MSRI
Mathematical Sciences Research Institute

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Final Report
on the
Mathematical Sciences Research Institute
2014–15 Activities
supported by
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Mathematical Sciences Research Institute
NSA Final Report for 2014–15

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 coming for various period. 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 2014–15 academic year, aside from the Complementary Program, MSRI hosted a total of four programs. Two semester-long programs *New Geometric Methods in Number Theory and Automorphic Forms* and *Geometric Representation Theory* took place in the Fall 2014, and *Dynamics on Moduli Spaces of Geometric Structures* and *Geometric and Arithmetic Aspects of Homogeneous Dynamics* took place in the Spring 2015.

Approximately 250 researchers participated in these programs for period of one month or longer. Of those, four postdoctoral fellows were funded by NSA Grant H98230-14-1-0156. More information about these four postdocs can be found in Section 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.

In addition to the scientific workshops that run parallel with the programs, MSRI hosted a Hot Topics workshop on surface subgroups and cube complexes. (Every year MSRI holds a Hot Topics workshop in an area of intense mathematical activity). Scientific workshops are briefly summarized in Section II.B.

MSRI also hosts and co-hosts Education & Outreach Workshops. These workshops focus on improving the skills of K–12 math teachers. Their descriptions, as well as lists of speakers, talks and participants, can be found on the MSRI web site at http://www.msri.org/web/msri/education/for-k-12-educators. They are also briefly summarized in Section II.C.

Another essential activity at MSRI is its series of Summer Graduate Schools which target advanced graduate students in mathematics. During the summer of 2014, MSRI hosted three on-site and three off-site Summer Graduate Schools, with themes ranging from algebraic topology topics to geometry and analysis. A complete description can be found at the URL http://www.msri.org/web/msri/scientific/workshops/summer-graduate-school with a summary in Section II.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 2014 MSRI-UP workshop in Arithmetic Aspects of Elementary Functions is a successful and popular workshop, with 18 anticipated undergraduate participants. (See Section II.E, for a brief summary). Since MSRI-UP is funded by an independent NSA grant, its report is filed separately.

For a comprehensive view of the entire year's activities, we have listed all of MSRI scientific and educational activities even those not funded by the NSA grant, H98230-14-1-0156.

II. OVERVIEW OF ACTIVITIES 2014–15

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 future tense. In the list of organizers of each activity, an asterisk (*) denotes lead organizer(s).

Program 1: New Geometric Methods in Number Theory and Automorphic Forms
August 11, 2014 - December 12, 2014
*Organizers: Pierre Colmez (Institut de Mathématiques de Jussieu), *Wee Teck Gan (National University of Singapore), Michael Harris (Institut de Mathématiques de Jussieu), Elena Mantovan (California Institute of Technology), Ariane Mézard (Institut de Mathématiques de Jussieu), Akshay Venkatesh (Stanford University)*

The branches of number theory most directly related to the arithmetic of automorphic forms have seen much recent progress, with the resolution of many longstanding conjectures. These breakthroughs have largely been achieved by the discovery of new geometric techniques and insights. The goal of this program is to highlight new geometric structures and new questions of a geometric nature which seem most crucial for further development. In particular, the program will emphasize geometric questions arising in the study of Shimura varieties, the p-adic Langlands program, and periods of automorphic forms.

Workshops associated with the New Geometric Methods in Number Theory and Automorphic Forms:

Workshop 1: Connections for Women: New Geometric Methods in Number Theory and Automorphic Forms
August 14, 2014 - August 15, 2014
*Wenching Li (Pennsylvania State University), *Elena Mantovan (California Institute of Technology), Sophie Morel (Princeton University), Ramdorai Sujatha (University of British Columbia)*

This 2-day workshop will showcase the contributions of female mathematicians to the three main themes of the associated MSRI program: Shimura varieties, p-adic automorphic forms, periods and L-functions. It will bring together women who are working in these areas in all stages of their careers, featuring lectures by both established leaders and emerging researchers. In addition, there will be a poster session open to all participants and an informal panel discussion on career issues.

Workshop 2: Introductory Workshop: New Geometric Methods in Number Theory and Automorphic Forms
August 18, 2014 - August 22, 2014
*Laurent Berger (École Normale Supérieure de Lyon), Ariane Mézard (Institut de Mathématiques de Jussieu), *Akshay Venkatesh (Stanford University), Shou-Wu Zhang (Princeton University)*
The goal of this workshop is to give a practical introduction to some of the main topics and techniques related to the August-December 2014 MSRI program, "New geometric methods in number theory and automorphic forms." The workshop is aimed at graduate students and interested researchers in number theory or related fields.

There will be lecture series on periods of automorphic forms, Shimura varieties, and representations of p-adic groups, as well as more advanced topics, including p-adic Hodge theory and the cohomology of arithmetic groups.

Workshop 3: Automorphic forms, Shimura varieties, Galois representations and L-functions
December 01, 2014 - December 05, 2014
*Organizers: *Pierre Colmez (Institut de Mathématiques de Jussieu), Stephen Kudla (University of Toronto), Elena Mantovan (California Institute of Technology), Ariane Mézard (Institut de Mathématiques de Jussieu), Richard Taylor (Institute for Advanced Study)*

L-functions attached to Galois representations coming from algebraic geometry contain subtle arithmetic information (conjectures of Birch and Swinnerton-Dyer, Deligne, Beilinson, Bloch and Kato, Fontaine and Perrin-Riou). Langlands has predicted the existence of a correspondence relating these L-functions to L-functions of automorphic forms which are much better understood. The workshop will focus on recent developments related to Langlands correspondence (construction of Galois

representations attached to automorphic forms via the cohomology of Shimura varieties, modularity of Galois representations...) and arithmetic of special values of L-functions.

It will be dedicated to Michael Harris as a tribute to his enormous influence on the themes of the workshop.

Organized in partnership with Clay Mathematics Institute. Additional funding provided by ArShiFo and the European Research Council under the European Community's Seventh Framework Programme (FP7/2007-2013) / ERC Grant agreement n¬° 290766 (AAMOT).

Program 2: Geometric Representation Theory

August 18, 2014 - December 19, 2014

*Organizers: *David Ben-Zvi (University of Texas), Ngô Bảo Châu (University of Chicago), Thomas Haines (University of Maryland), Florian Herzig (University of Toronto), Kevin McGerty (University of Oxford), David Nadler (University of California, Berkeley), Catharina Stroppel (Hausdorff Research Institute for Mathematics, University of Bonn), Eva Viehmann (TU München)*

Representation theory is the study of the basic symmetries of mathematics and physics. Symmetry groups come in many different flavors: finite groups, Lie groups, p-adic groups, loop groups, adelic groups,.. A striking feature of representation theory is the persistence of fundamental structures and unifying themes throughout this great diversity of settings. One such theme is the Langlands philosophy, a vast nonabelian generalization of the Fourier transform of classical harmonic analysis, which serves as a visionary roadmap for the subject and places it at the heart of number theory.

The fundamental aims of geometric representation theory are to uncover the deeper geometric and categorical structures underlying the familiar objects of representation theory and harmonic analysis, and to apply the resulting insights to the resolution of classical problems. A groundbreaking example of its success is Beilinson-Bernstein's generalization of the Borel-Weil-Bott theorem, giving a uniform construction of all representations of Lie groups via the geometric study of differential equations on flag varieties.

The geometric study of representations often reveals deeper layers of structure in the form of categorification. Categorification typically replaces numbers (such as character values) by vector spaces (typically cohomology groups), and vector spaces (such as representation rings) by categories (typically of sheaves). It is a primary explanation for miraculous integrality and positivity properties in algebraic combinatorics. A recent triumph of geometric methods is Ngô's proof of the Fundamental Lemma, a key technical ingredient in the Langlands program. The proof relies on the cohomological interpretation of orbital integrals, which makes available the deep topological tools of algebraic geometry (such as Hodge theory and the Weil conjectures).

A primary goal of the MSRI program is to explore the potential impact of geometric methods and ideas in the Langlands program by bringing together researchers working in the diverse areas impacted by the Langlands philosophy, with a particular emphasis on representation theory over local fields. More generally, participants in the program will seek to explore new principles and paradigms within geometric representation theory. A major source of inspiration comes from theoretical physics, where new perspectives on the central objects of geometric representation theory arise in the study supersymmetric gauge theory, integrable systems and topological string theory. The impact of these ideas is only beginning to be absorbed and the program will provide a forum for their dissemination and development.

Workshops associated with the Geometric Representation Theory:

Workshop 1: Connections for Women: Geometric Representation Theory
August 28, 2014 - August 29, 2014
**Monica Vazirani (University of California, Davis), Eva Viehmann (TU München)*

Within the broad range of geometric representation theory the Connections Workshop will focus on three research topics in which we expect particularly striking new developments within the next few years:
* Categorical and geometric structures in representation theory and Lie superalgebras
* Geometric construction of representations via Shimura varieties and related moduli spaces
* Hall algebras and representations

The workshop will bring together researchers from these different topics within geometric representation theory and will thus facilitate a successful start of the semester program. It will give junior researchers from each of these parts of geometric representation theory a broader picture of possible applications and of new developments, and will establish a closer contact between junior and senior researchers.

This workshop is aimed at encouraging and increasing the active participation of women and members of under-represented groups in the MSRI program.

All are welcome to participate in the scientific portions of the workshop and the panel discussion, regardless of gender.

Workshop 2: Introductory Workshop: Geometric Representation Theory
September 02, 2014 - September 05, 2014
**David Ben-Zvi (University of Texas), Kevin McGerty (University of Oxford)*

Geometric Representation Theory is a very active field, at the center of recent advances in Number Theory and Theoretical Physics. The principal goal of the Introductory Workshop will be to provide a gateway for graduate students and new post-docs to the rich and exciting, but potentially daunting, world of geometric representation theory. The aim is to explore some of the fundamental tools and ideas needed to work in the subject,

helping build a cohort of young researchers versed in the geometric and physical sides of the Langlands philosophy.

Workshop 3: Categorical Structures in Harmonic Analysis
November 17, 2014 - November 21, 2014
*Thomas Haines (University of Maryland), Florian Herzig (University of Toronto), *David Nadler (University of California, Berkeley)*

The workshop will focus on the role of categorical structures in number theory and harmonic analysis, with an emphasis on the setting of the Langlands program. Celebrated examples of this theme range from Lusztig's character sheaves to Ngo's proof of the Fundamental Lemma. The workshop will be a forum for researchers from a diverse collection of fields to compare problems and strategies for solutions.

Organized in partnership with Clay Mathematics Institute.

Program 3: Dynamics on Moduli Spaces of Geometric Structures
January 12, 2015 to May 22, 2015
*Richard Canary (University of Michigan), William Goldman (University of Maryland), François Labourie (Université de Nice Sophia Antipolis), *Howard Masur (University of Chicago), Anna Wienhard (Ruprecht-Karls-Universität Heidelberg)*

Our program will focus on the deformation theory of geometric structures on manifolds, and the resulting geometry and dynamics. Formally a subfield of differential geometry and topology, with a heavy infusion of Lie theory, its richness stems from close relations to dynamical systems, algebraic geometry, representation theory, Lie theory, partial differential equations, number theory, and complex analysis.

Hyperbolic structures on surfaces provide the first nontrivial examples, and the classical Teichmuller space is the prototype of a deformation space of locally homogeneous structures. More general deformation spaces arise from the space of representations of the fundamental group of a manifold in a Lie group, which appears also as the moduli space of flat connections on the manifold. These "character varieties" have played an important role in developing topological invariants of manifolds, particularly in dimensions 3 and 4.

Teichmuller space can be realized as subset of the space of representations of a surface group into PSL(2,R). What has recently been called "higher Teichmuller theory" by Fock and Goncharov concerns certain deformation spaces arising from subsets of the space of representations of a surface groups into Lie groups of higher rank, e.g.PSL(n,R), which share some of the properties of classical Teichmuller space.

Recent interest in this subject has also come from mathematical physics, through Witten's suggestion relating representations in the Hitchin components, which furnish examples of higher Teichmuller spaces, to W_n-algebras, and applications of Hitchin representations to the geometric Langlands program. These unexpected inter-relationships underscore this subject's richness, timeliness and diversity. A central goal of the program will be to

bring together researchers who work in the more fully developed areas of Teichmuller geometry and deformation spaces of hyperbolic structures in low dimensions with researchers studying more general deformation spaces in order to explore these new connections.

Workshops associated with the Dynamics on Moduli Spaces of Geometric Structures Program:

Workshop 1: Connections for Women: Dynamics on Moduli Spaces of Geometric Structures
January 15, 2015 - January 16, 2015
*Virginie Charette (University of Sherbrooke), *Fanny Kassel (Université de Lille I (Sciences et Techniques de Lille Flandres Artois)), Karin Melnick (University of Maryland), Anna Wienhard (Ruprecht-Karls-Universität Heidelberg)*
This two-day workshop will consist of various talks given by prominent female mathematicians in the field. These will be appropriate for graduate students, post-docs, and researchers in areas related to the program. The workshop will also include a professional development session.

This workshop is open to all mathematicians.

Workshop 2: Introductory Workshop: Dynamics on Moduli Spaces of Geometric Structures
January 20, 2015 - January 23, 2015
*Richard Canary (University of Michigan), *William Goldman (University of Maryland), Ursula Hamenstädt (Universität Bonn), Alessandra Iozzi (Eidgenössische TH Zürich-Hönggerberg)*

The deformation theory of geometric structures on manifolds is a subfield of differential geometry and topology, with a heavy infusion of Lie theory. Its richness stems from close relations to dynamical systems, algebraic geometry, representation theory, Lie theory, partial differential equations, number theory, and complex analysis.

The introductory workshop will serve as an overview to the program. It aims to familiarize graduate students, post-docs, and other researchers to the major topics of the program. There will be a number of short courses.

Workshop 3: Dynamics on Moduli Spaces
April 13, 2015 - April 17, 2015
*Marc Burger (Eidgenössische TH Zürich-Hönggerberg), *David Dumas (University of Illinois at Chicago), Olivier Guichard (Université de Strasbourg I (Louis Pasteur)), François Labourie (Université de Nice Sophia Antipolis), Anna Wienhard (Ruprecht-Karls-Universität Heidelberg)*

The Research Workshop of the "Dynamics on moduli spaces of geometric structures" will concentrate on some of the following general interrelated themes:

(1) Geometric structures on the spaces of geometric structures which extend and generalize classical constructions on Teichmüller spaces, such as the Weil-Petersoon metric, the pressure metric, the Teichmüller metric and its geodesic flow, Fenchel-Nielsen coordinates, Fock-Goncharov Thurson-Penner coordinates, and the symplectic and Poisson geometries

(2) Relations with harmonic maps, Riemann surfaces, complex geometry: specifically Higgs bundles, holomorphic differentials (quadratic, cubic, etc.) as parameters for representations of the fundamental group, hyperkähler and complex symplectic geometry of moduli spaces, lifts of Teichmüller geodesic flows to flat bundles of character varieties

(3) Asymptotic properties of higher Teichmüller spaces, including generalized measured geodesic laminations, Culler-Morgan-Shalen asymptotics of character varieties, degenerations of geometric structures and discrete subgroups

(4) Actions of mapping class groups and outer automorphism groups, properness criteria for Anosov representations and their generalizations, properness criteria for non-discrete representations, chaotic actions of mapping class groups and the monodromy map from structures to representations

(5) Classification of exotic geometric structures, tameness criteria, generalizations of ending lamination-type invariants to higher rank structures, rigidity and flexibility for thin subgroups, arithmeticity conditions, and geometric transitions.

Program 4: Geometric and Arithmetic Aspects of Homogeneous Dynamics
January 19, 2015 to May 29, 2015
**Dmitry Kleinbock (Brandeis University), Elon Lindenstrauss (Hebrew University), Hee Oh (Yale University), Jean-François Quint (Université de Bordeaux I), Alireza Salehi Golsefidy (University of California, San Diego)*

Homogeneous dynamics is the study of asymptotic properties of the action of subgroups of Lie groups on their homogeneous spaces. This includes many classical examples of dynamical systems, such as linear Anosov diffeomorphisms of tori and geodesic flows on negatively curved manifolds. This topic is related to many branches of mathematics, in particular, number theory and geometry. Some directions to be explored in this program include: measure rigidity of multidimensional diagonal groups; effectivization, sparse equidistribution and sieving; random walks, stationary measures and stiff actions; ergodic theory of thin groups; measure classification in positive characteristic. It is a companion program to “Dynamics on moduli spaces of geometric structures”.

Workshop 1: Connections for Women: Geometric and Arithmetic Aspects of Homogeneous Dynamics
January 29, 2015 - January 30, 2015
*Elon Lindenstrauss (Hebrew University), *Hee Oh (Yale University)*

This workshop will consist of several mini-courses given by prominent female mathematicians in the field, intended for graduate students, post-docs, and researchers in areas related to the program. The workshop will also include an informal panel discussion session among female researchers on career issues. This workshop is open to all mathematicians.

Workshop 2: Introductory Workshop: Geometric and Arithmetic Aspects of Homogeneous Dynamics
February 02, 2015 - February 06, 2015
*Manfred Einsiedler (Eidgenössische TH Zürich-Hönggerberg), Dmitry Kleinbock (Brandeis University), *Jean-François Quint (Université de Bordeaux I), Barbara Schapira (Université de Picardie (Jules Verne))*

This Introductory Workshop will consist of several introductory lectures and series of lectures on the recent trends in the field, given by experts in the domain. In addition, there will be several shorter talks by young researchers.

Please note that immediately preceding this workshop there is a Connections for Women workshop which will also be introductory in nature.

Workshop 3: Advances in Homogeneous Dynamics
May 11, 2015 - May 15, 2015
Dmitry Kleinbock (Brandeis University), Hee Oh (Yale University), Alireza Salehi Golsefidy (University of California, San Diego), Ralf Spatzier (University of Michigan)

The Advances in Homogeneous Dynamics workshop will feature the speakers whose work is at the forefront of the field. There will be a panel discussion accompanied by an open problem session to lay out possible directions for the research in homogeneous dynamics. Talks will be in a broad range of topics and this will help to build more connections between researchers interested in dynamical systems, number theory and geometry. For example we hope that the involvement of the participants of the other program held at MSRI during the same academic year (Dynamics on Moduli Spaces of Geometric Structures, Spring 2015) would create new connections between the topics. There will be shorter talks presented by early-career researchers.

Program 5: Complementary Program (2014–15)
August 11, 2014 to May 29, 2015

MSRI had a small Complementary Program comprised of twelve researchers, David Ben-Zvi (University of Texas), Valerio Capraro (University of Southampton), Indira Chatterji (Universite d'Orleans), Hailong Dao (University of Kansas), Eric Flapan (Pomona College), Elon Lindenstrauss (Hebrew University of Jerusalem), Ariane Mezard (Institut de Mathématiques de Jussieu), Grigory Mikhalkin (University of Geneva), Stephen Morgan (University of Toronto), Frank Schreyer (Universität des Sarrlandes), Volkmar Welker (Universitaet Marburg and Gufang Zhao (Northeastern University).

B. Other Scientific Workshops

Workshop 1: Breaking the Neutral Code
October 29, 2014 - November 01, 2014
*Larry Abbott (Columbia University), Ingrid Daubechies (Duke University), Michael Jordan (University of California), *Liam Paninski (Columbia University)*

For decades, neuroscientists have dreamed about the possibility of recording from all the neurons in a brain, or of having access to a complete large brain wiring diagram, or ideally to obtain both of these datasets simultaneously, in the same brain. Recent technical advances have brought this dream close to reality in some cases. Now the challenge will be to understand these massive datasets. A few domains will be particularly relevant:

Inferring network structure from noisy and incomplete data
Inferring computational input-output function from structure
Optimal experimental design (incl. compressive sensing methods) for observation of networks
Modeling structured stochastic network dynamics
Optimal control of network dynamics
Inferring low-dimensional dynamics from high-dimensional observations

There's a strong need in neuroscience for deep new ideas from mathematics and statistics, and our hope is that this small, focused workshop without many formal talks will spark collaborations that will lead to breakthroughs in the areas described above.

This workshop is by invitation only.

This workshop is supported by a generous donation from Sanford Grossman. No report will be included in this annual report.

Workshop 2: Bay Area Differential Geometry Seminar (BADGS) Fall 2014
November 01, 2014
*David Bao (San Francisco State University), Joel Hass (University of California, Davis), *David Hoffman (Stanford University), Rafe Mazzeo (Stanford University), Richard Montgomery (University of California, Santa Cruz)*

The Bay Area Differential Geometry Seminar is a 1-day seminar on recent developments in differential geometry and geometric analysis, broadly interpreted. Typically, it runs from mid-morning until late afternoon, with 3-4 speakers. Lunch will be available and the final talk will be followed by dinner.

Workshop 3: Pacific Northwest and Bay Area Differential Geometry Seminar (BADGS) Spring 2015
Location: Stanford University

February 21, 2015
*Organizers: David Bao (San Francisco State University), Joel Hass (University of California, Davis), *David Hoffman (Stanford University), Rafe Mazzeo (Stanford University), Richard Montgomery (University of California, Santa Cruz)*
The Bay Area Differential Geometry Seminar meets 3 times each year and is a 1-day seminar on recent developments in differential geometry and geometric analysis, broadly interpreted. Typically, it runs from mid-morning until late afternoon, with 3-4 speakers. Lunch will be available and the final talk will be followed by dinner.

Workshop 4: Hot Topics: Kadison-Singer, Interlacing Polynomials, and Beyond
March 09, 2015 - March 13, 2015
*Sorin Popa (University of California),*Daniel Spielman (Yale University), Nikhil Srivastava (University of California, Berkeley), Cynthia Vinzant (North Carolina State University)*

In a recent paper, Marcus, Spielman and Srivastava solve the Kadison-Singer Problem by proving Weaver's KS2 conjecture and the Paving Conjecture. Their proof involved a technique they called the "method of interlacing families of polynomials" and a "barrier function" approach to proving bounds on the locations of the zeros of real stable polynomials. Using these techniques, they have also proved that there are infinite families of Ramanujan graphs of every degree, and they have developed a very simple proof of Bourgain and Tzafriri's Restricted Invertibility Theorem. The goal of this workshop is to help build upon this recent development by bringing together researchers from the disparate areas related to these techniques, including Functional Analysis, Spectral Graph Theory, Free Probability, Convex Optimization, Discrepancy Theory, and Real Algebraic Geometry.

C. Education & Outreach Workshops

Workshop 1: Critical Issues in Mathematics Education 2015: Developmental Mathematics: For whom? Toward what ends?
March 18, 2015 - March 20, 2015
*Organizers: Duane Cooper (Morehouse College), Mark Hoover (University of Michigan), *Robert Megginson (University of Michigan), Richard Sgarlotti (Bay College), Katherine Stevenson (California State University, Northridge)*

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. Key questions that will be addressed are:

1. How do we teach content in ways that acknowledge and leverage each student's prior learning experiences? In particular, how do we take advantage of a student's maturity while refining his or her learning habits where necessary?

2. How can developmental mathematics instruction move students through mathematics which must be relearned while simultaneously gaining momentum on more advanced mathematics (including the development of mathematical practices needed for meaningful mathematical work)?

3. What are strategies for supporting the needs of the wide range of students in developmental mathematics programs--those developing mathematical skills for life in general as well as those developing the foundation necessary to proceed towards a STEM major? How can we successfully address equity issues raised for students from groups underrepresented in STEM fields? How can developmental mathematics instruction blend synchronous and asynchronous instruction to achieve maximal efficiency and impact?

4. What is the proper balance between addressing the needs of the wide range of students mentioned in the preceding point and keeping instruction and course offerings concise?

5. What are the characteristics, training, and practices of a successful developmental mathematics teacher?

6. What support services enhance the success of a developmental mathematics program?

Workshop 2: Mathematics Institutes' Modern Math Workshop at SACNAS
NSF supplemental grant DMS 1126721
Location: Los Angeles, California
October 15, 2014 to October 16, 2014
Organized by Statistical and Applied Mathematical Sciences Institute (SAMSI)

As part of the Mathematical Sciences Collaborative Diversity Initiatives, nine mathematics institutes (including ICERM) are pleased to host their annual pre-conference event, the 2013 Modern Math Workshop. This event precedes the SACNAS National Conference. If you are also attending the SACNAS National Conference then you must also register separately with SACNAS online.

The Modern Math Workshop is intended to re-invigorate the focus of mathematics students and faculty at minority-serving institutions and the research careers of minority mathematicians.

A report of this event is submitted to the NSF by SAMSI.

Workshop 3: Blackwell-Tapia Conference and Awards Ceremony
NSF supplemental grant DMS 1126721
Location: Los Angeles, California
November 14, 2014 to November 15, 2014
Organized by IPAM

IPAM is honored to host the 2014 Blackwell-Tapia Conference and Awards Ceremony. The conference and prize honors David Blackwell and Richard Tapia (who won the National Medal of Science in 2010), two seminal figures who inspired a generation of African-American, Native American and Latino/Latina students to pursue careers in mathematics. This will be the eighth conference since 2000, held every other year.

The conference will offer a mix of activities including scientific talks, poster presentations, panel discussions, ample opportunities for discussion and interaction, and the awarding of the Blackwell-Tapia Prize. Participants will come from all career stages and will represent institutions of all sizes across the country, including Puerto Rico.

The goals of the conference are:

Recognize and showcase mathematical excellence by minority researchers
Recognize and disseminate successful efforts to address under-representation
Inform students and mathematicians about career opportunities in mathematics, especially outside academia
Provide networking opportunities for mathematical researchers at all points in the higher education/career trajectory

The Blackwell-Tapia Prize recognizes a mathematician who has contributed significantly to research in his or her area of expertise, and who has served as a role model for mathematical scientists and students from underrepresented minority groups, or has contributed in other significant ways to addressing the program of underrepresentation of minorities in math.

The National Blackwell-Tapia Committee has selected Jacqueline M. Hughes-Oliver to receive the 2014 Blackwell-Tapia Prize. Hughes-Oliver has been a professor of statistics at North Carolina State University since 1992. She is visiting George Mason University until May 2014. She has made important contributions in a number of statistical research areas including methodological research on prediction and classification, variable and model selection with dimension reduction, design of experiments, and spatial modeling. She has worked passionately on the cause of increasing diversity of individuals working of the statistical and mathematical sciences. Read the press release.

Organizing Committee
Ricardo Cortez (Tulane University)
Monica Jackson (American University, Mathematics and Statistics)
Trachette Jackson (University of Michigan, Dept of Mathematics)
Herbert Medina (Loyola Marymount University, Mathematics)

A report of this event is submitted to the NSF by IPAM.

Workshop 4: Infinite Possibilities Conference 2015: Celebrating and Promoting Diversity in the Mathematical Sciences

NSF supplemental grant DMS 1126721
Location: Oregon State University, Corvallis, Oregon
March 2, 2015 to March 3, 2015
Organized by MBI

The Infinite Possibilities Conference 2015 (IPC) will be held at Oregon State University (OSU) on March 2-3, 2015. IPC is a national conference designed to promote, educate, encourage and support minority women interested in mathematics and statistics. IPC 2015 is co-hosted by Building Diversity in Science and OSU.
IPC 2015 and the NSF-sponsored Mathematical Biological Institute will also offer a Short Course on Biostatistics for IPC participants on Sunday March 1, 2015.
The Dr. Etta Z. Falconer Awards Banquet will be held on Tuesday evening, March 3, 2014.
A report of this event is submitted to the NSF by MBI.

D. Summer Graduate Schools 2014

SGS 1: Dispersive Partial Differential Equations
June 16, 2014 - June 27, 2014
Organizers: Natasa Pavlovic (University of Texas), Nikolaos Tzirakis (University of Illinois at Urbana-Champaign)

The purpose of the workshop is to introduce graduate students to the recent developments in the area of dispersive partial differential equations (PDE).

Dispersive equations have received a great deal of attention from mathematicians because of their applications to nonlinear optics, water wave theory and plasma physics. We will outline the basic tools of the theory that were developed with the help of multi-linear Harmonic Analysis techniques. The exposition will be as self-contained as possible.

SGS 2: Seminaire de Mathematiques Superieures 2014: Counting Arithmetic Objects
Location: Montreal, Canada
June 23, 2014 - July 04, 2014
Organizers: Henri Darmon (McGill University), Andrew Granville (Université de Montréal), Benedict Gross (Harvard University)

In the past decade tremendous progress has been achieved on certain key problems involving counting objects of arithmetic interest, such as number fields (or étale algebras) of given degree, naturally ordered by the size of their discriminants, as well as 2 or 3-torsion elements in Selmer groups of elliptic curves. This progress, which blends elegant algebraic techniques with brilliant and powerful analytic ideas, has led, most recently, to striking upper bounds on the size of Selmer groups (and therefore ranks) of elliptic curves and even Jacobians of hyperelliptic curves of higher genus. The goal of this summer school will be to take stock of the recent breakthroughs and bring young researchers to the forefront of research in this exciting and fast-evolving area.

SGS 3: IAS/PCMI 2014: Mathematics and Materials
June 29, 2014 - July 19, 2014
Location: Park City, Utah
Organizers: Mark Bowick (Syracuse University), David Kinderlehrer (Carnegie Mellon University), Govind Menon (Brown University), Charles Radin (University of Texas)

The program in 2014 will bring together a diverse group of mathematicians and scientists with interests in fundamental questions in mathematics and the behavior of materials. The meeting addresses several themes including computational investigations of material properties, the emergence of long- range order in materials and self-assembly, the geometry of soft condensed matter and the calculus of variations, phase transitions and statistical mechanics. The program will cover several topics in discrete and differential geometry that are motivated by questions in materials science. Many central topics, such as the geometry of packings, problems in the calculus of variations and phase transitions, will be discussed from the complementary points of view of mathematicians and physicists.

SGS 4: Algebraic Topology
June 30, 2014 - July 11, 2014
*Organizers: *Jose Cantarero-Lopez (Centro de Investigación en Matemáticas), Michael Hill (University of Virginia)*

Modern algebraic topology is a broad and vibrant field which has seen recent progress on classical problems as well as exciting new interactions with applied mathematics. This summer school will consist of a series of lecture by experts on major research directions, including several lectures on applied algebraic topology. Participants will also have the opportunity to have guided interaction with the seminal texts in the field, reading and speaking about the foundational papers.

SGS 5: Stochastic Partial Differential Equations
July 07, 2014 - July 18, 2014
Organizers: Yuri Bakhtin (New York University, Courant Institute), LEAD Ivan Corwin (Columbia University), James Nolen (Duke University)

Stochastic Partial Differential Equations (SPDEs) serve as fundamental models of physical systems subject to random inputs, interactions or environments. It is a particular challenge to develop tools to construct solutions, prove robustness of approximation schemes, and study properties like ergodicity and fluctuation statistics for a wide variety of SPDEs.

The purpose of this two week workshop is to educate graduate students on the state-of-the-art methods and results in SPDEs. The three courses which will be run simultaneously will highlight different (though related) aspects of this area including (1) Fluctuation theory of PDEs with random coefficients (2) Ergodic theory of SPDEs and (3) Exact solvability of SPDEs.

SGS 6: Geometry and Analysis
July 28, 2014 - August 08, 2014
Organizers: Hans-Joachim Hein (Imperial College, London), LEAD Aaron Naber (Massachusetts Institute of Technology)

Geometric and complex analysis is the application of tools from analysis to study questions from geometry and topology. This two week summer course will provide graduate students with the necessary background to begin studies in the area. The first week will consist of introductory courses on geometric analysis, complex analysis, and Riemann surfaces. The second week will consist of more advanced courses on the regularity theory of Einstein manifolds, Kahler-Einstein manifolds, and the analysis of Riemann surfaces.

E. Undergraduate Program

MSRI-UP 2014: Arithmetic Aspects of Elementary Functions
June 21, 2014 - August 03, 2014
*Duane Cooper (Morehouse College), Ricardo Cortez (Tulane University), *Herbert Medina (Loyola Marymount University), Ivelisse M. Rubio (University of Puerto Rico), Suzanne Weekes (Worcester Polytechnic Institute)*

The MSRI Undergraduate Program (MSRI--UP) is a comprehensive summer program designed for undergraduate students who have completed two years of university-level mathematics courses and would like to conduct research in the mathematical sciences. The main objective of the MSRI-UP is to identify talented students, especially those from underrepresented groups, who are interested in mathematics and make available to them meaningful research opportunities, the necessary skills and knowledge to participate in successful collaborations, and a community of academic peers and mentors who can advise, encourage and support them through a successful graduate program.

The academic and research portion of the 2014 MSRI-UP will be led by Prof. Victor Moll from Tulane University.

The question of evaluation of finite sums with entries in a reasonable largeclass (of hypergeometric type) has been settled by the algorithms developed by H. Wilf, D. Zeilberger and collaborators. On the other hand, arithmetic properties of these sums offer interesting challenges. For instance, it is an elementary result that the central binomial coefficient is always even. This motivates the natural question: what is the exact power of 2 that divides these coefficients? Is there a closed-form formula for this?

The fact that binomial coefficients satisfy certain recurrences, for example in the formation of Pascal's triangle, has been used to analyze their arithmetic properties. What can be said about sequences generated by similar recurrences? For example, factorials n! satisfy xn=nxn−1. Is it possible to describe arithmetic properties for yn=P(n)yn−1 with a polynomial P? Very few results are known.

Graphical representations offer some indication of the complexity involved. For example, there is a marked difference between the power of two that divides n2+1 and n2+7. What is the reason behind this? The second graph looks almost random compared to the first. Is there a way to quantify this phenomena?

Some sequences with surprising arithmetical properties include Stirling numbers, Catalan numbers that count legal typing words using parenthesis, the ASM numbers that count the number of matrices with entries from {0,±1} satisfying an ordering condition and many other coming from Combinatorics. Recent symbolic experiments include sequences such as the harmonic numbers Hn=1+12+⋯+1n and the sequence of formed by partial sums of the exponential function.

These type of problems are ideal for introduction to undergraduates: they can be explained with a minimal amount of background, data can be obtained by using symbolic languages and partial results are available in the literature. Thus, this REU is accessible to students who have had three semesters of calculus, linear algebra, and a course in which they have had to write proofs.

During the summer, each of the 18 student participants will:

- participate in the mathematics research program under the direction of Dr. Victor Moll, Tulane University, a post-doc and two graduate students
- complete a research project done in collaboration with other MSRI-UP students
- give a presentation and write a technical report on his/her research project
- attend a series of colloquium talks given by leading researches in their fields
- attend workshops aimed at developing skills and techniques needed for research careers in the mathematical sciences and
- learn techniques that will maximize a student's likelihood of admissions to graduate programs as well as the likelihood of winning fellowships
- receive a $3100 stipend, lodging, meals and round trip travel to Berkeley, CA.

After the summer, each student will:

- have an opportunity to attend a national mathematics or science conference where students will present their research
- be part of a network of mentors that will provide continuous advice in the long term as the student makes progress in his/her studies

be contacted regarding future research opportunities

III. PARTICIPATION SUMMARY

a. NSA supported members

The table below lists the postdoctoral fellows supported by the NSA grant H98230-14-1-0156 in each activity that took place at MSRI during the 2014–15 academic year. Note that these postdoctoral fellows are all US citizen or US permanent resident.

Activity	**Name**
Geometric Representation Theory	Postdoc: Dodd, Christopher Postdoc: Rostami, Sean Postdoc: Rozenblyum, Nikita
New Geometric Methods in Number Theory & Automorphic Forms	Postdoc: Lomeli, Luis

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 2014–15 academic year.

2. 2014-15 PROGRAM AND WORKSHOP PARTICIPANT SUMMARY

Time	*Activity Type*	*Activity Title*	*No. of participants*	*MSRI Postdocs*	*PD/RMs*
Fall 2014	Scientific Program	New Geometric Methods in Number Theory and Automorphic Forms	66	Zavosh Amir-Khosravi Hansheng Diao Daniel Disegni Christian Johansson Arno Kret Bao Le Hung Luis Lomeli Jasmin Matz	none
August 14, 2014 - August 15, 2014	Programmatic Workshop	Connections for Women: New Geometric Methods in Number Theory and Automorphic Forms	36		
August 18, 2014 - August 22, 2014	Programmatic Workshop	Introductory Workshop: New Geometric Methods in Number Theory and Automorphic Forms	100		
December 01, 2014 - December 05, 2014	Programmatic Workshop	Automorphic forms, Shimura varieties, Galois representations and L-functions	191		

Fall 2014	Scientific Program	Geometric Representation Theory	62	Alexis Bouthier Zsuzsanna Dansco Christopher Dodd Dragos Fratila Sam Gunningham Paul Hamacher Sean Rostami Nikita Rozenblyum Yaping Yang	Ian Le
August 28, 2014 - August 29, 2014	Programmatic Workshop	Connections for Women: Geometric Representation Theory	50		
September 02, 2014 - September 05, 2014	Programmatic Workshop	Introductory Workshop: Geometric Representation Theory	120		
November 17, 2014 - November 21, 2014	Programmatic Workshop	Categorical Structures in Harmonic Analysis	110		

Time	*Activity Type*	*Activity Title*	*No. of participants*	*MSRI Postdocs*	*PD/RMs*
Spring 2015	Scientific Program	Dynamics on Moduli Spaces of Geometric Structures	59	Caleb Ashley Shinpei Baba Guillaume Dreyer Qiongling Li Sara Maloni Kathryn Mann Maria Beatrice Pozzetti	Jeffrey Danciger Gye-Seon Lee
January 15, 2015 - January 16, 2015	Programmatic Workshop	Connections for Women: Dynamics on Moduli Spaces of Geometric Structures	62		
January 20, 2015 - January 23, 2015	Programmatic Workshop	Introductory Workshop: Dynamics on Moduli Spaces of Geometric Structures	132		
April 13, 2015 - April 17, 2015	Programmatic Workshop	Dynamics on Moduli Spaces	134		

Spring 2015	Scientific Program	Geometric and Arithmetic Aspects of Homogeneous Dynamics	64	Nicolas de Saxce Etienne Le Masson Han Li Ronggang Shi Alexander Wright Lei Yang	Ilya Vinogradov
January 29, 2015 - January 30, 2015	Programmatic Workshop	Connections for Women: Geometric and Arithmetic Aspects of Homogeneous Dynamics	63		
February 02, 2015 - February 06, 2015	Programmatic Workshop	Introductory Workshop: Geometric and Arithmetic Aspects of Homogeneous Dynamics	118		
May 11, 2015 - May 15, 2015	Programmatic Workshop	Advances in Homogeneous Dynamics	107		

Whole Year 2014-15	Scientific Program	Complementary Program 2014-15	13		

June 21, 2014 - August 03, 2014	Scientific Activities Directed at Underrepresented Groups in Mathematics	MSRI-UP 2014: Arithmetic Aspects of Elementary Functions	18		
October 15, 2014 - October 16, 2014	Scientific Activities Directed at Underrepresented Groups in Mathematics	Modern Math Workshop (SAMSI)	off site		
November 14, 2014 - November 15, 2014	Scientific Activities Directed at Underrepresented Groups in Mathematics	Blackwell-Tapia Conference and Awards Ceremony (IPAM)	off site		
March 2, 2015 - March 3, 2015	Scientific Activities Directed at Underrepresented Groups in Mathematics	Infinite Possibilities Conference 2015 Celebrating and Promoting Diversity in the Mathematical Sciences (MBI)	off site		

June 16, 2014 - June 27, 2014	Summer Graduate School (2014)	Dispersive Partial Differential Equations	50		
June 23, 2014 - July 04, 2014	Summer Graduate School (2014)	Seminaire de Mathematiques Superieures 2014: Counting Arithmetic Objects	26		
June 29, 2014 - July 19, 2014	Summer Graduate School (2014)	IAS/PCMI 2014: Mathematics and Materials	15		
June 30, 2014 - July 11, 2014	Summer Graduate School (2014)	Algebraic Topology (Guanajuato, Mexico)	16		
July 07, 2014 - July 18, 2014	Summer Graduate School (2014)	Stochastic Partial Differential Equations	58		
July 28, 2014 - August 08, 2014	Summer Graduate School (2014)	Geometry and Analysis	53		

Time	*Activity Type*	*Activity Title*	*No. of participants*	
October 29, 2014- November 1, 2014	Other Scientific Workshop	Breaking the Neutral Code	13	
November 1, 2014	Other Scientific Workshop	Bay Area Differential Geometry Seminar (BADGS) Fall 2014	40	
May 2, 2015	Other Scientific Workshop	Bay Area Differential Geometry Seminar (BADGS) Spring 2015	off site	
March 09, 2015 - March 13, 2015	Other Scientific Workshop	Hot Topics: Kadison-Singer, Interlacing Polynomials, and Beyond	46	

March 18, 2015 - March 20, 2015	Education & Outreach Workshop	Critical Issues in Mathematics Education 2015: Developmental Mathematics: For whom? Toward what ends?	123	

c. NSA supported Postdoctoral Fellows

MSRI allocated NSF, NSA and private funding to financially support 29 postdoctoral fellows during the 2014–15 academic year. Of those 29 postdoctoral fellows, four were financially supported by the NSA grant, H98230-14-1-0156.

Christopher Dodd was given a stipend (plus fringe benefits) for five months for his participation in *Geometric Representation Theory* Program. Below is the information regarding his work during his stay at MSRI:

Dodd, Christopher

Name: Christopher Dodd
Year of Ph.D: 2011
Institution of Ph.D.: Massachusetts Institute of Technology
Dissertation title: Equivariant Coherent Sheaves, Soergel Bimodules, and Categorification of Affine Hecke Algebras
Ph.D. advisor: Roman Bezrukavnikov

Mentor while at MSRI: Kevin McGerty

Institution prior to obtaining the MSRI PD fellowship: University of Toronto
Position at that institution: Postdoctoral Fellow
Mentor (if applicable): Joel Kamnitzer

Institution (or company) where you are going after the MSRI PD fellowship: University of Toronto
Position: Postdoctoral Fellow
Anticipated length: 1 semester

Postdoctoral fellow's comments:

At MSRI, I mostly worked on understand flat connections in two contexts: first of all, the theory of wild flat connections in characteristic zero and its analogues in positive characteristic, and secondly, the theory of connection with p-curvature zero. In both cases, I made substantial progress during the semester; in particular, conversations with other members allowed me to correct misconceptions, fix errors in my thinking, and prove several new theorems. I haven't published anything from this time, but I expect the ideas formulated there to be the basis of several publications in the future. So the whole semester was highly beneficial.

Sean Rostami was given a stipend of (plus fringe benefits) for five months for his participation in *Geometric Representation Theory* Program. Below is the information regarding his work during his stay at MSRI:

Rostami, Sean

Name: Sean Rostami
Year of Ph.D: 2012
Institution of Ph.D.: University of Maryland, College Park
Dissertation title: Kottwitz's nearby cycles conjecture for a class of unitary Shimura varieties
Ph.D. Advisor: Thomas Haines
Mentor while at MSRI: Matthias Strauch

Institution prior MSRI: University of Wiscsonsin, Madison
Position at that institution: Van Vleck Visiting Assistant Professor (postdoc)
Mentor (if applicable): Tonghai Yang

Institution (or company) where you are going after the MSRI PD fellowship: will return to UW for AY2015/2016
Position/Mentor: same as above
Anticipated length: (if it is a tenure track position just write tenure-track)
1 year (continue and finish existing 3-year postdoc position)

Postdoctoral fellow's comments:

(1) For approximately the first month, I worked on a dessins d'enfants project that was started in the middle of Spring 2014, and I was able to state and prove a nice characterization theorem (I tried to to this in summer but was unsuccessful). This is an important first step in the bigger project, which I will return to in the coming months.
(2) For approximately the next 2 months, I mainly did a mixture of three things. The first was to begin an algebraic geometry question with obvious value to geometric representation theory. Although I learned something and enjoyed thinking about it, no compelling progress was made and I was eventually convinced to postpone the question. The second was to prepare my thesis for publication (for various reasons, it was not published at the time of graduation), which required both expositional and mathematical changes (correcting errors and filling gaps, which required me to read and understand some things that I did not know before). The third was to edit a paper submitted in January 2014, in response to a referee report that I received while at MSRI.
(3) For the past three weeks, and probably for the next couple weeks and into 2015, I am working with a collaborator on a question concerning Gross-Reeder "simple" supercuspidal representations. It's going very well so far.
(4) Finally, there is another potential project that arose from conversations I had with another visitor to MSRI, and we plan to work on this together in the next few months. I think I could have 2 preprints, based on material (1) and (3), ready by summer; I'm not totally sure if anything conclusive will ever come of (2), and I think (4) is a good project but may require more time. The time I spent here was extremely beneficial. Besides the great working conditions (people, environment, freedom from distractions), I feel like I have a lot of momentum and energy to carry into the next year. I suspect it will allow me to be much more successful in the future than I would have been otherwise.

Nikita Rozenblyum was given a stipend (plus fringe benefits) for five months for his participation in *Geometric Representation Theory* Program. Below is the information regarding his work during his stay at MSRI:

Rozenblyum, Nikita

Your Name: Nikita Rozenblyum
Year of Ph.D: 2011
Institution of Ph.D.: MIT
Dissertation title: Connections on conformal blocks
Ph.D. advisor: Jacob Lurie
Mentor while at MSRI: David Treumann

Institution prior to obtaining the MSRI PD fellowship: Northwestern University
Position at that institution: Simons Postdoctoral Fellow

Institution (or company) where you are going after the MSRI PD fellowship: University of Chicago
Position: Assistant Professor
Anticipated length: 3 years

Postdoctoral fellow's comments:

I have benefitted a great deal from the program. Particularly beneficial for me were discussions between the geometric representation theory program and the number theory program. During the semester many new connections were established, and it was a wonderful learning experience for me. I expect these ideas will play a significant role in my future work.

Luis Lomeli was given a stipend (plus fringe benefits) for five months for his participation in *New Geometric Methods in Number Theory & Automorphic Forms* Program. Below is the information regarding his work during his stay at MSRI:

Lomeli, Luis

Name: Luis Lomeli
Year of Ph.D.: 2007
Institution of Ph.D.: Purdue University
Dissertation title: Functoriality for the classical groups over function fields
Ph.D. advisor: Freydoon Shahidi
Mentor while at MSRI: Dipendra Prasad

Institution prior to obtaining the MSRI PD fellowship: University of Oklahoma
Position at that institution: Visiting Assistant Professor (Postdoc)
Mentor (if applicable): Alan Roche

Institution (or company) where you are going after the MSRI PD fellowship: Max-Planck Institute for Mathematics
Position: Postdoctoral fellow
Anticipated length: (if it is a tenure track position just write tenure-track) Spring/Summer 2015

Postdoctoral fellow's comment:

I have completed a crucial step that makes the Langlands-Shahidi method available in complete generality in the case of function fields. The Langlands-Shahidi method over number fields, being due to Shahidi. I am currently working on writing the article and working on a couple of interesting applications which include a proof of the Ramanujan conjecture for the unitary groups over function fields. Unfortunately, I will probably finish writing the article in Max-Planck, yet much of the work was done here at MSRI and I am very thankful.

Was your experience at MSRI beneficial?

Extremely beneficial. In addition to solving the problem of completing the Langlands-Shahidi method over function fields, I was able to network properly and meet many great professors. My travels were professional. At my undergraduate institution in the neighboring state of Baja California, I was invited to give a general audience Number Theory talk, which went well and I linked it to a trip to LA. I gave seminar talks at UCLA and Caltech.