Farbod Shokrieh**, Cornell University.

Computational Algebraic Geometry and Applications to Science and Engineering, **Daniel Brake** and **Dhagash Mehta**, North Carolina State University, Raleigh.

Developments from MSRI Programs in Commutative Algebra and Noncommutative Algebraic Geometry and Representation Theory, **Kenneth Chan**, University of Washington, and **Jack Jeries**, University of Utah.

Geometry of Submanifolds, **Yun Myung Oh**, Andrews University, **Bogdan D. Suceava**, California State University, Fullerton, and **Mihaela B. Vajiac**, Chapman University.

Hamiltonian Partial Differential Equations, **Marius Beceanu**, University of California, Berkeley, **Magdalena Czubak**, Binghamton University, **Dong Li**, University of British Columbia, and **Xiaoyi Zhang**, University of Iowa.

High-Dimensional Convexity and Applications, **Luis Rademacher**, Ohio State University, **Stanislaw Szarek**, Case Western Reserve University and Université Pierre et Marie Curie-Paris 6, and **Elisabeth Werner**, Case Western Reserve University, Université de Lille 1, UFR de Mathématique.

Homotopy Theory, **Julie Bergner**, University of California, Riverside, and **Angélica Osorno**, Reed College.

Interactions between Knots and Manifolds, **Stanislav Jabuka** and **Swatee Naik**, University of Nevada, Reno, and **Cornelia Van Cott**, University of San Francisco.

Nonlinear Partial Differential Equations, **Nathan Glatt-Holtz**, Virginia Tech, **Geordie Richards**, University of Rochester, and **Vlad Vicol**, Princeton University.

Polyhedral Number Theory, **Matthias Beck**, San Francisco State University, **Martin Henk**, Universität Magdeburg, and **Joseph Gubeladze**, San Francisco State University.

Probabilistic and Statistical Problems in Stochastic Dynamics, **Alexandra Piryatinska**, San Francisco State University.

Recent Progress in Geometric Analysis, **David Bao**, San Francisco State University, and **Ovidiu Munteanu**, University of Connecticut.

Recent Progress in Harmonic Analysis and Several Complex Variables, **Gustavo Hoepfner** and **Paulo Liboni**, Universidade Federal de São Carlos, and **Irina Mitrea**, Temple University.

Topological Combinatorics and Combinatorial Commutative Algebra, **Anton Dochtermann**, University of Miami, **Augustine O'Keefe**, University of Kentucky, and **Alexander Engstrom**, Aalto University.

Greensboro, North Carolina

University of North Carolina at Greensboro

November 8–9, 2014

Saturday – Sunday

Meeting #1105

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 25, 2014
Program issue of electronic *Notices*: November 2014
Issue of *Abstracts*: Volume 35, Issue 4

Deadlines

For organizers: Expired
For abstracts: September 23, 2014

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

Invited Addresses

Susanne C. Brenner, Louisiana State University, *Novel finite element methods for optimal control problems with PDE constraints.*

Skip Garibaldi, Emory University, *E_8 and other exceptional groups.*

Stavros Garoufalidis, Georgia Institute of Technology, *Knots and q-series.*

James Sneyd, University of Auckland, *The dynamics of calcium: Oscillations, waves, theories, and experiments* (AMS-NZMS Maclaurin Lecture).

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at http://www.ams.org/cgi-bin/abstracts/abstract.pl.

Algebraic Structures Motivated by Knot Theory (Code: SS 9A), **Jozef H. Przytycki**, George Washington University, and **Radmila Sazdanovic**, North Carolina State University.

Algorithms for Local Fields (Code: SS 14A), **Chad Awtrey**, Elon University, and **Sebastian Pauli**, University of North Carolina at Greensboro.

Automorphic Forms and Related Topics (Code: SS 11A), **Matthew Boylan**, University of South Carolina, **Jayce Getz**, Duke University, and **Dan Yasaki**, University of North Carolina at Greensboro.

Connections in Number Theory (Code: SS 20A), **Joseph Vandehey**, University of Georgia.

Difference Equations and Applications (Code: SS 1A), **Michael A. Radin**, Rochester Institute of Technology, and **Youssef Raffoul**, University of Dayton.

Discontinuous Galerkin Finite Element Methods (Code: SS 13A), **Susanne C. Brenner** and **Joscha Gedicke**, Louisiana State University, and **Thomas Lewis**, University of North Carolina at Greensboro.

Discrete Structures in Classical Geometries (Code: SS 4A), **Philip L. Bowers**, Florida State University.

Exceptional Groups in Physics, Algebra, and Geometry (Code: SS 17A), **Asher Auel**, Yale University, **Anthony Ruozzi**, Emory University, and **George McNinch**, Tufts University.

Galois Theory and Its Interactions with Algebra and Number Theory (Code: SS 12A), **Chad Awtrey**, Elon University, and **Michael Bush**, Washington and Lee University.

Geometric Analysis (Code: SS 6A), **Hubert Bray**, Duke University, and **Andrew Cooper**, North Carolina State University.

Geometry and Combinatorics on Homogeneous Spaces (Code: SS 10A), **Leonardo C. Mihalcea**, Virginia Tech University, and **Richard Rimanyi**, University of North Carolina Chapel Hill.

Knot Theory and Its Applications (Code: SS 7A), **Elizabeth Denne**, Washington & Lee University, and **Laura Taalman**, James Madison University.

Mirror Symmetry (Code: SS 18A), **Matthew Ballard**, University of South Carolina, and **David Favero**, University of Alberta.

Movement in Mathematical Biology (Code: SS 19A), **Jonathan T. Rowell** and **Jan Rychtar**, University of North Carolina at Greensboro.

Multiple Combinatorial Numbers and Associated Identities (Code: SS 16A), **Hasan Coskun**, Texas A&M University Commerce.

Nonlinear Boundary Value Problems (Code: SS 5A), **Maya Chhetri**, University of North Carolina at Greensboro, and **Stephen Robinson**, Wake Forest University.

Partial Differential Equations Related to Fluids (Code: SS 15A), **Dhanapati Adhikari**, Marywood University.

Recent Advances in Numerical Methods for Fluid Flow Problems (Code: SS 2A), **Leo Rebholz**, Clemson University, and **Zhu Wang**, University of South Carolina.

Recent Developments in Graph Theory and Hypergraph Theory (Code: SS 3A), **David Galvin**, University of Notre Dame, and **Clifford Smyth**, University of North Carolina at Greensboro.

Set Theoretic Topology (Code: SS 8A), **Peter J. Nyikos**, University of South Carolina, and **Jerry Vaughan**, University of North Carolina at Greensboro.

San Antonio, Texas

Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio

January 10–13, 2015
Saturday – Tuesday

Meeting #1106
Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th 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 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2015
Issue of *Abstracts*: Volume 36, Issue 1

Deadlines
For organizers: Expired
For abstracts: Expired
The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/national.html`.

Joint Invited Addresses
Jordan Ellenberg, University of Wisconsin-Madison, Title to be announced. 11:10 a.m. (AMS-MAA).

Donald G. Saari, University of California, Irvine, *From voting paradoxes to the search for "dark matter"*; Saturday, 3:30 p.m. (MAA-AMS-SIAM Gerald and Judith Porter Public Lecture)

Richard Tapia, Rice University, Title to be announced. 11:10 a.m. (AMS-MAA**).**

Joint Prize Session
In order to showcase the achievements of the recipients of various prizes, the AMS and MAA are cosponsoring this event at 4:25 p.m. on Sunday. A cash bar reception will immediately follow. All participants are invited to attend. The AMS, ASA, MAA, and SIAM will announce the JPBM Communications Award winner. The AMS, MAA, and SIAM will award the Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student. The AMS will announce the winners of the George David Birkhoff Prize, Frank Nelson Cole Prize in Algebra, Levi L. Conant Prize, Ruth Lyttle Satter Prize, Leroy P. Steele Prizes, and the Albert Leon Whiteman Memorial Prize. The MAA will award the Beckenbach Book Prize, Chauvenet Prize, Euler Book Prize, Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching of Mathematics, Yueh-Gin Gung and Dr. Charles Y. Hu Award for Distinguished Service to Mathematics. The AWM will present the Louise Hay Award for Contributions to Mathematics Education, M. Gweneth Humphreys Award for Mentorship of Undergraduate Women in Mathematics,and the Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman.

121st Meeting of the AMS

AMS Invited Addresses
Ian Agol, University of California, Berkeley, Title to be announced; Tuesday, 9:00 a.m.

Henri Darmon, McGill University, *Elliptic curves and explicit class field theory*; Sunday, 2:15 p.m.

Susan Holmes, Stanford University, *Statistically relevant metrics for complex data*; Sunday, 3:20 p.m.

Michael Hopkins, Harvard University, *Title to be announced.* Saturday–Monday, 1:00 p.m. (Colloquium Lectures)

Russell Lyons, Indiana University, Bloomington, *Random orderings and unique ergodicity of automorphism groups*; Saturday, 10:05 a.m.

Irena Peeva, Cornell University, *Matrix factorizations and complete intersection rings*; Monday, 10:05 a.m.

Daniel A. Spielman, Yale University, *Graphs, vectors, and matrices*; Saturday, 8:30 p.m. (Josiah Willard Gibbs Lecture)

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 `http://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.

Accelerated Advances in Multiobjective Optimal Control Problems and Mathematical Programming Based on Generalized Invexity Frameworks, **N. J. Huang**, Sichuan University, **R. N. Mohapatra**, University of Central Florida, **Ram Verma**, Texas State University, and **Alexander Zaslavski**, Israel Institute of Technology.

Advances in Coding Theory, **Felice Manganiello** and **Gretchen L. Matthews**, Clemson University, and **Judy L. Walker**, University of Nebraska.

Algebraic Combinatorics and Representation Theory, **Zajj Daugherty**, Dartmouth College, and **Ben Salisbury**, Central Michigan University.

Algebraic and Geometric Methods in Applied Discrete Mathematics (a Mathematics Research Communities Session), **Heather Harrington**, University of Oxford, **Mohamed Omar**, Harvey Mudd College, and **Matthew Wright**, Institute for Mathematics and its Applications, University of Minnesota.

Applications of Dynamical Systems to Biological Models, **Yu Jin**, University of Nebraska-Lincoln, and **Xiang-Sheng Wang**, Southeast Missouri State University.

Beyond First-Order Model Theory, **John T. Baldwin**, University of Illinois at Chicago, **Xavier Caicedo**, Universidad de los Andes, **Rami Grossberg**, Carnegie Mellon University, **Jose Iovino**, University of Texas at San Antonio, and **Boris Zilber**, Oxford University (AMS-ASL).

Classification Problems in Operator Algebras, **Arnaud Brothier**, Vanderbilt University, **Ionut Chifan**, The University of Iowa, **Darren Creutz**, Vanderbilt University, **Remus Nicoara**, University of Tennessee, and **David Penneys**, University of Toronto.

Cluster Algebras (a Mathematics Research Communities session), **Andrew T. Carroll**, DePaul University, **Ian T. Le**, University of Chicago, and **Greg Muller**, University of Michigan.

Computing Intensive Modeling in Mathematical and Computational Biology, **Timothy D. Comar**, Benedictine University, **Olcay Akman**, Illinois State University, and **Daniel Hrozencik**, Chicago State University.

Continued Fractions, **James Mc Laughlin**, West Chester University, and **Nancy J. Wyshinski**, Trinity College.

Creating Coherence in K–12 Mathematics, **Brigitte Lahme**, Sonoma State University, **William McCallum** and **Cody Patterson**, University of Arizona, **Kristin Umland**, University of New Mexico, and **Ellen Whitesides**, University of Arizona.

Current Trends in Classical Dynamical Systems, **Lennard Bakker** and **Skyler Simmons**, Brigham Young University.

Difference Equations and Applications, **Steven Miller**, Williams College, and **Michael A. Radin**, Rochester Institute of Technology.

Differential Geometry and Statistics, **Susan Holmes**, Stanford University.

Enumerative Combinatorics, **Brian K. Miceli**, Trinity University, and **Jay Pantone** and **Vince Vatter**, University of Florida.

Ergodic Theory and Dynamical Systems, **Mrinal Kanti Roychowdhury**, University of Texas-Pan American.

Factorization Theory and Its Applications, **Nicholas Baeth**, University of Central Missouri, **Scott Chapman**, Sam Houston State University, **Jim Coykendall**, Clemson University, and **Alfred Geroldinger**, Karl Franzens University.

Fixed Point Theory and Applications, **Clement Boateng Ampadu**.

Fractional, Stochastic, and Hybrid Dynamic Systems with Applications, **John R. Graef**, University of Tennessee at Chattanooga, **G. S. Ladde**, University of South Florida, and **A. S. Vatsala**, University of Louisiana at Lafayette.

Frames and Their Applications, **Radu Balan** and **Kasso Okoudjou**, University of Maryland, and **Rachel Ward**, University of Texas.

Geometries Defined by Differential Forms, **Sergey Grigorian**, University of Texas-Pan American, **Sema Salur**, University of Rochester, and **Albert J. Todd**, University of California, Riverside.

Geosystems Mathematics, **Willi Freeden**, University of Kaiserslautern, **Volker Michel**, University of Siegen, and **M. Zuhair Nashed**, University of Central Florida.

Graphs, Matrices, and Related Problems, **Cheryl Grood** and **Thomas Hunter**, Swarthmore College, and **Sharon McCathern**, Azusa Pacific University.

Groups, Algorithms, and Cryptography, **Bren Cavallo** and **Delaram Kahrobaei**, City University of New York Graduate Center.

Heavy-Tailed Distributions and Processes, **U. Tuncay Alparslan** and **John P. Nolan**, American University.

History of Mathematics, **Sloan Despeaux**, Western Carolina University, **Patti Hunter**, Westmont College, **Deborah Kent**, Drake University, and **Adrian Rice**, Randolph-Macon College (AMS-MAA).

Holomorphic Dynamics in One and Several Variables, **Tanya Firsova**, State University of New York at Stony Brook and Kansas State University, and **Thomas Sharland**, State University of New York at Stony Brook.

Hopf Algebras and Tensor Categories, **Susan Montgomery**, University of Southern California, **Siu-Hung Ng**, Louisiana State University and Iowa State University, and **Sarah Witherspoon**, Texas A&M University.

Inequalities and Quantitative Approximation, **Feng Dai**, University of Alberta, and **Mourad E. H. Ismail**, University of Central Florida.

Inverse Problems, **Peter Muller**, Rensselaer Polytechnic Institute, and **Kaitlyn Voccola**, Colorado State University.

Knot Theory, **Tim Cochran** and **Shelly Harvey**, Rice University.

Limits of Discrete Structures, **Peter Diao**, **Dominique Guillot**, **Apoorva Khare**, and **Bala Rajaratnam**, Stanford University.

Math Teachers Circles and the K–20 Continuum, **Brian Conrey**, American Institute of Mathematics, **Michael Nakamaye** and **Kristin Umland**, University of New Mexico, and **Diana White**, University of Colorado at Denver.

Mathematics in Natural Resource Modeling, **Shandelle M. Henson**, Andrews University, and **Catherine A. Roberts**, College of the Holy Cross.

Mathematics in Poland: Interbellum, World War II, and Immediate Post-War Developments, **Mohammad Javaheri** and **Emelie A. Kenney**, Siena College.

Model Theory and Applications, **David Marker**, University of Illinois at Chicago, **Sergei Starchenko**, University of Notre Dame, and **Carol Wood**, Wesleyan University.

Network Science (a Mathematics Research Communities session), **Bailey Fosdick**, Colorado State University, **Franklin Kenter**, Rice University, **Christine Klymko**, Lawrence Livermore National Laboratory, and **Johan Ugander**, Microsoft Research.

Noncommutative Function Theory, **Paul S. Muhly**, University of Iowa, and **Gelu F. Popescu**, University of Texas at San Antonio.

Operator Algebras and Their Applications: A Tribute to Richard V. Kadison, **Robert S. Doran** and **Efton Park**, Texas Christian University.

Partitions, q-Series, and Modular Forms, **Atul Dixit**, Tulane University, **Tim Huber**, University of Texas-Pan American, **Amita Malik**, University of Illinois, and **Ae Ja Yee**, Pennsylvania State University.

Positivity and Matrix Inequalities, **Dominique Guillot**, **Apoorva Khare**, and **Bala Rajaratnam**, Stanford University.

Probability and Applications, **Rick Kenyon**, Brown University, and **Russell Lyons**, Indiana University.

Progress in Multivariable Operator Theory, **Ron Douglas**, Texas A&M University, and **Constanze Liaw**, Baylor University.

Quantum Information and Fusion Categories (a Mathematics Research Communities session), **Paul Bruillard**, Pacific Northwest National Laboratory, **Henry J. Tucker**, University of Southern California, and **Amanda Young**, University of California, Davis.

Quantum Markov Chains, Quantum Walks, and Related Topics, **Chaobin Liu**, Bowie State University, **Takuya Machida**, University of California, Berkeley, **Salvador E. Venegas-Andraca**, Tecnologicó de Monterrey, Campus Estado de México, and **Nelson Petulante**, Bowie State University.

Recent Advances in Discrete and Intuitive Geometry, **Andras Bezdek**, Auburn University, **Ted Bisztriczky**, University of Calgary, and **Wlodek Kuperberg**, Auburn University.

Recent Advances in the Analysis and Applications of Modern Splitting Methods, **Abdul Q. M. Khaliq**, Middle Tennessee State University, **Qin Sheng**, Baylor University, and **Bruce Wade**, University of Wisconsin-Milwaukee.

Recent Developments in Algebraic Number Theory, **Wen-Ching Winnie Li**, Pennsylvania State University, **Tong Liu**, Purdue University, and **Ling Long**, Iowa State University and Louisiana State University (AMS-AWM).

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

Ricci Curvature for Homogeneous Spaces and Related Topics, **Megan Kerr**, Wellesley College, and **Tracy Payne**, Idaho State University.

Selmer Groups, **Mirela Ciperiani**, University of Texas, and **Henri Darmon**, McGill University.

Set-Valued Optimization and Variational Problems with Applications, **Akhtar A. Khan**, Rochester Institute of Technology, **Mau Nam Nguyen**, Portland State University, **Miguel Sama**, Universidad Nacional de Educacion a Distancia, Madrid, and **Christiane Tammer**, Martin Luther University of Halle-Wittenberg.

Studies in Interconnections among Parameters in Graph Theory, Combinatorics, and Discrete Geometry, **Cong X. Kang** and **Eunjeong Yi**, Texas A&M University at Galveston.

Successes and Challenges in Teaching Mathematics, **Ellina Grigorieva**, Texas Woman's University, and **Natali Hritonenko**, Prairie View A&M University.

Syzygies, **Giulio Caviglia**, Purdue University, **Jason McCullough**, Rider University, and **Irena Peeva**, Cornell University.

The Scottish Book, **Krystyna Kuperberg**, Auburn University, **R. Daniel Mauldin**, University of North Texas, and **Jan Mycielski**, University of Colorado.

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

Topological Measures of Complexity: Inverse Limits, Entropy, and Structure of Attractors, **Loribeth M. Alvin**, University of Denver, **Jan P. Boroński**, National Supercomputing Centre IT4Innovations, Ostrava, **James Keesling**, University of Florida, **Olga Lukina**, University of Illinois at Chicago, and **P. Oprocha**, AGH University of Science and Technology, Krakow.

What's New in Group Theory?, **Arturo Magidin**, University of Louisiana at Lafayette, and **Elizabeth Wilcox**, Oswego State University.

AMS Sessions for Contributed Papers

There will be sessions of ten-minute contributed talks. Although an individual may present only one contributed paper at a meeting, any combination of joint authorship may be accepted, provided no individual speaks more than once on the program. Contributed papers will be grouped together by related subject classifications into sessions.

Submission of Abstracts for AMS Sessions

Authors must submit abstracts of talks through `jointmathematicsmeetings.org/meetings/abstracts/abstact.pl?type=jmm`. Indicate the number of authors for the paper, click on the "New Abstract" button, and you will be taken to the submission form. Simply follow the step-by-step instructions (read them carefully) until you receive your unique abstract receipt number. No submission is complete until you are given this number. **The deadline for all submissions is September 16, 2014**. Late papers cannot be accommodated. Please email `abs-coord@ams.org` if you have questions. If you make an inquiry about your specific abstract, please include your abstract receipt number.

Other AMS Sessions

AMS Committee on the Profession Panel Discussion, Saturday, 4:30 p.m.–6:00 p.m., title and panelists to be announced.

Counting from Infinity: Yitang Zhang and the Twin Primes Conjecture, Saturday, 6:20 p.m.–7:40 p.m. In April 2013, a lecturer at the University of New Hampshire submitted a paper to the *Annals of Mathematics*. Within weeks word spread—a little-known mathematician, with no permanent job, working in complete isolation had made an important breakthrough towards solving the Twin Primes Conjecture. Yitang Zhang's techniques for bounding the gaps between primes soon led to rapid progress by the Polymath Group, and a further innovation by James Maynard. The film is a study of Yitang Zhang's rise from obscurity and a disadvantaged youth to mathematical celebrity. The story of Zhang's quiet perseverance amidst adversity, and his preference for thinking and working in solitude, is interwoven with a history of the Twin Primes Conjecture as told by several mathematicians, many of whom have wrestled with this enormously challenging problem in Number Theory—Daniel Goldston, Kannan

Soundararajan, Andrew Granville, Peter Sarnak, Enrico Bombieri, James Maynard, Nicholas Katz, David Eisenbud, Ken Ribet, and Terry Tao. This film was directed by **George Csicsery**, and produced by MSRI. Cosponsored by the AMS and MAA.

Conversation on Nonacademic Employment, Sunday, 10:30 a.m.–noon. This session will concentrate on how to find nonacademic positions, types of jobs, the interview process, work environments, and advancement opportunities. The discussion will be led by a panel of mathematical scientists working in government and industry.

Active Learning Strategies for Mathematics, Sunday, 1:00 p.m.–2:30 p.m., organized by **David Bressoud**, Macalester College; **Ruth Charney**, Brandeis University; **Jesus Antonio DeLoera**, University of California, Davis; and **Douglas Mupasiri**, University of Northern Iowa. The AMS recognizes the importance of active learning strategies and is working with organizations such as Transforming Post-Secondary Education in Mathematics (TPSE Math) to clarify what this means for our community and to promote best practices in teaching the mathematical sciences. This panel will highlight some of the active learning strategies for which we have evidence of effectiveness. Sponsored by the AMS Committee on Education.

Concept Inventories beyond Differential Calculus: An Invitation, Sunday, 3:00 p.m.–4:00 p.m., organized by **Stephen DeBacker**, University of Michigan; and **Gavin LaRose**, University of Michigan. We are interested in developing tools to assess student learning in mathematics that are environment-independent; that is, tools that can be used to assess learning outcomes independent of teaching style, school, future courses of the students, instructor, etc. As far as we know, the only such tool available to the math community is the Calculus Concept Inventory (CCI), which focuses on differential calculus. (For more information, see, for example, Esptein, Jerome, "The Calculus Concept Inventory—Measurement of the effect of teaching methodology in mathematics," *Notices* of the AMS, vol. 60, No. 10 (September 2013), pp. 1018-1026.)

We would like the community to develop environment-independent tools that will address other mathematical subjects including: precalculus, integral calculus, sequences and series, multivariable calculus, differential equations, and linear algebra. We invite others who might be interested in such tools to join us for an informal discussion. Sponsored by the Committee on Education.

The Mathematics of Being Human, Sunday, 6:00 p.m.–7:20 p.m. In the not-too-distant future, English professor Naomi Kessler and mathematics professor Mike Pearson are forced to co-teach a course by a university bent on promoting interdisciplinarity at any cost. Battle lines are drawn as they jockey not only over the syllabus but also the different intellectual cultures and modes of inquiry favored by the humanities vs. mathematics. To win over the class, they must bridge their own preconceptions and prejudices and explore common ground. Only through the effort of two of their students do they catch a glimpse of true synthesis. Come see this live performance, co-written by **Michele Osherow**, professor of English and Director of Judaic Studies at the University of Maryland Baltimore County, and **Manil Suri**, professor of mathematics, University of Maryland Baltimore County. There will be ample time after the performance for discussion and questions. Cosponsored by AMS and MAA.

Grad School Fair, Monday, 8:30 a.m.–10:30 a.m. Here is the opportunity for undergrads to meet representatives from mathematical sciences graduate programs from universities all over the country. January is a great time for juniors to learn more, and college seniors may still be able to refine their search. This is your chance for one-stop shopping in the graduate school market. At last year's meeting about 300 students met with representatives from 50 graduate programs. If your school has a graduate program and you are interested in participating, a table will be provided for your posters and printed materials for US$75 (registration for this event must be made by a person already registered for the JMM), and you are welcome to personally speak to interested students. Complimentary coffee will be served. Cosponsored by the the AMS and MAA.

Who Wants to Be a Mathematician—National Contest, organized by **Michael A. Breen**, AMS, and **William T. Butterworth**, DePaul University; Monday, 9:30 a.m.–11:00 a.m. This event features a special performance by **Tim Chartier**, Davidson College. See ten of the nation's best high school students compete for a US$5,000 first prize for themselves and US$5,000 for their school's math department. Semifinals are at 9:30 a.m. and finals at 10:30 a.m. You are invited to come and match wits with the contestants.

Current Events Bulletin, organized by **David Eisenbud**, Mathematical Sciences Research Institute; Monday, 1:00 p.m.–5:00 p.m. Speakers in this session follow the model of the Bourbaki Seminars in that mathematicians with strong expository skills speak on work not their own. Written versions of the talks will be distributed at the meeting and will also be available online at `www.ams.org/ams/current-events-bulletin.html` after the conclusion of the meeting.

Committee on Science Policy Panel Discussion, Monday, 2:30 p.m.–4:00 p.m.

Congressional Fellowship Session, organized by **Samuel M. Rankin III, AMS**; Monday, 4:30 p.m.–6:30 p.m. This fellowship provides a public policy learning experience, demonstrates the value of science-government interaction and brings a technical background and external perspective to the decision-making process in Congress. Learn more about this program and speak with current and former AMS Fellows. Application deadline for the 2015–16 AMS Congressional Fellowship is February 15, 2015.

Other AMS Events

Council, Friday, 2:30 p.m.

Business Meeting, Tuesday, 11:45 a.m. The secretary notes the following resolution of the Council: Each person who attends a business meeting of the Society shall be willing and able to identify himself as a member of the Society. In further explanation, it is noted that each person who is to vote at a meeting is thereby identifying himself as and claiming to be a member of the American Mathematical Society. The Society has a Committee on the Agenda for Business Meetings. The purpose is to make business meetings orderly and effective. The committee does not have legal or administrative power. It is intended that the committee consider what may be called "quasipolitical" motions. The committee has several possible courses of action on a proposed motion, including but not restricted to:

(a) doing nothing,

(b) conferring with supporters and opponents to arrive at a mutually accepted amended version to be circulated in advance of the meeting,

(c) recommending and planning a format for debate to suggest to a business meeting,

(d) recommending referral to a committee, and

(e) recommending debate followed by referral to a committee.

There is no mechanism that requires automatic submission of a motion to the committee. However, if a motion has not been submitted through the committee, it may be thought reasonable by a business meeting to refer it rather than to act on it without benefit of the advice of the committee.

In order that a motion for this business meeting receive the service offered by the committee in the most effective manner, it should be in the hands of the AMS Secretary by **December 13, 2014**.

AMS Short Course on Finite Frame Theory: A Complete Introduction to Overcompleteness

This two-day course will take place on Thursday and Friday before the meeting actually begins. It is organized by **Kasso A. Okoudjou**, Norbert Wiener Center, Department of Mathematics, University of Maryland, College Park, who will give a talk on *Preconditioning techniques in frame theory and probabilistic frames,* and also features these talks by **Radu Balan**, Department of Mathematics, University of Maryland, College Park, *Frames and phaseless reconstruction;* **John Benedetto**, Norbert Wiener Center, Department of Mathematics, University of Maryland, College Park, *Construction of finite frames with optimal ambiguity function behavior*; **Peter G. Casazza**, Frame Research Center, University of Missouri, *An introduction to finite frame theory;* **Dustin G. Mixon**, Air Force Institute of Technology, *A primer on finite unit norm tight frames;* **Guangliang Chen**, San Jose State University and **Deanna Needell**, Claremont Mckenna College, *Compressed sensing and dictionary learning*; **Nate Strawn**, Duke University, *Algebro-geometric techniques and geometric insights for finite frames.*

There are separate registration fees to participate in this course. Advance registration (before December 23): Member, $108; Nonmember, $155; Student, unemployed, or emeritus, $54. Onsite registration: Member, $140; Nonmember, $185; Student, unemployed, or emeritus, $75. Please see the complete article on page 1123 in this issue or at `http://www.ams.org/meetings/short-courses/short-course-general`.

NSF-EHR Grant Proposal Writing Workshop

Developing a Competitive Proposal for NSF-EHR, Thursday, 3:00 p.m.–6:00 p.m. Workshop goals are to familiarize participants with current direction/priorities in EHR, familiarize participants with key EHR education research and development programs, consider common issues of competitive proposals, and prepare participants to write a competitive proposal. There is no registration fee for this workshop, but attendees must register separately in advance. Please contact the AMS Washington Office at 401-455-4116 or `amsdc@ams.org` for further information.

Department Chairs Workshop

This annual one-day workshop for department chairs and leaders is held on Friday, 8:00 a.m.–6:00 p.m., the day before the JMM actually begins, and is designed to stimulate discussion on a wide range of issues facing departments today, including personnel issues (staff and faculty), long-range planning, hiring, promotion and tenure, budget management, assessments, outreach, stewardship, junior faculty development, communication, and departmental leadership. There is a separate registration and fee to participate. Interested attendees should also consider attending the NSF-EHR Grant Proposal Writing Workshop to be held on Thursday, January 8. For further information, please contact the AMS Washington Office at 401-455-4116 or `amsdc@ams.org`.

98th Meeting of the MAA

MAA Invited Addresses

Robert Devaney, Boston University, *Cantor and Sierpinski, Julia and Fatou: Crazy Topology in Complex Dynamics* (MAA Retiring Presidential Address); Tuesday, 10:05 a.m.

Catherine O'Neil, Johnson Research Labs, *Making the case for data journalism*; Monday, 4:00 p.m.

Ken Ono, Emory University, *Golden numbers and identities: The legacy of Rogers and Ramanujan*; Sunday, 9:00 a.m.

Christiane Rousseau, University of Montreal, *Divergent series and differential equations: past, present, future…*; Monday, 9:00 a.m.

Diana Thomas, Montclair State University, *Dispelling obesity myths through mathematical modeling*; Saturday, 2:15 p.m.

Presentations by MAA Teaching Award Recipients

Monday, 2:00 p.m.–3:20 p.m., organized by MAA Secretary **Barbara Faires**, Westminster College, and MAA President **Robert Devaney**, Boston University. Winners of the Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching will give presentations on the secrets of their success.

MAA Invited Paper Sessions

Fractal Geometry and Dynamics, **Michel L. Lapidus**, University of California Riverside, and **Robert G. Niemeyer**, University of New Mexico; Saturday, morning and afternoon. This session brings together a number of researchers interested in the intricate relationship between fractal geometry and dynamics. It will highlight the many ways fractal geometry is present in a variety of subfields of dynamical systems, especially complex dynamics. The talks will be mostly of an expository nature and therefore be accessible to a broad cross-section of the participants in the Joint Mathematics Meetings. This session accompanies the MAA Retiring Presidential Address by Robert Devaney.

The Mathematics of Rogers and Ramanujan, organized by **Ken Ono**, Emory University; Monday morning. Over 100 years ago, Rogers and Ramanujan independently derived two strange power series identities. We now know that these identities are related to so much beautiful mathematics: golden ratio, partitions in number theory, representation theory, conformal field theory, and so on. This session will include lectures by world experts on the history of these identities, and the beautiful theories that have been inspired by their simplicity and deeper meaning. This MAA Invited Paper Session accompanies the MAA Invited Address by Ken Ono.

The Mathematics of Planet Earth, **Hans Kaper,** Georgetown University and Mathematics and Climate Research Network, and **Christiane Rousseau**, University of Montreal; Sunday morning and afternoon. This session will explore several topics related to Mathematics of Planet Earth (MPE). They are chosen from celestial mechanics, ecology, and geophysics to illustrate the wide range of challenging mathematical problems encountered in MPE.

Mathematics and Voting Theory, **Michael Jones**, *Mathematical Reviews*; **Tommy Ratliff**, Wheaton College; and **Russel Caflisch**, UCLA; Tuesday morning. Election procedures may be viewed as functions from voters' preferences to an ordering of the candidates and can be used to elect a single winner or a subset of the candidates. The study of the properties and behavior of election procedures applies ideas from combinatorics, algebra, and geometry. Recent work has also focused on issues related to computational complexity and probability. The talks in this session will highlight the application of mathematics to voting theory at an accessible level. This session accompanies the MAA-AMS-SIAM Gerald and Judith Porter Public Lecture by Donald Saari.

Mathematical Techniques for Signature Discovery, **Emilie Hogan** and **Paul Bruillard**, Pacific Northwest National Laboratory; Saturday afternoon. A signature is a distinguishing measurement, pattern, or collection of data that identifies a phenomenon of interest. Signatures are ubiquitous in the sciences, for example: acoustic signals distinguish types of boats, biomarkers identify diseases, and fingerprints distinguish individuals. In this invited paper session we will survey various approaches to the signature discovery process. For example, manifold learning techniques are being used to identify bone and brain abnormalities in humans to aid in the diagnostic process. Sparse data representations are used to analyze and decompose hyperspectral images. Tensor decomposition techniques are being applied to gain insight into protein function and phylogeny. And genetic algorithms are being coupled with abstract algebra to extract features from arbitrary discrete data.

Recent Advances in Mathematical Modeling of the Environment and Infectious Diseases, **Linda J. S. Allen,** Texas Tech University; Saturday morning. The impact of environmental variation that accurately reflects the impact of changes on an ecological or epidemiological system has always been a challenge in mathematical modeling. Heterogeneity and variability of the environment has been incorporated in models in a variety of ways, through differential and difference equations that account for spatial patterns or temporal variation or through stochastic differential equations that account for random variation. In this session, some recent advances in model formulations and analyses that study environmental effects in unique ways in either deterministic or stochastic settings will be presented. Speakers will discuss, for example, models that include the impact of the environment on disease outbreaks, link the environment to disease dynamics at multiple scales, relate population extinction to stage-structure and the environment, and incorporate both demographic and environmental variability.

Making the Case for Faculty Relevance: Case Studies in Best Practices for Classroom Teaching, **Martha Abell**, Georgia Southern University; Monday morning. The MAA Committee on the Teaching of Undergraduate Mathematics (CTUM) is creating the first ever pedagogy guide for mathematical instruction at the post-secondary level in an effort to address the "how to teach" questions encountered in the development process for the CUPM Curriculum Guide. The purpose of this session is to highlight several areas that will be included in the Pedagogy Guide.

MAA Minicourses

MAA Minicourses are open only to persons who register for the Joint Meetings and pay the Joint Meetings registration fee in addition to the appropriate minicourse fee. The MAA reserves the right to cancel any minicourse that is undersubscribed. Participants should read the descriptions of each minicourse thoroughly as some require participants to bring their own laptops and special software; laptops will not be provided in any minicourse. The enrollment in each minicourse is limited to 50; the cost is US$85.

Minicourse #1. ***Introductory Proposal Writing for Grant Applications to the NSF EHR/Division of Undergraduate Education***, presented by **John Haddock** and **Lee Zia**, Division of Undergraduate Education, National Science Foundation; Part A., Friday, 9:00 a.m.–11:00 a.m., and Part B, Friday, 2:00 p.m.–4:00 p.m. The presenters will describe the general NSF grant proposal process and consider particular details relevant to programs in the Division of Undergraduate Education. This course is geared toward those who have not submitted a proposal to NSF and are unfamiliar with the organization. If you believe you have an idea, project, or program worthy of Federal support that will positively impact undergraduate education in mathematics, you should attend this session. This two-part minicourse will provide information on the specific components of a NSF proposal, demonstrate the NSF peer review process, provide access to previously funded proposals, and explicate the NSF merit review criteria by which proposals are reviewed. Participants should leave this course with a draft of a project summary.

N.B. This course is offered on Friday, January 9, the day before the Joint Mathematics Meetings officially begin.

Minicourse #2. ***Developing Departmental Self-Studies,*** presented by **Donna Beers**, Simmons College, and **Rick Gillman**, Valparaiso University; Part A, Sunday, 1:00 p.m.–3:00 p.m., and Part B, Tuesday, 1:00 p.m.–3:00 p.m. Self-study is a critical component of departmental program review. It is retrospective, engaging department members and other interested parties (e.g., other departments and the administration) in examining all aspects of departmental programs. It is also forward-looking, anticipating new areas for growth and contribution. Self-study entails discussion of issues confronting a department; as such, it is both a process of reflection and a report. The goal of this minicourse is to help faculty from mathematical science departments plan and lay the groundwork for undertaking an effective self-study of their departments. It will enable participants to determine how a self-study, an administrative mandate, can be a positive opportunity for departmental renewal.

Minicourse #3. ***Introduction to Process Oriented Guided Inquiry Learning (POGIL) in Mathematics Courses***, presented by **Catherine Beneteau**, University of South Florida; **Zdeňka Guadarrama**, Rockhurst University; **Jill E. Guerra**, University of Arkansas Fort Smith; and **Laurie Lenz**, Marymount University; Part A, Saturday, 9:00 a.m.–11:00 a.m., and Part B, Monday, 9:00 a.m.–11:00 a.m. This minicourse will introduce faculty to the guided inquiry instructional method called POGIL (Process Oriented Guided Inquiry Learning). Participants will use hands-on activities to learn the crucial elements in a successful guided inquiry classroom. The workshop will provide participants with a basic introduction to facilitation techniques and an opportunity to reflect on how facilitation can enhance or interfere with student learning as well as how facilitation strategies can be critical in the development of student process skills. By the end of the minicourse, participants will be trained to begin implementing guided inquiry activities in their own mathematics classrooms.

Minicourse #4. ***A Dynamical Systems Approach to the Differential Equations Course***, presented by **Paul Blanchard**, Boston University; Part A, Saturday,4:45 p.m.–6:45 p.m., and Part B. Monday, 3:30 p.m.–5:30 p.m. This minicourse will give an overview of the Boston University Differential Equations Project, originally funded by the National Science Foundation. The BU project involves a complete redesign of the sophomore-level ODE course. It includes more emphasis on qualitative and geometric methods as well as the incorporation of technology and numerical methods throughout. This minicourse will be useful to college instructors wishing to restructure their ODE courses.

Although the minicourse will include technology demonstrations, the BU project is independent of any particular type of technology. Students must have some access to technology, however.

Minicourse #5. ***Visual Topics Using Undergraduate Complex Analysis***, presented by **Mike Brilleslyper,** U.S. Air Force Academy, and **Michael Dorff**, Brigham Young University; Part A, Saturday, 9:00 a.m.–11:00 a.m., and Part B, Monday, 9:00 a.m.–11:00 a.m. An introduction to two visual topics using complex analysis. The first topic is an overview of minimal surfaces including generating models soap films on wire frames and the mathematics needed for 3D printing of minimal surface models. The second is the dynamics of the set of zeros for a family of polynomials. Using technology, we generate animations that reveal surprising patterns and generate numerous questions concerning the localization of zeros. The goal is to expose participants to these interesting areas, provide ideas and materials for incorporating these topics into various undergraduate courses, and plant the seeds for possible undergraduate research projects.

Participants must bring their own computers with a current version of Mathematica, Maple, Matlab, Sage, or some other CAS.

Minicourse #6. ***Public- and Private-key Cryptography***, presented by **Chris Christensen**, Northern Kentucky University; Part A, Sunday, 1:00 p.m.–3:00 p.m., and Part B, Tuesday, 1:00 p.m.–3:00 p.m. The interesting mathematical aspects of public-key ciphers have sparked interest by mathematics faculty in these ciphers as applications of mathematics that can be presented in undergraduate courses. Often ignored, however, are the modern private-key ciphers, "the workhorses of cryptography." Modern private-key ciphers are equally mathematically interesting. In this minicourse, we will explore both modern public-key and private-key ciphers and their mathematical foundations. We will also briefly explore the historical evolution of both types of ciphers. No previous experience with these topics is assumed.

Minicourse #7. ***Teaching Introductory Statistics*** (for instructors new to teaching statistics), presented by **Carolyn Cuff**, Westminster College, and **Leigh Lunsford** Longwood University; Part A, Sunday, 9:00 a.m.–11:00 a.m., and Part B, Tuesday, 9:00 a.m.–11:00 a.m. This minicourse is intended for instructors new to teaching statistics or those seeking to move from a lecture-based course to an interactive course. Material for the course is drawn from the big ideas of introductory statistics and the ASA-endorsed Guidelines for Assessment and Instruction in Statistics Education (GAISE) report. The course considers ways to engage students in statistical literacy and thinking, and contrasts conceptual and procedural understanding in the first statistics course. Participants will work through many of the classic activities that all statistics instructors should know. Internet sources of real data, activities, and best practices articles will be examined. Participants will find out how they can continue to learn about the best practices for the first course in statistics by becoming involved in statistics education related conferences, newsletters, and groups.

Minicourse #8. ***Doing the Scholarship of Teaching and Learning in Mathematic***s, presented by **Jackie**

Dewar, Loyola Marymount University, and **Pam Crawford**, Jacksonville University; Part A, Sunday, 9:00 a.m.–11:00 a.m., and Part B, Tuesday, 9:00 a.m.–11:00 a.m. This course will introduce participants to the scholarship of teaching and learning (SoTL) in mathematics and help them begin projects of their own. We describe a taxonomy of SoTL questions, provide examples of SoTL projects in mathematics, and discuss methods for investigation. Participants will learn about collecting and analyzing different types of evidence, conducting literature searches, dealing with human subjects requirements, and selecting venues for presenting or publishing their work. With the presenters' guidance, participants interactively select and transform a teaching problem of their own into a question for scholarly investigation and identify several types of evidence to gather.

Minicourse #9. ***Teaching College Mathematics*** (for instructors new to teaching at the collegiate level and for instructors who prepare GTA's for their first teaching experience); presented by **Ann Humes**, Michigan Technological University; Part A, Saturday, 2:15 p.m.–4:15 p.m., and Part B, Monday, 1:00 p.m.–3:00 p.m. This minicourse presents a model for a comprehensive program for preparing GTA's to teach at the collegiate level. Participants will be engaged in a lesson cycle used in the semester-long training. Participants will also learn about how to navigate the blended learning course, handle online management systems, prepare assessments, and deal with student conflicts as required at Michigan Technological University.

Minicourse #10. ***Humanistic Mathematics***, presented by **Gizem Karaali**, Pomona College, and **Eric Marland**, Appalachian State University; Part A, Saturday, 2:15 p.m.–4:15 p.m., and Part B, Monday, 1:00 p.m.–3:00 p.m. As a scholarly stance, humanistic mathematics describes an approach to mathematics that views it as a human endeavor and focuses on its aesthetic, cultural, historical, literary, pedagogical, philosophical, psychological, and sociological aspects. As a pedagogical framework, humanistic mathematics explores and builds on the relationship of mathematics with its nontraditional partners in the humanities, the fine arts, and social sciences, providing additional perspective for the role of mathematics in a liberal arts education. This minicourse exposes participants to both facets of humanistic mathematics.

In the first session, participants will learn about the implications of a humanistic approach to teaching and explore how it can contribute to a more sophisticated understanding of mathematics, for all students. Also included will be a discussion of common implementation issues and an overview of a spectrum of materials available to use in the classroom. In the second session, participants will engage with the scholarship of humanistic mathematics, a body of literature that eschews disciplinary jargon in favor of reaching a more diverse audience. After a thorough introduction, participants will, through guided group work, initiate their own scholarly projects. Possible venues of communication, collaboration, and dissemination of work in humanistic mathematics will be discussed.

Minicourse #11. ***Healthcare Applications and Projects for Introductory College Mathematics Courses***, presented by **Theresa Laurent,** St. Louis College of Pharmacy; Part A, Sunday, 1:00 p.m.–3:00 p.m., and Part B, Tuesday, 1:00 p.m.–3:00 p.m. Mathematics teachers continuously face the challenge of getting students to recognize the relevance of the concepts learned in class to "real life" situations. This minicourse provides the background knowledge necessary to introduce healthcare applications into precalculus and introductory calculus courses. Applications and projects will include calculating blood alcohol content, determining proper dosing for drugs, analyzing results of drug trials, comparing different contraceptive methods, analyzing the dosing of Zithromax Z-Pak, and serving as a consultant in a malpractice lawsuit. Participants will leave the minicourse with problems and projects ready to use in the classroom, complete with all background information needed.

Minicourse #12. ***Introducing Matroids to Undergraduates***, presented by **Jenny McNulty**, University of Montana, and **Gary Gordon**, Lafayette College; Part A, Saturday, 4:45 p.m.–6:45 p.m., and Part B, Monday, 3:30 p.m.–5:30 p.m. Matroids offer a unique way to incorporate and unify several topics typically studied at the undergraduate level. Matroid Theory is an ideal topic for a capstone-type course; an introduction to the subject includes connections to linear algebra (through bases, independent sets, determinants, etc.), abstract algebra (matroid representations over finite and infinite fields, field extensions), finite geometry (affine and projective planes), graph theory (the prototypical examples of matroids), and combinatorics (matchings in bipartite graphs, counting various classes of subsets). Participants will learn how matroids demonstrate the power of generalization in mathematics: proving one theorem for matroids automatically gives a corresponding result in graph theory, linear algebra, geometry, and matching theory.

Our goal is to share the beauty of matroids and the interconnectedness of mathematics with undergraduate teachers so they in turn can share this with their students. This workshop will be structured in the same manner as our classrooms; interactive sessions with hands-on activities using examples and questions to motivate the concepts. In addition, materials with numerous exercises will be provided for classroom use, including research projects for students.

Minicourse #13. ***WeBWorK: An Open Source Alternative for Generating and Delivering Online Homework Problems***, presented by **Paul Pearson**, Hope College; **Geoff Goehle**, Western Carolina University; and **Peter Staab**, Fitchburg State University; Part A, Saturday, 4:45 p.m.–6:45 p.m., and Part B, Monday, 3:30 p.m.–5:30 p.m. This minicourse introduces participants to the WeBWorK online homework system. Supported by grants from NSF, WeBWorK has been adopted by well over 700 colleges, universities, and secondary schools and is a popular open-source alternative to commercial products. WeBWorK can handle problems in college algebra, calculus, linear algebra, ODEs, and more and comes with an extensive library of over 25,000 problems across the mathematics curriculum. WeBWorK recognizes a multitude of mathematical objects and allows for elegant solution checking. This minicourse will introduce participants to WeBWorK and equip participants with the knowledge and skills to use WeBWorK in a course.

Minicourse #14. ***Teaching Statistics using R and RStudio***, presented by **Randall Pruim**, Calvin College; **Daniel Kaplan**, Macalester College; and **Nicholas Horton**, Amherst College; Part A, Saturday, 9:00 a.m.–11:00 a.m., and Part B, Monday, 9:00 a.m.–11:00 a.m. R is a freely available language and environment for statistical computing and graphics that has become popular in academia and in many industries. But can it be used with students? This mini-course will introduce participants to teaching applied statistics courses using computing in an integrated way. The presenters have been using R to teach statistics to undergraduates at all levels for the last decade and will share their approach and some of their favorite examples. Topics will include workflow in the RStudio environment, providing novices with a powerful but manageable set of tools, data visualization, basic statistical inference using R, and resampling. Much of this will be facilitated using the mosaic package.

The minicourse is designed to be accessible to those with little or no experience teaching with R, and will provide participants with skills, examples, and resources that they can use in their own teaching.

Minicourse #15. ***How to Run a Successful Math Circle,*** presented by **Amanda Katharine Serenevy**, Riverbend Community Math Center; **Philip B. Yasskin**, Texas A&M University; and **Paul Zeitz**, University of San Francisco; Part A, Saturday, 2:15 p.m.–4:15 p.m., and Part B, Monday, 1:00 p.m.–3:00 p.m. A math circle brings together K–12 students and professional mathematicians on a regular basis to explore engaging topics. This course will focus on the logistics involved in organizing and sustaining a math circle as well as the fine art of conducting lively sessions. Facilitators will discuss how to adapt a promising topic for math circle use, provide tips for keeping a circle running smoothly, and address issues such as publicity and funding. Participants will craft a math circle lesson plan and take away a variety of materials including sample topics and a list of book and Web resources.

Minicourse #16. *Using Games in an Introductory Statistics Course*, presented by **Rod Sturdivant**, Ohio State University, and **Shonda Kuiper**, Grinnell College. Part A, Sunday, 9:00 a.m.–11:00 a.m., and Part B, Tuesday, 9:00 a.m.–11:00 a.m. Participants experience Web-based games and corresponding class activities that effectively teach statistical thinking and the process of scientific inquiry. By grappling with intriguing real-world problems, these labs encourage students to experience the role of research scientist as they conduct hypothesis tests and regression analysis. Our games are designed to 1) engage students, 2) have a low threat of failure early on with optional additional challenges, 3) create realistic, adaptable, and straightforward models representing current research in a variety of disciplines, 4) provide an intrinsic motivation for students to want to learn, and 5) provide teacher instructions for easy, successful implementation.

MAA Contributed Papers

The MAA Committee on Contributed Paper Sessions solicits papers pertinent to the sessions listed below. Contributed Paper Session presentations are limited to fifteen minutes, except in the general session where they are limited to ten minutes. Each session room is equipped with a computer projector, an overhead projector, and a screen. Please note that the days and times scheduled for these sessions remain tentative. Several of these sessions have specific suggestions for the appropriateness of submissions. Potential submitters are advised to read the full descriptions of these sessions at `jointmathematics meetings.org/meeting/national/jmm2015/2168_maacall`.

The deadline for submission of abstracts is Tuesday, September 16, 2014.

Contributed Paper Sessions with Themes

Activities, Demonstrations, and Projects that Enhance the Study of Undergraduate Geometry, organized by **Sarah Mabrouk**, Framingham State University; Sunday afternoon.

Best Practices for Teaching the Introductory Statistics Course; organized by **Randall Pruim**, Calvin College; **Scott Alberts**, Truman State University; and **Patti Frazer Lock**, St. Lawrence University; Saturday afternoon.

Cartography and Mathematics: Imaging the World Around Us, organized by **Emek Kose** and **Casey Douglas**, St. Mary's College of Maryland; Monday morning.

Collaborations between Two-Year and Four-Year Institutions that Create Pathways to a Math Major, organized by **Nancy Sattler**, Terra State Community College; **Judy Ackerman**, Montgomery College Rockville Campus; and **Elizabeth Teles**, National Science Foundation; Monday morning.

Cryptology for Undergraduates, organized by **Robert Lewand**, Goucher College, and **Chris Christensen**, Northern Kentucky University; Saturday morning.

Discovery and Insight in Mathematics, organized by **Dan Sloughter**, Furman University, and **Bonnie Gold**, Monmouth University; Tuesday afternoon. Sponsored by the SIGMAA on the Philosophy of Mathematics.

Ethnomathematics: A Tribute to Marcia Ascher, organized by **Ximena Catepillan**, Millersville University; **Amy Shell-Gellasch**, Montgomery College; and **Janet Beery**, University of Redlands; Monday morning.

First-Year Calculus: Fresh Approaches for Jaded Students, organized by **Bob Sachs**, George Mason University, and **Caren Diefenderfer**, Hollins University; Tuesday afternoon.

Helping Students See Beyond Calculus, organized by **David Strong**, Pepperdine University; **Courtney Davis**, Pepperdine University; **Angela Spalsbury**, Youngstown State University; and **James Tanton**, MAA; Sunday afternoon.

Humor and Teaching Mathematics, organized by **Semra Kilic-Bahi**, Colby-Sawyer College; **Gizem Karaali**, Pomona College; and **Debra Borkovitz**, Wheelock College; Saturday morning.

Incorporating Formal Symbolic Reasoning into Mathematics Courses, organized by **Christopher Shaw** and **Daniel Jordan**, Columbia College Chicago; Sunday morning.

Infusing Quantitative Literacy into Mathematics and Nonmathematics Courses, organized by **Andrew Miller**, Belmont University; **Aaron Montgomery**, Central Washington University; and **Gary Franchy**, Mott Community College; Tuesday afternoon.

Innovative and Effective Ways to Teach Linear Algebra, organized by **David Strong**, Pepperdine University; **Gilbert Strang**, MIT; and **Megan Wawro**, Virginia Tech; Sunday morning.

Inquiry-Based Learning in First-Year and Second-Year Courses, organized by **Dana Ernst**, Northern Arizona University; **Angie Hodge**, University of Nebraska at Omaha; and **Theron Hitchman**, University of Northern Iowa; Sunday morning.

Mathematics and the Arts, organized by **Douglas Norton**, Villanova University; Saturday morning and afternoon. Sponsored by the SIGMAA on Mathematics and the Arts.

Mathematics and Sports, organized by **R. Drew Pasteur**, College of Wooster, and **John David**, Virginia Military Institute; Saturday afternoon.

Mathematics Experiences in Business, Industry, and Government, organized by **Carla Martin**, Department of Defense; **Phil Gustafson**, Mesa State University; and **Michael Monticino**, University of North Texas; Sunday afternoon.

Original Sources and Archives in the Classroom, organized by **Amy Shell-Gellasch**, Montgomery College, and **Dominic Klyve**, Central Washington University; Tuesday morning.

Perspectives and Experiences on Mentoring Undergraduate Students in Research, organized by **Aihua Li**, Montclair State University; **Thomas Hagedorn**, College of New Jersey; and **Jan Rychtar**, The University of North Carolina at Greensboro; Saturday morning.

Program and Assessment Implications of Common Core State Standards Implementation, organized by **William Martin**, North Dakota State University; **Bonnie Gold**, Monmouth University; and **John Carter**, Westlake High School; Monday afternoon.

Research on the Teaching and Learning of Undergraduate Mathematics, organized by **Karen Keene**, North Carolina State University; **Timothy Fukawa-Connelly**, Drexel University; and **Michelle Zandieh**, Arizona State University; Sunday morning and afternoon.

Revitalizing Complex Analysis at the Undergraduate Level, organized by **Russell Howell**, Westmont College; **Paul Zorn**, St. Olaf College; and **Alan Noell**, Oklahoma State University; Saturday afternoon.

The Scholarship of Teaching and Learning in Collegiate Mathematics, organized by **Jackie Dewar**, Loyola Marymount University; **Thomas Banchoff**, Brown University; **Curtis Bennett**, Loyola Marymount University; **Pam Crawford**, Jacksonville University; and **Edwin Herman**, University of Wisconsin-Stevens Point; Saturday morning and afternoon.

Statistics Education beyond the Introductory Statistics Course, organized by **Randall Pruim**, Calvin College; **Scott Alberts**, Truman State University; and **Patti Frazer Lock**, St. Lawrence University; Sunday afternoon.

Teaching Inquiry, organized by **Brian Katz**, Augustana College, and **Elizabeth Thoren**, University of California Santa Barbara; Tuesday afternoon.

Teaching Proof Writing Techniques within a Content-Based Mathematics Course, organized by **Kristi Meyer**, Wisconsin Lutheran College, and **Jessie Lenarz**, St. Catherine University; Tuesday morning.

Technology, the Next Generation: Integrating Tablets into the Mathematics Classroom, organized by **Kevin Charlwood** and **Janet Sharp**, Washburn University; Saturday afternoon.

The Times They are a Changin': Successful Innovations in Developmental Mathematics Curricula and Pedagogy, organized by **Suzanne Dorée**, Augsburg College; **Joanne Peeples**, El Paso Community College; **Donald Small**, USMA; **Bruce Yoshiwara**, Los Angeles Pierce College; and **Chris Oehrlein**, Oklahoma City Community College; Monday morning.

Trends in Undergraduate Mathematical Biology Education, organized by **Timothy Comar**, Benedictine University; Monday afternoon.

USE Math: Undergraduate Sustainability Experiences in the Mathematics Classroom, organized by **Ben Galluzzo**, Shippensburg University, and **Corrine Taylor**, Wellesley College; Tuesday morning.

Using Flipping Pedagogy to Engage Students in Learning Mathematics, organized by **Jean McGivney-Burelle**, **Larissa Schroeder**, **Fei Xue**, and **John Williams**, University of Hartford; Tuesday morning.

Wavelets in Undergraduate Education, organized by **Caroline Haddad**, SUNY Geneseo; **John Merkel**, Ogle-thorpe University; and **Edward Aboufadel**, Grand Valley State University; Monday afternoon.

Well-Designed Online Assessment: Well-Formed Questions, Discovery-Based Explorations, and Their Success in Improving Student Learning, organized by **Paul Seeburger**, Monroe Community College, and **Matthew Leingang**, New York University; Monday afternoon.

What Makes a Successful Math Circle: Organization and Problems, organized by **Philip Yasskin**, Texas A&M University; **Tatiana Shubin**, San Jose State University; **Paul Zeitz**, University of San Francisco; and **Katherine Morrison**, University of Northern Colorado; Sunday morning.

General Contributed Paper Sessions, organized by **Kristen Meyer**, Wisconsin Lutheran College; **Bem Cayco**, San Jose State University; and **Kimberly Presser**, Shippensburg University of Pennsylvania; Saturday, Sunday, Monday, and Tuesday mornings and afternoons. These sessions of 10-,minute talks accept contributions in all areas of mathematics, curriculum, and pedagogy. When you submit your abstract you will be asked to classify it under one of the following areas: *Assessment*, *History or Philosophy of Mathematics*, *Interdisciplinary Topics in Mathematics*, *Mathematics and Technology*, *Mentoring*, *Modeling or Applications*, *Outreach*, *Probability or Statistics*, *Research in Algebra, Research in Analysis*, *Research* *in Applied Mathematics*, *Research in Geometry, Research in Graph Theory, Research in Linear Algebra*, *Research in Logic or Foundations*, *Research in Number Theory, Research in Topology, Teaching or Learning Advanced Mathematics*, *Teaching or Learning Calculus*, *Teaching or Learning Developmental Mathematics*, *Teaching or Learning Introductory Mathematics*, or *Assorted Topics*.

Submission Procedures for MAA Contributed Paper Abstracts

Abstracts may be submitted electronically at `http://jointmathematicsmeetings.org/meetings/abstracts/abstract.pl?type=jmm`. Simply fill in the number of authors, click "New Abstract," and then follow the step-by-step instructions. **The deadline for abstracts is Tuesday, September 16, 2014.**

Each participant may give at most one talk in any one themed contributed paper session or the general contributed paper session. If your paper cannot be accommodated in the session in which it is submitted, it will automatically be considered for one of the general sessions.

The organizer(s) of your session will automatically receive a copy of the abstract, so it is not necessary for you to send it directly to the organizer. All accepted abstracts are published in a book that is available to registered participants at the meeting. Questions concerning the submission of abstracts should be addressed to `abs-coord@ams.org`.

MAA Panels, Posters, Workshops, and Other Sessions

NSF Funding Opportunities for the Learning and Teaching of the Mathematical Sciences, organized by **John Haddock** and **Lee Zia,** Division of Undergraduate Education, NSF; **Karen King**, Division of Research on Learning, NSF; **Tasha Inniss**, Division of Human Resource Development, NSF: **Jennifer Slimowitz Pear**l, Division of Mathematical Sciences, NSF. A number of NSF divisions offer a variety of grant programs that support innovations in learning and teaching in the mathematical sciences. These programs will be discussed along with examples of successful projects in two sessions. Anticipated budget highlights and other new initiatives for the next fiscal year, as appropriate, will also be presented. Sponsored by the MAA Committee on Professional Development.

Part I: Undergraduate/Graduate Education Programs, Workforce, and Broadening Participation (DUE/DGE/DMS, HRD) Saturday, 8:00 a.m.– 9:20 a.m., and

Part II: The K–16 Continuum: Learning Science & Research and Pre- and In-Service Teachers (DUE/DRL) Saturday, 9:35 a.m.–10:55 a.m.

Freeman A. Hrabowski, Sylvester James Gates, and Richard A. Tapia Lecture Series, co-chaired by **Carlos Castillo-Chavez**, Arizona State University, and **Lloyd Douglas**, chair of the MAA Committee on Minority Participation in Mathematics; Saturday, 9:30 a.m.–11:00 a.m. Presentations by F. A. Hrabowski, S. J. Gates, and R. A. Tapia at the 2014 JMM provided the impetus and motivation for the establishment of this lecture series. This year, the research and trajectories of two past recent recipients of the David Blackwell and Richard Tapia Award will be highlighted.

Through multiple mechanisms, the series expects to facilitate and accelerate the participation of mathematical scientists in the building of sustainable communities of mathematicians and mathematical scientists. In particular, the intention is to systematically recruit, welcome, encourage, mentor, and support individuals from underrepresented groups in the USA. The speakers for this meeting are **Richard Tapia**, Rice University, *Introductory remarks on the inaugural Freeman A. Hrabowski, Sylvester James Gates, and Richard A Tapia Lecture*; **Ricardo Cortez**, Tulane University, *Advances in computational modeling of microorganism motility*; and **Trachette Jackson**, University of Michigan, *Mathematical models of tumor vessel formation and targeted therapies that attack the vascular supply*.

This activity was first conceived by the MAA Committee on Minority Participation in Mathematics and is jointly supported by the MAA, AMS, and SIAM.

MOOCs and Me: Massive Online Materials for My Students, organized by **John Travis**, Mississippi College; Saturday, 9:35 a.m.–10:55 a.m. This panel will include several creators of mathematics MOOCs to discuss the opportunities realized and challenges encountered through developing and presenting one of these large online courses. Ideas for how MOOC course materials can be used for independent study as well as incorporated into standard university classes will be presented. Each of the panelists, including **Jim Fowler**, Ohio State University; **Petra Bonfert-Taylor**, Wesleyan University; **Tom Morley**, Georgia Tech University; and **Grace Lyo**, Stanford University, will focus on special features of their courses and on advantages and disadvantages related to their course environment provider. Costs—both financial and personal—will be considered and compared to those normally associated with teaching an online course. Philosophical reasons for supporting MOOCs will be addressed. Significant time will be reserved for questions from the audience and between the panelists. Sponsored by the MAA Committee on Technologies in Mathematics Education and WebSIGMAA.

Recommendations for the 21st Century Mathematical Sciences Major, organized by **Martha J. Siegel**, Towson University, and Carol Schumacher, Kenyon College*;* Saturday, 2:15 p.m.–3:35 p.m. At these Joint Mathematics Meetings, the MAA Committee on the Undergraduate Program (CUPM) is announcing the release of the *2015 Curriculum Guide to Majors in the Mathematical Sciences*. The Society for Industrial and Applied Mathematics (SIAM) and the American Statistical Association (ASA) have recently prepared their own recommendations for undergraduate majors in applied mathematics and statistics, respectively. The MET II report gave recommendations for the preparation of future mathematics secondary school teachers. Representatives of the MAA, SIAM, ASA, and MAA's Committee on the Mathematical Education of Teachers (COMET), including **Rachel Levy**, Harvey Mudd College; **Nicholas J. Horton**, Amherst College; and **Elizabeth A. Burroughs**, Montana State University, will discuss the highlights of their reports and the 21st century challenges to mathematics departments offering undergraduate degrees. Sponsored by the MAA Committee on the Undergraduate Program in Mathematics (CUPM) and the MAA Committee on the Mathematical Education of Teachers (COMET)

What Every Student Should Know about the JMM, organized by **Pamela Richardson**, Westminster College; Saturday, 2:15 p.m.–3:35 p.m. Navigating a large conference can be overwhelming, even for those who have previously attended such an event. Panelists **Jennifer Bowen**, College of Wooster; **Frank Morgan**, Williams College; and **George Yates**, Youngstown College, will provide guidance for students attending the Joint Mathematics Meetings, including answers to some common questions: How do I get the most out of the program? What sessions are especially for students? What other events should I be on the lookout for? Will I understand any of the invited addresses or should I not bother attending them? If I am presenting a poster, where do I go to set it up? How can I get some cool, free math stuff? Students and their faculty mentors are encouraged to attend. Sponsored by the MAA Committee for Undergraduate Student Activities and Chapters

YMN/Project NExT Poster Session, organized by **Jonathan Needleman**, Le Moyne College, and **Kim Roth**, Juniata College, Saturday, 2:15 p.m.–4:15 p.m. This session is intended to highlight the research activities, both mathematical and pedagogical, of recent or future Master's/Ph.D.'s in mathematics and related fields. The organizers seek to provide an open venue for people who are near completion, or have finished their graduate studies in the last five years, to present their work and make connections with other same-stage professionals, in much the same spirit as YMN and Project NExT. The poster size will be 48" wide by 36" high. Poster boards and materials for posting pages on the posters will be provided on site. We expect to accept about forty posters from different areas within the mathematical sciences. To apply, send a poster abstract, when and where you have or will receive your Ph.D. or master's degree, and your current college or university affiliation to the organizers. Potential applicants should send a poster abstract to one of the organizers, Kim Roth, `roth@juniata.edu`, or Jonathan Needleman, `needlejs@lemoyne.edu`, to apply for the session. The deadline for submissions is December 15, 2014. Sponsored by the Young Mathematicians' Network and Project NExT.

Recruiting, Retaining, Mentoring, and Evaluating "Contract Faculty," organized by **Amy Cohen**, Rutgers University; **Judy Walker**, University of Nebraska Lincoln; and **David Manderscheid,** The Ohio State University; Saturday, 3:50 p.m.– 5:10 p.m. Many institutions of higher education are developing career tracks for full-time instructional staff for whom active research in mathematics is not the primary job criterion. These are not tenure-track positions. They carry a variety of titles including "Professor of the Practice," "Clinical Professor," "Lecturer," "Teaching Professor," and "Instructor," sometimes with modifiers like "Assistant," "Associate," or "Senior." There has been little formal discussion within our profession of such topics as the purposes of such positions; criteria for hiring, retention, and promotion; mentoring such colleagues, and evaluating their impact of our students and our departments. Panelists **David Manderscheid**, The Ohio State University; **Sue Geller**, Texas A&M University; and **Ellen Kirkman**, Wake Forest University, have experience and concerns about this change in faculty structure. A moderator will lead a discussion after the presentations. Cosponsored by the MAA and AMS.

Graduate School: Choosing One, Getting In, Staying In, organized by **Nick Scoville**, Ursinus College, and **Kristine Roinestad**, Georgetown College; Saturday, 3:50 p.m.–5:10 p.m. You've made the decision to apply to graduate school. Now you must sift through all the available information, match schools to your academic and research interests, narrow down your list to a handful of schools, and submit outstanding applications. How do you accomplish all this and hopefully increase the likelihood of getting into your first- or second-choice program? Then, once accepted, how do you successfully complete the program and earn your degree? How do you use your time in graduate school to better prepare for your postgraduate goals? Panelists **Bill Velez**, University of Arizona; **Annalisa Crannell**, Franklin & Marshall College; **Peter Howard**, Texas A&M University; and **Brian Miceli**, Trinity University, will discuss these and other important issues for those considering graduate school, transferring to a different graduate school, or switching graduate programs. Sponsored by the Young Mathematicians' Network.

Managing Your Own Course, organized by **Ralucca Gera**, Naval Postgraduate School; **Timothy Goldberg**, Lenoir-Rhyne University; and **Gwyneth Whieldon**, Hood College; Saturday, 5:00 p.m.–6:00 p.m. One of the many challenges facing new faculty members (and sometimes advanced teaching assistants) is managing their own courses. This event will consist of small group discussions based on types of courses and perhaps types of institutions, with the goal of sharing ideas and experiences about managing one's own course. This may also include discussions on creating a new course. Sponsored by the Young Mathematicians' Network.

Counting from Infinity: Yitang Zhang and the Twin Primes Conjecture, Saturday, 6:20 p.m.–7:40 p.m. In April 2013, a lecturer at the University of New Hampshire submitted a paper to the *Annals of Mathematics*. Within weeks word spread—a little-known mathematician, with no permanent job, working in complete isolation had made an important breakthrough towards solving the Twin Primes Conjecture. Yitang Zhang's techniques for bounding the gaps between primes soon led to rapid progress by the Polymath Group, and a further innovation by James Maynard. The film is a study of Yitang Zhang's rise from obscurity and a disadvantaged youth to mathematical celebrity. The story of Zhang's quiet perseverance amidst adversity, and his preference for thinking and working in solitude, is interwoven with a history of the Twin Primes Conjecture as told by several mathematicians, many of whom have wrestled with this enormously challenging problem in Number Theory—Daniel Goldston, Kannan Soundararajan, Andrew Granville, Peter Sarnak, Enrico Bombieri, James Maynard, Nicholas Katz, David Eisenbud, Ken Ribet, and Terry Tao. This film was directed by

George Csicsery, and produced by MSRI. Cosponsored by the MAA and AMS.

Panel Discussions by NSF-DUE Principal Investigators, organized by **John Haddock** and **Lee Zia**, Division of Undergraduate Education, National Science Foundation.

Presenters will describe their experiences with the general NSF grant proposal process and share their expertise in putting together proposals for specific programs.

Part 1: Panel of successful PIs talking about their experiences (CCLI/TUES/IUSE); Sunday, 8:00 a.m.–8:50 a.m.;

Part 2: Panel of successful PIs talking about their experiences (DRK-12, Noyce, STEM-CP & MSP); Sunday, 9:00 a.m.–9:50 a.m.

Part 3: General session; audience shares potential ideas, PIs and NSF staff are available for feedback; Sunday, 10:00 a.m.–11:20 a.m.

Sponsored by the MAA Committee on Professional Development.

MAA Session for Chairs: Program Assessment: Making it Easier and Better, organized by **Catherine M. Murphy**, Purdue University Calumet, and **Daniel Maki**, Indiana University; Sunday, 8:00 a.m.–9:20 a.m. The results of assessment of Student Learning Outcomes are used to inform curriculum decisions as well as provide data for departmental reviews, and regional accreditation documents. Panelists **Barbara Loud**, Regis College; **William O. Martin**, North Dakota State University; **Deborah Pace**, Stephen F. Austin State University; and **Elizabeth C. Yanik**, Emporia State University, will address organizational principles that may ease the transition from data to information. In particular, the following topics—focused goals and objectives, management of data, rubrics, and the feedback loop—will be discussed. Sessions for Chairs are designed to encourage attendees' interaction with panelists. Please share your successes and concerns with assessment during the Session.

Mathematical Outreach Programs, organized by **Elizabeth Yanik**, Emporia State University; Sunday, 9:00 a.m.–11:00 a.m. This poster session is designed to highlight special programs that have been developed to encourage students to maintain an interest in and commitment to succeeding in mathematics. These programs might include such activities as after-school clubs, weekend activities, one-day conferences, mentoring opportunities, summer camps, etc. This poster session encompasses a wide variety of outreach efforts for a variety of age groups. For example, programs might be designed to reach out to underrepresented groups. The projects supported by MAA Tensor and Summa grants will find this an ideal venue in which to share the progress of their funded projects. Another possible type of outreach might involve mathematical enrichment programs. For example recipients of Dolciani Mathematics Enrichment Grants might wish to highlight their programs. Other examples might include innovative programs to motivate undergraduates to study mathematics. We encourage everyone involved with offering mathematical outreach activities to consider submitting an abstract to the session organizer, Betsy Yanik, `eyanik@emporia.edu`.

Undergraduate Research: Viewpoints from the Student Side, organized by **Herbert A. Medina**, Loyola Marymount University, and **Angel R. Pineda**, California State University, Fullerton; Sunday, 10:35 a.m.–11:55 a.m. The number of undergraduates engaging in mathematical sciences research has increased dramatically the past few years. Indicators of this growth are the size of the undergraduate poster session at the Joint Mathematics Meetings (e.g., over 300 posters at the 2014 meeting), the number of mathematics Research Experiences for Undergraduates (now close to 70), and the recent creation of journals devoted to mathematics undergraduate research (e.g., *Involve* at UC Berkeley). Undergraduate research is now a major factor in preparing students for graduate school and industrial careers.

The panel will ask current undergraduate and graduate students who have engaged in undergraduate research to share some of their experiences and what they view as the "dos" and "don'ts" of undergraduate research, both from the student side and their perception of the faculty mentor side. Their viewpoints should prove useful to both fellow undergraduates and current and future faculty mentors of undergraduate research. Sponsored by the MAA Subcommittee on Research by Undergraduates.

On-Campus Interview Survival Guide, organized by **Thomas Wakefield**, Youngstown State University, and **Jacob A. White**, Texas A&M University; Sunday, 1:00 p.m.–2:20 p.m. Applying for an academic position can be a daunting task! In this session, panelists will offer their perspective on the academic job search, and specifically provide advice and tips regarding the on-campus interview. Panelists **Antonia Cardwell**, Millersville University of Pennsylvania; **Greta Panova**, UCLA; and **Frank Sottile**, Texas A&M University, represent faculty and recent PhD.'s on the job market. Learn some tips to help prepare for the next step in the job application process. Sponsored by the Young Mathematicians' Network.

Writing Competitive Grant Applications, organized by **Semra Kilic-Bahi**, Colby-Sawyer College, and **Kimberly A. Roth**, Juniata College; Sunday, 1:00 p.m.–2:20 p.m. Panelists **Florence Fasanelli**, MAA; **Elizabeth Teles**, Division of Undergraduate Education, NSF; **Jennifer Slimowitz Pearl**, Division of Mathematical Sciences, NSF; and **Roselyn E. Williams**, Florida Agricultural and Mechanical University, will discuss process and give tips for writing successful grant proposals with a focus on proposals that target underrepresented groups, especially women. Each panelist will give a 15–18 minute presentation addressing key points and the common features of competitive grant applications. The presentations will be followed by questions from the audience. Sponsored by the MAA Committee on Participation of Women in Mathematics

Out in Mathematics: LGBTQ Mathematicians in the Workplace, organized by **David Crombecque**, University of Southern California, and **Ron Buckmire**, Occidental College; Tuesday, 8:35 a.m.-10:55 a.m. We will discuss questions such as: Should I be out to my Ph.D. advisor? Should I mention anything on my CV, or during a job interview, for a postdoc, for a tenure-track position, etc.? And if so, what are the ways to be out in these circumstances?

Panelists **Andrew Bernoff**, Harvey Mudd College; **Mike Hill**, University of Virginia; and **Lily Khadjavi**, Loyola Marymount University, will discuss these and many more questions relevant to the well-being and inclusion of future successful LGBTQ mathematicians.

Projects Supported by the NSF Division of Undergraduate Education, organized by **Jon Scott**, Montgomery College; Sunday, 2:00 p.m.–4:00 p.m. This session will feature principal investigators (PIs) presenting progress and outcomes from various NSF funded projects in the Division of Undergraduate Education. The poster session format will permit ample opportunity for attendees to engage in small group discussions with the PIs and to network with each other. Information about presenters and their projects will appear in the program.

Mathematicians Write: Publishing Options and Outlets Beyond the Standard Research Journal, organized by **Gizem Karaali**, Pomona College; Sunday, 2:35 p.m.–3:55 p.m. Mathematicians are trained to write research papers and are often comfortable with the norms and expectations of a standard research journal. However many find that they have other things to say, other ideas to explore. This leads to an unfamiliar territory. How does one get an expository piece published? Can a pedagogical innovation idea develop into a publishable article? What kinds of different audiences can I address with my writing? Panelists **Brian Hopkins**, Saint Peter's University (*College Mathematics Journal*); **Marjorie Senechal**, Smith College (*The Mathematical Intelligencer*); **Janet Beery**, University of Redlands (*Convergence*); **Jo Ellis-Monaghan**, Saint Michael's College (PRIMUS); and **Gizem Karaali**, Pomona College (*Journal of Humanistic Mathematics*), all editors of prominent journals and magazines that populate the mathematical publishing universe and enrich its offerings, will provide some concrete answers to such questions. Besides these, the panelists will respond to the following questions: What does it take to get published in your journal? What differentiates manuscripts you publish from those you don't? What else do you recommend for prospective authors? The panel will conclude with an interactive Q&A session.

Find a Research Collaborator, organized by **Ralucca Gera**, Naval Postgraduate School; **Timothy Goldberg**, Lenoir-Rhyne University; and **Gwyneth Whieldon**, Hood College; Sunday, 5:30 p.m.– 6:30 p.m. As freshly graduated PhD.'s will start their research career at a new institution, one of the obstacles observed is finding (1) collaborators in other departments or institutions, and (2) finding topics to work on. This event will consist of small group discussions based on research interests, with the goal of sharing ideas of how to find collaborators and topics, as well as possibly finding a collaborator during the event. Sponsored by the Young Mathematicians' Network.

Poetry Reading, Sunday, 5:30 p.m.–7:00 p.m. All mathematical poets and those interested in mathematical poetry are invited. Share your poetry or simply enjoy the company of like-minded poetic-math people! The reading is sponsored by the *Journal of Humanistic Mathematics* (`http://scholarship.claremont.edu/jhm`) and will be hosted by **Gizem Karaali** and **Larry Lesser**. Though we do not discourage last-minute decisions to participate, we invite and encourage poets to submit poetry (≤ 3 poems, ≤ 5 minutes) and a bio in advance, and, as a result, be listed on our printed program. Inquiries and submissions (by December 1, 2014) may be made to Gizem Karaali (`gizem.karaali@pomona.edu`).

The Mathematics of Being Human, Sunday, 6:00 p.m.–7:20 p.m. In the not-too-distant future, English professor Naomi Kessler and mathematics professor Mike Pearson are forced to co-teach a course by a university bent on promoting interdisciplinarity at any cost. Battle lines are drawn as they jockey not only over the syllabus but also the different intellectual cultures and modes of inquiry favored by the humanities vs. mathematics. To win over the class, they must bridge their own preconceptions and prejudices and explore common ground. Only through the effort of two of their students do they catch a glimpse of true synthesis. Come to see tense situation unfold during this live performance, cowritten by **Michele Osherow**, professor of English and Director of Judaic Studies at the University of Maryland Baltimore County, and **Manil Suri**, professor of mathematics, University of Maryland Baltimore County. There will be ample time after the performance for discussion and questions. Cosponsored by the MAA and AMS.

Benefits and Challenges of Introducing Multivariate Topics Earlier in the Calculus Sequence, organized by **Mark Gruenwald**, University of Evansville, and **Ken Luther**, Valparaiso University; Monday, 9:35 a.m.–10:55 a.m. Many voices within STEM disciplines have recommended that (some) multivariate topics be introduced earlier in the calculus sequence. Thus far, attempts to restructure the calculus sequence with this goal in mind have not gained widespread adoption, though several recent initiatives show promise. Panelists **Dave Dwyer**, University of Evansville; **Stephen Davis,** Davidson College; and **Jim Fowler**, The Ohio State University, will share experiences with introducing multivariate calculus topics earlier in the curriculum—in both traditional courses and in MOOCs—and the challenges of swimming against the calculus current.

Mathematics and the Sciences: Necessary Dialogue, organized by **Martha J. Siegel**, Towson University, and **Peter Turner**, Clarkson University*;* Monday, 1:00 p.m.–2:20 p.m. Recent reports and meetings (e.g., the 2012 PCAST report Engage to Excel; activities of the TPSE Math (Transforming Post-Secondary Education in Mathematics) group) have raised important questions. How creatively and effectively does the mathematics community support undergraduate scientific and STEM education? How can we attract more, and more diverse, students? How well informed are the mathematics and science communities about each other's efforts and innovations? What new (and old) mathematics do our scientific siblings want our students to know, and when should they know it? Such questions are especially timely now, when MAA, SIAM, and the American Statistical Association have all produced reports and recommendations for undergraduate education. (MAA's *2015 Curriculum Guide*, historically published about once each decade, is one example.) We should hear each other's views and perspectives. Sponsored by the MAA Committee on the Undergraduate Program in Mathematics (CUPM).

Actuarial Science: What Faculty Need to Know, organized by **Kevin Charlwood**, Washburn University; **Robert Buck**, Slippery Rock University; **Patrick Brewer**, Lebanon Valley College; **Bettye Anne Case**, Florida State University; **Michelle Guan**, Indiana University Northwest; and **Steve Paris**, Florida State University; Monday, 5:00 p.m.–7:00 p.m. The panel features a diverse group of actuaries, publishers, and actuarial educators. The pace of change in actuarial science is faster than in most academic areas, and this session aims to help faculty adjust curriculum and activities to meet student needs and expectations. A member representing actuarial science from the MAA Committee on the Undergraduate Program (CUPM) will present the group's forthcoming recommendations. Another panel speaker will address the unique challenges of meeting the needs of international students in actuarial programs. A speaker from an actuarial firm will focus on the changing landscape of actuarial internships. These are a few of the topics for discussion for our panelists, **Michelle Guan**, Indiana University Northwest; **Mike Boa**, Casualty Actuarial Society; **Bettye Anne Case,** Florida State University; **Catherine Taylor**, USAA P&C Casualty; and **Susan Staples**, Texas Christian University

Mathematically Bent Theater, featuring **Colin Adams** and the **Mobiusbandaid Players**; Monday, 6:00 p.m.–7:00 p.m. Why is it that math and humor are considered synonymous? Why do students laugh maniacally when they see their score on the calculus final? How did the Bernoulli Brothers bring down the house in their first comedy appearance? Who came up with the word "functor"? Who dented the bumper of my car at the Joint Meetings in Baltimore? These are just a few of the questions we will not answer in this theatrical presentation of several short mathematically inclined humorous pieces.

A Positive Feedback Loop? Impact of Mathematics Education Research and K–12 Instructional Changes on Our Teaching of Undergraduate Mathematics, organized by **Ben Ford**, Sonoma State University, and **Klay Kruczek**, Southern Connecticut State University; Tuesday, 8:00 a.m.–9:20 a.m. The field of mathematics education research (K–12 and undergraduate) is developing rapidly, at the same time as K–12 mathematics instruction is experiencing major change. What do these forces imply for our teaching of undergraduate mathematics, especially for future teachers? What research findings hold across all ages; which are age-specific? Will our incoming students have different mindsets, skills, and understanding? What will be required (mathematically) of our graduates who become teachers, and how can they develop those abilities while in our classes? Panelists include **Chris Rasmussen**, San Diego State University; **Klay Kruczek**, Southern Connecticut State University; and **Elise Lockwood**, Oregon State University. Sponsored by the MAA Committee on the Mathematical Education of Teachers (COMET)

Creating a Course in Mathematical Modeling, organizeed by **Dan Teague**, North Carolina School of Science and Mathematics; Tuesday, 8:00 a.m.–10:00 a.m. Applied mathematics, with mathematical modeling at its core, is growing in importance in the mathematics curriculum. Modeling offers student a vision of mathematics and an opportunity to engage in mathematical creativity that is largely absent from the standard mathematics major coursework. A modeling course invites creative students into the major who currently choose other disciplines which offer more interesting challenges to their creativity and ingenuity, particularly early in their college career. This workshop will discuss the structure and share materials from a modeling course taught at the NC School of Science and Mathematics since 1985. Students in the course have written eleven Outstanding Winner papers in the Mathematical Contest in Modeling (MCM and ICM), capturing two INFORMS Prize papers, two SIAM Prize papers, and this year's MAA Prize paper in the process. Information on the mathematical modeling competitions available to university students (MCM, ICM) and to high school students (HiMCM, Moody's) will also be shared. Sponsored by SIGMAA TAHSM and the MAA Council on Outreach.

"Poster Plus 5" Session on Open Source Resources in Mathematics, organized by **Stan Yoshinobu**, Cal Poly San Luis Obispo; Tuesday, 8:00 a.m.–10:55 a.m. and 1:00–5:00 p.m. The availability of high-quality, open source resources that support teaching and research in mathematics is changing opportunities and pedagogical options for mathematics educators. In this hybrid contributed paper/poster session, we invite presentations on the effective use of available open-source resources in the classroom. Each speaker will present for 5 minutes on his/her topic, and then the session will break into an interactive poster session in which speakers enter into active dialogues with session attendees to provide additional details and information. Applicants should send a poster abstract to the organizer, Stan Yoshinobu, `styoshin@calpoly.edu`. The deadline for receiving applications is December 15, 2014. Sponsored by the MAA Committee on Professional Development.

The New Mathways Project's STEM Prep Initiative: A Re-Conceptualized Pathway to Calculus, organized by **Frank Savina**, University of Texas at Austin, and **Stuart Boersma**, Central Washington University; Tuesday, 1:00 p.m.–2:20 p.m. The Charles A. Dana Center's New Mathways Project has begun the work of designing a STEM Prep Pathway serving students from developmental math to calculus. For the past year two teams of leading researchers and educators have been gleaning promising practices from the field and synthesizing them to determine the content and structure of this re-conceptualized pathway to calculus. The goal of this workshop is to share the work of the design teams in a manner that will be useful to mathematics faculty and departments. In this hands-on workshop participants will be given an overview of the guiding principles of the curriculum at the New Mathways Project, will join in an interactive discussion on the challenges of preparing students for calculus, will have the opportunity to look over drafts of the curriculum, and be provided an overview of the findings from the research on promising practices from the design teams.

Special Interest Groups of the MAA (SIGMAAs)

SIGMAAs will be hosting a number of activities, sessions, and guest lectures. There are currently twelve such focus groups in the MAA offering members opportunities to interact, not only at meetings, but throughout the year, via newsletters and email-based communications. For more information visit www.maa.org/community/sigmaas.

SIGMAA Officers Meeting, Sunday, 10:30 a.m. to noon

SIGMAA on Mathematics and the Arts (SIGMAA ARTS)

Mathematics and the Arts, Saturday morning and afternoon (see MAA Contributed Paper Sessions)

SIGMAA on Business, Industry, and Government (BIG SIGMAA)

Mathematics Experiences in Business, Industry, and Government (see MAA Contributed Paper Sessions)

Guest Lecture, Sunday, 5:30 p.m.–6:20 p.m., **Kyle Myers**, Division of Imaging and Applied Mathematics, Office of Science and Engineering Laboratories, Center for Devices and Radiological Health, US FDA, *Mathematical challenges in the evaluation of medical imaging*.

Business Meeting, Sunday, 7:00 p.m.–7:30 p.m.

SIGMAA on Mathematical and Computational Biology (BIO SIGMAA)

Reception, Sunday, 6:00 p.m.–6:20 p.m.

Business Meeting, Sunday, 6:30 p.m.–6:50 p.m.

Guest Lecture, Sunday, 7:00 p.m.–7:50 p.m. **Jim Cushing**, University of Arizona, title to be announced.

Trends in Undergraduate Mathematical Biology Education (see MAA Contributed Papers Section)

SIGMAA on Environmental Mathematics (SIGMAA EM)

USE Math: Undergraduate Sustainability Experiences in the Mathematics Classroom (see MAA Contributed Paper Sessions)

SIGMAA on the History of Mathematics (HOM SIGMAA)

Ethnomathematics (see MAA Contributed Paper Sessions)

SIGMAA on Math Circles for Students and Teachers (SIGMAA MCST)

What Makes a Successful Math Circle: Organization and Problems (see MAA Contributed Paper Sessions)

SIGMAA on the Philosophy of Mathematics (POM SIGMAA)

Discovery and Insight in Mathematics (see MAA Contributed Paper Sessions)

Reception, Monday, 5:30 p.m.–5:50 p.m.

Business Meeting, Monday, 6:00 p.m.–6:20 p.m.

Guest Lecture, Monday, 6:30 p.m.–7:20 p.m., **Matt Jones**, California State University Dominguez Hills, *Mathematical authority and inquiry-based learning*.

SIGMAA on Quantitative Literacy (SIGMAA QL)

Infusing Quantitative Literacy into Mathematics and Nonmathematics Courses (see MAA Contributed Paper Sessions)

SIGMAA on Research in Undergraduate Mathematics Education (SIGMAA RUME)

Research on the Teaching and Learning of Undergraduate Mathematics (see MAA Contributed Paper Sessions)

SIGMAA on Statistics Education (SIGMAA Stat Ed)

Statistics Education beyond the Introductory Statistics Course (see MAA Contributed Paper Sessions)

Reception, Sunday, 5:30 p.m.–5:50 p.m.

Business Meeting, Sunday, 6:00 p.m.–6:20 p.m.

Guest Lecture, Sunday, 6:30 p.m.–7:20 p.m., **Hadley Wickham**, RStudio and Rice University, *Reactive documents for teaching.*

Best Practices for Teaching the Introductory Statistics Course (see MAA Contributed Paper Sessions)

SIGMAA on the Teaching of Advanced High School Mathematics (SIGMAA TAHSM)

Creating a Course in Mathematical Modeling (see MAA panels, etc.)

First-Year Calculus: Fresh Approaches for Jaded Students (see MAA Contributed Paper Sessions)

SIGMAA on Mathematics Instruction Using the Web (WEB SIGMAA)

Well-Designed Online Assessment: Well-formed Questions, Discovery-based Explorations, and their Success in Improving Student Learning (see MAA Contributed Paper Sessions)

Business Meeting, Monday, 5:30 p.m.–5:50 p.m.

Guest Lecture, Monday, 6:00 p.m.–6:50 p.m., **William Stein**, University of Washington, *SageMathCloud—integrated mathematical tools in the cloud.*

MOOCs and Me: Massive Online Materials for My Students (see MAA Panels, etc.)

MAA Sessions for Students

Speed Interviewing Marathon for Students, organized by **Jenna Carpenter**, Louisiana Tech University, and **Michael Dorff**, Brigham Young University; Sunday, 1:00 p.m.– 2:15 p.m. Employers suggest that communication skills are a critical component when considering a mathematics major for a job. An important time to demonstrate good communication skills is during the job interview. This session for undergraduate students, graduate students, and early career mathematicians will start with an overview of best practices and tips on job interviewing, then guide participants in several speed interviewing sessions of 10 minutes each, where they can practice what they have learned and hone their interviewing skills. Speed interviewing sessions will include individual feedback for participants, as well as opportunities to network with fellow interviewees. Sponsored by the MAA Committee on Professional Development, MAA Committee on Graduate

Students, and the MAA Committee on Undergraduate Student Activities and Chapters

Grad School Fair, Monday, 8:30 a.m.–10:30 a.m. Here is the opportunity for undergrads to meet representatives from mathematical sciences graduate programs from universities all over the country. January is a great time for juniors to learn more, and college seniors may still be able to refine their search. This is your chance for one-stop shopping in the graduate school market. At last year's meeting about 300 students met with representatives from 50 graduate programs. If your school has a graduate program and you are interested in participating, a table will be provided for your posters and printed materials for US$75 (registration for this event must be made by a person already registered for the JMM), and you are welcome to personally speak to interested students. Complimentary coffee will be served. Cosponsored by the MAA and AMS.

MAA Lecture for Students, Monday, 1:00 p.m.–1:50 p.m., will be given by **George Hart**, Stony Brook University, on *Math is cool!*

MAA Student Poster Session, organized by **Joyati Debnath**, Winona State University; Monday, 4:30 p.m.–6:00 p.m. This session features research done by undergraduate students. First-year graduate students are eligible to present if the research was done while they were still undergraduates. Research done by high school students can be accepted if the research was conducted under the supervision of a faculty member at a post-secondary institution.

Appropriate poster material includes, but is not limited to: a new result, a new proof of a known result, a new mathematical model, an innovative solution to a Putnam problem, or a method of solution to an applied problem. Purely expository material is not appropriate for this session.

Students should submit an abstract describing their research in 250 words or less by midnight, October 11, 2014. Notification of acceptance or rejection will be sent by November 1, 2014. See `http://www.maa.org/students/undergrad/jmmposterindex.html` for further details and a link to the abstract submission form. See `http://www.maa.org/students/writing%20abstracts.pdf` for "A Guide to Writing an Abstract." See `http://www.ncsu.edu/project/posters/NewSite/CreatePosterOverview.html` for "Creating an Effective Poster." See `http://www.maa.org/programs/students/undergraduate-research/jmm-poster-session/examples-of-outstanding-student-posters` for exemplary posters from past years.

Posters will be judged during the session and award certificates will be mailed to presenters with the highest scores. Trifold, self-standing 48" by 36" tabletop poster boards will be provided. Additional materials and equipment are the responsibility of the presenters. Participants must set up posters between 2:30 and 3:30 p.m. and must be available from 3:30 to 6:00 p.m. for judging and public viewing. Judges' results will be available at the MAA Pavilion in the Exhibit Hall the following day until the exhibits close.

Questions regarding this session should be directed to Joyati Debnath at `jdebnath@winona.edu`. A list of frequently asked questions and other information can be found at `http://www.maa.org/programs/students/undergraduate-research/jmm-poster-session/student-poster-session-faqs`.

Some more advanced students might be interested in these sessions listed elsewhere in this announcement: ***What Every Student Should Know about the JMM***, Saturday at 2:15 p.m.; ***YMN/Project NExT Poster Session***, Saturday at 2:15 p.m.; ***Graduate School: Choosing One, Getting In, Staying In***, Saturday at 3:50 p.m.; ***Undergraduate Research: Viewpoints from the Student Side***, Sunday at 10:35 a.m. See the full descriptions in the "MAA Panels..." section. You may also be interested in the ***AMS-MAA-SIAM Special Session on Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs,*** Saturday morning, Sunday afternoon, and Tuesday all day; see the listing under AMS Special Sessions.

Other MAA Events

Board of Governors, Friday, 9:00 a.m.–5:00 p.m.

Department Liaisons Meeting, Saturday, 9:30 a.m.–11:00 a.m.

MAA Section Officers Meeting, Saturday, 4:00 p.m.–5:00 p.m., chaired by **Rick Gillman**, Valparaiso University.

SIGMAA Officers Meeting, Sunday, 10:30 a.m.–12:00 noon, chaired by **Karen A Marrongelle**, Portland State University.

MAA Business Meeting, Tuesday, 11:10 a.m.–11:40 a.m., chaired by MAA President **Robert Devaney**, Boston University.

MAA Ancillary Workshops (these take place on Friday, January 9, before the JMM actually begins)

National Research Experiences for Undergraduates Workshop, organized by **Dennis Davenport**, Howard University; Friday, 9:00 a.m.–4:30 p.m. This workshop will teach participants how to write a competitive grant proposal. This workshop is a hands-on experience where participants write a summary of a proposal and rate an NSF awarded proposal in a mock panel review. Participants will also learn many helpful hints and fatal flaws to proposal writing. This workshop is appropriate for current PIs of MAA's NREUP grants and for those who were denied funding for an MAA grant.

Embedding Undergraduate Research into a Living-Learning Community, organized by **Mark Daniel Ward**, Purdue University; Friday, 9:00 a.m.–4:00 p.m. The goal is to enable participants to incorporate their undergraduate research programs into a living-learning community. This is especially appropriate for courses in calculus, linear algebra, combinatorics, mathematical modeling, and introductory proof-based courses, or for early statistics courses such as exploratory data analysis, probability, or introduction to statistics. We will discusses best-practices for going far beyond the curriculum in training students, e.g., having a holistic program that integrates the student (1) curriculum, (2) research, (3) residential life, and (4) professional development experiences. We will share examples, activities, projects, syllabi, calendars, and research topics from Purdue's NSF-funded Living-Learning Community. We will discuss how to integrate computational aspects of the curriculum and research into a living-learning community, using software such as Maple, Mathematica, Matlab, Sage, and/or R or SAS. The workshop is an outreach activity of NSF grant DMS-1246818.

Advanced registration is required. Send an email to the organizer at mdw@purdue.edu to register for the workshop. Space in the workshop is limited. Participants are encouraged to bring a laptop to the workshop.

Activities of Other Organizations

This section includes scientific sessions. Several organizations or special groups are having receptions or other social events. Please see the "Social Events" section of this announcement for those details.

Association for Symbolic Logic (ASL)

This two-day program on Monday and Tuesday will include sessions of contributed papers as well as Invited Addresses by **Ekaterina Fokina**, University of Vienna; **Menachem Magidor**, Einstein Institute of Mathematics; **Rehana Patel**, Franklin W. Olin College of Engineering; **Anand Pillay**, University of Leeds; **Robin Tuckerdrob**, Rutgers University; **Richard A. Shore**, Cornell University; and **Trevor Wilson**, University of California, Irvine.

See also the session cosponsored by the ASL on *Beyond First-Order Model Theory* on Saturday and Sunday in the "AMS Special Sessions" listings.

Association for Women in Mathematics (AWM)

Thirty-Sixth Annual Noether Lecture, Sunday, 10:05 a.m., will be given by **Wen-Ching Winnie Li,** Pennsylvania State University, title to be announced.

Also see the session on **Recent Developments in Algebraic Number Theory**, jointly sponsored by the AWM, in the "AMS Special Sessions" listings.

Breaking the Glass Ceiling Permanently, organized by **Bettye Anne Case**, Florida State University; **Deleram Kahrobaei**, City University of New York, Graduate Center and New York City College of Technology; **Kathryn Leonard,** California State Channel Islands; and **Christina Sormani,** City University of New York, Graduate Center and Lehman College; Saturday, 2:15 p.m.–3:40 p.m. Over the past century, women mathematicians have achieved unprecedented success. Universities that never hired women before, now have women faculty in their ranks. Departments that rarely promoted women before, now have women who are tenured full professors. Institutes that didn't exist before are now being directed by women mathematicians. In every field of mathematics, there are key results, cited daily, that were proven by women. Despite these great strides, young women today encounter many of the same hurdles that the women before them had to face. In this panel we will discuss how successful women mathematicians, at all levels, can work to break through the glass ceiling and bring the next generation of women through with them. Panelists include **Lenore Blum,** Carnegie Mellon University; **Estela Gavosto,** Kansas University; **Susan Hermiller,** University of Nebraska; **Megan Kerr,** Wellesley College; **Joan Leitzel,** University of New Hampshire; and **Jill Pipher,** Director of ICERM. See https://sites.google.com/site/awmpanel2015/ for the latest information.

Business Meeting, Saturday, 3:45 p.m.–4:15 p.m.

Workshop Poster Presentations and Reception, Monday, 6:00 p.m.–7:15 p.m. With funding from the National Science Foundation, AWM will conduct its workshop poster presentations by women graduate students. Organizers for these presentations are **Gizem Karaali**, Pomona College; **Lerna Pehlivan**, York University; and **Brooke Shipley**, University of Illinois at Chicago.

AWM Workshop on Homotopy Theory, Tuesday, 8:00 a.m.–5:00 p.m. With funding from the National Science Foundation, AWM will conduct its workshop with presentations by senior and junior women researchers. All mathematicians (female and male) are invited to attend the entire program. Departments are urged to help graduate students and recent Ph.D.'s who do not receive funding to obtain some institutional support to attend the workshop and other meeting sessions. Updated information about the workshop is available at www.awm-math.org/workshops.html. AWM seeks volunteers to serve as mentors for workshop participants. If you are interested, please contact the AWM office; inquiries regarding future workshops may be made to the office at awm@awm-math.org.

Reception, Saturday, 9:30 p.m.–11:00 p.m. See the listing in the "Social Events," section of the announcement.

National Association of Mathematicians (NAM)

Granville-Brown-Hayes Session of Presentations by Recent Doctoral Recipients in the Mathematical Sciences, Monday, 1:00 p.m.–4:00 p.m.

Cox-Talbot Address, to be given Monday after the banquet, speaker and title to be announced.

Panel Discussion, Tuesday, 9:00 a.m.–9:50 a.m.

Business Meeting, Tuesday, 10:00 a.m.–10:50 a.m.

Claytor-Woodward Lecture, Tuesday, 1:00 p.m., speaker and title to be announced.

See details about the banquet on Monday in the "Social Events" section.

National Science Foundation (NSF)

The NSF will be represented at a booth in the exhibit area. NSF staff members will be available to provide counsel and information on NSF programs of interest to mathematicians. The booth is open the same days as the exhibitis. Times that staff will be available will be posted at the booth.

Pi Mu Epsilon (PME)

Council Meeting, Sunday, 8:00 a.m.–11:00 a.m.

Society for Industrial and Applied Mathematics (SIAM)

This program consists of an Invited Address at 11:10 a.m. on Sunday given by a speaker to be announced, and a series of Minisymposia to include ***Modeling Across the***

Curriculum, **Rachel Levy**, Harvey Mudd College; and **Peter Turner**, Clarkson University; and several others to be announced.

Others

Mathematical Art Exhibition, organized by **Robert Fathauer**, Tessellations Company; **Nathaniel A. Friedman**, ISAMA and SUNY Albany, **Anne Burns**, Long Island University C. W. Post Campus, **Reza Sarhangi**, Towson University, and **Nathan Selikoff**, Digital Awakening Studios. A popular feature at the Joint Mathematics Meetings, this exhibition provides a break in your day. On display are works in various media by artists who are inspired by mathematics and by mathematicians who use visual art to express their findings. Topology, fractals, polyhedra, and tiling are some of the ideas at play here. Don't miss this unique opportunity for a different perspective on mathematics. The exhibition will be located inside the Joint Mathematics Exhibits and open during the same exhibit hours.

Summer Program for Women in Mathematics (SPWM) Reunion, organized by **Murli M. Gupta,** George Washington University; Sunday, 1:00 p.m.–3:00 p.m. This is a reunion of the summer program participants from the past 19 years (1995-2013) who are in various states of their mathematical careers: some are students (undergraduate or graduate), others are in various jobs, both in academia as well as government and industry. The participants will describe their experiences relating to all aspects of their careers. There will also be a presentation on the increasing participation of women in mathematics over the past two decades and the impact of SPWM and similar programs. See `http://www.gwu.edu/~spwm`.

Effective Self-Promotion to Advance Your Career in Mathematics, organized by **Christine Guenther**, Pacific University; **Patricia Hale,** California State Polytechnic University, Pomona; and **Tanya Leise**, Amherst College; Sunday,1:00 p.m.–2:30 p.m. Panelists **Pam Cook** , University of Delaware; **Deborah Lockhardt** , National Science Foundation; **Dana Randall**, Georgia Institute of Technology; and **Sara Y. Del Valle**, Los Alamos National Labs, will focus on how women (and men) pursuing mathematical careers can and should "lean in," while recognizing that current cultural norms can pose obstacles that we must find ways to overcome. A persistent gender wage gap has been linked to, among other things, the greater competitiveness and confidence of men compared to women on average. A recent US Department of Education survey found that at doctoral universities women's salaries are only 80% of men's salaries. We will discuss how mathematicians can promote themselves: avoiding self-deprecation, actively applying for grants, pursuing opportunities for giving talks and getting nominated for prizes, and persisting past initial failures by resubmitting revised grants and papers. Issues of how to choose a mentor and how to be a good mentor will also be addressed, particularly with reference to learning how to successfully self-promote. The panelists' advice will be beneficial to both men and women seeking to advance their mathematical careers. Sponsored by the Joint Committee on Women in the Mathematical Sciences.

Expeditions in Training, Research, and Education for Mathematics and Statistics through Quantitative Explorations of Data (EXTREEMS-QED), organized by **Tor A. Kwembe**, Jackson State University; Sunday, 2:00 p.m.–4:00 p.m. Presenters in this poster session will share their experiences under this new NSF program designed to promote the integration of computational and data-enabled science (CDS&E) in undergraduate mathematics and statistics curricula. Funded activities are expected to provide opportunities for undergraduate research and hands-on experiences centered on CDS&E, result in significant changes to the undergraduate mathematics and statistics curriculum, have broad institutional support and department-wide commitment that encourage collaborations within and across disciplines, and include professional development activities for faculty or for K–12 teachers.

Pure and Applied Talks by Women Math Warriors presented by EDGE (Enhancing Diversity in Graduate Education), organized by **Amy Buchmann**, University of Notre Dame; and **Candice Price**, United States Military Academy, West Point; Tuesday, 1:00 p.m.–5:50 p.m. Since its beginning in 1998 nearly two hundred women have participated in the EDGE program. Approximately seventy are currently working towards a Ph.D., over one hundred have earned Masters and fifty-four have gone on to successfully complete Ph.D's. This session will be comprised of research talks in a variety of different subdisciplines given by women involved with the EDGE program. For more information on the EDGE program see `http://www.edgeforwomen.org/`.

Social Events

All events listed are open to all registered participants. It is strongly recommended that for any event requiring a ticket, tickets should be purchased through advance registration. Only a very limited number of tickets, if any, will be available for sale on site. If you must cancel your participation in a ticketed event, you may request a 50% refund by returning your tickets to the Mathematics Meetings Service Bureau (MMSB) by **January 6, 2015.** After that date no refunds can be made. Special meals are available at banquets upon advance request, but this must be indicated on the Advanced Registration/Housing Form.

2015 AMS Dinner Celebration: Attend the AMS Dinner for an evening of celebrating the spirit of connection and collaboration which is found throughout the mathematical community. Reconnect with colleagues and friends while enjoying a delicious meal from gourmet food stations, listening to music, and entering to win fun prizes at our raffle table. Experience a special program which will honor long-term members of the AMS and highlight new developments within the Society. It will be held on Tuesday evening with a reception at 6:30 p.m. and dinner will be served at 7:30 p.m. Tickets are US$67 including tax and gratuity. The student ticket price is US$25.

Association of Christians in the Mathematical Sciences (ACMS) Reception and Lecture, Sunday, 5:30 p.m.–7:30 p.m. The reception will take place between

5:30 p.m. and 6:30 p.m. and will be followed by a lecture given by **Anthony Tongen** of James Madison University. An opportunity will be provided afterwards for delegates to go to dinner at local restaurants in small groups.

Association of Lesbian, Gay, Bisexual, and Transgendered Mathematicians Reception, Sunday, 6:00 p.m.–8:00 p.m. This annual reception is for lesbian, gay, bisexual, and transgender mathematicians, as well as their allies. We are affiliated with NOGLSTP, the National Organization of Gay and Lesbian Scientists and Technical Professionals, Inc.

AWM Reception: This open reception takes place on Saturday at 9:30 p.m. after the AMS Gibbs Lecture and has been a popular, well-attended event in the past. At 10:00 p.m. the AWM President will recognize all of the honorees of the AWM Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman, the recipient of the AWM-Joan & Joseph Birman Research Prize in Topology and Geometry, and the AWM Service Awards.

Backgammon! organized by **Arthur Benjamin**, Harvey Mudd College; Monday, 8:00 p.m.–10:00 p.m. Learn to play backgammon from expert players. It's a fun and exciting game where players with a good mathematics background have a decisive advantage. Boards and free lessons will be provided by members of the US Backgammon Federation. Stop by anytime on Monday evening.

Budapest Semesters in Mathematics Annual Alumni Reunion, Sunday, 5:30 p.m.–7:00 p.m.

University of Chicago, Mathematics Alumni Reception, Sunday, 6:00 p.m.–7:00 p.m.

Reception for Graduate Students and First-Time Participants, Saturday, 5:30 p.m.–6:30 p.m. The AMS and MAA cosponsor this social hour. Graduate students and first-timers are especially encouraged to come and meet some old-timers to pick up a few tips on how to survive the environment of a large meeting. Light refreshments will be served.

Knitting Circle, Sunday, 8:15 p.m.–9:45 p.m. Bring a project (knitting/crochet/tatting/beading/etc.) and chat with other mathematical crafters!

MAA/Project NExT Reception, Monday, 8:00 p.m.–10:00 p.m., organized by **Julia Barnes**, Western Carolina University; **Alissa Crans**, Loyolla Marymount University; **Matt DeLong,** Taylor University; **Dave Kung**, St. Mary's College of Maryland; and **Anthony Tongen**, James Madison University. All Project NExT Fellows, consultants, and other friends of Project NExT are invited.

MAA Two-Year College Reception, Saturday, 5:45 p.m.–7:00 p.m., is open to all meeting participants, particularly two-year faculty members. This is a great opportunity to meet old friends and make some new ones. There will be hot and cold refreshments and a cash bar.

***Mathematical Reviews* Reception**, Monday, 6:00 p.m.–7:00 p.m. All friends of the *Mathematical Reviews* (MR) are invited to join reviewers and MR editors and staff (past and present) for a special reception in honor of the 75th anniversary of MR (1940–2015), and to acknowledge all of the efforts that go into the creation and publication of the Mathematical Reviews Database. Refreshments will be served.

Mathematical Institutes Open House, Saturday, 5:30 p.m.–8:00 p.m. Participants are warmly invited to attend this open house which is cosponsored by several of the mathematical science institutes in North America. This reception precedes the Gibbs Lecture. Come find out about the latest activities and programs at each of the institutes that may be suited to your own research. We hope to see you there! `http://www.msri.org/openhouse/2015`.

National Association of Mathematicians Banquet, Monday, 6:00 p.m.–8:40 p.m. A cash bar reception will be held at 6:00 p.m., and dinner will be served at 6:30 p.m. Tickets are US$63 each, including tax and gratuity. The Cox-Talbot Invited Address will be given after the dinner.

NSA Women in Mathematics Society Networking Session, Sunday, 6:00 p.m.–8:00 p.m. All participants are welcome to this annual event. Please stop by the NSA booth in the exhibit hall for information and the location of the event.

Pennsylvania State University Mathematics Alumni Reception, Sunday, 5:30 p.m.–7:30 p.m. Please join us for hors d'oeuvres and beverages and mingle with math alumni, faculty, and College of Science representatives.

Project NExT Reception, Monday, Monday, 8:00 p.m.–10:00 p.m. All Project NExT Fellows, consultants, and other friends of Project NExT are invited.

Student Hospitality Center, Saturday–Monday, 9:00 a.m.–5:00 p.m., and Tuesday, 9:00 a.m.–3:00 p.m., organized by **Richard** and **Araceli Neal**, American Society for the Communication of Mathematics, and sponsored by the MAA Committee for Undergraduate Student Activities.

University of Tennessee, Math Alumni and Friends Reception, Sunday, 5:30 p.m.–7:00 p.m. Anyone who has ever been a part of the UT Math Department, or is considering joining our department as a new graduate student or faculty, is invited to gather for some friendly conversation.

Reception for Undergraduates, Saturday, 4:00 p.m.–5:00 p.m.

Registering in Advance

The importance of registering for the meeting cannot be overemphasized. Advanced registration fees are considerably lower than on-site registration fees. The AMS and the MAA encourage all participants to register for the meeting as the importance of JMM registration cannot be overemphasized. When a participant pays the registration fee, he or she is helping to support a wide range of activities associated with planning, organizing, and execution of the meetings.

All participants who wish to attend sessions are expected to register and should be prepared to show their badges if so requested. Badges are required to enter the JMM Exhibits, the Employment Center, or to obtain discounts at the AMS and MAA Book Sales and to cash a check with the Joint Meetings cashier.

All JMM registrations are processed by the MMSB. Participants who register by **November 18, 2014**, may receive their badges, programs, and tickets (where applicable) in advance by U.S. mail approximately three weeks before the meetings. Those who do not want their materials mailed should check the appropriate box on the Registration and Housing Form. Materials cannot be mailed to Canada, Mexico, or other countries outside of the U.S. Participants from these countries must pick up their materials at the Joint Meeting Registration Desk, which will be located on the first floor of the Henry B. Gonzales Convention Center. Please note that a US$5 replacement fee will be charged for programs and badges that were mailed but not brought to the meeting.

Online Registration: The form to register for the meeting and to reserve a hotel room online is located at `www.jointmathematicsmeetings.org/meetreg?meetnum=2168`. VISA, MasterCard, Discover, and American Express are the only methods of payment accepted for online registrations, and charges to credit cards will be made in U.S. funds. All registration acknowledgments will be sent by email to all email addresses provided.

Paper Form Registration: The form to register for the meeting and to reserve a hotel room by paper is located at `www.jointmathematicsmeetings.org/meetings/national/jmm2015/jmm15_regform.pdf`. Forms must be mailed or faxed to the MMSB at MMSB, P.O. Box 6887, Providence, RI 02940 or 401-455-4004. For security reasons, credit card numbers by email or fax cannot be accepted. If a participant is registering by paper form and would like to pay for the registration or guarantee your hotel reservation by credit card, he or she should indicate this on the form and someone from the MMSB will call that person.

Participant Lists and Mailing Lists: If any participant would like to opt-out of any mailing lists or participant lists that are generated for the meeting, he or she should check the appropriate box on the Registration and Housing Form. All participants who do not opt-out will be included in all mailing lists and participant lists that are generated for the meeting and distributed.

Cancellation Policy: Participants who cancel their registration for the meetings, minicourses, or short course by **January 6, 2015**, will be eligible to receive a 50% refund of fees paid. Participants who cancel their banquet tickets by **January 5, 2015**, will be eligible to receive a 50% refund of monies paid. No refunds will be issued after these deadlines.

Joint Mathematics Meetings Registration Fees

	Advance (by Dec. 23)	at meeting
Member of AMS, ASL, CMS, MAA, SIAM	US$252	US$331
Nonmember	400	510
Graduate Student Member of AMS, MAA	56	66
Graduate Student Nonmember	90	100
Undergraduate Student	56	66
Temporarily Employed	205	235
Emeritus Member of AMS, MAA; Unemployed; High School Teacher; Developing Countries; Librarian	56	66
High School Student	5	11
One-Day Member of AMS, ASL, CMS, MAA, SIAM	N/A	180
One-Day Nonmember	N/A	281
Non-mathematician Guest	16	16
Commercial Exhibitor	0	0
MAA Minicourses	85	85
Grad School Fair Table	75	75
AMS Short Course		
Member of AMS	108	142
Nonmember	160	190
Student/Unemployed/Emeritus	56	77

Registration Category Definitions

Full-Time Students: Any person who is currently working toward a degree or diploma is eligible for this category. Students are asked to determine whether their status can be described as a graduate (working toward a degree beyond the bachelor's), an undergraduate (working toward a bachelor's degree), or high school (working toward a high school diploma) and to mark the Registration and Housing Form accordingly.

Graduate Student Member: Any graduate student who is a member of the AMS or MAA is eligible for this category. Students should check with their department administrator to check their membership status.

Emeritus: Any person who has been a member of the AMS for twenty years or more and who retired because of age or long-term disability from his or her latest position is eligible for this category. Any person who has been a member of the MAA for 25 years and who is 70+ years of age is eligible for this category.

Librarian: Any librarian who is not a professional mathematician is eligible for this category.

Unemployed: Any person who is currently unemployed, actively seeking employment, and is not a student is eligible for this category. This category is not intended to include any person who has voluntarily resigned or retired from his or her latest position.

Developing Country Participant: Any person employed in developing countries where salary levels are radically not commensurate with those in the U.S. is eligible for this category.

Temporarily Employed: Any person currently employed but who will become unemployed by June 1, 2015, and who is actively seeking employment is eligible for this category.

Nonmathematician Guest: Any family member or friend, who is not a mathematician, and who is accompanied by a participant in the meetings is eligible for this category. Guests will receive a badge and may accompany a mathematician to a session or talk and may also enter the exhibit area.

How to Obtain Hotel Accommodations – 2015 Joint Mathematics Meetings

Importance of Staying in an Official Joint Mathematics Meetings Hotel

The importance of reserving a hotel room at one of the official Joint Mathematics Meetings (JMM) hotels cannot be stressed enough. The AMS and the MAA make every effort to keep participants expenses at the meeting, registration fees, and hotel rooms for the meeting as low as possible. They work hard to negotiate the best hotel rates and to make the best use of your registration dollars to keep the meetings affordable. The AMS and MAA encourage all participants to register for the meeting. When anyone pays the registration fee and reserves a room with an official JMM hotel, he or she is helping to support not only the JMM in 2015, but also future meetings.

General

Participants are encouraged to register for the JMM in order to reserve hotel rooms at the contracted JMM rates. If a participant needs to reserve a hotel room before they are registered for the JMM, he or she must contact the MMSB at mmsb@ams.org or 1-800-321-4267 ext. 4137 or ext. 4144 for further instructions.

Special rates have been negotiated exclusively for this meeting at the following hotels: Grand Hyatt San Antonio (headquarters), San Antonio Marriott Rivercenter, San Antonio Marriott Riverwalk, Hilton Palacio del Rio, Hyatt Regency San Antonio, LaQuinta Inn and Suites, Westin Riverwalk, Hotel Contessa, Crockett Hotel, SpringHill Suites by Marriott San Antonio Downtown/Alamo Plaza, Fairfield Inn & Suites by Marriott San Antonio Downtown/Alamo Plaza, and Red Roof Plus San Antonio Downtown. (See details on these hotels below.)

To receive the JMM rates, reservations for these hotels must be made through the Mathematics Meetings Service Bureau (MMSB). The hotels will not be able to accept reservations directly until after **December 19, 2014** and at that time, rooms and rates will be based on availability. Any rooms reserved directly with the hotels before **December 19, 2014** are subject to rates higher than the JMM rates.

A link to the 2015 JMM housing site will be included at the end of the online registration form. It will also be included in the email confirmation that will be sent for registration for the meeting. If anyone needs to have the link emailed to him or her, please send the request to mmsb@ams.org. If anyone cannot reserve a room online, please complete the housing section of the Registration and Housing Form and send it by email to the MMSB at mmsb@ams.org or to them by fax at 401-455-4004 before **December 17.** Sorry, reservations cannot be accepted over the phone

All reservations must be guaranteed by either a credit card or check deposit in an amount equivalent to the first night's stay. Only a credit card guarantee can be accepted for any reservation made online. If a paper form is used to reserve a room, a credit card or a check maybe given for the guarantee. For security reasons, credit card numbers will not be accepted by postal mail, email, or fax. If anyone who is reserving a room by paper form wants to guarantee his or her room by credit card, he or she should call the MMSB at 1-800-321-4267, ext. 4137 or 4144. Note that the paper version of the registration form is located at the end of this announcement.

ADA Accessibility

We strive to take the appropriate steps required to ensure that no individual with a disability is excluded, denied services, segregated, or otherwise treated differently. If special assistance, auxiliary aids, or other reasonable accommodations to fully participate in this meeting is required, it should be indicated in the appropriate section on the Registration and Housing Form or emailed to the MMSB at mmsb@ams.org. Requests for ADA-accessible rooms should also be clearly indicated when making hotel reservations. All requests for special accommodations under the Americans with Disabilities Act of 1990 (ADA) must be made allowing enough time for evaluation and appropriate action by the AMS and MAA. Any information obtained about any disability will remain confidential.

Cancellation Policies

- The Hyatt Regency San Antonio, LaQuinta Inn Suites, Crockett Hotel, SpringHill Suites, and Fairfield Inn & Suites have a 24-hour cancellation policy prior to check-in.
- The Grand Hyatt, Marriott Rivercenter, Marriott Riverwalk, Westin Riverwalk, and Hotel Contessa have a 48-hour cancellation policy prior to check-in.
- The Hilton Palacio del Rio and Red Roof Plus have a 72-hour cancellation policy prior to check-in.

Check-in/Check-out

- Check-in at the Hilton Palacio del Rio, Hyatt Regency, LaQuinta Inn & Suites, Westin Riverwalk, Crockett, and Red Roof Inn is 3:00 p.m.
- Check-in at the Grand Hyatt, Marriott Rivercenter, Marriott Riverwalk, Hotel Contessa, SpringHill Suites, and Fairfield Inn & Suites is 4:00 p.m.
- Check-out at the Grand Hyatt, Hotel Contessa, and Red Roof Plus is 11:00 a.m. Check-out at all of the other hotels is noon.

Complimentary Room Drawing

Participants who register and reserve a hotel room by **November 3, 2014,** will be included in a lottery for complimentary hotel room nights during the meeting. Rooms with multiple occupants will be included. The winners will be notified by phone and/or email prior to **December 23, 2014**.

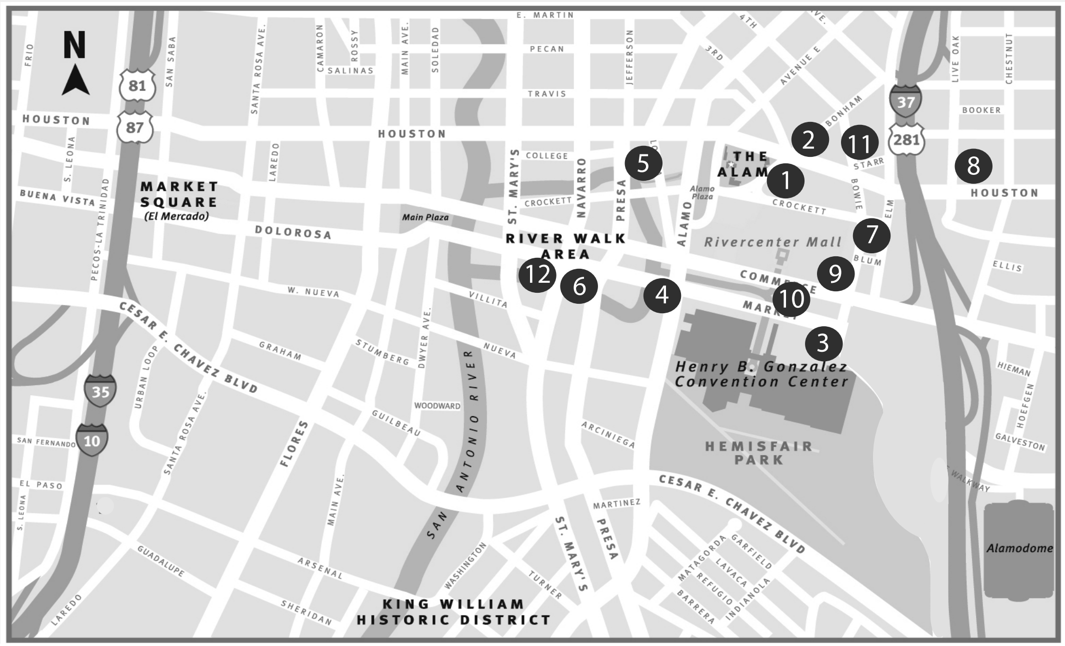
Confirmations

An immediate and real-time email confirmation number will be provided for each hotel reservation made online. This confirmation number will provide participants with direct access to edit reservations up to **December 17, 2014**. After this date, a second email confirmation for the hotel reservation will be sent from the hotel, with the exception of the Hotel Contessa, which will send a second confirmation only if contacted directly. Those who did not receive a confirmation number from their hotels or who have any questions about the reservation process should contact the MMSB at mmsb@ams.org or 1-800-321-4267, ext. 4137 or 4144.

Deadlines

· Complimentary Room Drawing:	**November 3**
· Badge/Program Mailed:	**November 18**
· Reservations, Changes, and Cancellations through the MMSB:	**December 17**

	Hotels	Address	Distance to Conv Center (in blocks)	Walk to Conv Center (in minutes)
1	The Crockett	320 Bonham Street	2.5	7
2	Fairfield Inn & Suites San Antonio Downtown / Alamo Plaza	422 Bonham Street	4	9
3	Grand Hyatt San Antonio (Headquarters)	600 E Market Street	Adjacent	2
4	Hilton Palacio del Rio	200 S Alamo Street	1	4
5	Hyatt Regency San Antonio	123 Losoya Street	3	5
6	Hotel Contessa	306 W Market Street	2	5
7	La Quinta Inn & Suites Convention Center	303 Blum	2	6
8	Red Roof Plus San Antonio Downtown	1011 E Houston Street	5	14
9	San Antonio Marriott Rivercenter	101 Bowie Street	1.5	4
10	San Antonio Marriott Riverwalk	889 E Market Street	Across street	2
11	SpringHill Suites San Antonio Downtown / Alamo Plaza	411 Bowie Street	4	11
12	The Westin Riverwalk San Antonio	420 W Market Street	3	5



Map courtesy of the San Antonio Convention and Visitor's Bureau

Environmental Policies

All of the hotels listed have environmental-friendly programs in place.

Internet Access/Wireless

· The Hyatt Regency, Hotel Contessa, Crockett, La Quinta Inn & Suites, SpringHill Suites, Fairfield Inn & Suites, and Red Roof Plus offer complimentary wireless in the guest rooms and all public areas, including the lobby.

· The Grand Hyatt offers complimentary wireless in all public areas, and wired or wireless Internet connections in the guest rooms for a daily usage fee of US$14.95 per day.

· The Marriott Rivercenter, Marriott Riverwalk, and Hilton Palacio del Rio offer complimentary wireless in the lobby and public areas and wired or wireless Internet in the guest rooms for a daily usage fee of US$12.95.

· The Westin Riverwalk offers complimentary wireless Internet in all public areas and wireless access in the guest rooms for a daily usage fee of US$13.95.

Looking for a Roommate?

For participants looking for a roommate, an interactive search board is available at: http://bboards.jointmathematicsmeetings.org.

Rates

All rates are subject to applicable local and state taxes in effect at the time of check-in; currently 16.75% state tax.

Parking Options

Please see the Parking section under "Travel" for additional parking options.

JOINT MATHEMATICS MEETINGS
SAN ANTONIO · JAN 10-13, 2015
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

Grand Hyatt San Antonio (Headquarters)	San Antonio Marriott Rivercenter	San Antonio Marriott Riverwalk
456 feet (next door) to the Henry B. Gonzalez Convention Center 600 East Market Street San Antonio, TX 78205 Single Rate: US$189 Double Rate: $209 Student Single/Double Rate: US$159 Smoke-free hotel. Restaurants: Ruth's Chris Steak House, Perk Coffee & More, Bar Rojo; Fitness center; Heated outdoor lap pool; Whirlpool sun deck; 24-hour business center available to registered guests; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows do not open; Children under 18 free in room with an adult; Cribs available upon request at no charge; Rollaways available in king-bedded rooms only at no charge; Dogs under 50 pounds only allowed for an additional charge; Valet parking US$37 per day with in/out privileges; Self-parking US$27 per day with in/out privileges; Parking rates are subject to change. The hotel does not provide airport shuttle transportation. Confirmations sent by email only.	**0.2 miles from the Henry B. Gonzalez Convention Center** 101 Bowie Street San Antonio, TX 78205 Single/Double Rate: US$185 Student Single/Double Rate: US$175 Smoke-free hotel. Restaurants: Sazo's, The Bar, Starbucks Coffee; Fitness center; Indoor/Outdoor pool; UPS Store/Business center, 24-hour access for registered guests; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows do not open; Children under 18 free in room with an adult; Cribs available upon request at no charge; Rollaways - US$15 one-time charge in king-bedded rooms only; Pets are not allowed except for service animals; Valet parking US$35 per day with in/out privileges; Self-parking US$25 per day with in/out privileges; Parking rates are subject to change. This hotel does not provide airport shuttle service. Confirmations sent by email only.	**292 feet (across the street) from the Henry B. Gonzalez Convention Center** 889 East Market Street San Antonio, TX 78205 Single/Double Rate: US$185 Student Single/Double Rate: US$175 Smoke-free hotel. Restaurants: The Cactus Flower, The Bar, Starbucks Coffee; Fitness center; Indoor/Outdoor pool; Business center with 24-hour access for registered guests; Full amenities in guest rooms; Windows do not open; Children under 18 free in room with an adult; Cribs available upon request at no charge; Rollaways - US$15 one-time charge in king-bedded rooms only; Pets are not allowed except for service animals; Valet parking US$35 per day with in/out privileges; Self-parking US$25 per day with in/out privileges; Parking rates are subject to change. This hotel does not provide an airport shuttle. Confirmations sent by email only.
Hilton Palacio del Rio	**Hyatt Regency San Antonio**	**Hotel Contessa**
0.3 miles from the Henry B. Gonzalez Convention Center 200 South Alamo Street San Antonio, TX 78205 Single/Double Rate: US$179 Student Single/Double Rate: US$159 Smoke-free hotel. Restaurants: Ricon Alegre Lobby Bar, Durty Nelly's Irish Pub, Texas Riverwalk Sports Bar, The River's Edge Cafe; Fitness center; Outdoor pool; UPS Store/Business center; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows do not open; Children under 18 free in room with an adult; Cribs available upon request at no charge; Air mattresses (no rollaways) - US$25 one-time charge in king-bedded rooms only; Pets not allowed except for service animals; Valet parking US$39 per day with in/out privileges; Self-parking US$27 per day with in/out privileges; Parking rates are subject to change. This hotel does not provide an airport shuttle. Confirmations sent by email only.	**0.3 miles from the Henry B. Gonzalez Convention Center** 123 Losoya Street San Antonio, TX 78205 Single/Double Rate: US$159 Student Single/Double Rate: US$135 Smoke-free hotel. Restaurants: Q Restaurant, Starbucks Coffee, Einstein Bros Bagels; Fitness center; Heated rooftop pool; Fedex Business center with 24-hour access to registered guests; Safe deposit boxes at front desk; Full amenities in guest rooms; Windows do not open; Children under 12 free in room with an adult; Cribs available upon request at no charge; Rollaways US$25 daily charge in king-bedded rooms only; Pets not allowed except for service animals; Valet parking US$35 per day with in/out privileges; Self-parking US$25 per day with in/out privileges; Parking rates are subject to change. Airport shuttle reservations can be made online through SATRANS Airport Shuttle. Confirmations sent by email only.	**0.3 miles from the Henry B. Gonzalez Convention Center** 306 West Market Street San Antonio, TX 78205 Single/Double Rate: US$140 Student Single/Double Rate: US$130 Smoke-free hotel. Restaurants: Cork Bar, Las Ramblas, and Cafe Contessa; Fitness center; Heated rooftop pool; 24-hour business center available to registered guests; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows do not open; Children under 17 free in room with an adult; Cribs available upon request at no charge; No rollaways; All rooms have sleeper sofas; Small dogs are allowed, call for details; Self-parking only for US$30 per day with in/out privileges; Limited parking spaces available for oversized vehicles, guests must call in advance to reserve. The hotel does not provide an airport shuttle. 2nd confirmation sent from hotel by request only.

La Quinta Inn & Suites

0.3 miles from the Henry B. Gonzalez Convention Center

303 Blum Street
San Antonio, TX 78205
Single/Double Rate: US$135
Student Single/Double Rate: US$125

Smoke-free hotel. A complimentary hot breakfast is served daily and a full-service lounge offers food service daily after 5:00 p.m. Fitness center; Outdoor pool; 24-hour business center available to registered guests; Full amenities in guest rooms; Safety deposit boxes available in the front office; Children under 18 free in room with an adult; Cribs available upon request at no charge; No rollaways; Pets are allowed at no charge; Valet parking US$25 per day with in/out privileges; Self-parking US$21 per day with in/out privileges; Parking rates are subject to change. This hotel does not provide an airport shuttle. Confirmations sent by email only.

The Westin Riverwalk, San Antonio

0.2 miles from the Henry B. Gonzalez Convention Center

420 West Market Street
San Antonio, TX 78205
Single/Double Rate: US$135

Smoke-free hotel. Restaurants: Cafecito Café, Zocca Restaurant & Bar; Fitness center; Heated outdoor pool; Spa; 24-hour business center available to registered guests; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows do not open; Children under 17 free in room with an adult; Cribs available upon request at no charge; Rollaways available in king-bedded rooms only at no charge; Dogs up to 40 lbs. allowed; Valet parking for US$35 per day with in/out privileges; Self-parking US$16 per day without in/out privileges; Parking rates are subject to change. This hotel does not provide an airport shuttle. Confirmations sent by email only.

The Crockett

0.4 miles from the Henry B. Gonzalez Convention Center

320 Bonham Street
San Antonio, TX 78205
Single/Double Rate: US$130
Student Single/Double Rate: US$120

Historic hotel, wheelchair entry access is limited. Smoke-free hotel. This hotel offers complimentary breakfast daily and room service; 24-hour business center available to registered guests; Full amenities in guest rooms; Safe deposit boxes at front desk; Windows do not open. Children under 18 free in room with an adult; Cribs available upon request at no charge; Rollaways-US$25 one-time charge in king-bedded rooms only; Pets are allowed with a US$60 nonrefundable deposit; Valet parking only for US$25 per day with in/out privileges; Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations sent by email only.

SpringHill Suites by Marriott Downtown/Alamo Plaza

0.4 miles from the Henry B. Gonzalez Convention Center

411 Bowie Street
San Antonio, TX 78205
Single/Double Rate: US$94
Student Single/Double Rate: US$84

Smoke-free hotel. The hotel offers a complimentary hot breakfast daily. Fitness center; Outdoor heated pool; 24-hour business center available to registered guests; Full amenities in guest rooms; Windows do not open; Children under 17 free in room with an adult; Cribs available upon request at no charge; No rollaways; Pets are not allowed except for service animals; Valet parking only for US$21 per day with in/out privileges; Parking rates are subject to change. This hotel does not provide an airport shuttle. Confirmations sent by email only.

Fairfield Inn & Suites by Marriott Downtown/Alamo Plaza

0.5 miles from the Henry B. Gonzalez Convention Center

422 Bonham Street
San Antonio, TX 78205
Single/Double Rate: US$94
Student Single/Double Rate: US$84

Smoke-free hotel. The hotel offers a complimentary hot breakfast daily. Fitness center; Outdoor pool; 24-hour business center available to registered guests; Full amenities in guest rooms; Windows do not open; Children under 17 free in room with an adult; Cribs available upon request at no charge; No rollaways; Pets are not allowed except for service animals; Valet parking only for US$21 per day with in/out privileges; Parking rates are subject to change. This hotel does not provide an airport shuttle. Confirmations sent by email only.

Red Roof Plus San Antonio Downtown

0.5 miles from the Henry B. Gonzalez Convention Center

1011 East Houston Street
San Antonio, TX 78205
Single/Double Rate: US$83
Student Single/Double Rate: US$73

Smoke-free hotel. There are no restaurants on property, but complimentary continental breakfast is served each morning. Outdoor pool; 24-hour business center available to registered guests; Full amenities in guest rooms; Laptop-sized safes in guest rooms for US$1.50 daily; Windows do not open; Children under 17 free in room with an adult; Portable cribs available upon request at no charge; No rollaways; Pets allowed; Self-parking only for US$10 per night with in/out privileges; Parking rates are subject to change. This hotel does not provide an airport shuttle. Confirmations sent by email only.

Registration Deadlines

There are three separate registration deadlines, each with its own benefits:

EARLY meetings registration (free room drawing) is **November 3**;

ORDINARY meeting registration (badge materials mailed) is **November 18**;

FINAL meeting registration (advanced registration, short course, minicourses, and banquets) is **December 23**;

Early Registration: Participants who **register by the early deadline of November 3** will be included in a random drawing to select winners of complimentary hotel room nights during the meeting. Rooms with multiple occupants will be included in the drawing. The location of these rooms will be based on the number of complimentary room nights earned in the various hotels. Therefore, a free room will not necessarily be in winner's first-choice hotel. All winners will be notified by phone and email prior to December 23, so register early!

Ordinary Registration: Participants who register **after November 3 and by the ordinary deadline of November 18** are encouraged to reserve a hotel room to ensure that they receive their preferred hotel of choice. However, those who register by this date are not eligible for the room drawing. They may also elect to receive their badges and programs by mail in advance of the meeting.

Final Registration: Participants who register **after November 18 and by the final deadline of December 23** must pick up their badges, programs, and any tickets for social events at the meeting. Unfortunately it is sometimes not possible to provide final participants with housing, so everyone is strongly urged to make their hotel reservations by November 18. Please note that the final deadline of December 23 is firm. Any forms received after that date will be returned with full refunds. Registration materials may be picked up at the Meetings Registration Desk located on the first floor of the Henry B. Gonzalez Convention Center.

Miscellaneous Information

Audio-Visual Equipment: Standard equipment in all session rooms is one overhead projector and screen. Invited 50-minute speakers are automatically provided with an ELMO visual presenter (document camera/projector), one overhead projector, and a laptop projector; AMS Special Sessions and Contributed Papers, and MAA Invited and Contributed Paper Sessions, are provided with the standard equipment and a laptop projector. Blackboards are not available, nor are Internet hookups in session rooms. Any request for additional equipment should be sent to meet@ams.org and **received by November 1**.

Equipment requests made at the meetings most likely will not be granted because of budgetary restrictions. Unfortunately no audiovisual equipment can be provided for committee meetings or other meetings or gatherings not on the scientific program.

Childcare: The AMS and the MAA will provide reimbursement grants of US$250 per family to help with the cost of child care for a number of registered participants at JMM2015. The funds may be used for child care that frees a parent to participate more fully in JMM.

Information about and deadlines for requesting support for child care will be available prior to the opening of advance registration in September; watch the website at jointmathematicsmeetings.org/meetings/national/jmm2015/2168_intro.

Email Services: Limited email access for all Joint Meetings participants will be available in an email center located near the JMM Registration Desk, East Lobby, on the first level in the Henry B. Gonzales Convention Center. The hours of operation will be published in the program. Participants should be aware that **complimentary Internet access** will be available in the networking center located in Bridge Hall, first level of the convention center.

Information Distribution: Tables are set up in the exhibit area for dissemination of general information of possible interest to the members and for the dissemination of information of a mathematical nature not promoting a product or program for sale. Information must be approved by the director of meetings prior to being placed on these tables.

If a person or group wishes to display information of a mathematical nature promoting a product or program for sale, they may do so in the exhibit area at the Joint Books, Journals, and Promotional Materials exhibit for a fee of US$50 (posters are slightly higher) per item. Please contact the exhibits manager, MMSB, P.O. Box 6887, Providence, RI 02940, or by email at cpd@ams.org for further details.

The administration of these tables is in the hands of the AMS-MAA Joint Meetings Committee, as are all arrangements for Joint Mathematics Meetings.

Local Information: For information about the city see visitsanantonio.com.

Photograph and Video Policy: The videotaping of any AMS or joint sponsored events, talks, and sessions is strictly forbidden without the explicit written permission of the AMS Director of Meetings and Conferences. The policy for videotaping of any MAA events, talks, and sessions is posted at http://www.maa.org/about-maa/policies-and-procedures/recording-or-broadcasting-of-maa-events. Photographs and videos of meeting interactions will be taken by professional photographers hired by the Joint Mathematics Meetings or by AMS and MAA staff. These photographs and videos may occasionally be used for publicity purposes. By participating in the Joint Mathematics Meetings, attendees acknowledge that their photograph or a video that includes them may be published in material produced by the Joint Meetings, AMS or MAA. AMS and MAA are not responsible for unauthorized photographs or other images not taken by professional photographers hired by the Joint Mathematics Meetings or AMS and MAA staff.

Telephone Messages: It will be possible to leave a message for any registered participant at the meetings registration desk from January 10 through 13 during the hours that the desk is open. These messages will be posted on the Mathematics Meetings Message Board in the networking center; however, staff at the desk will try to locate a participant in the event of a bona fide emergency.

The telephone number will be published in the program and daily newsletter.

Travel/Transportation

San Antonio is on Central Standard Time. The principal airport is the San Antonio International Airport (SAT), http://www.sanantonio.gov/SAT/, which is served by all major airlines, and is located nine miles north of downtown San Antonio. The street address of the airport is 9800 Airport Boulevard, San Antonio, Texas 78216. The 2015 Joint Mathematics Meetings will be held in the Henry B. Gonzalez Convention Center, located at 200 Market Street, San Antonio, TX 78205.

Airline: The official airline for this meeting is Delta. Participants are encouraged to book their flights for the meeting, if possible, with Delta and receive special pricing (in most cases a 5% discount) on scheduled service to San Antonio. Discounts are applicable to U.S. and Canada originating passengers. The discount is not valid with other discounts, certificates, coupons, or promotional offers. To make a reservation, go to www.delta.com, and click on the box that says "Book a Trip." At the bottom of the drop-down, click on "More Search Options" (includes Flexible Airport and Meeting Event Code). On the reservation screen, please enter the **Meeting Event Code NMJYY**. It will be to the right of "Number of Passengers." Reservations can also be made by calling Delta Meeting Network reservations at 1-800-328-1111 and citing the meeting event code. A direct ticketing charge will apply for booking by phone.

Ground Transportation: Options are located curbside in front of Terminal A and B baggage claim areas. Uniformed transportation agents (wearing red shirts) can provide assistance. A terminal map is located at http://www.sanantonio.gov/SAT/IntheAirport/TerminalMaps.aspx.

Airport Shuttle: GO Airport Shuttle, www.citytoursinc.com, 210-281-9900, is San Antonio Airport's authorized airport shuttle service. Shuttles depart every 15 minutes from 7:00 a.m. to 1:30 a.m. daily to the downtown hotels. The fare is US$19 per person one way, or US$34 for a round trip. There is currently a fuel surcharge of US$1.25 each way. Tickets may be purchased in the baggage claim area. You may also book a shuttle online at https://citytoursinc.com/reservations.

Car Rental: All major car rental services are available at the San Antonio International Airport. Car rental counters are located on the lower level of Terminal A. If the rental counters are closed, passengers can use the courtesy phones provided in the baggage claim area to request shuttle transport to the car rental company of their choice.

Hertz is the official car rental company for the meeting. A brochure with the information on this meeting is located at http://jointmathematicsmeetings.org/meetings/national/jmm2015/Hertz-info-SanAntonio.pdf. To access the JMM special meeting rates at www.hertz.com, please click the box that says "Enter a discount or promo code" and enter **04N30005** as the convention number (CV#). Reservations can also be made by calling Hertz directly at 800-654-2240 (U.S. and Canada) or 405-749-4434. Meeting rates include unlimited mileage and are subject to availability. Advance reservations are recommended and blackout dates may apply. Government surcharges, taxes, tax reimbursement, airport-related fees, vehicle licensing fees and optional items are extra. Standard rental conditions and qualifications apply. Minimum rental age is 20 (age differential charge for 20–24 applies). At the time of your reservation, the meeting rates will be automatically compared to other Hertz rates and you will be quoted the best comparable rate available.

Driving directions from the airport to the Convention Center: Take Highway 281 South toward downtown San Antonio. Take the Commerce Street exit, 141A, toward downtown. Keep right to take the ramp toward Downtown/The Alamo. Merge onto East Commerce Street. Turn left onto Losoya Street. Turn left onto East Market Street. The Convention Center is located on your right.

Taxi: Taxis are available at the lower level curbside outside the baggage claim area. Fares to downtown San Antonio start at US$29.

Public Transportation: VIA Metropolitan Transport (http://www.viainfo.net), 210-362-2020 or 866-362-2020, is San Antonio's public transportation agency. To take public transportation downtown from the airport, exit the baggage claim area in Terminals A and B and go to the Lower Roadway across the marked crosswalk to the outer curb. The VIA bus stop is halfway between Terminals A and B.

Take VIA bus 5-McCullough (South) to the St. Mary's and Commerce stop. To get to the Convention Center, walk down St. Mary's Street one block to the intersection of St. Mary's and Market Street, and take the 22-Hayes (East) bus down Market. The second stop after Market and St. Mary's is the Convention Center. Note: 5-McCullough continues as 30-Rigsby (South) after St. Mary's and Pecan; you do not have to change buses. The stop after St. Mary's and Commerce is St. Mary's and Villita, where you can pick up the 301 Streetcar as an alternative for some destinations.

The trip from the airport to the Convention Center takes approximately 50 minutes. The 5-McCullough runs from 5:30 a.m. to 9:40 p.m. every day, approximately every 30 minutes until 7:30 p.m. The last two buses are 60 minutes apart.

Please call VIA directly and ask to speak to an agent, or check the route finder at http://www.viainfo.net/BusService/RiderTool.aspx?ToolChoice=Schedules if you would like directions to other locations. Prices and schedules are subject to change. The fare is currently US$1.20 per ride; US$2.50 for Express. A VIA day pass is US$4, and can be obtained at the San Antonio Visitor Center at 317 Alamo Plaza.

Two VIA Streetcar routes, Red (301) and Blue (305), serve many of the popular destinations in downtown San Antonio. The streetcars circulate every 10 minutes, seven days a week. Hours of operation are 7:00 a.m. to 10:30 p.m., Monday through Friday, and 9:00 a.m. to 10:30 p.m. on weekends. Information and a map of the routes can be found at www.viainfo.net/BusService/Docs/StreetcarBrochure.pdf.

Note that the VIA 7-Sightseer Special bus travels to the San Antonio Children's Museum, the San Antonio Museum of Art, Brackenridge Park, the San Antonio Zoo, Witte Museum, and the Botanical Garden. See `http://www.viainfo.net/BusService/Schedules.aspx`.

Parking: The city of San Antonio has a parking page at `http://downtownsanantonio.org/park/parkingoverview`, which has an interactive map and a pdf map of parking locations. The Henry B. Gonzalez Convention Center lists the following parking garages as being the closest available. Prices are subject to change.

Grand Hyatt Parking Garage, (210-451-6464), Bowie and Market Streets; flat rates are US$9 for up to 3 hours, US$16 for 3–4 hours, US$21 for 4–5 hours, and US$27 for 5+ hours or overnight (per day).

Marina Garage, (210-207-8266), Bowie and Commerce Streets; daily flat rate is US$9.

Riverbend Garage, (877-717-0004), Alamo and Market Streets; daily flat rate is US$12, overnight rate is US$15.

Tower of the Americas Parking, (210-223-3101), 801 Cesar Chavez Blvd.; daily flat rate is US$8.

Washington, District of Columbia

Georgetown University

March 7–8, 2015

Saturday – Sunday

Meeting #1107

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2015
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: March 2015
Issue of *Abstracts*: Volume 36, Issue 2

Deadlines

For organizers: Expired
For abstracts: January 20, 2015

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

Invited Addresses

Frederico Rodriguez Hertz, Pennsylvania State University, *Title to be announced.*

Nancy Hingston, The College of New Jersey, *Title to be announced.*

Simon Tavaré, Cambridge University, *Title to be announced* (Einstein Public Lecture in Mathematics).

Yitang Zhang, University of New Hampshire, *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 `http://www.ams.org/cgi-bin/abstracts/abstract.pl`.

Algebra and Representation Theory (Code: SS 13A), **Ela Celikbas** and **Olgur Celikbas**, University of Connecticut, and **Frank Moore**, Wake Forest University.

Algebraic Structures Motivated by and Applied to Knot Theory (Code: SS 18A), **Jozef H. Przytycki**, George Washington University, and **Radmilla Sazdanovic**.

Computable Structure Theory (Code: SS 8A), **Rumen Dimitrov**, Western Illinois University, **Valentina Harizanov**, George Washington University, and **Russell Miller**, Queens College and Graduate Center, City University of New York.

Conceptual Mathematical Models in Climate Science (Code: SS 5A), **Hans Engler** and **Hans Kaper**, Georgetown University.

Convexity and Combinatorics (Code: SS 9A), **Jim Lawrence** and **Valeriu Soltan**, George Mason University.

Crossing Numbers of Graphs (Code: SS 3A), **Paul Kainen**, Georgetown University.

History and Philosophy of Mathematics (Code: SS 15A), **V. Frederick Rickey**, West Point Military Academy, and **James J. Tattersall**, Providence College.

Iterated Integrals and Applications (Code: SS 12A), **Ivan Horozov**, Washington University in St. Louis.

Mathematical Fluid Dynamics and Turbulence (Code: SS 17A), **Zachary Bradshaw**, University of British Columbia, **Aseel Farhat**, Indiana University, and **Michele Coti Zelati**, University of Maryland.

Nonlinear Partial Differential Equations in Sciences and Engineering. (Code: SS 16A), **Lorena Bociu**, North Carolina State University, **Ciprian Gal**, Florida International University, and **Daniel Toundykov**, University of Nebraska.

Nonlinear Dispersive and Wave Equations with Applications to Fluids. (Code: SS 14A), **Pierre Germain** and **Zaher Hani**, New York University, and **Benoit Pausader**, Princeton University.

Operator Theory on Analytic Function Spaces (Code: SS 11A), **Robert F. Allen**, University of Wisconsin, La Cross, and **Flavia Colonna**, George Mason University.

Qualitative Behavior of Solutions of Partial Differential Equations (Code: SS 7A), **Junping Shi**, College of William and Mary, and **Jiuyi Zhu**, Johns Hopkins University.

Quantum Algebras, Representations, and Categorifications (Code: SS 2A), **Sean Clark** and **Weiqiang Wang**, University of Virginia.

Somos Sequences and Nonlinear Recurrences (Code: SS 10A), **Andrew Vogt**, Georgetown University.

Spatial Evolutionary Models and Biological Invasions (Code: SS 6A), **Judith Miller**, Georgetown University, and **Yuan Lou**, Ohio State University.

Topology in Biology (Code: SS 4A), **Paul Kainen**, Georgetown University.

Within-Host Disease Modeling (Code: SS 1A), **Stanca Ciupe**, Virginia Polytechnic Institute, and **Sivan Leviyang**, Georgetown University.

East Lansing, Michigan

Michigan State University

March 14–15, 2015
Saturday – Sunday

Meeting #1108

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: January 2015
Program first available on AMS website: January 29, 2015
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 36, Issue 2

Deadlines

For organizers: Expired
For abstracts: January 20, 2015

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

Invited Addresses

Philippe Di Francesco, University of Illinois, *Title to be announced*.

Alexander Furman, University of Illinois at Chicago, *Title to be announced*.

Vera Mikyoung Hur, University of Illinois at Urbana-Champaign, *Title to be announced*.

Mihnea Popa, University of Illinois at Chicago, *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 http://www.ams.org/cgi-bin/abstracts/abstract.pl.

Algebraic Combinatorics (Code: SS 19A), **Carolina Benedetti**, **Peter Magyar**, and **Bruce Sagan**, Michigan State University.

Approximation Theory in Signal Processing and Computer Science (Code: SS 5A), **Mark Iwen**, Michigan State University, **Rayan Saab**, University of California San Diego, and **Aditya Viswanathan**, Michigan State University.

Arithmetic of Hyperelliptic Curves (Code: SS 3A), **Tony Shaska**, Oakland University.

Complex Analysis in Several Variables and its Applications (Code: SS 11A), **Debraj Chakrabarti**, Central Michigan University, and **Yunus Zeytuncu**, University of Michigan at Dearborn.

Conformal Geometry and Statistical Physics (Code: SS 20A), **Ilia Binder**, University of Toronto, and **Dapeng Zhan**, Michigan State University.

Fractals and Tilings (Code: SS 10A), **Sze-Man Ngai**, Georgia Southern University, **Erin Pearse**, California Polytechnic State University, **Yang Wang**, Hong Kong University of Science and Technology, and **Yimin Xiao**, Michigan State University.

Fractional Calculus and Nonlocal Operators (Code: SS 1A), **Mark M. Meerschaert** and **Russell Schwab**, Michigan State University.

Frames, Wavelets and Their Applications (Code: SS 16A), **Palle Jorgensen**, University of Iowa, **Darrin Speegle**, St. Louis University, and **Yang Wang**, Hong Kong University of Science and Technology.

Geometry and Invariants of 3-Manifolds (Code: SS 22A), **Oliver Dasbach**, Louisiana State University, and **Effie Kalfagianni**, Michigan State University.

Geometry of Manifolds, Singular Spaces, and Groups (Code: SS 18A), **Benjamin Schmidt**, Michigan State University, and **Meera Mainkar**, Central Michigan University.

Groups and Representations (Code: SS 9A), **Amanda Schaeffer Fry**, Metropolitan State University of Denver, **Jonathan Hall**, Michigan State University, and **Hung Nguyen**, University of Akron.

High-Frequency Problems (Code: SS 14A), **Shlomo Levental** and **Mark Schroder**, Michigan State University.

Homotopy Continuation Methods and Their Applications to Science and Engineering (Code: SS 6A), **Tianran Chen**, Michigan State University, and **Dhagash Mehta**, North Carolina State University.

Inverse Problems and Imaging (Code: SS 21A), **Yulia Hristova**, University of Michigan-Dearborn, and **Linh Nguyen**, University of Idaho.

Modeling, Numerics, and Analysis of Electro-Diffusion Phenomena (Code: SS 17A), **Peter W. Bates**, Michigan State University, **Weishi Liu**, University of Kansas, and **Mingji Zhang**, MIchigan State University.

New Developments in Actuarial Mathematics (Code: SS 15A), **Emiliano A. Valdez**, Michigan State University.

New Developments in Stochastic Analysis, Stochastic Control and Related Fields (Code: SS 7A), **Chao Zhu**, University of Wisconsin-Milwaukee.

Nonlinear Waves: Dynamics and Stability (Code: SS 23A), **Keith Promislow** and **Qiliang Wu**, Michigan State University.

Phase Retrieval in Theory and Practice (Code: SS 8A), **Matthew Fickus**, Air Force Institute of Technology, **Mark Iwen**, Michigan State University, and **Dustin Mixon**, Air Force Institute of Technology.

Random Fields and Long Range Dependence (Code: SS 2A), **Mark M. Meerschaert** and **Yimin Xiao**, Michigan State University.

Recent Advances in the Geometry of Submanifolds, Dedicated to the Memory of Franki Dillen (1963-2013) (Code: SS 12A), **Alfonso Carriazo Rubio**, University of Sevilla, **Yun Myung Oh**, Andrews University, **Bogdan D. Suceavă**, California State University, Fullerton, and **Joeri Van der Veken**, KU Leuven.

Stochastic Partial Differential Equations and Applications (Code: SS 4A), **Leszek Gawarecki**, Kettering University, and **Vidyadhar Mandrekar**, Michigan State University.

Survey of Biomathematics (Code: SS 13A), **Hannah Callender**, University of Portland, **Peter Hinow**, University of Wisconsin, Milwaukee, and **Deena Schmidt**, Case Western Reserve University.

Huntsville, Alabama

University of Alabama in Huntsville

March 27–29, 2015

Friday – Sunday

Meeting #1109

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: January 2015
Program first available on AMS website: February 11, 2015
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 36, Issue 2

Deadlines

For organizers: Expired
For abstracts: February 4, 2015

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

Invited Addresses

Eva Bayer-Fluckiger, EPFL, *Title to be announced.*

M. Gregory Forest, University of North Carolina at Chapel Hill, *Title to be announced.*

Dan Margalit, Georgia Institute of Technology, *Title to be announced.*

Paul Pollack, University of Georgia, *Title to be announced.*

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at http://www.ams.org/cgi-bin/abstracts/abstract.pl.

Fractal Geometry and Ergodic Theory (Code: SS 1A), **Mrinal Kanti Roychowdhury**, University of Texas-Pan American.

New Developments in Population Dynamics and Epidemiology (Code: SS 4A), **Jia Li**, University of Alabama in Huntsville, **Maia Martcheva**, University of Florida, and **Necibe Tuncer**, Florida Atlantic University.

Recent Trends in Mathematical Biology (Code: SS 3A), **Wandi Ding** and **Zachariah Sinkala**, Middle Tennessee State University.

Stochastic Processes and Related Topics (Code: SS 2A), **Paul Jung**, University of Alabama at Birmingham, **Erkan Nane**, Auburn University, and **Dongsheng Wu**, University of Alabama in Huntsville.

Topology and Topological Methods in Dynamical Systems (Code: SS 5A), **John Mayer** and **Lex Oversteegen**, University of Alabama at Birmingham.

Las Vegas, Nevada

University of Nevada, Las Vegas

April 18–19, 2015

Saturday – Sunday

Meeting #1110

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: February 2015
Program first available on AMS website: March 5, 2015
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 36, Issue 2

Deadlines

For organizers: September 18, 2014
For abstracts: February 24, 2015

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

Invited Addresses

Joel Hass, University of California, Davis, *Title to be announced.*

Ko Honda, University of California, Los Angeles, *Title to be announced.*

Brendon Rhoades, University of California, San Diego, *Title to be announced.*

Bianca Viray, 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 http://www.ams.org/cgi-bin/abstracts/abstract.pl.

Algebraic Structures in Knot Theory (Code: SS 7A), **Sam Nelson**, Claremont McKenna College, and **Radmila Sazdanović**, North Carolina State University.

Algebraic and Enumerative Combinatorics (Code: SS 8A), **Drew Armstrong**, University of Miami, and **Brendon Rhoades**, University of California, San Diego.

Cloaking and Metamaterials (Code: SS 9A), **Jichun Li**, University of Nevada, Las Vegas, and **Fernando Guevera Vasquez**, University of Utah.

Data Analysis and Physical Processes (Code: SS 4A), **Hanna Makaruk**, Los Alamos National Laboratory, and **Eric Machorro**, National Security Technologies.

Developments of Numerical Methods and Computations for Fluid Flow Problems (Code: SS 11A), **Monika Neda**, University of Nevada, Las Vegas.

Extremal and Structural Graph Theory (Code: SS 10A), **Bernard Lidický** and **Derrick Stolee**, Iowa State University.

Inverse Problems and Related Mathematical Methods in Physics (Code: SS 1A), **Hanna Makaruk**, Los Alamos National Laboratory, and **Robert Owczarek**, University of New Mexico, Albuquerque.

Nonlinear Conservation Laws and Applications (Code: SS 6A), **Matthias Youngs**, Indiana University-Purdue University Columbus, **Cheng Yu**, University of Texas at Austin, and **Kun Zhao**, Tulane University.

Stochastic Analysis and Rough Paths (Code: SS 2A), **Fabrice Baudoin**, Purdue University, **David Nualart**, University of Kansas, and **Cheng Ouyang**, University of Illinois at Chicago.

Topics in Graph Theory: Structural and Extremal Problems (Code: SS 3A), **Jie Ma**, Carnegie Mellon University, **Hehui Wu**, Simon Fraser Univerisy, and **Gexin Yu**, College of William & Mary.

Porto, Portugal

University of Porto

June 10–13, 2015

Wednesday – Saturday

Meeting #1111

First Joint International Meeting involving the American Mathematical Societry (AMS), the European Mathematical Society (EMS), and the Sociedade de Portuguesa Matematica (SPM).
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: Expired
For abstracts: To be announced

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

Invited Addresses

Marcus du Sautoy, *The secret mathematicians* (Public Lecture, Wednesday evening, 8:30 p.m.)

Rui Loja Fernandes, University of Illinois at Urbana-Champaign, *Title to be announced*.

Irene Fonseca, Carnegie Mellon University, *Title to be announced*.

Annette Huber, Albert-Ludwigs-Universität, *Title to be announced*.

Mikhail Khovanov, Columbia University, *Title to be announced*.

André Neves, Imperial College London, *Title to be announced*.

Sylvia Serfaty, Université Pierre et Marie Curie Paris 6, *Title to be announced*.

Gigliola Staffilani, Massachusetts Institute of Technology, *Title to be announced*.

Marcelo Viana, Instituto de Matemática Pura e Aplicada, Brasil, *Title to be announced*.

Chicago, Illinois

Loyola University Chicago

October 3–4, 2015

Saturday – Sunday

Meeting #1112

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: June 2015
Program first available on AMS website: August 20, 2015
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 36, Issue 4

Deadlines

For organizers: March 10, 2015
For abstracts: August 11, 2015

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

Invited Addresses

Julia Chuzhoy, Toyota Technological Institute at Chicago, *Title to be announced*.

Andrew Neitzke, The University of Texas at Austin, *Title to be announced*.

Sebastien Roch, University of Wisconsin-Madison, *Title to be announced*.

Peter Sarnak, Princeton University, *Title to be announced* (Erdős Memorial Lecture).

Memphis, Tennessee

University of Memphis

October 17–18, 2015

Saturday – Sunday

Meeting #1113

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: August 2015
Program first available on AMS website: September 3, 2015
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 36, Issue 3

Deadlines

For organizers: March 17, 2015
For abstracts: August 25, 2015

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

Invited Addresses

Mark van Hoeij, Florida State University, *Title to be announced*.

Vaughan Jones, Vanderbilt University, *Title to be announced.*

Mette Olufsen, 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 `http://www.ams.org/cgi-bin/abstracts/abstract.pl`.

Computational Analysis (Code: SS 1A), **George Anastassiou**, University of Memphis.

Fractal Geometry and Dynamical Systems (Code: SS 2A), **Mrinal Kanti Roychowdhury**, University of Texas-Pan American.

Fullerton, California

California State University, Fullerton

October 24–25, 2015

Saturday – Sunday

Meeting #1114

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2015
Program first available on AMS website: September 10, 2015
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 36, Issue 4

Deadlines

For organizers: March 27, 2015
For abstracts: September 1, 2015

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

Invited Addresses

Mina Aganagic, University of California, Berkeley, *Title to be announced.*

John Lott, University of California, Berkeley, *Title to be announced.*

Eyal Lubetzky, Microsoft Research, Redmond, *Title to be announced.*

Zhiwei Yun, Stanford 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 `http://www.ams.org/cgi-bin/abstracts/abstract.pl`.

Geometric Analysis (Code: SS 1A), **John Lott**, University of California, Berkeley, and **Aaron Naber**, Northwestern University.

New Brunswick, New Jersey

Rutgers University

November 14–15, 2015

Saturday – Sunday

Meeting #1115

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: September 2015
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: November 2015
Issue of *Abstracts*: Volume 36, Issue 4

Deadlines

For organizers: April 14, 2015
For abstracts: September 22, 2015

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

Invited Addresses

Lee Mosher, Rutgers University, *Title to be announced.*

Jill Pipher, Brown University, *Title to be announced.*

David Vogan, Massachusetts Institute of Technology, *Title to be announced.*

Wei Zhang, Columbia 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 `http://www.ams.org/cgi-bin/abstracts/abstract.pl`.

Applications of CAT(0) Cube Complexes (Code: SS 1A), **Sean Cleary**, City College of New York and the City University of New York Graduate Center, and **Megan Owen**, Lehman College of the City University of New York.

Seattle, Washington

Washington State Convention Center and the Sheraton Seattle Hotel

January 6–9, 2016

Wednesday – Saturday

Joint Mathematics Meetings, including the 122nd Annual Meeting of the AMS, 99th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL),

with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2015
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2016
Issue of *Abstracts*: Volume 37, Issue 1

Deadlines

For organizers: April 1, 2015
For abstracts: To be announced

Salt Lake City, Utah

University of Utah

April 9–10, 2016

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

Fargo, North Dakota

North Dakota State University

April 16–17, 2016

Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

Atlanta, Georgia

Hyatt Regency Atlanta and Marriott Atlanta Marquis

January 4–7, 2017

Wednesday – Saturday
Joint Mathematics Meetings, including the 123rd Annual Meeting of the AMS, 100th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: October 2016
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2017
Issue of *Abstracts*: Volume 38, Issue 1

Deadlines

For organizers: April 1, 2016
For abstracts: To be announced

Charleston, South Carolina

College of Charleston

March 10–12, 2017

Friday – Sunday
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: November 10, 2016
For abstracts: To be announced

Bloomington, Indiana

Indiana University

April 1–2, 2017

Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

Pullman, Washington

Washington State University

April 22–23, 2017
Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: To be announced
For abstracts: To be announced

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 10–13, 2018
Wednesday – Saturday
Joint Mathematics Meetings, including the 124th Annual Meeting of the AMS, 101st Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2017
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

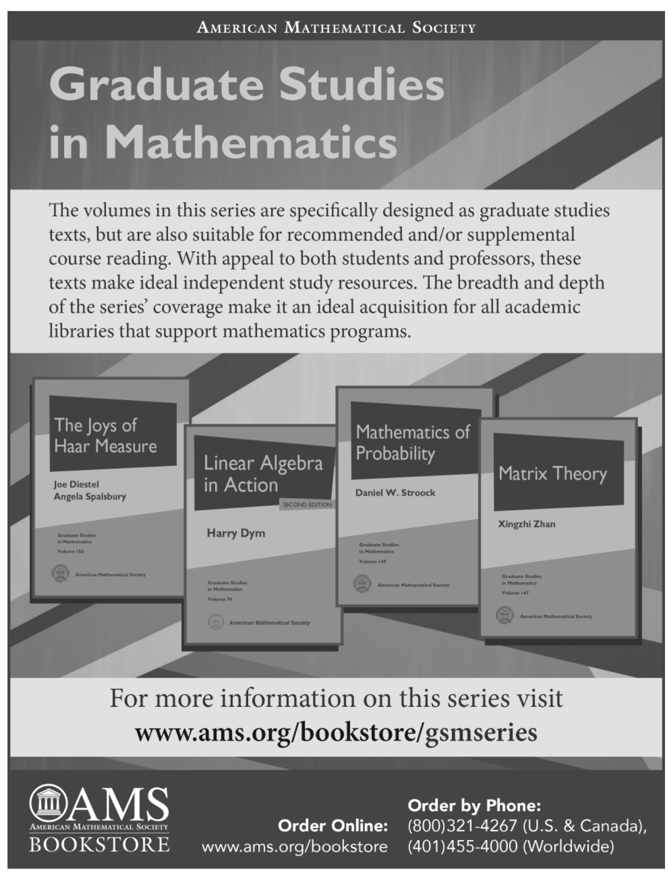
Deadlines
For organizers: April 1, 2017
For abstracts: To be announced

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
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: April 2, 2018
For abstracts: To be announced



Program at a Glance

This document provides a thumbnail sketch of all scientific and social events so you can easily see which events may overlap and better plan your time.

JOINT MATHEMATICS MEETINGS
SAN ANTONIO • JAN 10-13, 2015
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

Thursday, January 08

8:00 a.m.–5:00 p.m. **AMS SHORT COURSE ON FINITE FRAME THEORY: A COMPLETE INTRODUCTION TO OVERCOMPLETENESS, PART I**

3:00 p.m.–6:00 p.m. **NSF-EHR GRANT PROPOSAL WRITING WORKSHOP**

Friday, January 09

8:00 a.m.–5:00 p.m. **AMS SHORT COURSE ON FINITE FRAME THEORY: A COMPLETE INTRODUCTION TO OVERCOMPLETENESS, PART II**

8:00 a.m.–6:30 p.m. **AMS DEPARTMENT CHAIRS WORKSHOP**

9:00 a.m.–11:00 a.m. **MAA MINICOURSE #1: PART A** *Introductory proposal writing for grant applications to the NSF EHR Division of Undergraduate Education.*

9:00 a.m.–4:30 p.m. **MAA ANCILLARY WORKSHOP** *National research experiences for undergraduates.*

9:00 a.m.–4:00 p.m. **MAA ANCILLARY WORKSHOP** *Embedding undergraduate research into a living-learning community.*

9:00 a.m.–5:00 p.m. **MAA BOARD OF GOVERNORS**

2:00 p.m.–4:00 p.m. **MAA MINICOURSE #1: PART B** *Introductory proposal writing for grant applications to the NSF EHR Division of Undergraduate Education.*

2:30 p.m.–10:00 p.m. **AMS COUNCIL**

3:00 p.m.–8:00 p.m. **JOINT MEETINGS REGISTRATION**, East Registration, Convention Center

3:00 p.m.–8:00 p.m. **EMAIL CENTER**

Saturday, January 10

7:30 a.m.–6:00 p.m. **JOINT MEETINGS REGISTRATION**, East Registration, Convention Center

7:30 a.m.–9:30 p.m. **EMAIL CENTER**

AMS SPECIAL SESSIONS

8:00 a.m.–10:50 a.m. *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, I (AMS-MAA-SIAM)*

8:00 a.m.–10:50 a.m. *History of Mathematics, I (AMS-MAA)*

8:00 a.m.–10:50 a.m. *Beyond First-Order Model Theory, I (AMS-ASL)*

8:00 a.m.–10:50 a.m. *Factorization Theory and Its Applications, I*

8:00 a.m.–10:50 a.m. *Applications of Dynamical Systems to Biological Models, I*

8:00 a.m.–10:50 a.m. *Advances in Coding Theory, I*

8:00 a.m.–10:50 a.m. *Set-Valued Optimization and Variational Problems with Applications, I*

8:00 a.m.–10:50 a.m. *Recent Advances in Discrete and Intuitive Geometry, I*

8:00 a.m.–10:50 a.m.	*Ergodic Theory and Dynamical Systems, I*
8:00 a.m.–10:50 a.m.	*Frames and Their Applications, I*
8:00 a.m.–10:50 a.m.	*Algebraic Combinatorics and Representation Theory, I*
8:00 a.m.–10:50 a.m.	*Difference Equations and Applications, I*
8:00 a.m.–10:50 a.m.	*Operator Algebras and Their Applications: A Tribute to Richard V. Kadison, I*
8:00 a.m.–10:50 a.m.	*Model Theory and Applications, I*
8:00 a.m.–10:50 a.m.	*Holomorphic Dynamics in One and Several Variables, I*
8:00 a.m.–10:50 a.m.	*Ricci Curvature for Homogeneous Spaces and Related Topics, I*
8:00 a.m.–10:55 a.m.	**AMS CONTRIBUTED PAPER SESSIONS**
	MAA INVITED PAPER SESSIONS
8:00 a.m.–10:55 a.m.	*Recent Advances in Mathematical Modeling of the Environment and Infectious Diseases*
8:00 a.m.–11:00 a.m.	*Fractal Geometry and Dynamics*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 a.m.–11:00 a.m.	*The Scholarship of Teaching and Learning in Collegiate Mathematics, I*
8:00 a.m.–11:00 a.m.	*Humor and Teaching Mathematics*
8:00 a.m.–11:00 a.m.	*Cryptology for Undergraduates*
8:00 a.m.–11:00 a.m.	*Perspectives and Experiences on Mentoring Undergraduate Students in Research*
8:00 a.m.–11:00 a.m.	*Mathematics and the Arts, I*
8:00 a.m.–10:55 a.m.	**MAA GENERAL CONTRIBUTED PAPER SESSIONS**
8:00 a.m.–9:20 a.m.	**MAA COMMITTEE ON PROFESSIONAL DEVELOPMENT WORKSHOPS: NSF FUNDING OPPORTUNITIES FOR THE LEARNING AND TEACHING OF THE MATHEMATICAL SCIENCES, PART I.** *Undergraduate/graduate education programs; workforce; and broadening participation (DUE, DGE, DMS, HRD).*
8:30 a.m.–5:30 p.m.	**EMPLOYMENT CENTER**
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #14: PART A** *Teaching statistics using R and RStudio.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #3: PART A** *Introduction to process-oriented, guided-inquiry learning (POGIL) in mathematics courses.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #5: PART A** *Two visual topics using undergraduate complex analysis.*
9:30 a.m.–11:00 a.m.	**MAA-AMS-SIAM FREEMAN A. HRABOWSKI, SYLVESTER JAMES GATES, AND RICHARD A. TAPIA LECTURE SERIES**
9:30 a.m.–11:00 a.m.	**MAA DEPARTMENT LIAISONS MEETING**
9:35 a.m.–10:55 a.m.	**MAA COMMITTEE ON TECHNOLOGIES IN MATHEMATICS EDUCATION AND SIGMAA ON MATHEMATICS INSTRUCTION USING THE WEB PANEL DISCUSSION** *MOOCs and me: Massive online materials for my students.*
9:35 a.m.–10:55 a.m.	**MAA COMMITTEE ON PROFESSIONAL DEVELOPMENT WORKSHOPS: NSF FUNDING OPPORTUNITIES FOR THE LEARNING AND TEACHING OF THE MATHEMATICAL SCIENCES, PART II.** *The K–12 continuum: Learning science and research and pre- and in-service teachers (DUE/DRL).*
10:05 a.m.–10:55 a.m.	**AMS INVITED ADDRESS** *Random orderings and unique ergodicity of automorphism groups.* **Russell Lyons**
11:10 a.m.–12:00 p.m.	**AMS-MAA INVITED ADDRESS** *Title to be announced.* **Jordan Ellenberg**
12:15 p.m.–5:30 p.m.	**EXHIBITS AND BOOK SALES**
1:00 p.m.–1:50 p.m.	**AMS COLLOQUIUM LECTURES, LECTURE I** *Title to be announced.* **Michael Hopkins**
2:15 p.m.–3:05 p.m.	**MAA INVITED ADDRESS** *Dispelling obesity myths through mathematical modeling.* **Diana L. Thomas**
	AMS SPECIAL SESSIONS
2:15 p.m.–6:05 p.m.	*History of Mathematics, II (AMS-MAA)*
2:15 p.m.–6:05 p.m.	*Factorization Theory and Its Applications, II*
2:15 p.m.–6:05 p.m.	*Theory and Application of Reaction Diffusion Models, I*

2:15 p.m.–6:05 p.m. *Applications of Dynamical Systems to Biological Models, II*
2:15 p.m.–6:05 p.m. *Inequalities and Quantitative Approximation, I*
2:15 p.m.–6:05 p.m. *Current Trends in Classical Dynamical Systems, I*
2:15 p.m.–6:05 p.m. *Groups, Algorithms, and Cryptography, I*
2:15 p.m.–6:05 p.m. *Enumerative Combinatorics, I*
2:15 p.m.–6:05 p.m. *Recent Advances in Discrete and Intuitive Geometry, II*
2:15 p.m.–6:05 p.m. *Frames and Their Applications, II*
2:15 p.m.–6:05 p.m. *Probability and Applications, I*
2:15 p.m.–6:05 p.m. *Partitions, q-Series, and Modular Forms, I*
2:15 p.m.–6:05 p.m. *Difference Equations and Applications, II*
2:15 p.m.–6:05 p.m. *Operator Algebras and Their Applications: A Tribute to Richard V. Kadison, II*
2:15 p.m.–6:05 p.m. *Model Theory and Applications, II*
2:15 p.m.–6:05 p.m. *Accelerated Advances in Multiobjective Optimal Control Problems and Mathematical Programming Based on Generalized Invexity Frameworks, I*

2:15 p.m.–5:55 p.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**

MAA INVITED PAPER SESSIONS

2:15 p.m.–6:00 p.m. *Mathematical Techniques for Signature Discovery*
2:15 p.m.–6:00 p.m. *Fractal Geometry and Dynamics*

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #10: PART A** *Humanistic mathematics.*

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #15: PART A** *How to run a successful math circle.*

2:15 p.m.–4:15 p.m. **MAA MINICOURSE #9: PART A** *Teaching college mathematics (for instructors new to teaching at the collegiate level and for instructors who prepare GTAs for their first teaching experience).*

MAA CONTRIBUTED PAPER SESSIONS

2:15 p.m.–6:00 p.m. *Technology, the Next Generation: Integrating Tablets into the Mathematics Classroom*
2:15 p.m.–6:00 p.m. *The Scholarship of Teaching and Learning in Collegiate Mathematics, II*
2:15 p.m.–6:00 p.m. *Revitalizing Complex Analysis at the Undergraduate Level*
2:15 p.m.–6:00 p.m. *Mathematics and the Arts, II*
2:15 p.m.–6:00 p.m. *Mathematics and Sports*
2:15 p.m.–6:00 p.m. *Best Practices for Teaching the Introductory Statistics Course*

2:15 p.m.–5:55 p.m. **MAA GENERAL CONTRIBUTED PAPER SESSIONS**

2:15 p.m.–3:35 p.m. **MAA COMMITTEE FOR UNDERGRADUATE STUDENT ACTIVITIES AND CHAPTERS PANEL DISCUSSION** *What every student should know about the JMM.*

2:15 p.m.–3:35 p.m. **MAA COMMITTEE ON THE UNDERGRADUATE PROGRAM IN MATHEMATICS-MAA COMMITTEE ON THE MATHEMATICAL EDUCATION OF TEACHERS PANEL DISCUSSION** *Recommendations for the 21st century mathematical sciences major.*

2:15 p.m.–4:15 p.m. **YOUNG MATHEMATICIANS' NETWORK-PROJECT NEXT POSTER SESSION**

2:15 p.m.–3:40 p.m. **ASSOCIATION FOR WOMEN IN MATHEMATICS PANEL DISCUSSION** *Breaking the glass ceiling permanently.*

3:30 p.m.–4:30 p.m. **MAA-AMS-SIAM GERALD AND JUDITH PORTER PUBLIC LECTURE** *From Voting Paradoxes to the Search for "Dark Matter".* **Donald G. Saari**

3:45 p.m.–4:15 p.m. **AWM BUSINESS MEETING**

3:50 p.m.–5:10 p.m. **MAA PANEL DISCUSSION** *Recruiting, retaining, mentoring, and evaluating "contract faculty"*

3:50 p.m.–5:10 p.m. **MAA-YMN PANEL DISCUSSION** *Graduate school: Choosing one, getting in, staying in.*

4:00 p.m.–5:00 p.m. **MAA SECTION OFFICERS**

4:00 p.m.–5:00 p.m. **RECEPTION FOR UNDERGRADUATE STUDENTS**

4:40 p.m.–6:00 p.m. **AMS COMMITTEE ON THE PROFESSION PANEL DISCUSSION** *Title to be announced.*

4:45 p.m.–6:45 p.m. **MAA MINICOURSE #12: PART A** *Introducing matroids to undergraduates.*

4:45 p.m.–6:45 p.m. **MAA MINICOURSE #13: PART A** *WeBWorK: An open source alternative for generating and delivering online homework problems.*

4:45 p.m.–6:45 p.m. **MAA MINICOURSE #4: PART A** *A dynamical systems approach to the differential equations course.*

5:00 p.m.–6:00 p.m. **MAA-YOUNG MATHEMATICIANS' NETWORK PANEL DISCUSSION** *Managing your own course.*

5:30 p.m.–6:30 p.m. **RECEPTION FOR GRADUATE STUDENTS AND FIRST-TIME PARTICIPANTS**

5:30 p.m.–8:00 p.m. **MATHEMATICAL INSTITUTES OPEN HOUSE**

6:20 p.m.–7:40 p.m. **AMS-MAA SPECIAL FILM PRESENTATION** *Counting from Infinity: Yitang Zhang and the Twin Primes Conjecture.*

8:30 p.m.–9:30 p.m. **AMS JOSIAH WILLARD GIBBS LECTURE** *Graphs,vectors,and matrices.* **Daniel A. Spielman**

9:30 p.m.–11:00 p.m. **ASSOCIATION FOR WOMEN IN MATHEMATICS RECEPTION AND AWARDS PRESENTATION**

Sunday, January 11

7:00 a.m.–7:50 a.m. **ASSOCIATION FOR CHRISTIANS IN THE MATHEMATICAL SCIENCES NONDENOMINATIONAL WORSHIP SERVICE** *All are welcome.*

7:30 a.m.–4:00 p.m. **JOINT MEETINGS REGISTRATION**, East Registration, Convention Center

7:30 a.m.–8:00 p.m. **EMAIL CENTER**

AMS SPECIAL SESSIONS

8:00 a.m.–11:50 a.m. *History of Mathematics, III (AMS-MAA)*

8:00 a.m.–11:50 a.m. *Beyond First-Order Model Theory, II (AMS-ASL)*

8:00 a.m.–11:50 a.m. *Recent Advances in the Analysis and Applications of Modern Splitting Methods, I*

8:00 a.m.–11:50 a.m. *Current Trends in Classical Dynamical Systems, II*

8:00 a.m.–11:50 a.m. *Computing Intensive Modeling in Mathematical and Computational Biology, I*

8:00 a.m.–11:50 a.m. *Groups, Algorithms, and Cryptography, II*

8:00 a.m.–11:50 a.m. *Enumerative Combinatorics, II*

8:00 a.m.–11:50 a.m. *Probability and Applications, II*

8:00 a.m.–11:50 a.m. *Partitions, q-Series, and Modular Forms, II*

8:00 a.m.–11:50 a.m. *Classification Problems in Operator Algebras, I*

8:00 a.m.–11:50 a.m. *Inverse Problems, I*

8:00 a.m.–11:50 a.m. *Accelerated Advances in Multiobjective Optimal Control Problems and Mathematical Programming Based on Generalized Invexity Frameworks, II*

8:00 a.m.–11:50 a.m. *Cluster Algebras (a Mathematics Research Communities Session), I*

8:00 a.m.–11:50 a.m. *Algebraic and Geometric Methods in Applied Discrete Mathematics(a Mathematics Research Communities Session), I*

8:00 a.m.–11:50 a.m. *Quantum Information and Fusion Categories (a Mathematics Research Communities Session), I*

8:00 a.m.–11:50 a.m. *Network Science (a Mathematics Research Communities Session), I*

8:00 a.m.–11:55 a.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**

MAA INVITED PAPER SESSIONS

8:00 a.m.–11:50 a.m. *The Mathematics of Planet Earth, I*

MAA CONTRIBUTED PAPER SESSIONS

8:00 a.m.–12:00 p.m. *Inquiry-Based Learning in First-Year and Second-Year Courses*

8:00 a.m.–12:00 p.m. *Research on the Teaching and Learning of Undergraduate Mathematics, I*

8:00 a.m.–12:00 p.m. *Incorporating Formal Symbolic Reasoning into Mathematics Courses*

8:00 a.m.–12:00 p.m. *Innovative and Effective Ways to Teach Linear Algebra*

8:00 a.m.–12:00 p.m. *What Makes a Successful Math Circle: Organization and Problems*

8:00 a.m.–11:55 a.m. **MAA GENERAL CONTRIBUTED PAPER SESSIONS**

8:00 a.m.–9:20 a.m. **MAA SESSION FOR CHAIRS** *Program assessment: Making it easier and better.*

8:00 a.m.–11:20 a.m. **MAA COMMITTEE ON PROFESSIONAL DEVELOPMENT PANEL DISCUSSIONS** *Presenters from the NSF describe experiences with the general NSF grant proposal process; see the full description in detail in MAA Panels, etc.*

8:00 a.m.–11:00 a.m.	**SIAM MINISYMPOSIUM ON MODELING ACROSS THE CURRICULUM**
8:30 a.m.–5:30 p.m.	**EMPLOYMENT CENTER**
9:00 a.m.–9:50 a.m.	**MAA INVITED ADDRESS** *Golden numbers and identities: The legacy of Rogers and Ramanujan.* **Ken Ono**
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #16: PART A** *Using games in an introductory statistics course.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #7: PART A** *Teaching introductory statistics (for instructors new to teaching statistics).*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #8A: PART A** *Doing the scholarship of teaching and learning in mathematics.*
9:00 a.m.–11:00 a.m.	**MAA POSTER SESSION** *Mathematical outreach programs.*
9:30 a.m.–5:30 p.m.	**EXHIBITS AND BOOK SALES**
10:30 a.m.–12:00 p.m.	**AMS SPECIAL PRESENTATION** *A conversation on nonacademic employment.*
10:30 a.m.–12:00 p.m.	**SIGMAA OFFICERS MEETING**
10:35 a.m.–11:55 a.m.	**MAA SUBCOMMITTEE ON RESEARCH BY UNDERGRADUATES PANEL DISCUSSION** *Undergraduate research: Viewpoints from the student side.*
1:00 p.m.–1:50 p.m.	**AMS COLLOQUIUM LECTURES, LECTURE II** *Title to be announced.* **Michael Hopkins**
	AMS SPECIAL SESSIONS
1:00 p.m.–3:50 p.m.	*Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, II (AMS-MAA-SIAM)*
1:00 p.m.–3:50 p.m.	*History of Mathematics, IV (AMS-MAA)*
1:00 p.m.–3:50 p.m.	*Beyond First-Order Model Theory, III (AMS-ASL)*
1:00 p.m.–3:50 p.m.	*Advances in Coding Theory, II*
1:00 p.m.–3:50 p.m.	*Set-Valued Optimization and Variational Problems with Applications, II*
1:00 p.m.–3:50 p.m.	*Ergodic Theory and Dynamical Systems, II*
1:00 p.m.–3:50 p.m.	*Frames and Their Applications, III*
1:00 p.m.–3:50 p.m.	*Algebraic Combinatorics and Representation Theory, II*
1:00 p.m.–3:50 p.m.	*Operator Algebras and Their Applications: A Tribute to Richard V. Kadison, III*
1:00 p.m.–3:50 p.m.	*Creating Coherence in K–12 Mathematics, I*
1:00 p.m.–3:50 p.m.	*Holomorphic Dynamics in One and Several Variables, II*
1:00 p.m.–3:50 p.m.	*Cluster Algebras (a Mathematics Research Communities Session), II*
1:00 p.m.–3:50 p.m.	*Algebraic and Geometric Methods in Applied Discrete Mathematics (a Mathematics Research Communities Session), II*
1:00 p.m.–3:50 p.m.	*Quantum Information and Fusion Categories (a Mathematics Research Communities Session), II*
1:00 p.m.–3:50 p.m.	*Network Science (a Mathematics Research Communities Session), II*
1:00 p.m.–3:50 p.m.	*Ricci Curvature for Homogeneous Spaces and Related Topics, II*
	MAA INVITED PAPER SESSIONS
1:00 p.m.–4:10 p.m.	*The Mathematics of Planet Earth, II*
1:00 p.m.–3:00 p.m.	**MAA MINICOURSE #11: PART A** *Healthcare applications and projects for introductory college mathematics courses.*
1:00 p.m.–3:00 p.m.	**MAA MINICOURSE #2: PART A** *Developing departmental self-studies.*
1:00 p.m.–3:00 p.m.	**MAA MINICOURSE #6: PART A** *Public- and private-key cryptography.*
	MAA CONTRIBUTED PAPER SESSIONS
1:00 p.m.–4:15 p.m.	*Helping Students See Beyond Calculus*
1:00 p.m.–4:15 p.m.	*Research on the Teaching and Learning of Undergraduate Mathematics, II*
1:00 p.m.–4:15 p.m.	*Activities, Demonstrations, and Projects that Enhance the Study of Undergraduate Geometry*
1:00 p.m.–4:15 p.m.	*Mathematics Experiences in Business, Industry, and Government*
1:00 p.m.–4:15 p.m.	*Statistics Education beyond the Introductory Statistics Course*
1:00 p.m.–2:30 p.m.	**AMS COMMITTEE ON EDUCATION PANEL DISCUSSION** *Active learning strategies for mathematics.*

1:00 p.m.–4:10 p.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**

1:00 p.m.–2:30 p.m. **AMS COMMITTEE ON EDUCATION PANEL DISCUSSION** *Active learning strategies for mathematics.*

1:00 p.m.–4:10 p.m. **MAA GENERAL CONTRIBUTED PAPER SESSIONS**

1:00 p.m.–2:20 p.m. **MAA COMMITTEE ON THE PARTICIPATION OF WOMEN IN MATHEMATICS PANEL DISCUSSION** *Writing competitive grant applications.*

1:00 p.m.–2:20 p.m. **MAA-YOUNG MATHEMATICIANS' NETWORK PANEL DISCUSSION** *On-campus interview survival guide.*

1:00 p.m.–2:15 p.m. **MAA SPECIAL PRESENTATION** *Speed interviewing marathon for students.*

1:00 p.m.–2:30 p.m. **JOINT COMMITTEE ON WOMEN IN THE MATHEMATICAL SCIENCES PANEL DISCUSSION** *Effective self-promotion to advance your career in mathematics.*

1:00 p.m.–3:00 p.m. **SUMMER PROGRAM FOR WOMEN IN MATHEMATICS (SPWM) REUNION**

2:00 p.m.–4:00 p.m. **MAA POSTER SESSION ON PROJECTS SUPPORTED BY THE NSF DIVISION OF UNDERGRADUATE EDUCATION**

2:00 p.m.–4:00 p.m. **POSTERS ON EXPEDITIONS IN TRAINING, RESEARCH, AND EDUCATION FOR MATHEMATICS AND STATISTICS THROUGH QUANTITATIVE EXPLORATIONS OF DATA (EXTREEMS-QED)**

2:15 p.m.–3:05 p.m. **AMS INVITED ADDRESS** *Elliptic curves and explicit class field theory.* **Henri Darmon**

2:35 p.m.–3:55 p.m. **MAA PANEL DISCUSSION** *Mathematicians write: Publishing options and outlets beyond the standard research journal.*

3:20 p.m.–4:10 p.m. **AMS INVITED ADDRESS** *Statistically relevant metrics for complex data.* **Susan Holmes**

4:25 p.m.–5:25 p.m. **JOINT PRIZE SESSION**

5:30 p.m.–6:20 p.m. **SIGMAA ON BUSINESS, INDUSTRY, AND GOVERNMENT GUEST LECTURE, RECEPTION, AND BUSINESS MEETING**

5:30 p.m.–6:30 p.m. **MAA-YOUNG MATHEMATICIANS' NETWORK PANEL DISCUSSION** *Find a research collaborator.*

5:30 p.m.–7:00 p.m. **MAA-*JOURNAL OF HUMANISTIC MATHEMATICS* POETRY READING**

5:30 p.m.–5:50 p.m. **SIGMAA ON STATISTICS EDUCATION RECEPTION, BUSINESS MEETING, AND GUEST LECTURE**

5:30 p.m.–7:30 p.m. **ASSOCIATION OF CHRISTIANS IN THE MATHEMATICAL SCIENCES ANNUAL RECEPTION AND LECTURE** *All are welcome.*

5:30 p.m.–7:00 p.m. **BUDAPEST SEMESTERS IN MATHEMATICS REUNION**

5:30 p.m.–7:30 p.m. **PENNSYLVANIA STATE UNIVERSITY MATHEMATICS ALUMNI RECEPTION**

5:30 p.m.–7:00 p.m. **UNIVERSITY OF TENNESSEE MATH ALUMNI AND FRIENDS RECEPTION**

6:00 p.m.–7:20 p.m. **AMS-MAA DRAMATIC PRESENTATION** The *Mathematics of Being Human.*

6:00 p.m.–6:20 p.m. **SIGMAA ON MATHEMATICAL AND COMPUTATIONAL BIOLOGY RECEPTION, BUSINESS MEETING, AND GUEST LECTURE**

6:00 p.m.–8:00 p.m. **NSA'S WOMEN IN MATHEMATICS SOCIETY NETWORKING SESSION**

8:15 p.m.–9:45 p.m. **KNITTING CIRCLE** *Knitting Circle: Bring a project (knitting/crochet/tatting/beading/etc.) and chat with other mathematical crafters!*

Monday, January 12

7:30 a.m.–4:00 p.m. **JOINT MEETINGS REGISTRATION**, East Registration, Convention Center

7:30 a.m.–7:00 p.m. **EMAIL CENTER**

AMS SPECIAL SESSIONS

8:00 a.m.–10:50 a.m. *Fixed Point Theory and Applications, I*

8:00 a.m.–10:50 a.m. *Noncommutative Function Theory, I*

8:00 a.m.–10:50 a.m. *Advances in Coding Theory, III*

8:00 a.m.–10:50 a.m.	*Limits of Discrete Structures, I*
8:00 a.m.–10:50 a.m.	*Computing Intensive Modeling in Mathematical and Computational Biology, II*
8:00 a.m.–10:50 a.m.	*Algebraic Combinatorics and Representation Theory, III*
8:00 a.m.–10:50 a.m.	*Mathematics in Poland: Interbellum, World War II, and Immediate Post-War Developments, I*
8:00 a.m.–10:50 a.m.	*Continued Fractions, I*
8:00 a.m.–10:50 a.m.	*Mathematics in Natural Resource Modeling, I*
8:00 a.m.–10:50 a.m.	*Differential Geometry and Statistics, I*
8:00 a.m.–10:50 a.m.	*Classification Problems in Operator Algebras, II*
8:00 a.m.–10:50 a.m.	*Creating Coherence in K–12 Mathematics, II*
8:00 a.m.–10:50 a.m.	*Holomorphic Dynamics in One and Several Variables, III*
8:00 a.m.–10:50 a.m.	*Selmer Groups, I*
8:00 a.m.–10:50 a.m.	*Fractional, Stochastic, and Hybrid Dynamic Systems with Applications, I*
8:00 a.m.–10:50 a.m.	*Ricci Curvature for Homogeneous Spaces and Related Topics, III*
	MAA INVITED PAPER SESSIONS
8:00 a.m.–10:55 a.m.	*Making the Case for Faculty Relevance: Case Studies in Best Practices for Classroom Teaching*
8:00 a.m.–10:55 a.m.	*The Mathematics of Rogers and Ramanujan*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 a.m.–11:00 a.m.	*Ethnomathematics: A Tribute to Marcia Ascher*
8:00 a.m.–11:00 a.m.	*The Times They Are a Changin': Successful Innovations in Developmental Mathematics Curricula and Pedagogy*
8:00 a.m.–11:00 a.m.	*Cartography and Mathematics: Imaging the World Around Us*
8:00 a.m.–11:00 a.m.	*Collaborations between Two-Year and Four-Year Institutions that Create Pathways to a Math Major*
8:00 a.m.–10:55 a.m.	**AMS SESSIONS FOR CONTRIBUTED PAPERS**
8:00 a.m.–10:55 a.m.	**MAA GENERAL CONTRIBUTED PAPER SESSIONS**
8:00 a.m.–11:00 a.m.	**PME COUNCIL MEETING**
8:30 a.m.–10:30 a.m.	**AMS-MAA GRAD SCHOOL FAIR** *Undergrads! Take this opportunity to meet representatives from mathematical science graduate programs.*
8:30 a.m.–5:30 p.m.	**EMPLOYMENT CENTER**
9:00 a.m.–9:50 a.m.	**MAA INVITED ADDRESS** *Divergent series and differential equations: Past, present, future...* **Christiane Rousseau**
9:00 a.m.–11:00 a.m.	**MINICOURSE #14: PART B** *Teaching statistics using R and RStudio.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #3: PART B** *Introduction to process-oriented, guided-inquiry learning (POGIL) in mathematics courses.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #5: PART B** *Two visual topics using undergraduate complex analysis.*
9:30 a.m.–11:00 a.m.	**AMS SPECIAL PRESENTATION** *Who wants to be a mathematician—National contest.*
9:30 a.m.–5:30 p.m.	**EXHIBITS AND BOOK SALES**
9:35 a.m.–10:55 a.m.	**MAA PANEL DISCUSSION** *Benefits and challenges of introducing multivariate topics earlier in the calculus sequence.*
10:05 a.m.–10:55 a.m.	**AMS INVITED ADDRESS** *Matrix factorizations and complete intersection rings.* **Irena Peeva**
11:10 a.m.–12:00 p.m.	**AMS-MAA INVITED ADDRESS** *Title to be announced.* **Richard Tapia**
1:00 p.m.–1:50 p.m.	**AMS COLLOQUIUM LECTURES, LECTURE III** *Title to be announced.* **Michael Hopkins**
1:00 p.m.–1:50 p.m.	**MAA LECTURE FOR STUDENTS** *Math is Cool!* **George Hart**
1:00 p.m.–4:45 p.m.	**CURRENT EVENTS BULLETIN**
	AMS SPECIAL SESSIONS
1:00 p.m.–5:50 p.m.	*Knot Theory, I*
1:00 p.m.–5:50 p.m.	*Theory and Application of Reaction Diffusion Models, II*
1:00 p.m.–5:50 p.m.	*Recent Advances in the Analysis and Applications of Modern Splitting Methods, II*
1:00 p.m.–5:50 p.m.	*Noncommutative Function Theory, II*

1:00 p.m.–5:50 p.m. *Inequalities and Quantitative Approximation, II*
1:00 p.m.–5:50 p.m. *Limits of Discrete Structures, II*
1:00 p.m.–5:50 p.m. *Geometries Defined by Differential Forms, I*
1:00 p.m.–5:50 p.m. *Math Teachers Circles and the K–20 Continuum*
1:00 p.m.–5:50 p.m. *Mathematics in Poland: Interbellum, World War II, and Immediate Post-War Developments, II*
1:00 p.m.–5:50 p.m. *Continued Fractions, II*
1:00 p.m.–5:50 p.m. *Mathematics in Natural Resource Modeling, II*
1:00 p.m.–5:50 p.m. *Differential Geometry and Statistics, II*
1:00 p.m.–5:50 p.m. *Inverse Problems, II*
1:00 p.m.–5:50 p.m. *Selmer Groups, II*
1:00 p.m.–5:50 p.m. *Fractional, Stochastic, and Hybrid Dynamic Systems with Applications, II*
1:00 p.m.–5:50 p.m. *Hopf Algebras and Tensor Categories, I*

1:00 p.m.–3:00 p.m. **MAA MINICOURSE #10: PART B** *Humanistic mathematics.*

1:00 p.m.–3:00 p.m. **MAA MINICOURSE #15: PART B** *How to run a successful math circle.*

1:00 p.m.–3:00 p.m. **MAA MINICOURSE #9: PART B** *Teaching college mathematics (for instructors new to teaching at the collegiate level and for instructors who prepare GTAs for their first teaching experience).*

MAA CONTRIBUTED PAPER SESSIONS

1:00 p.m.–6:00 p.m. *Trends in Undergraduate Mathematical Biology Education*
1:00 p.m.–6:00 p.m. *Wavelets in Undergraduate Education*
1:00 p.m.–5:00 p.m. *Well-Designed Online Assessment: Well-Formed Questions, Discovery-Based Explorations, and Their Success in Improving Student Learning*
1:00 p.m.–6:00 p.m. *Program and Assessment Implications of Common Core State Standards Implementation*

1:00 p.m.–2:50 p.m. **NAM GRANVILLE-BROWN-HAYNES SESSION OF PRESENTATIONS BY RECENT DOCTORAL RECIPIENTS IN THE MATHEMATICAL SCIENCES**

1:00 p.m.–5:55 p.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**

1:00 p.m.–5:55 p.m. **MAA GENERAL CONTRIBUTED PAPER SESSIONS**

1:00 p.m.–2:20 p.m. **MAA COMMITTEE ON THE UNDERGRADUATE PROGRAM IN MATHEMATICS PANEL DISCUSSION** *Mathematics and the sciences: Necessary dialogue.*

2:00 p.m.–3:20 p.m. **PRESENTATIONS BY MAA TEACHING AWARD PARTICIPANTS**

2:15 p.m.–4:00 p.m. **ROCKY MOUNTAIN MATHEMATICS CONSORTIUM BOARD OF DIRECTORS MEETING**

2:30 p.m.–4:00 p.m. **AMS COMMITTEE ON SCIENCE POLICY PANEL DISCUSSION** *Title to be announced.*

3:30 p.m.–5:30 p.m. **MAA MINICOURSE #12: PART B** *Introducing matroids to undergraduates.*

3:30 p.m.–5:30 p.m. **MAA MINICOURSE #13: PART B** *WeBWorK: An open source alternative for generating and delivering online homework problems.*

3:30 p.m.–5:30 p.m. **MAA MINICOURSE #4: PART B** *A dynamical systems approach to the differential equations course.*

4:00 p.m.–4:50 p.m. **MAA INVITED ADDRESS** *Making the case for data journalism.* **Catherine O'Neil**

4:30 p.m.–6:00 p.m. **AMS CONGRESSIONAL FELLOWSHIP SESSION**

4:30 p.m.–6:00 p.m. **MAA STUDENT POSTER SESSION**

5:00 p.m.–7:00 p.m. **MAA PANEL DISCUSSION** *Actuarial science: What faculty need to know.*

5:30 p.m.–5:50 p.m. **SIGMAA ON THE PHILOSOPHY OF MATHEMATICS RECEPTION, BUSINESS MEETING, AND GUEST LECTURE**

6:00 p.m.–7:15 p.m. **AWM WORKSHOP POSTER PRESENTATIONS AND RECEPTION**

6:00 p.m.–7:00 p.m. **MAA SPECIAL DRAMATIC PRESENTATION** *Mathematically Bent Theater*

6:00 p.m.–7:00 p.m. **AMS *MATHEMATICAL REVIEWS* RECEPTION**

6:00 p.m.–8:40 p.m. **NAM RECEPTION AND BANQUET**

7:45 p.m.–8:35 p.m. **NAM COX-TALBOT ADDRESS** *Speaker and title to be announced.*

Tuesday, January 13

7:30 a.m.–2:00 p.m.	**JOINT MEETINGS REGISTRATION**, East Registration, Convention Center
7:30 a.m.–2:00 p.m.	**EMAIL CENTER**
	AMS SPECIAL SESSIONS
8:00 a.m.–10:50 a.m.	*Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, III (AMS-MAA-SIAM)*
8:00 a.m.–10:50 a.m.	*Recent Developments in Algebraic Number Theory, I (AMS-AWM)*
8:00 a.m.–10:50 a.m.	*Fixed Point Theory and Applications, II*
8:00 a.m.–10:50 a.m.	*The Scottish Book, I*
8:00 a.m.–10:50 a.m.	*What's New in Group Theory?, I*
8:00 a.m.–10:50 a.m.	*Progress in Multivariable Operator Theory, I*
8:00 a.m.–10:50 a.m.	*Graphs, Matrices, and Related Problems, I*
8:00 a.m.–10:50 a.m.	*Syzygies, I*
8:00 a.m.–10:50 a.m.	*Topological Measures of Complexity: Inverse Limits, Entropy, and Structure of Attractors, I*
8:00 a.m.–10:50 a.m.	*Positivity and Matrix Inequalities, I*
8:00 a.m.–10:50 a.m.	*Studies in Interconnections among Parameters in Graph Theory, Combinatorics, and Discrete Geometry, I*
8:00 a.m.–10:50 a.m.	*Creating Coherence in K–12 Mathematics, III*
8:00 a.m.–10:50 a.m.	*Heavy-Tailed Distributions and Processes, I*
8:00 a.m.–10:50 a.m.	*Geosystems Mathematics, I*
8:00 a.m.–10:50 a.m.	*Hopf Algebras and Tensor Categories, II*
8:00 a.m.–10:50 a.m.	*Quantum Markov Chains, Quantum Walks, and Related Topics, I*
	MAA INVITED PAPER SESSION
8:00 a.m.–10:55 a.m.	*Mathematics and Voting Theory*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 a.m.–	11:00 a.m. *USE Math: Undergraduate Sustainability Experiences in the Mathematics Classroom*
8:00 a.m.–11:00 a.m.	*Using Flipping Pedagogy to Engage Students in Learning Mathematics*
8:00 a.m.–11:00 a.m.	*Teaching Proof Writing Techniques within a Content-Based Mathematics Course*
8:00 a.m.–11:00 a.m.	*Original Sources and Archives in the Classroom*
8:00 a.m.–5:00 p.m.	**AWM WORKSHOP ON HOMOTOPY THEORY**
8:00 a.m.–10:55 a.m.	**AMS SESSIONS FOR CONTRIBUTED PAPERS**
8:00 a.m.–10:55 a.m.	**MAA COMMITTEE ON PROFESSIONAL DEVELOPMENT SESSION, I** *"Post Plus 5" session on open source resources in mathematics.*
8:00 a.m.–10:55 a.m.	**MAA GENERAL CONTRIBUTED PAPER SESSIONS**
8:00 a.m.–9:20 a.m.	**MAA COMMITTEE ON THE MATHEMATICAL EDUCATION OF TEACHERS PANEL DISCUSSION** *A positive feedback loop? The impact of mathematics education research and K–12 instructional changes on our teaching of undergraduate mathematics.*
8:00 a.m.–10:00 a.m.	**SIGMAA ON THE TEACHING OF ADVANCED HIGH SCHOOL MATHEMATICS-MAA COUNCIL ON OUTREACH WORKSHOP** *Creating a course in mathematical modelling.*
9:00 a.m.–9:50 a.m.	**AMS INVITED ADDRESS** *Title to be announced.* **Ian Agol**
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #16: PART B** *Using games in an introductory statistics course.*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #7: PART B** *Teaching introductory statistics (for instructors new to teaching statistics).*
9:00 a.m.–11:00 a.m.	**MAA MINICOURSE #8A: PART B** *Doing the scholarship of teaching and learning in mathematics.*
9:00 a.m.–9:50 a.m.	**NAM PANEL DISCUSSION** *Title to be announced*
9:00 a.m.–12:00 p.m.	**EXHIBITS AND BOOK SALES**
9:00 a.m.–12:00 p.m.	**EMPLOYMENT CENTER**

10:00 a.m.–10:50 a.m.	**NAM BUSINESS MEETING**
10:05 a.m.–10:55 a.m.	**MAA RETIRING PRESIDENTIAL ADDRESS** *Cantor and Sierpinski, Julia and Fatou: Crazy Topology in Complex Dynamics.* **Robert L. Devaney**
11:10 a.m.–11:40 a.m.	**MAA BUSINESS MEETING**
11:45 a.m.–12:15 p.m.	**AMS BUSINESS MEETING**
1:00 p.m.–1:50 p.m.	**NAM CLAYTOR-WOODARD LECTURE** *Speaker and title to be announced.*
	AMS SPECIAL SESSIONS
1:00 p.m.–5:50 p.m.	*Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, IV (AMS-MAA-SIAM)*
1:00 p.m.–5:50 p.m.	*Recent Developments in Algebraic Number Theory, II (AMS-AWM)*
1:00 p.m.–5:50 p.m.	*Knot Theory, II*
1:00 p.m.–5:50 p.m.	*The Scottish Book, II*
1:00 p.m.–5:50 p.m.	*What's New in Group Theory?, II*
1:00 p.m.–5:50 p.m.	*Progress in Multivariable Operator Theory, II*
1:00 p.m.–5:50 p.m.	*Graphs, Matrices, and Related Problems, II*
1:00 p.m.–5:50 p.m.	*Syzygies, II*
1:00 p.m.–5:50 p.m.	*Topological Measures of Complexity: Inverse Limits, Entropy, and Structure of Attractors, II*
1:00 p.m.–5:50 p.m.	*Positivity and Matrix Inequalities, II*
1:00 p.m.–5:50 p.m.	*Geometries Defined by Differential Forms, II*
1:00 p.m.–5:00 p.m.	*Studies in Interconnections among Parameters in Graph Theory, Combinatorics, and Discrete Geometry, II*
1:00 p.m.–5:50 p.m.	*Successes and Challenges in Teaching Mathematics*
1:00 p.m.–5:50 p.m.	*Heavy-Tailed Distributions and Processes, II*
1:00 p.m.–5:50 p.m.	*Geosystems Mathematics, II*
1:00 p.m.–5:50 p.m.	*Quantum Markov Chains, Quantum Walks, and Related Topics, II*
1:00 p.m.–3:00 p.m.	**MAA MINICOURSE #11: PART B** *Healthcare applications and projects for introductory college mathematics courses.*
1:00 p.m.–3:00 p.m.	**MAA MINICOURSE #2: PART B** *Developing departmental self-studies.*
1:00 p.m.–3:00 p.m.	**MAA MINICOURSE #6: PART B** *Public- and private-key cryptography.*
	MAA CONTRIBUTED PAPER SESSIONS
1:00 p.m.–5:00 p.m.	*Teaching Inquiry*
1:00 p.m.–5:00 p.m.	*Infusing Quantitative Literacy into Mathematics and Nonmathematics Courses*
1:00 p.m.–5:00 p.m.	*First-Year Calculus: Fresh Approaches for Jaded Students*
1:00 p.m.–5:00 p.m.	*Discovery and Insight in Mathematics*
1:00 p.m.–5:55 p.m.	**AMS SESSIONS FOR CONTRIBUTED PAPERS**
1:00 p.m.–5:00 p.m.	**MAA COMMITTEE ON PROFESSIONAL DEVELOPMENT SESSION, II** *"Post Plus 5" session on open source resources in mathematics.*
1:00 p.m.–4:55 p.m.	**MAA GENERAL CONTRIBUTED PAPER SESSIONS**
1:00 p.m.–2:20 p.m.	**MAA WORKSHOP** *The New Mathways Project's STEM prep initiative: A reconceptualized pathway to calculus.*
1:00 p.m.–5:50 p.m.	**PURE AND APPLIED TALKS BY WOMEN MATH WARRIORS PRESENTED BY EDGE (ENHANCING DIVERSITY IN GRADUATE EDUCATION)**

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

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The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information can be found at** www.ams.org/meetings/.

Meetings:

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 99 in the January 2014 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset in LaTeX. Visit http://www.ams.org/cgi-bin/abstracts/abstract.pl. Questions about abstracts may be sent to abs-info@ams.org. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences in Cooperation with the AMS: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

November 7–9, 2014: 7th International Conference on Science and Mathematics Education in Developing Countries, Mandalay University, Myanmar.

December 8–12, 2014: ICPAM-Goroka 2014: International Conference on Pure and Applied Mathematics, University of Goroka, Papua, New Guinea.

April 2–5, 2015: The Second International Conference on Mathematics and Statistics (AUS-ICMS '15). American University of Sharjah, United Arab Emirates.

2015 Joint Mathematics Meetings Advance Registration/Housing Form

JOINT MATHEMATICS MEETINGS
SAN ANTONIO • JAN 10-13, 2015
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

Name ______________________________
(please write name as you would like it to appear on your badge)

Mailing Address ______________________________

____

Telephone ______________________ Fax: ______________________

In case of emergency (for you) at the meeting, call: Day #______________ Evening #:______________

Email Address ______________________ Additional email address for receipt ______________

Acknowledgment of this registration and any hotel reservations will be sent to the email address(s) given here. **Check this box to receive a copy in U.S. Mail:** ☐

Affiliation for badge ______________________ Nonmathematician guest badge name: ______________________
(company/university) (Note fee of US$15)

☐ **I DO NOT want my program and badge to be mailed to me on 12/12/14. (Materials will be mailed to the address listed above unless you check this box.)**

Registration Fees

Membership please ✓ all that apply. First row is eligible to register as a JMM member.

☐ AMS ☐ MAA ☐ ASL ☐ CMS ☐ SIAM
☐ AWM ☐ NAM ☐ YMN ☐ AMATYC

Joint Meetings	**by Dec 23**	**at mtg**	**Subtotal**
☐ Member AMS, MAA, ASL, CMS, SIAM	US$ 252	US$ 331	
☐ Nonmember	US$ 400	US$ 510	
☐ Graduate Student (Mem. of AMS or MAA)	US$ 56	US$ 66	
☐ Graduate Student (Nonmember)	US$ 90	US$ 100	
☐ Undergraduate Student	US$ 56	US$ 66	
☐ High School Student	US$ 5	US$ 11	
☐ Unemployed	US$ 56	US$ 66	
☐ Temporarily Employed	US$ 205	US$ 235	
☐ Developing Countries Special Rate	US$ 56	US$ 66	
☐ Emeritus Member of AMS or MAA	US$ 56	US$ 66	
☐ High School Teacher	US$ 56	US$ 66	
☐ Librarian	US$ 56	US$ 66	
☐ Press	US$ 0	US$ 0	
☐ Exhibitor (Commercial)	US$ 0	US$ 0	
☐ Artist Exhibitor (work in JMM Art Exhibit)	US$ 0	US$ 0	
☐ Nonmathematician Guest of registered mathematician	US$ 16	US$ 16	
			$________

AMS Short Course: *Finite Frame Theory: A Complete Introduction to Overcompleteness (1/8–1/9)*

☐ Member of AMS	US$ 108	US$ 142	
☐ Nonmember	US$ 160	US$ 190	
☐ Student, Unemployed, Emeritus	US$ 56	US$ 77	
			$________

MAA Minicourses (see listing in text)

I would like to attend: ☐ One Minicourse ☐ Two Minicourses
Please enroll me in MAA Minicourse(s) #______ and #______
Price: US$ 85 for each minicourse.
(For more than 2 minicourses, call or email the MMSB.) $________

Graduate School Fair

☐ Graduate Program Table US$ 75 US$ 75
(includes table, posterboard & electricity) $________

Receptions & Banquets

☐ Graduate Student/First Time Attendee Reception? (1/10) (no charge)
☐ NAM Banquet (1/12) US$63 #____Chicken #____Vegan #____Kosher
(Additional fees may apply for Kosher meals.)

☐ AMS Dinner (1/13) Regular Price #____US$ 67
Student Price) #____US$ 25
$________

Total for Registrations and Events $________

Registration for the Joint Meetings is not required for the short course but it is required for the minicourses and the Employment Center. To register for the Employment Center, go to www.ams.org/profession/employment-services/employment-center.

Payment

Registration & Event Total (total from column on left)	$ ____________
Hotel Deposit (only if paying by check)	$ ____________
Total Amount To Be Paid	**$** ____________

Method of Payment

☐ **Check**. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates. For all check payments, please keep a copy of this form for your records.

☐ **Credit Card**. All major credit cards accepted. For your security, we do not accept credit card numbers by postal mail, email or fax. If the MMSB receives your registration form by fax or postal mail, it will contact you at the phone number provided on this form. For questions, contact the MMSB at mmsb@ams.org.

Signature:______________________________

☐ **Purchase Order** #____________________ (please enclose copy)

Other Information

Mathematical Reviews field of interest # ______________________

☐ I am a mathematics department chair.

☐ For planning purposes for the MAA Two-year College Reception, please check if you are a faculty member at a two-year college.

☐ Please do not include my name and postal address on any promotional mailing lists. (The JMM does not share email addresses.)

☐ Please do not include my name on any list of JMM participants other than the scientific program if I am, in fact, making a presentation that is part of the meeting.

☐ Please ✓ this box if you have a disability requiring special services.

Deadlines

Eligible for the complimentary room drawing:	**Nov. 3, 2014**
Receiving badges/programs in the mail:	**Nov. 18, 2014**
Housing reservations, changes/cancellations through the JMM website:	**Dec. 17, 2014**
Advance registration for the Joint Meetings, short course, minicourses, and tickets:	**Dec. 23, 2014**
50% refund on banquets, cancel by	**Jan. 5, 2015***
50% refund on advance registration, minicourses, and short course, cancel by	**Jan. 6, 2015***

***no refunds issued after this date**

Mailing Address/Contact:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887 **Fax**: 401-455-4004; **Email:** mmsb@ams.org
Telephone: 401-455-4144 or 1-800-321-4267 x4144 or x4137

2015 Joint Mathematics Meetings Hotel Reservations – San Antonio, TX

(Please see the hotel page in the announcement or on the web for detailed information on each hotel.) To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc. in the column on the left and by circling the requested bed confirguration. If your requested hotel and room type is no longer available, you will be assigned a room at the next available comparable rate. Please call the MMSB for details on suite configurations, sizes, availability, etc. All reservations, including suite reservations, must be made through the MMSB to receive the JMM rates. Reservations made directly with the hotels before **December 19, 2014** may be changed to a higher rate. All rates are subject to a 16.75% sales/occupancy tax. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

☐ **Deposit enclosed (see front of form**)

☐ **Hold with my credit card**. **For your security, we do not accept credit card numbers by postal mail, email or fax.** If the MMSB receives your registration form by postal mail or fax, we will contact you at the phone number provided on the reverse of this form.

Date and Time of Arrival ____________ **Date and Time of Departure** ____________ **Number of adult guests in room** ____________

Name of Other Adult Room Occupant ____________ **Arrival Date** ____________ **Departure Date** ____________

Name of Other Adult Room Occupant ____________ **Arrival Date** ____________ **Departure Date** ____________

Housing Requests:.(example: rollaway cot, crib, nonsmoking room, low floor) ____________

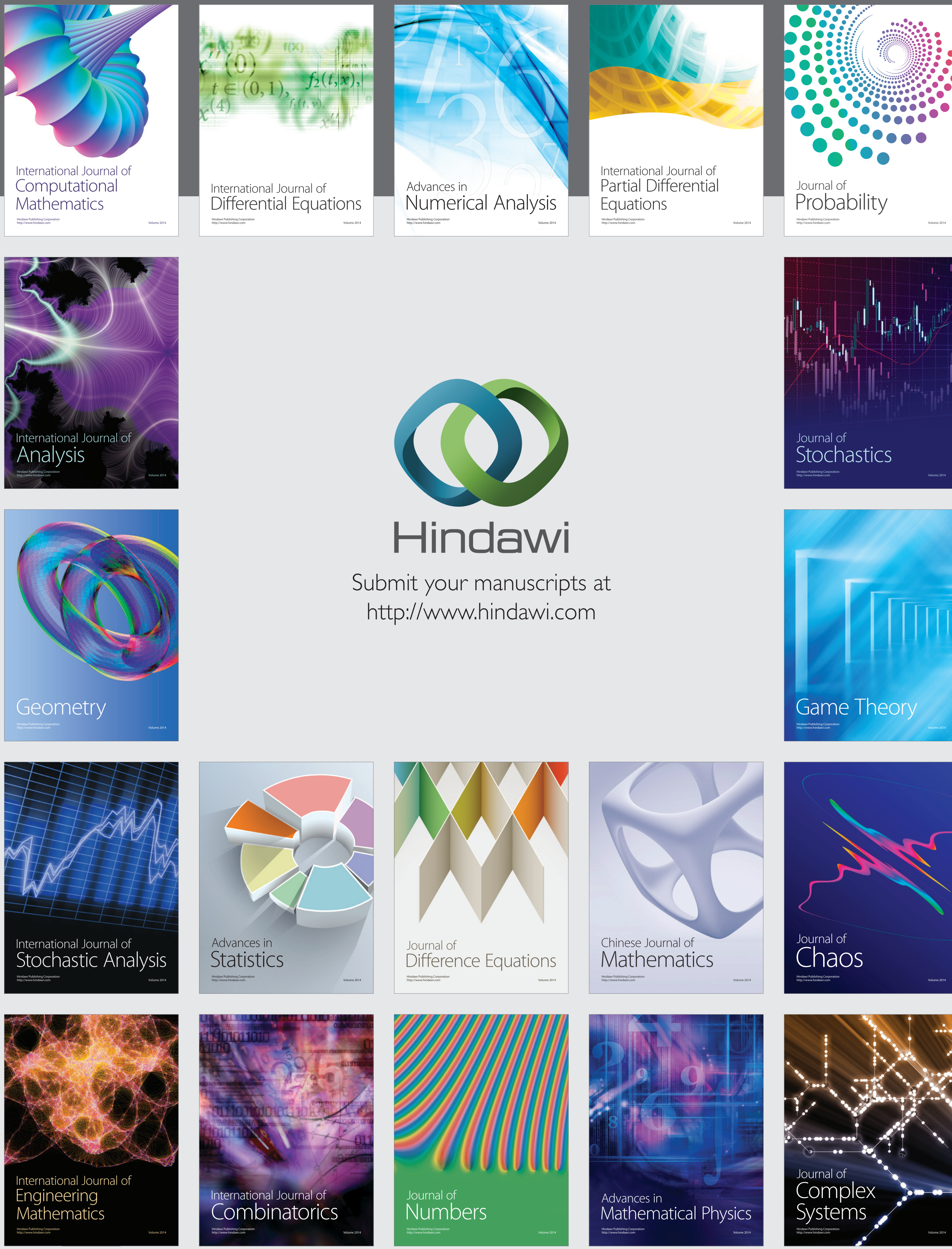
☐ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are: ____________

☐ I am a member of a hotel frequent-travel club and would like to receive appropriate credit. The hotel chain and card number are: ____________

☐ I am not reserving a room. I am sharing with ____________, who is making the reservation.

Order of choice	Hotel	Single (1 adult) Rate	Double Rate (2 adults - 1 bed)	Double Rate (2 adults - 2 beds)	Triple (3 adults) Rate	Quad (4 adults) Rate	Rollaway Cot Fee (add to special requests)
	Grand Hyatt San Antonio (hqtrs)	US$ 189	US$ 209	US$ 209	US$ 229	US$ 249	No charge, king rooms only
	Student Rate	US$ 159	US$ 159	US$ 159	US$ 179	US$ 199	No charge, king rooms only
	San Antonio Marriott Rivercenter	US$ 185	US$ 185	US$ 185	US$ 205	US$ 225	US$ 15 one-time fee, king rooms only
	Student Rate	US$ 175	US$ 175	US$ 175	US$ 195	US$ 215	US$ 15 one-time fee, king rooms only
	San Antonio Marriott Riverwalk	US$ 185	US$ 185	US$ 185	US$ 205	US$ 225	US$ 15 one-time fee, king rooms only
	Student Rate	US$ 175	US$ 175	US$ 175	US$ 195	US$ 215	US$ 15 one-time fee, king rooms only
	Hilton Palacio del Rio	US$ 179	US$ 179	US$ 179	US$ 199	US$ 219	air mattresses at US$ 25 one-time fee instead of rollaways, king rooms only
	Student Rate	US$ 159	US$ 159	US$ 159	US$ 179	US$ 199	air mattresses at US$ 25 one-time fee instead of rollaways, king rooms only
	Hyatt Regency San Antonio	US$ 159	US$ 159	US$ 159	US$ 184	US$ 209	US$ 25 per day, king rooms only
	Student Rate	US$ 135	US$ 135	US$ 135	US$ 155	US$ 175	US$ 25 per day, king rooms only
	Hotel Contessa	US$ 140	US$ 140	US$ 140	US$ 190	US$ 215	no rollaways, all rooms have sleeper sofas
	Student Rate	US$ 130	US$ 130	US$ 130	US$ 155	US$ 180	no rollaways, all rooms have sleeper sofas
	LaQuinta Inn & Suites	US$ 135	US$ 135	US$ 135	US$ 135	US$ 135	no rollaways on property
	Student Rate	US$ 125	US$ 125	US$ 125	US$ 125	US$ 125	no rollaways on property
	The Westin Riverwalk San Antonio	US$ 135	US$ 135	US$ 135	US$ 175	US$ 195	No charge, king rooms only
	The Crockett	US$ 130	US$ 130	US$ 130	US$ 140	US$ 150	US$ 25 per day, king rooms only
	Student Rate	US$ 120	US$ 120	US$ 120	US$ 130	US$ 140	US$ 25 per day, king rooms only
	Springhill Suites by Marriott	US$ 94	US$ 94	US$ 94	US$ 94	US$ 94	no rollaways on property; all suites include a sofa-sleeper
	Student Rate	US$ 84	US$ 84	US$ 84	US$ 84	US$ 84	no rollaways on property; all suites include a sofa-sleeper
	Fairfield Inn & Suites by Marriott	US$ 94	US$ 94	US$ 94	US$ 94	US$ 94	no rollaways on property
	Student Rate	US$ 84	US$ 84	US$ 84	US$ 84	US$ 84	no rollaways on property
	Red Roof Plus San Antonio Downtown	US$ 83	US$ 83	US$ 83	US$ 88	US$ 93	no rollaways on property
	Student Rate	US$ 73	US$ 73	US$ 73	US$ 78	US$ 83	no rollaways on property

People interested in suites should contact the MMSB directly by email at mmsb@ams.org or by calling 800-321-4267, ext. 4137 or 4144 (401-455-4137 or 401-455-41144).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