MSRI
Mathematical Sciences Research Institute

17 Gauss Way Berkeley, CA 94720-5070 p: 510.642.0143 f: 510.642.8609 www.msri.org

Annual Report
on the
Mathematical Sciences Research Institute
2010–11 Activities
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Mathematical Sciences Research Institute
NSA Annual Report for 2010–11

I. INTRODUCTION

The main scientific activities of MSRI are its Programs and Workshops. Typically, MSRI will host one year-long program and two semester-long programs or four semester-long programs each year. Each program has about forty mathematicians in residence at any given time, including seven to eight graduate students. Each year, MSRI also runs a one-year Complementary Program, with five to ten researchers. The purpose of the Complementary Program is to host mathematicians whose research expertise, while not directly in the area of the main programs held at MSRI that year, remains sufficiently close to it so as to promote interdisciplinary interactions among researchers.

During the 2010–11 academic year, aside from the Complementary Program, MSRI hosted a total of four programs. Two semester-long programs *Random Matrix Theory, Interacting Particle Systems and Integrable Systems* and *Inverse Problems and Applications* in the fall and two semester-long programs *Free Boundary Problems, Theory and Applications* and *Arithmetic Statistics* in the spring. In addition, MSRI had an NSF supplemental grant to fund ten postdoctoral fellows who held their fellowships at other academic institutions.

Approximately 250 researchers participated in these programs for period of one month or longer. Of those, 18 were funded either entirely or partially by NSA Practical & Intellectual (P&I) Grant H98230-10-1-0242. Among those 18 members, three of them were postdoctoral fellows: Karl Liechty and Igor Rumanov were postdoctoral fellows in the *Random Matrix Theory, Interacting Particle Systems* program, while Jacob White was in the *Complementary* program. More information about these three postdocs can be found in Chapter III.

Generally, each semester-long program features three workshops that are held at MSRI during the program. The program begins with a *Connections for Women* Workshop, which is designed to encourage the participation of women in the research activities of the program. If the area of mathematics is one that traditionally has a large number of women, then the workshop can be used to highlight and to showcase their individual work. However, if the number of women in the field is low, then the workshop is marketed to a wider female audience in an effort to stimulate interest in the area. In addition, another goal is to encourage new connections among the women early in the program as a catalyst for eventual collaborations. This workshop is then followed by an Introductory Workshop, the purpose of which is to introduce the subject to the broader mathematical community. Later during the program, there is a Topical Workshop, which is designed to explore some of the themes of the program in depth. A total of 12 of these programmatic workshops took place at MSRI during the 2010–11 academic year. One workshop, *Connections for Women in Random Matrix Theory*, was partially funded by a separate NSA grant (H98230-10-1-0189).

In addition to the scientific workshops that run parallel with the programs, MSRI hosted a Hot Topics workshop on the Kervaire Invariant. (Every year MSRI holds a Hot Topics workshop in an area of intense mathematical activity.) This workshop focused on the

ideas surrounding the recent solution to the Arf-Kervaire invariant problem in stable homotopy theory by Mike Hill, Mike Hopkins, and Doug Ravenel. Scientific workshops are briefly summarized in Chapter II, section B.

MSRI also hosts Educational & Outreach Workshops. These workshops focus on improving the skills of K–12 math teachers. Four Educational & Outreach Workshops took place during the 2010–11 academic year. Their descriptions, as well as lists of speakers, talks and participants, can be found on the MSRI web site at https://secure.msri.org/calendar/index_workshops. They are also briefly summarized in Chapter II, section C.

Another essential activity at MSRI is its series of Summer Graduate Workshops which target advanced graduate students in mathematics. During the summer of 2010, MSRI hosted six Summer Graduate Workshops, with themes ranging from climate change topics to operator algebras. A complete description can be found at the URL https://secure.msri.org/calendar/index_sgw with a summary in Chapter II, section D.

Last but not least, each summer since 2007, MSRI has hosted a summer school (MSRI-UP) for undergraduate students with the aim of increasing the number of PhDs among members of under-represented groups. These summer schools are co-funded by the NSA and the NSF. The 2011 MSRI-UP workshop in Mathematical Finance was a successful and popular workshop, with 18 undergraduate participants. (See Chapter II, section E, for a brief summary). Since MSRI-UP was funded by an NSA grant independent of the Practical and Intellectual Training one, its report has been filed separately.

II. OVERVIEW OF ACTIVITIES 2010–11

A. Major Programs and their Associated Workshops

Note: The description of each activity is provided to MSRI by the organizers prior to the beginning of each activity; therefore, the verbs are in the future tense. In the list of organizers of each activity, an asterisk (*) denotes lead organizer(s).

Program 1: Random Matrix Theory, Interacting Particle Systems and Integrable Systems (RMT)
August 16, 2010 to December 17, 2010
Organized by Jinho Baik (University of Michigan), Alexei Borodin (California Institute of Technology), Percy A. Deift (New York University, Courant Institute), Alice Guionnet (École Normale Supérieure de Lyon, France), Craig A. Tracy (University of California, Davis), and Pierre van Moerbeke, (Université Catholique de Louvain, Belgium)*

RMT has emerged as a model for an extraordinary variety of problems in mathematics, physics and engineering. Applications run the gamut from the scattering of neutrons in nuclear physics to the distribution of the zeros of the Riemann zeta function on the critical line and include:

• combinatorics,
• the representation theory of large groups,
• multivariate statistics,
• numerical analysis and the estimation problem for condition numbers of random,
• linear systems,
• tiling problems,
• enumerative topology,
• Painleve theory,
• interacting particle systems,
• transportation problems,
• random growth processes,
• quantum transport problems, and
• wireless communications.

RMT is now well-recognized in the mathematics, physics, and engineering communities. The Tracy-Widom distributions for the largest eigenvalue of a random matrix are entering the standard toolkit of the probabilist.

In addition to showcasing the above applications, the Program will also focus on internal questions in RMT, such as universality for eigenvalue distributions of invariant ensembles, and the more recent work on Wigner ensembles. The role of asymptotic methods from the theory of integrable systems, such as the steepest descent method for Riemann-Hilbert problems, will also be highlighted.

Workshops associated with the Random Matrix Theory, Interacting Particle Systems and Integrable Systems Program:

Workshop 1: Random Matrix Theory and Its Applications I
September 13, 2010 to September 17, 2010
Organized by Jinho Baik (University of Michigan), Percy Deift (Courant Institute of Mathematical Sciences), Alexander Its (Indiana University-Purdue University Indianapolis), Kenneth McLaughlin (University of Arizona), and Craig A. Tracy (University of California, Davis)*

Random matrix theory (RMT) was introduced into the theoretical physics community by Eugene Wigner in the 1950's as a model for scattering resonances of neutrons off large nuclei. In multivariante statistics, random matrix models were introduced in the late 1920s by John Wishart and subsequently developed by Anderson, James, and others. Since these early beginnings, RMT has found an extraordinary variety of mathematical, physical, and engineering applications include number theory, stochastic growth models, tiling problems, and wireless communications.

Workshop 2: Connections for Women: An Introduction to Random Matrices
September 20, 2010 to September 21, 2010

Organized by Estelle Basor (American Institute of Mathematics, Palo Alto), Alice Guionnet (Ecole Normale Supérieure de Lyon), and Irina Nenciu (University of Illinois at Chicago)*

One of the aims of this workshop is to present basic notions from random matrix theory, with a particular focus on providing background material so all participants can interact successfully with more experienced and senior researchers involved in the program. Many of the senior participants are experts in one area of random matrix theory and have less familiarity with techniques and results from other related topics. We hope this workshop will broaden the knowledge of all participants so they might more fully interact with all aspects of the program. In conjunction with the workshop, we plan to organize discussion sessions which will explore open problems and directions of research that emerged during the week-long workshop held the preceding week.

Workshop 3: Random Matrix Theory and Its Applications II
December 6, 2010 to December 10, 2010
Organized by Alexei Borodin (California Institute of Technology), Percy Deift (Courant Institute of Mathematical Sciences), Alice Guionnet (Ecole Normale Supérieure de Lyon), Pierre van Moerbeke (Universite Catholique de Louvain and Brandeis University), and Craig A.Tracy (University of California, Davis)*

In the spring of 1999, MSRI hosted a very successful and influential one-semester program on RMT and its applications. At the accompanied workshops to the program, the brand new and very recent results generated a sense of excitement. The goal of the 2010 Program is to showcase the many remarkable developments that have taken place since 1999, to spur further developments in RMT and related areas of interacting particle systems (IPS) and integrable systems (IS), and to highlight various applications of RMT.

Program 2: Inverse Problems and Applications (IPA)
August 16, 2010 to December 17, 2010
Organized by Liliana Borcea (Rice University), Maarten V. de Hoop (Purdue University), Carlos E. Kenig (University of Chicago), Peter Kuchment (Texas A&M University), Lassi Päivärinta (University of Helsinki, Finland), Gunther Uhlmann (University of Washington), and Maciej Zworski (University of California, Berkeley)*

Inverse Problems are problems where causes for a desired or an observed effect are to be determined. They lie at the heart of scientific inquiry and technological development. Applications include a number of medical and other imaging techniques, location of oil and mineral deposits in the earth's substructure, creation of astrophysical images from telescope data, finding cracks and interfaces within materials, shape optimization, model identification in growth processes and, more recently, modeling in the life sciences. During the last 10 years, there have been significant developments in both the mathematical theory and applications of inverse problems. The purpose of the program is to bring together people working on different aspects of the field, to appraise the current status of development and to encourage interaction between mathematicians, scientists, and engineers working directly with the applications.

Workshops associated with the Inverse Problems and Applications Program:

Workshop 1: Connections for Women: Inverse Problems and Applications
August 19, 2010 to August 20, 2010
Organized by Tanya Christiansen (University of Missouri, Columbia), Alison Malcolm (Massachusetts Institute of Technology), Shari Moskow (Drexel University), Chrysoula Tsogka (University of Crete), and Gunther Uhlmann (University of Washington)*

The workshop will consist of four mini-courses of two hours each that will give an introduction to several of the topics discussed in the Introductory Workshop the following week and topics that will be discussed during the Fall semester. A brief description of each mini-course follows.

Workshop 2: Introductory Workshop on Inverse Problems and Applications
August 23, 2010 to August 27, 2010
Organized by Margaret Cheney (Rensselaer Polytechnic Institute), Gunther Uhlmann (University of Washington), Michael Vogelius (Rutgers), and Maciej Zworski (University of California, Berkeley)*

The workshop will consist of six mini-courses of three or four hours each addressing a broad range of the theoretical and practical issues arising in inverse problems, including, imaging in random media, radar imaging, thermoacoustic and photoacoustic tomography, travel time tomography, and electromagnetic imaging.

Workshop 3: Inverse Problems: Theory and Applications
November 8, 2010 to November 12, 2010
Organized by Liliana Borcea (Rice University), Carlos Kenig (University of Chicago), Maarten de Hoop (Purdue University), Peter Kuchment (Texas A&M University), Lassi Paivarinta (University of Helsinki), and Gunther Uhlmann (University of Washington)*

The speakers in the workshop will cover a broad range of the most recent developments in the theory and applications of inverse problems.

Program 3: Free Boundary Problems, Theory and Applications (FBP)
January 10, 2011 to May 20, 2011
Organized by Luis Caffarelli (University of Texas, Austin), Henri Berestycki (Centre d'Analyse et de Mathématique Sociales, France), Laurence C. Evans (University of California, Berkeley), Mikhail Feldman (University of Wisconsin, Madison), John Ockendon (University of Oxford, United Kingdom), Arshak Petrosyan (Purdue University), Henrik Shahgholian (The Royal Institute of Technology, Sweden), Tatiana Toro (University of Washington), and Nina Uraltseva (Steklov Mathematical Institute, Russia)*

This program aims at the study of various topics within the area of Free Boundaries Problems, from the viewpoints of theory and applications. Many problems in physics,

industry, finance, biology, and other areas can be described by partial differential equations that exhibit apriori unknown sets, such as interfaces, moving boundaries, shocks, etc. The study of such sets, also known as free boundaries, often occupies a central position in such problems. The aim of this program is to gather experts in the field with knowledge of various applied and theoretical aspects of free boundary problems.

Workshops associated with the Free Boundary Problems, Theory and Applications Program:

Workshop 1: Connections for Women: Free Boundary Problems, Theory and Applications
January 13, 2011 to January 14, 2011
Organized by Catherine Bandle (University of Basel), Claudia Lederman (University of Buenos Aires), and Noemi Wolanski (University of Buenos Aires)

This workshop is intended to bring together women working in areas related to Free Boundary Problems.

On the one hand, distinguished mathematicians will present their current research. Considering that this is the first workshop in the Program, some survey suitable for people who are not specialists will be also included. In these talks, the speakers will briefly comment on their experiences as women mathematicians.

On the other hand, the workshop is open to "Contributed Talks". Moreover, there will be some free time for informal discussions.

One of the major goals besides the scientific aspects of this workshop is to encourage women mathematicians to interact and learn about each other´s experiences.

Workshop 2: Introductory Workshop: Free Boundary Problems, Theory and Applications
January 18, 2011 to January 21, 2011
Organized by Tatiana Toro (University of Washington)*

Many problems in physics, industry, finance, biology, and other areas can be described by partial differential equations that exhibit apriori unknown sets, such as interfaces, moving boundaries or shocks. The study of such sets, also known as free boundaries, often plays a central role in the understanding of such problems. The aim of this workshop is to introduce several free boundary problems that arise in completely different areas.

Workshop 3: Free Boundary Problems, Theory and Applications
March 7, 2011 to March 11, 2011
Organized by John King (University of Nottingham), Arshak Petrosyan (Purdue University), Henrik Shahgholian (Royal Institute of Technology), and Georg Weiss (University of Dusseldorf)*

Many problems in physics, industry, finance, biology, and other areas can be described by partial differential equations that exhibit apriori unknown sets, such as interfaces, moving boundaries, or shocks. The study of such sets, also known as free boundaries, often occupies a central position in such problems. The main objective of the workshop is to bring together experts in various theoretical and applied aspects of free boundary problems.

Program 4: Arithmetic Statistics (AS)
January 10, 2011 to May 20, 2011
Organized by Brian Conrey (American Institute of Mathematics), John Cremona (University of Warwick, United Kingdom), Barry Mazur (Harvard University), Michael Rubinstein (University of Waterloo, Canada), Peter Sarnak (Princeton University), Nina Snaith (University of Bristol, United Kingdom), and William Stein (University of Washington)*

L-functions attached to modular forms and/or to algebraic varieties, and algebraic number fields are prominent in quite a wide range of number theoretic issues. Our recent growth of understanding of the analytic properties of L-functions has already led to profound applications regarding among other things the statistics related to arithmetic problems. This program will emphasize statistical aspects of L-functions, modular forms, and associated arithmetic and algebraic objects from several different perspectives — theoretical, algorithmic, and experimental.

We will bring together experts on modular forms, analytic number theory, arithmetic and algebraic geometry, mathematical physics, and computational number theory to investigate several difficult problems in number theory from the point of view of understanding their limiting behavior. Some of the specific problems we will consider include: the moments and value distribution of L-functions, statistics of the zeros of L -functions, the distribution of Fourier coefficients of automorphic forms, statistics of Maass forms, asymptotics of number fields, and asymptotics of ranks of elliptic curves.

Workshops associated with the Arithmetic Statistics Program:

Workshop 1: Connections for Women: Arithmetic Statistics
January 27, 2011 to January 28, 2011
Organized by Chantal David (Concordia University) and Nina Snaith (University of Bristol)*

The format of this two-day workshop will be colloquium-style presentations designed to introduce some of the major topics touched on by the "Arithmetic Statistics" program. They will be pitched for researchers with a variety of mathematical backgrounds. The talks are designed broadly as a lead-in to the program's initial workshop which take place the following week and will include topics such as the Sato-Tate conjecture, random matrix theory, and enumeration of number fields. The purpose will be to provide background and to present the exciting areas where progress is happening fast, where

major problems have been solved, or where there are significant open questions that need to be tackled. With this workshop we aim to provide motivation for the participants to involve themselves with the remainder of the program.

Workshop 2: Introductory Workshop: Arithmetic Statistics
January 31, 2011 to February 4, 2011
Organized by Barry Mazur (Harvard University), Carl Pomerance (Dartmouth College), and Michael Rubinstein (University of Waterloo)*

Our Introductory Workshop will focus largely on the background, recent work, and current problems regarding:

- Selmer groups and Mordell-Weil groups, and the distribution of their ranks (and "sizes") over families of elliptic curves, including recent work of Manjul Bhargava and Arul Shankar where they have shown that the average size of the (2)-Selmer group of an elliptic curve over (mathbb{Q}) is (3) and thereby obtains information about the average rank of Mordell-Weil groups,
- Related work on the asymptotics of number fields,
- Certain natural families of (L)-functions and the statistical distribution of their zeros and values,
- Complementary algorithmic methods and experimental results regarding (L)-functions, automorphic forms, elliptic curves and number fields, and
- The statistical behavior of eigenvalues of Frobenius elements in Galois representations and of related trigonometric sums.

Workshop 3: Arithmetic Statistics
April 11, 2011 to April 15, 2011
Organized by Brian Conrey (American Institute of Mathematics), Barry Mazur (Harvard University), and Michael Rubinstein (University of Waterloo)*

The workshop will highlight some work relevant to or carried out during our program at MSRI, including, statistical results about ranks for elliptic curves, zeros of L-functions, curves over finite fields, and algorithms for L-functions, point counting, and automorphic forms.

Program 5: Complementary Program
August 16, 2010 to May 20, 2011

MSRI had a small Complementary Program comprised of one postdoctoral fellow, Jacob White from Arizona State University, a Field Medalist, Jean Bourgain from Institute for Advanced Study, and three research members, Brigitte Servatius from Worcester Polytechnic, Fatemeh Mohammadi from Ferdowsi University of Mashhad, and Wolkmar Welker from Hans-Meerweinstrasse of Marburg, Germany.

Program 6: Second year of Postdoctoral Program supported by the NSF Supplemental Grant DMS-0936277 to the Core Grant DMS-0441170 (2005–10)
August 16, 2010 to May 20, 2011

In the spring of 2009, MSRI (together with all the other NSF-funded mathematical institutions) proposed and received funds (DMS-0936277) for additional postdoctoral fellowships (PdFs). This funding supported the research of talented junior future professors and leading researcher who otherwise might have left the profession due to the challenging economic climate. One of the most critical aspects of the development of a young mathematician's career is his or her assimilation into the culture and network of the established researchers in the field. The MSRI fellowships were open to U.S. junior (within five years of obtaining a Ph.D.) researchers who had not been able to secure a position in academia.

While most of the PdF's time was spent at Sponsoring Institutions, the institute required commitments from all the mentors to follow MSRI mentoring guidelines.

In 2010–11, ten postdoctoral fellows were supported by this supplemental grant. MSRI refers to them as 'external postdocs' as they hold their fellowships not at MSRI but at hosting institutions all over North America. Please refer to the table below for the name and status of each postdoc.

MSRI's 10 postdoctoral fellows in 2009–11
Supported by the NSF Supplemental Grant

Name	PhD Year	Length of External Fellowship	Fall 2009	Spring 2010	Fall 2010	Spring 2011	Hosting Institute	Hosting Mentor
Angeltveit, Vigleik	2006	2 years	External	External	External	External	University of Chicago	Peter May
Bogart, Tristram	2007	1 year	Internal in TG	none	External	External	San Francisco State University	Federico Ardila
Crofts, Scott	2009	2 years	External	External	External	External	University of California, Santa Cruz	Martin Weissman
Dochtermann, Anton	2007	1 year	none	none	External	External	Stanford University	Gunnar Carlsson
Hillar, Christopher	2005	1.5 years	Internal in CP	External	External	External	Redwood Center (University of California, Berekeley)	Fritz Sommer
Katz, Eric	2004	1 year	Internal in TG	none	External	External	University of Texas, Austin	Sean Keel
Mahlburg, Karl	2006	2 years	External	External	External	External	Princeton University	Manjul Bhargava
Ma'u, Sikimeti	2008	1 year	Internal in SCGT	Internal in SCGT	External	External	Barnard College	Dusa McDuff
Smith, Abraham	2009	2 years	External	External	External	External	McGill University (Quebec)	Niky Karman
Speck, Jared	2008	1 year	none	none	External	External	Princeton University	Sergiu Klainerman

TG = Tropical Geometry Program
CP = Complementary Program 2009-10
SCGT = Symplectic and Contact Geometry and Topology Program

B. Other Scientific Workshops

Workshop 1: 21st Bay Area Discrete Math Day
October 16, 2010
Organized by Federico Ardila (San Francisco State University), Ruchira Datta (University of California, Berkeley), Tim Hsu (San Jose State University), Fu Liu (University of California, Davis), Carol Meyers (Lawrence Livermore National Laboratory), Raman Sanyal (University of California, Berkeley), Rick Scott (Santa Clara University), and Ellen Veomett (California State University, East Bay)*

BADMath Days are one-day meetings aimed at facilitating communication between researchers and graduate students of discrete mathematics around the San Francisco Bay Area. These days happen twice a year and strive to create an informal atmosphere to talk about discrete mathematics. The term 'discrete mathematics' includes at least the following topics: Algebraic and Enumerative Combinatorics, Discrete Geometry, Graph Theory, Coding and Design Theory, Combinatorial Aspects of Computational Algebra and Geometry, Combinatorial Optimization, Probabilistic Combinatorics, Combinatorial Aspects of Statistics, and Combinatorics in Mathematical Physics.

Workshop 2: Bay Area Differential Geometry Seminar (BADGS) 2010-11
October 23, 2010, February 05, 2011 and April 23, 2011
Organized by David Bao (San Francisco State University), Robert Bryant (Mathematical Sciences Research Institute), Joel Hass (University of California, Davis), David Hoffman (Stanford University), Rafe Mazzeo (Stanford University), and Richard Montgomery (University of California, Santa Cruz)*

The Bay Area Differential Geometry Seminar meets three times per year and is a one-day seminar on recent developments in differential geometry and geometric analysis, broadly interpreted. Typically, it runs from mid-morning until late afternoon with three to four speakers. Lunch will be available at MSRI (participants will be asked to make a donation to help defray their lunch expenses), and the final talk will be followed by dinner. The schedule (with speakers) will be posted as soon as it becomes available. The October 23rd meeting takes place on the 60th birthday of Rick Schoen, and the dinner will recognize this happy coincidence.

Workshop 3: Hot Topics: Kervaire Invariant
October 25, 2010 to October 29, 2010
Organized by Mike Hill (University of Virginia), Michael Hopkins (Harvard University), and Douglas C. Ravenel (University of Rochester)*

This workshop will focus on the ideas surrounding the recent solution to the Arf-Kervaire invariant problem in stable homotopy theory by Mike Hill, Mike Hopkins, and Doug Ravenel. There will be talks on relevant aspects of equivariant stable homotopy theory, including the norm functor and the slice tower. The pertinent parts of chromatic homotopy theory will be covered including formal groups and formal A-modules, the Hopkins-Miller theorem, finite subgroups of Morava stabilizer groups, and Ravenel's

1978 solution to the analogous problem at primes bigger than three. The organizers will present a detailed account of the proof of the main theorem. Finally, there will be a discussion of the questions raised by the unexpected statement of the theorem.

Workshop 4: SIAM/MSRI Workshop on Hybrid Methodologies for Symbolic-Numeric Computation
November 17, 2010 to November 19, 2010
Organized by Mark Giesbrecht (University of Waterloo), Erich Kaltofen (North Carolina State University), Daniel Lichtblau (Wolfram Research), Seth Sullivant (North Carolina State University), and Lihong Zhi (Chinese Academy of Sciences, Beijing)*

Hybrid symbolic-numeric computation methods, which first appeared some twenty years ago, have gained considerable prominence. Algorithms have been developed that improve numeric robustness (e.g. in quadrature or solving ODE systems) using symbolic techniques prior to, or during, a numerical solution. Likewise, traditionally symbolic algorithms have seen speed improvements from adaptation of numeric methods (e.g., lattice reduction methods). There is also an emerging approach of characterizing, locating, and solving 'interesting nearby problems', wherein one seeks an important event (for example, a nontrivial factorization or other useful singularities), that in some measure is close to a given problem (one that might have only imprecisely specified data). Many novel techniques have been developed in these complementary areas, but there is a general belief that a more overarching understanding and approach will foster future progress.

The workshop will explore problems that are driven by applications in computational physics (quadrature of singular integrals), dynamics (symplectic integrators), robotics (global solving of direct and inverse problems near singular manifolds), control theory (stability of models), and dynamic modeling of large-scale continuous and hybrid discrete-continuous dynamical systems. Emphasis will be given to validated (certified) outputs by 1. error estimation or 2. interval techniques or 3. global optimization strategies based on semidefinite programming and exact sums-of-squares.

C. Educational & Outreach Workshops

Workshop 1: Circle on the Road Spring 2011
March 18, 2011 to March 20, 2011
Organized by Dave Auckly (MSRI), Matthias Kawski (Arizona State University), Jeff Morgan (University of Houston), Mark Saul (Bronx High School, retired), and Sam Vandervelde (Saint Lawrence University)

Circle on the Road is the annual meeting of the National Association of Math Circles www.mathcircles.org. The workshop will bring together people with experience running math circles and people who wish to learn how to run a math circle.

Approximately one month before the festival, apprentices will be able to sign up with experienced circle leaders to prepare a math circle session offered on Saturday, March 19. These sample circle sessions will be open to the public. Friday and Sunday will feature presentations and discussions about math circles.

The sample sessions are listed at:
https://www.mathcircles.org/content/creating-lesson-plans

Workshop 2: Critical Issues in Mathematics Education 2011: Mathematical Education of Teachers
May 11, 2011 to May 13, 2011
Organized by Dave Auckly (MSRI), Sybilla Beckmann (University of Georgia), Jim Lewis (University of Nebraska Lincoln) and William McCallum (University of Arizona)*

This will be the eighth workshop in the CIME series. Two previous workshops have focused on issues related to educating teachers of mathematics. The second workshop addressed the mathematical knowledge needed for teaching, and the fourth workshop emphasized teaching mathematics teachers. The Critical Issues series returns to the topic of educating teachers of mathematics because:

- the Common Core State Standards, which have been adopted by most states, present both a challenge to ensure that the nation's teachers are prepared to teach to high standards and an opportunity to seek common standards for educating the next generation of teachers;
- it is appropriate to examine what has been learned from ongoing initiatives and research. For example, both NSF and the U.S. Department of Education have made a substantial and sustained investment in Math Science Partnerships;
- the Conference Board of the Mathematical Sciences has launched an initiative to revisit and update their publication, The Mathematical Education of Teachers;
- now more than ever, there is a need for an active, vibrant, interdisciplinary community that will drive a cycle of improvement in both the teaching of mathematics at all levels (elementary school to collegiate education) and knowledge about mathematics teaching.

These questions will guide the workshop design:

1. What are implications of the Common Core State Standards in Mathematics for the mathematical education of teachers?
2. What has been learned about the mathematical education of future and current teachers over the past decade?
3. How can we encourage, develop, and sustain an interdisciplinary community of mathematics educators and scholars, including teachers, mathematicians, mathematics educators, and education researchers, in such a way that different

communities communicate with and learn from each other, and, in so doing, drive a cycle of improvement in the teaching of mathematics at all levels?

The audience for the workshop includes mathematicians, mathematics educators, classroom teachers, and education researchers who are concerned with improving the teaching of mathematics and, in particular, the mathematical education of teachers. The workshop will showcase materials and successful teacher education programs, examine the Common Core State Standards and its implications, and explore how mathematics education research can improve practice.

MSRI and the workshop organizers are especially interested in encouraging mathematicians to participate actively in this workshop and to become engaged in the community of scholars working to improve mathematics teaching and especially the mathematical education of teachers.

Workshop 3: Summer Institute for the Professional Development of Middle School Teachers (Wu Summer 2010 Institute)
July 6, 2010 to July 23, 2010
Organized by Hung-Hsi Wu (University of California, Berkeley)

This is a fourteen-day institute on algebra together with five Saturday sessions spread over the 2010-2011 school year. The target audience is middle school teachers; preference will be given to teachers who attended the 2009 Pre-Algebra Institute and teams from the same school or same district. However, high school teachers and upper elementary school teachers will also be considered.

Workshop 4: Workshop on Mathematics Journals
February 14, 2011 to February 16, 2011
Organized by James M Crowley (Society for Industrial and Applied Mathematics), Susan Hezlet (London Mathematical Society), Robion C Kirby (University of California, Berkeley), and Donald E McClure (American Mathematical Society)*

Mathematics relies on its journal literature as the main conduit for peer review and dissemination of research, and it does so more heavily and differently than other scientific fields. The conflict between universal access and the traditional subscription model that funds the journals has been debated for the past decade, while hard data on financial sustainability and usage under the different models has been slow to appear. However, over the last ten years, electronic versions of journals have increased in importance. The workshop plans to take an evidence-based approach to discussing dissemination, access, and usage of mathematics journals.

The workshop will discuss what is important and unique to the publishing of mathematical research articles and how we can best ensure that publishing practices support peer reviewed research in the long term. Much of the current discussion is taking place between funders and publishers, including learned societies, but not directly with mathematicians. A second goal is to obtain a consensus of opinion on what is important

about journal publishing to mathematicians, i.e., where the balance lies between the desire for profits from publishing and the broader dissemination of research.

D. Summer Graduate Schools 2010

SGS 1: Summer School on Operator Algebras and Noncommutative Geometry
Location: University of Victoria - Victoria, BC, Canada
June 14, 2010 to June 25, 2010
Organized by Heath Emerson, (University of Victoria) Thierry Giordano, (University of Ottawa) Marcelo Laca, (University of Victoria), and Ian Putnam (University of Victoria)*

A famous theorem of Gelfand states that a space can be recovered from the algebra of continuous complex-valued functions on the space. Other algebras, namely those in which multiplication is not commutative, do not correspond to classical spaces; rather, they stand for 'noncommutative' or 'quantum' spaces. Based on this, Alain Connes' noncommutative geometry aims to develop the tools of geometry in the setting where a classical space is replaced by a non-commutative algebra of operators as the object of interest.

The summer school aims to expose participants to the classication of noncommutative spaces, the study of their homological and cohomological invariants, and the fascinating new connections between their symmetries and long standing problems in number theory.

SGS 2: Sage Days 22: Elliptic Curves
June 21, 2010 to July 2, 2010
Organized by William Stein (University of Washington)

This workshop will introduce graduate students to several central ideas in the arithmetic of elliptic curves. Participants will join a project group that will focus mainly on one topic, possibly involving elliptic curves over number fields, complex or *p*-adic *L*-functions, Heegner points and Kolyvagin classes, Iwasawa theory, and the Birch and Swinnerton-Dyer conjecture. The workshop will emphasize the essential interplay of abstract mathematics with explicit computation, which has played a central role in number theory ever since Birch and Swinnerton-Dyer made their famous conjecture in the 1960's. Participants will use and improve the free open-source Python-based mathematical software system Sage (http://www.sagemath.org) for computational projects.

SGS 3: Probability Workshop: 2010 PIMS Summer School in Probability
Location: University of Washington and Microsoft Research – Seattle, Washington
June 21, 2010 to July 10, 2010
Organized by Krzysztof Burdzy (University of Washington), Zhenqing Chen (University of Washington), Christopher Hoffman (University of Washington), Soumik Pal (University of Washington), and Yuval Peres (University of California, Berkeley)

The 2010 Pacific Institute for the Mathematical Sciences (PIMS) Summer School in Probability will be held at the University of Washington and Microsoft Research.

Main courses:

1. Exchangeable Coalescents - Jean Bertoin
2. Random surfaces and quantum gravity - Scott Sheffield

Short courses:

3. Dirichlet Form Theory and Invariance Principle - Zhenqing Chen
4. Scaling Limits and SLE - Gregory Lawler
5. Mixing Times of Markov Chains - Eyal Lubetzky, Yuval Peres and David Wilson

SGS 4: IAS/PCMI Research Summer School 2010: Image Processing
Location: Park City, Utah
June 27, 2010 to July 17, 2010
Organized by Tony Chan (University of California, Los Angeles), Ron Devore (University of South Carolina, Columbia), Stanley Osher (University of California, Los Angeles), and Hongkai Zhao (University of California, Irvine)

This workshop takes place at the Institute for Advanced Study – Park City Mathematics Institute and is reported independently by the organizers.

SGS 5: Mathematics of Climate Change
Location: NCAR, Boulder, Colorado
July 12, 2010 to July 23, 2010
Organized By Chris Jones (University of North Carolina and University of Warwick), Doug Nychka (National Center for Atmospheric Research), and Mary Lou Zeeman (Bowdoin College)

It is generally accepted in the scientific community that the world is undergoing a significant change in its climate. Mathematical models play a central role in climate change research. They are the basis for specific predictions of future changes and have been critical in elucidating the underlying physical processes. The involvement of mathematicians themselves in climate change research, however, has been modest and there is an opportunity for the mathematical sciences community to improve models for the Earth system in novel way. The goal of this summer graduate workshop is to introduce students to some of the central ideas and techniques of mathematical climate science and engage them in the process of uncovering the key mathematical problems of the area.

NCAR supports scientific research on nearly every aspect of the atmosphere and related components of the Earth's physical and biological systems. This includes developing state-of-the- art climate models, high performance computing, and innovative ways of observing the atmosphere and oceans. The Center has approximately 1000 staff members

and is supported primarily by the National Science Foundation. Part of the NCAR mission is to engage students in the problems of understanding climate and weather and thus provides an ideal context for this summer graduate workshop. The workshop is part a larger program at NCAR through the Institute for Mathematics Applied to Geosciences: Mathematicians and Climate.

The first week of the workshop will be an organized program of lectures, attendant discussions and computer labs. Themes will be drawn from:

- Introduction to climate issues and historical climate data,
- Basic climate modeling: balance and box models,
- Modeling climate process and their interactions,
- Large climate models,
- Mathematical techniques,
- Prediction and uncertainty,
- Time series analysis of data, and
- Data assimilation.

During the second week, we will transition to a structure of independent student research projects, interwoven with organized lectures on useful topics. The projects will be computationally based and students will collaborate in teams and receive guidance from both early career and senior researchers.

The emphasis of these activities will be on developing ideas and codes for solving problems that offer insight into the key issues of climate science. Students will also be mentored in preparing written reports and presentations of their work.

In addition to the research projects, students, faculty and NCAR scientists will form working groups to brainstorm on mathematical challenges in climate science. These working groups will provide an exciting opportunity for the students to be a part of a high-level effort to grapple with difficult questions and forge research directions that promise impact on both mathematical and climate change research.

SGS 6: Algebraic, Geometric, and Combinatorial Methods for Optimization
August 2, 2010 to August 13, 2010
Organized by Matthias Köppe (University of California, Davis) and Jiawang Nie (University of California, San Diego)

This workshop is intended to introduce graduate students to the main ideas of algebraic, geometric, and combinatorial methods in global optimization. We emphasize the major developments in the past few years from two viewpoints. The first one is that of the interaction of semi-definite programming and real algebraic geometry and includes topics such as linear matrix inequalities, positive polynomials, and sums of squares. The second viewpoint is that of primal methods and generating function methods in integer linear and nonlinear optimization.

E. MSRI-UP 2011: Undergraduate Program

June 11, 2011 to July 24, 2011

Organized by Duane Cooper (Morehouse College), Ricardo Cortez (Tulane University), Herbert Medina (Loyola Marymount University), Ivelisse Rubio (University of Puerto Rico, Rio Piedras Campus), and Suzanne Weekes (Worcester Polytechnic Institute)*

During the first two weeks of MSRI-UP, in preparation for their research, students will be introduced to several topics in mathematical finance, including special topics in probability and stochastic processes, arbitrage-free derivative pricing, the Black-Scholes-Merton partial differential equation, and liquidity models. During the remainder of the program, the students will work in teams on research projects. Below, we give examples of two research areas.

Project 1: Liquidity Modeling

In the fields of mathematical finance and financial engineering, a standard assumption is one of infinite liquidity of securities. Under this assumption, all market agents are price takers which means that one can buy or sell any number of shares of a security instantaneously at the market price without affecting that market price. In reality, this assumption does not hold. One popular model which relaxes the assumption of infinite liquidity is presented by Cetin, Jarrow, and Protter. This model postulates the existence of a supply curve S_t(x) which gives the price of an asset as a function of trade size and is an extension of the standard Black-Scholes-Merton model. For highly liquid stocks, this curve has been found to be a linear function of trade size with a slope that changes randomly in time. For assets which are illiquid, the supply curve lacks this linear property but seems to have a piecewise-linear structure in trade size. Using financial data, students will investigate the supply curve for moderately liquid and illiquid assets and research methods for modeling the supply curve in these cases. Models will be tested statistically for goodness of fit using spline techniques, and the distribution of model parameters will be examined using tools from probability and stochastic processes.

Project 2: Cointegration and the Capital Asset Pricing Model

The ability to predict excess returns has been a goal of financial economists for decades. The Capital Asset Pricing Model (CAPM) is a commonly used factor model for predicting expected returns, but there are several unrealistic assumptions associated with this model that make the results unreliable, such as, the assumption that supply equals demand for all assets and the assumption that investors act rationally when investing their money. This model, also relies solely on the riskiness of asset, is compared to the overall risk of the market portfolio when predicting returns. Fama and French improve the CAPM by incorporating additional risk factors into the model, but the predictive ability of this model is still in question. Students will use the statistical technique of co-integration to investigate long term relationships between macroeconomic factors, such as dividend yields and interest rates, and will use these results to build factor models that

expand on the CAPM and the Fama and French model. Financial data will be used to test the predictive power of the proposed factor models.

III. PARTICIPATION SUMMARY

a. NSA supported members

The table below lists the participants supported (fully/partially) by the NSA grant in each activity that took place at MSRI during the 2010–11 academic year. Note that these participants are all US citizen or US permanent resident.

Activities	*Member Names*
Random Matrix Theory	Postdoc: Karl Liechty Postdoc: Igor Rumanov Researcher: Alexei Borodin Researcher: Craig Tracy Researcher: Mark Adler Researcher: Ken McLaughlin
Inverse Problems Theory and Applications	Researcher: Liliana Borcea Researcher: Maarten de Hoop
Free Boundary Problems	Researcher: Tatiana Toro Researcher: Ricardo Nochetto
Arithmetic Statistics	Researcher: William Stein Researcher: Carl Pomerance Researcher: Alice Silverberg Researcher: Jonathan Hanke
Complementary Program 2010–11	Postdoc: Jacob White Researcher: Brigitte Servatius Researcher: John Shareshian
Complementary Program 2009–10	Postdoc: Christopher Severs

b. All MSRI members

The table on the next two pages indicates the number of participants for each activity that took place at MSRI during the 2010–11 academic year.

c. NSA supported postdoctoral fellows

MSRI allocated NSF, NSA and private funding to financially support 40 postdoctoral fellows during the 2010–11 academic year. Of those 40 postdoctoral fellows, three were financially supported by the NSA Practical & Intellectual H98230-10-1-0242 Grant. Detailed financial information can be found in Chapter V.

Karl Liechty was given a stipend for five months for his participation in *Random Matrix Theory* Program. Below is the information regarding his work during his stay at MSRI:

Karl Liechty

Karl Liechty received his Ph.D from Indiana University-Purdue University Indianapolis in 2010 under the supervision of Pavel Bleher. His dissertation was titled "Exact Solutions to the Six-Vertex Model with Domain Wall Boundary Conditions and Uniform Asymptotics of Discrete Orthogonal Polynomials on an Infinite Lattice". While at MSRI, Karl started a paper on "Non-intersecting random walks on an interval" with the mentorship of Pavel Bleher. He has also collaborated with Pavel Bleher on a monograph on "Random matrix theory and the six-vertex model." In addition to these projects, on which they made substantial progress, he also discussed several potential collaborations with fellow postdocs. It remains to be seen which of these gets off the ground, but he is optimistic that something will come directly from the collaborations. After his stay at MSRI, Karl Liechty continued as a Postdoctoral Assistant Professor for the University of Michigan.

Igor Rumanov was given for five months for his participation in the *Random Matrix Theory* Program. Below is the information regarding his work during his stay at MSRI:

Igor Rumanov

Igor Rumanov received his Ph.D. from the University of California at Davis in 2010 under the supervision of Craig A. Tracy. His dissertation was titled "Integrable Equations for Random Matrix Spectral Gap Probabilities". While at MSRI, he and Craig A. Tracy worked on new directions in Random Matrix (RM) Theory related research, e.g. increasing importance of probabilistic methods, theory of stochastic differential equations, new applications of conditioned non-intersecting Brownian Motion models to problems of statistical mechanics and combinatorics, and applications of rather traditional, the well developed theory of unitary invariant RM ensembles to physics and engineering problems. After his stay at MSRI, he continued as a Research Associate at the University of Colorado at Boulder. He finished a publication, "All the lowest order PDE's for spectral gaps of Gaussian matrices". He also worked on the derivation and properties of PDE's satisfied by the two-point distribution for the Airy process, obtained as a scaling limit of his previously derived PDE for two coupled finite size GUE matrices. He worked with Yang Chen on possible generalization of his approach to the derivation of PDE's for spectral gap probabilities, to non-classical unitary RME. He also started working on connections of the Asymmetric Simple Exclusion Process with the quantum XXZ chain.

Jacob White was given a stipend for ten months for his participation in the *Complementary Program 2010–11*. Below is the information regarding his work during his stay at MSRI:

Jacob White

Jacob White received his Ph.D. from Arizona State University in August 2010 under the supervision of Hélène Barcelo. His dissertation was titled "On the Complement of R-Disjoint K-Parabolic Subspace Arrangements". While at MSRI, Jacob finished writing up several papers for submission. The first is titled "Pentagonal Relations and the Exchange Module of the type A_n Cluster Algebra", which is joint work with Hélène Barcelo, and Christopher Severs. Jacob also submitted another paper, "On the Homology of the Real Complement of the k-Parabolic Arrangement" which is joint work with Christopher Severs. Motivated by some conversations with Matthias Beck, of San Francisco State University, Jacob investigated a multivariate chromatic polynomial associated to hypergraphs. The results of this investigation have been written up in a paper titled "On Multivariate Chromatic Polynomials of Hypergraphs and Hyperedge Elimination", and has been submitted to journal. While at MSRI, Jacob also continued studying Hopf monoids in the category of graphical species, a project that is currently being written up for publication. Portions of this work were done in collaboration with Marcelo Aguiar. Jacob also proved several results regarding the topology of simplicial complexes coming from the study of signed graphs. These results, obtained with Christopher Severs, are being written up for submission. Finally, Jacob engaged in collaboration with Fatemeh Mohammadi, and Volkmar Welker, during their visits to the MSRI. These collaborations investigated problems in combinatorial commutative algebra, and are still unfinished, and ongoing work. After leaving MSRI, Jacob accepted a one year postdoctoral position at Arizona State University, in Tempe, Arizona.

The NSA Practical & Intellectual H98230-10-1-0242 Grant also partially supported Postdoctoral Fellow Christopher Severs. Dr. Severs was a Postdoctoral Fellow in the *2009–10 Complementary Program* and thus was given a stipend for the month of May 2010. The information regarding his work during his stay at MSRI was presented in the previous 2009–10 annual report.

IV. PUBLICATIONS SUMMARY

18 research members (including four postdoctoral fellows) were funded either entirely or partially by NSA Practical & Intellectual (P&I) Grant H98230-10-1-0242. These members worked on a total of 28 papers during their stay at MSRI. The 28 papers are summarized as follows:

Manuscript Status	*Number of paper*
Accepted & Appeared	0
Submitted	3
Posted	4
Rough/Draft	14
Notes	7
Total	**28**

The table below provides complete details of the 28 papers:

Family Name	**First Name**	**Title**	**Co-authors**	**Manuscript Status**
Adler	Mark	Non-intersecting random walks in the neighborhood of a symmetric tacnode	P.van Moerbeke and P. Ferrari	posted
Adler	Mark	Consecutive Minors for Dyson's Brownian Motions	P.van Moerbeke and E. Nordenstam	posted
McLaughlin	Ken	Research project: random matrices beyond usual universality classes	A. Dembo, M. Stepanov	notes
McLaughlin	Ken	Research project: techniques from integrable systems and asymptotic analysis applied to d-bar problems from imaging.	T. Kriecherbauer	rough/draft
McLaughlin	Ken	trajectories of quadratic differentials and random matrix theory	N. Ercolani, A. Deano	rough/draft
McLaughlin	Ken	Statistical Mechanics of the Toda Lattice	L. Cioletti, J. Newport	rough/draft
Liechty	Karl	Non-Intersecting Random Walks on an Interval	Pavel Bleher	notes
Liechty	Karl	Average Arctic Curves	Tuca Auffinger	rough/draft
Liechty	Karl	A Shuffling Algorithm for the Six-Vertex Model	Ben Young	rough/draft
Rumanov	Igor	All the lowest order PDE for spectral gaps of Gaussian matrices		posted
Ercolani	Nicholas	Breaking Curves for 1-gap Random Matrices	Ken McLaughlin	notes

Borcea	Liliana	Pulse propagation in time dependent randomly layered media	Knut Solna	rough/draft
Borcea	Liliana	Uncertainty quantification for electrical impedance tomography with resistor networks	Fernando Guevara Vasquez, Alexander Mamonov	rough/draft
Borcea	Liliana	Pulse propagation in time dependent randomly layered media	Knust Solna	rough/draft
Borcea	Liliana	Uncertainty quantification for electrical impedance tomography with resistor networks	Fernando Guevara Vasquez, Alexander Mamonov	rough/draft
Vasy	Andreas	Local recovery of the singularities of metrics (no official title yet)	Maarten de Hoop and Gunther Uhlmann	notes
Stein	William	Questions About Finiteness of Shafarevich-Tate Groups of Higher Rank Elliptic Curves	Wei Ho	rough/draft
Stein	William	What is Riemann's Hypothesis	Barry Mazur	posted
Stein	William	Arithmetic of Higher Rank Elliptic Curves over Ring Class Fields	Robert Bradshaw	notes
Stein	William	Triple Product L-functions and Arithmetic	Xinyi Yuan	rough/draft
Lenstra	Hendrik	Primality testing with Gaussian periods	Carl Pomerance	rough/draft
Rubin	Karl	Elliptic curves with an isogeny of degree 7	Ralph Greenberg, Alice Silverberg	rough/draft
White	Jacob	On the homology of the real complement of the k-parabolic subspace arrangement	Helene Barcelo, Christopher Severs	submitted
White	Jacob	Pentagonal Relations and the Exchange Module of the type A_n Cluster Algebra	Helene Barcelo, Christopher Severs	submitted
White	Jacob	On Multivariate Chromatic Polynomials of Hypergraphs and Hyperedge Elimination	Jacob White	submitted
White	Jacob	On the complement of the r-disjoint k-equal arrangement		rough/draft
White	Jacob	On the Complex of Balanced Signed Graphs	Christopher Severs	notes
White	Jacob	Hopf Monoids and Graphical Species		notes