A letter from the Director

Dear friends and colleagues,

I am happy to report that ICERM has had a very successful and exciting 2014/2015 year, with about 1000 visitors to programs and events, our largest to date. The Fall 2014 program, High Dimensional Approximation, brought theorists and experimentalists together from several areas: approximation, optimization, compressed sensing, and discrepancy. The interplay between synergistic groups was dynamic and successful. The Spring 2015 program investigated phase transitions and emergent phenomena. Despite the challenge of launching this program and its first workshops during a series of extraordinary blizzards in the northeast, the organizers crafted an innovative and fruitful semester. In this newsletter you'll find a nugget from researchers in the program: R. Kenyon, D. Kral, C. Radin, and P. Winkler.

Our summer schedule has been packed with a variety of workshops and programs, including the Summer@ICERM undergraduate research program, the Research Experiences for Undergraduate Faculty (REUF) collaboration with AIM, and the GirlsGetMath@ICERM collaboration with AIM. A three-day introduction to Data Sciences for early-career mathematicians in late July is virtually "sold out". IdeaLab 2015 focused on inverse problems and uncertainty quantification, using some newly developed interactive software created by the organizers: Omar Ghattas, Youssef Marzouk and Noemi Petra. It was a special pleasure to host and co-sponsor the twenty-first annual CAARMS conference, founded and organized by William Massey of Princeton University, and this year co-organized by Ulrica Wilson, ICERM Associate Director and Professor at Morehouse College.

ICERM is currently accepting applications from students, faculty, and research scientists to participate in upcoming semester programs: in particular, we provide support for travel and local accommodations for graduate students who can spend most or all of the semester in residence, and we provide postdoctoral fellowships for periods ranging from one semester to a year. If your university is an academic sponsor, there are funds available now to support faculty and student visitors from your institution. To encourage more sponsorships from smaller schools, we have created a "small graduate program" level of support. More information can be found on our website.

Let me take this opportunity to point out that all of ICERM's scientific activities are generated by proposals. Indeed, the strength and impact of this institute depends upon the engagement of you, members of the broad mathematical community. Please consider submitting a proposal for an undergraduate research program, a small-group research program, a workshop, or a semester-long themed program. I encourage you to contact one of the directors for additional guidance in creating a strong proposal for review by ICERM's Science Board.

Some of ICERM's constituents may already know that our renewal proposal was submitted to the NSF in March, 2014, and was followed by a site visit in September. Many former organizers, visitors, postdocs and students participated in our site visit or in our surveys, and provided first-hand reports on their scientific experience at ICERM. These individual
reports were critically important to our renewal and I am grateful to all who shared this information and to those who volunteered to be interviewed by the NSF team. We were gratified to learn in December that the resulting written review by the site visit panelists was extremely positive. We now eagerly anticipate the official announcement of a continuing award, which has been recommended for funding by the Director of DMS. As we prepare for the next five-year grant cycle for ICERM, some important near-term changes are in the works. In this newsletter, we announce a new Deputy Director and Associate Director, new Board chairs, some new staff, a new program for small-group research projects, and a newly appointed incoming Director, Brendan Hassett, Brown University, who will take over in July 2016. ICERM even has some new signage in the lobby of 121 S. Main St., the beautiful downtown building we share with Brown’s School of Public Health.

In addition to receiving this newsletter and other updates from our mailing list, you are invited to get updates via Facebook or Twitter. Please feel free to pass on this newsletter to any colleagues and students who might like to be kept informed about activities and opportunities at ICERM.

Finally, a big thanks once again to ICERM staff for their dedication and efforts in the past year. A good research environment depends on many factors, not least of which is help from knowledgeable and welcoming staff.

Best wishes for a productive and delightful summer,

Jill

New ICERM Director Announced

ICERM is pleased to announce that Dr. Brendan Hassett has been appointed the next Director of ICERM. Before succeeding Jill Pipher in July 2016, he will spend this coming academic year ramping up and getting to know faculty and students in Brown’s Department of Mathematics as a full Professor.

Prior to the start of his Brown appointment, Dr. Hassett was the Milton Brockett Porter Professor at Rice University. His research is in the field of algebraic geometry and the geometry of solutions to algebraic equations. Dr. Hassett will bring extensive administrative experience to Brown and the institute. He served as chair of the Rice Department of Math from 2009 until 2014, and has organized numerous meetings and conferences. He currently serves on the Board of Trustees at the Mathematical Sciences Research Institute (MSRI) in Berkeley, CA, has been a panelist on multiple occasions for the NSF and Simons Foundation, and has served on the Program Committee for the Central Section of the American Mathematical Society, among other things.

Thanks to the search committee, co-chaired by Jeff Brock (Mathematics) and Bjorn Sandstede (Division of Applied Mathematics), for their tireless efforts on behalf of the institute.

Collaborate@ICERM: Our Newest Program

We are pleased to announce a new program for those interested in small-group research. Collabrate@ICERM offers teams of 3-6 researchers the opportunity to spend five days at the institute during the summer (May-August) or in the month of January. The team research project should have a computational or experimental component. ICERM provides access to a variety of software packages as well as to high-performance computing through Brown’s Center for Computation and Visualization.

Proposals are now invited and will be reviewed by the ICERM Science Board during their November meeting. Proposals should specify the team research project should have a computational or experimental component. ICERM provides access to a variety of software packages as well as to high-performance computing through Brown’s Center for Computation and Visualization.

Proposals are now invited and will be reviewed by the ICERM Science Board during their November meeting. Proposals should specify the following:

- Professional-development activities;
ICERM is seeking proposals for semester programs, topical workshops, Collaborate@ICERM (small group research), and Summer@ICERM (undergraduate research).

ICERM encourages proposals for programs that support its mission to foster and broaden the relationship between mathematics and computation.

Those interested in developing a proposal are encouraged to contact the ICERM Director at director@icerm.brown.edu to discuss program ideas prior to submission. For more details and proposal requirements, please visit our proposal page.

New Board Chairs Appointed

ICERM is extremely pleased to announce two new board chairs:

Dr. Anna Gilbert (University of Michigan) accepted the Board of Trustees’ invitation to assume the position of Scientific Advisory Board (SAB) chair starting March 2015. She replaces Dr. Andrea Bertozzi. Dr. Gilbert has served as an active and engaged member of the SAB, and as chair plays a central role in guiding the scientific direction of the institute. Dr. Gilbert’s research interests include analysis, probability, networking, and algorithms. She is the recipient of several awards, most recently the EURASIP Signal Processing Best Paper award (2010), and the SIAM Ralph E. Kleinman Prize (2013).

Dr. Sergei Tabachnikov (Penn State/ICERM) accepted Jill Pipher's invitation to assume the position of Chair of the Education Advisory Board (EAB) beginning May 2015. He replaces Dr. Thomas Banchoff. Dr. Tabachnikov has served as an ex officio member on all three of ICERM's boards during his tenure as Deputy Director of ICERM (2013-2015) and was instrumental in the development of the Summer@ICERM undergraduate research program. He was the faculty co-leader on the first two Summer@ICERM programs, both of which produced a high number of research outcomes and publishable papers. As chair of the EAB, he will play a central role in guiding the future directions of this committee. Dr. Tabachnikov works in geometry, topology, and dynamics. He combines theoretical research with computer experiments. Among other things, Dr. Tabachnikov is the Director of the NSF-funded semester-long MASS (Mathematics Advanced Study Semesters) Program at Penn State.

GirlsGetMath@ICERM is in its second year! 25 high-school girls from Rhode Island will attend our week-long summer day camp this August. 64% will be attending from public schools, 28% from charter schools, and 8% from independent schools.

MathBytes@ICERM introduces math topics in unique 10-20 minute video clips and features researchers who communicate their topics in concise and fun ways.

ICERM has an international summer research training program (VI-MSS) that provides graduate students with the opportunity to work in small teams. The teams work on projects and engage with a diverse group of graduate students from different countries and cultural backgrounds.

Each program is held in collaboration with a foreign university or institution. Partner institutions currently include EPFL (Switzerland), IMPA (Brazil), Kobe University (Japan), Tel-Aviv University (Israel), and Tübingen University (Germany).
We would like to take this opportunity to thank the outgoing chairs for their many years of service.

Research Nugget: Limits of Permutations

In a well-shuffled deck of cards, about half of the pairs of cards are out of order. Mathematically, we say that in a permutation $\pi$ of $[n] = \{1, 2, \ldots, n\}$ there are about $\frac{1}{2} \binom{n}{2}$ inversions, that is, pairs $i < j$ for which $\pi(j) < \pi(i)$. Suppose we are interested in studying permutations for which the number of inversions is exceptionally large or small, for example $\alpha \binom{n}{2}$ for some other $\alpha \in [0, 1]$. What can one say about the structure and properties of such a permutation? For example, typically how many double inversions (triples $i < j < k$ for which $\pi(k) < \pi(j) < \pi(i)$) might one expect?

Figure 1: A permutation with density $3/4$ of inversions.

Figure 1 is an illustration of the shape of a large permutation with a fraction $3/4$ of inversions ($\frac{3}{4} \binom{n}{2}$ total inversions), in a large-$n$ limit. What we are actually drawing is called a permutation: a probability measure on $[0,1]^n$ with uniform marginals (well, we're graphing its probability density function). How does a permutation describe a large permutation? A permutation is, in a well-defined sense, the limit of the scaled permutation matrices associated to larger and larger permutations. The permutation matrix associated to a permutation of $n = 300$ and $3/4$ fraction of inversions is shown in Figure 2.

Figure 2: A permutation matrix of a uniform random permutation with density $3/4$ of inversions.

Generally a pattern in a permutation is an order-sequence imposed on a finite subset of $[n]$; for instance, the permutation 34251 contains 5 copies of the pattern 231 (342, 341, 351, 451, and 251). The density of a pattern $\pi$ of length $k$ in a permutation $\sigma$ on $[n]$ is the number of occurrences of the pattern $\pi$, divided by $\binom{n}{k}$. If we fix the densities $d_1, d_2, \ldots$ of a few specific patterns, such as 12 and 123, the set of all permutations in $S_n$ with approximately those densities takes on a 'bulk persons,' or limit shape. Most permutations in the set look alike; for example, their other pattern densities match. Moreover, the limit shape, with these constraints, varies smoothly (in fact analytically) except for an occasional singularity when a 'phase boundary' is crossed. This is why we can assert that almost all permutations with density $3/4$ of inversions 'look like' Figure 1.

How do we find the permutation for a given set of densities? This can be realized with the recent derivation [Kenyon, Král', Radin, Winkler: arXiv:1506.02340] of a variational principle. Starting from the fact that the number of permutations in $S_n$ with given constraints $d$ is generally of the order $n! \exp(\alpha n)$, the (negative) entropy $s = -d \log d$, maximizing entropy allows one to find the

ICERM has a new math "Nuggets" page featuring brief summaries describing all or some portion of the research accomplished during a specific ICERM program.

Did you know?

ICERM hosts an 8-week summer undergraduate research program, Summer@ICERM is designed for a select group of 12-14 undergraduate scholars. Students work in groups of two or three, supervised by faculty advisors and aided by teaching assistants.

Since June, the 2015 cohort has been working on research topics ranging from applied topology, applied computational dynamics, and PDE models. They will give talks about their findings and write up their research into draft papers at the end of the program.

Did you know?

ICERM visitors have access to Brown University's Center for Computation and Visualization (CCV).

CCV provides a high performance computing environment for complex numerical simulation, modeling, and analysis.

Did you know?

ICERM was pleased to host the 21st annual Conference for African American Researchers in Mathematics (CAARMS).

CAARMS 21
ICERM invites early-career researchers to participate in its programs.

**Graduate Students:** ICERM welcomes applications from graduate students who wish to spend between 6 weeks and one semester at ICERM to participate in one of its semester-long programs. ICERM offers support for travel to the institute and local accommodations. Graduate students who present a poster at an ICERM workshop are typically awarded funding for local accommodations.

**Postdocs:** ICERM brings early-career mathematicians to the institute in order to support and expand their research and to create lasting career collaborations and connections. There are three ways to participate as a Postdoctoral Fellow in an ICERM semester program:

1. **Postdoctoral Institute Fellows:** The institute funds two academic-year postdoctoral positions that include a stipend and benefits. Each Institute Postdoc is a research participant in either the fall or spring semester program and is matched with a faculty mentor for the entire academic year. [Apply via Mathjobs.org](http://mathjobs.org)

2. **Postdoctoral Semester Fellows:** These postdoctoral researchers are associated with a specific program and are in residence for that semester, supported by a monthly stipend and benefits. [Apply via Mathjobs.org](http://mathjobs.org).

3. **Postdoctoral Visitors:** Postdoctoral researchers with support from their home institutions can apply for travel and/or lodging support to participate in an ICERM semester program.

**Upcoming ICERM Programs and Events**

**Semester Programs**

**Fall 2015:** *Computational Aspects of the Langlands Program*  
(September 9 - December 4, 2015)

Despite its many successes, the Langlands program remains vague in many of its predictions, due in part to an absence of data to guide a precise formulation away from a few special cases. In this thematic program, we will experiment with and articulate refined conjectures relating arithmetic-geometric objects to automorphic forms, improve the computational infrastructure underpinning the Langlands program, and assemble additional supporting data. Such data has proven valuable for researchers in number theory, and it will continue to be made available at the L-Functions and Modular Forms Database.
Spring 2016: *Dimension and Dynamics (February 1 - May 6, 2016)*

Since its introduction by Felix Hausdorff in 1919, the concept of the Hausdorff dimension of sets and measures has been a versatile and powerful tool in classical analysis, geometry and geometric measure theory, mathematical physics and their numerous applications. However, there has been a particularly important symbiosis between dynamical systems and dimension theory. This connection arises both from application of dimension theory to the classification and geometric analysis of dynamical systems (and their invariant sets and measures), and the fact that many classical objects of study in mathematics arise from (sometimes implicit) dynamical systems, which often play a role in the dimension theory of said objects. This semester program will focus on: (i) Ergodic, algebraic and combinatorial methods in dimension theory; (ii) Computations in fractal geometry in dynamical systems; and (iii) Fractal geometry and hyperbolic dynamics.

**Fall 2016: Topology in Motion (September 6, 2016 - December 9, 2016)**

This thematic semester aims at exploring those areas of topology where the research challenges stem from scientific and engineering problems and computer experiments rather than the intrinsic development of the topology proper. Some topics that will be covered: moduli spaces of linkages, hinges and origami; configuration spaces of hard disks and coverings; topological robotics; topology of random simplicial complexes and random varieties; topology in condensed matter; high-dimensional expanders; equipartitions and Tverberg-type theorems.

Spring 2017: *Singularities and Waves In Incompressible Fluids (January 30 - May 5, 2017)*

Incompressible fluids are an abundant source of mathematical and practical problems. The question of global-in-time regularity versus finite-time singularity formation for incompressible fluids, governed by the Navier-Stokes or Euler equations, has been one of the most challenging outstanding problems in applied PDE. There have also been new developments in the study of the onset of turbulence due to linear and nonlinear instabilities in incompressible fluids. Interfacial and surface water waves are physical phenomena that, in addition to the challenges outlined above, involve the evolution of free boundaries. These problems embody many of the mathematical challenges found in studies of nonlinear PDEs.

Topical Workshops
- **Mathematics in Data Science** (July 28-30, 2015)
- **Numerical Methods for Large-Scale Nonlinear Problems and Their Applications** (August 31 - September 4, 2015)

Summer Programs
- **Research Experiences for Undergraduate Faculty (REUF)** (July 20-24, 2015)
- **GirlsGetMath@ICERM** (August 17-21, 2015)

Special Events:
The mission of the Institute for Computational and Experimental Research in Mathematics (ICERM) is to support and broaden the relationship between mathematics and computation: specifically, to expand the use of computational and experimental methods in mathematics, to support theoretical advances related to computation, and address problems posed by the existence and use of the computer through mathematical tools, research and innovation.

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