MSRI
Mathematical Sciences Research Institute

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

Final Report on the Mathematical Sciences Research Institute 2019-20 Activities supported by NSA Grant H98230-19-1-0120 Support of Early Career Researchers at MSRI 5/17/2019 - 5/16/2020

July 2020

Mathematical Sciences Research Institute
NSA Final Report for H98230-19-1-0120

I. INTRODUCTION

The main scientific activities of MSRI are its Programs and Workshops. MSRI hosts two to four semester-long programs each year. Each program has about forty mathematicians in residence at any given time, including seven to eight graduate students.

Generally, each semester-long program features three workshops. A program begins with a *Connections Workshop*, which has three overarching goals: (1) to give accessible introductions to the main themes of the program and exciting new directions in related research; (2) to provide participants the opportunity to become acquainted with the work of women in the field; and (3) to connect early-career researchers, especially women, gender-expansive individuals, and minorities, to potential senior mentors. 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 greater depth.

In addition to the scientific workshops that run parallel with the programs, MSRI hosts a Hot Topics workshop. These workshops are intended to explore emerging topics in mathematics. (See Section II.B for a brief summary)

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.

Another essential activity at MSRI is its series of Summer Graduate Schools, which target advanced graduate students in mathematics. During the summer of 2019, MSRI hosted four on-site and six off-site Summer Graduate Schools, with themes ranging from commutative algebra to sympletic topology. A complete description can be found at:
http://www.msri.org/web/msri/scientific/workshops/summer-graduate-school.

Each summer since 2007, MSRI has hosted a summer research experience (MSRI-UP) for undergraduate students with the aim of increasing the number of Ph.D.'s among members of under-represented groups. These summer schools are often co-funded by the NSA and the NSF. The 2019 MSRI-UP, *Combinatorics and Discrete Mathematics,* was a successful and popular school, with 18 undergraduate participants. More information about MSRI-UP can be found at http://www.msri.org/web/msri/education/for-undergraduates/msri-up.

The MSRI project, *Summer Research for Women in Mathematics* (SWiM), is part of MSRI's overall activities aimed at strengthening the mathematical sciences by facilitating research and professional activities leading to or enhancing

successful, productive careers. The SWiM project provides space and funds for groups of 2-6 primarily women researchers to work on a research project for 2-3 weeks at MSRI during the summer. These are research projects that have already been started, perhaps at a conference such as *Women in Topology* or *Women in Numbers,* or could be freestanding activities. Originally started in the summer of 2017, the 2019 SWiM program received applications from 46 groups (totaling 153 women) and was able to accept 46 women forming 13 groups ranging in size from 2 to 6. More information concerning SWiM can be found at http://www.msri.org/web/msri/scientific/summer-research-for-women-in-mathematics

II. OVERVIEW OF ACTIVITIES 2019-20

The year 2019-20 was an exciting one. In fall 2019, we held two programs: *Mircolocal Analysis* led by Andras Vasy (Stanford University) and *Holomorphic Differentials in Mathematics and Physics* led by Jayadev Athreya (University of Washington). In spring 2020, we held two programs, *Higher Categories and Categorification* led by Emily Riehl (John Hopkins University) and *Quantum Symmetries* led by Scott Morrison (Australian National University). Unfortunately, due to the COVID-19 pandemic, on March 10th, 2020 MSRI moved all of its scientific activities online through virtual seminars, meetings, and workshops. MSRI also hosted a small Complementary Program for mathematicians whose interests were not closely related to the four programs. All programs are briefly summarized in Section II.

There were 229 researchers who participated in these programs. Of those members, there were 32 Postdoctoral Fellows, 69 Organizers & Research Professors, 88 Research Members, and 41 Program Associates (Graduate Students). Of the 229 researchers, 3 held dual memberships (2 of the Postdoctoral Fellows and 1 Research Professor also held research memberships in the Complementary Program).

The NSA grant H98230-19-1-0120 funded four Postdoctoral Fellows: Brian Collier who participated in the fall program, *Holomorphic Differentials in Mathematics and Physics;* Oran Gannot who participated in the fall program*, Microlocal Analysis;* Andrew Schopieray who participated in the spring program, *Quantum Symmetries*; and Jay Shah who participated in the spring program, *Higher Categories and Categorification*.

A. Major Programs and their Associated Workshops

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

Program 1: Holomorphic Differentials in Mathematics and Physics
August 12, 2019 - December 15, 2019
*Organizers: *Jayadev Athreya (University of Washington), Steven Bradlow (University of Illinois at Urbana-Champaign), Sergei Gukov (California Institute of Technology), Andrew Neitzke (Yale University), Anna Wienhard (Ruprecht-Karls-Universität Heidelberg), Anton Zorich (Institut de Mathematiques de Jussieu)*

Holomorphic differentials on Riemann surfaces have long held a distinguished place in low dimensional geometry, dynamics and representation theory. Recently it has become apparent that they constitute a common feature of several other highly active areas of current research in mathematics and also at the interface with physics. In some cases the areas themselves (such as stability conditions on Fukaya-type categories, links to quantum integrable systems, or the physically derived construction of so-called spectral networks) are new, while in others the novelty lies more in the role of the holomorphic differentials (for example in the study of billiards in polygons, special - Hitchin or higher Teichmuller - components of representation varieties, asymptotic properties of Higgs bundle moduli spaces, or in new interactions with algebraic geometry).

It is remarkable how widely scattered are the motivating questions in these areas, and how diverse are the backgrounds of the researchers pursuing them. Bringing together experts in this wide variety of fields to explore common interests and discover unexpected connections was the main goal of this program. The program was designed to be of interest to those working in many different fields, including low-dimensional dynamical systems (via the connection to billiards); differential geometry (Higgs bundles and related moduli spaces); and different types of theoretical physics (electron transport and supersymmetric quantum field theory).

Workshops associated with the Holomorphic Differentials in Mathematics and Physics program:

Workshop 1: Connections for Women: Holomorphic Differentials in Mathematics and Physics
August 15, 2019 – August 16, 2019
*Organizers: Laura Fredrickson (Stanford University), Lotte Hollands (Heriot-Watt University, Riccarton Campus), *Qiongling Li (Chern Institute of Mathematics),*

Anna Wienhard (Ruprecht-Karls-Universität Heidelberg), Grace Work (Massachusetts Institute of Technology)

This two-day workshop consisted of various talks given by prominent female mathematicians on topics of new developments in the role of holomorphic differentials on Riemann surfaces. These were appropriate for graduate students, post-docs, and researchers in areas related to the program.

This workshop was open to all mathematicians.

Workshop 2: Introductory Workshop: Holomorphic Differentials in Mathematics and Physics
August 19, 2019 – August 23, 2019
*Organizers: *Jayadev Athreya (University of Washington), Sergei Gukov (California Institute of Technology), Andrew Neitzke (Yale University), Anna Wienhard (Ruprecht-Karls-Universität Heidelberg)*

Holomorphic differentials on Riemann surfaces have long held a distinguished place in low dimensional geometry, dynamics and representation theory. Recently it has become apparent that they constitute a common feature of several other highly active areas of current research in mathematics and also at the interface with physics. In this introductory workshop, we brought junior and senior researchers from this diverse range of subjects together in order to explore common themes and unexpected connections.

Workshop 3: Holomorphic Differentials in Mathematics and Physics
November 18, 2019 – November 22, 2019
*Organizers: *Jayadev Athreya (University of Washington), Steven Bradlow (University of Illinois at Urbana-Champaign), Sergei Gukov (California Institute of Technology), Andrew Neitzke (Yale University), Laura Schaposnik (University of Illinois at Chicago), Gabriela Weitze-Schmithuesen (Universität des Saarlandes), Anton Zorich (Institut de Mathematiques de Jussieu)*

Holomorphic differentials on Riemann surfaces have long held a distinguished place in low dimensional geometry, dynamics and representation theory. Recently it has become apparent that they constitute a common feature of several other highly active areas of current research in mathematics and also at the interface with physics. In some cases the areas themselves (such as stability conditions on Fukaya-type categories, links to quantum integrable systems, or the physically derived construction of so-called spectral networks) are new, while in others the novelty lies more in the role of the holomorphic differentials (for example in the study of billiards in polygons, special - Hitchin or higher Teichmuller - components of representation varieties, asymptotic properties of Higgs bundle moduli spaces, or in new interactions with algebraic geometry).

It is remarkable how widely scattered are the motivating questions in these areas, and how diverse are the backgrounds of the researchers pursuing them.

Bringing together experts in this wide variety of fields to explore common interests and discover unexpected connections is the main goal of our program. This workshop was designed to be of interest to those working in many different fields, including low-dimensional dynamical systems (via the connection to billiards); differential geometry (Higgs bundles and related moduli spaces); and different types of theoretical physics (electron transport and supersymmetric quantum field theory).

Program 2: Microlocal Analysis
August 12, 2019 – December 13, 2019
*Organizers: Pierre Albin (University of Illinois at Urbana-Champaign), Nalini Anantharaman (Université de Strasbourg), Kiril Datchev (Purdue University), Raluca Felea (Rochester Institute of Technology), Colin Guillarmou (Université de Paris XI (Paris-Sud)), *Andras Vasy (Stanford University)*

Microlocal analysis provides tools for the precise analysis of problems arising in areas such as partial differential equations or integral geometry by working in the phase space, i.e. the cotangent bundle, of the underlying manifold. It has origins in areas such as quantum mechanics and hyperbolic equations, in addition to the development of a general PDE theory, and has expanded tremendously over the last 40 years to the analysis of singular spaces, integral geometry, nonlinear equations, scattering theory… This program brought together researchers from various parts of the field to facilitate the transfer of ideas, and provided a comprehensive introduction to the field for postdocs and graduate students.

Workshops associated with the *Microlocal Analysis* program:

Workshop 1: Connections for Women: Microlocal Analysis
August 29, 2019 – August 30, 2019
*Organizers: Tanya Christiansen (University of Missouri), *Raluca Felea (Rochester Institute of Technology)*

This workshop provided a gentle introduction to a selection of applications of microlocal analysis. These were drawn from among geometric microlocal analysis, inverse problems, scattering theory, hyperbolic dynamical systems, quantum chaos and relativity. The workshop also provided a panel discussion, a poster session and an introduction/research session.

This workshop was open to all mathematicians.

Workshop 2: Introductory Workshop: Microlocal Analysis
September 3, 2019 – September 6, 2019
*Organizers: Pierre Albin (University of Illinois at Urbana-Champaign), *Raluca Felea (Rochester Institute of Technology), Andras Vasy (Stanford University)*

Microlocal analysis provides tools for the precise analysis of problems arising in areas such as partial differential equations or integral geometry by working in the phase space, i.e. the cotangent bundle, of the underlying manifold. It has origins in areas such as quantum mechanics and hyperbolic equations, in addition to the development of a general PDE theory, and has expanded tremendously over the last 40 years to the analysis of singular spaces, integral geometry, nonlinear equations, scattering theory… This workshop provided a comprehensive introduction to the field for postdocs and graduate students as well as specialists outside the field, building up from standard facts about the Fourier transform, distributions and basic functional analysis.

Workshop 3: Recent Developments in Microlocal Analysis
October 14, 2019 – October 18, 2019
*Organizers: *Pierre Albin (University of Illinois at Urbana-Champaign), Nalini Anantharaman (Université de Strasbourg), Colin Guillarmou (Université de Paris XI (Paris-Sud))*

Microlocal analysis provides tools for the precise analysis of problems arising in areas such as partial differential equations or integral geometry by working in the phase space, i.e. the cotangent bundle, of the underlying manifold. It has origins in areas such as quantum mechanics and hyperbolic equations, in addition to the development of a general PDE theory, and has expanded tremendously over the last 40 years to the analysis of singular spaces, integral geometry, nonlinear equations, scattering theory, hyperbolic dynamical systems, probability… As this description shows, microlocal analysis has become a very broad area. Due to its breadth, it is a challenge for researchers to be aware of what is happening in other parts of the field, and the impact this may have in their own research area. The purpose of this workshop was to bring together researchers from different parts of microlocal analysis and its applications to facilitate the transfer of new ideas.

Program 3: Quantum Symmetries
January 21, 2019 – May 29, 2020
*Organizers: Vaughan Jones (Vanderbilt University), *Scott Morrison (Australian National University), Victor Ostrik (University of Oregon), Emily Peters (Loyola University), Eric Rowell (Texas A & M University), *Noah Snyder (Indiana University), Chelsea Walton (University of Illinois at Urbana-Champaign)*

Symmetry, as formalized by group theory, is ubiquitous across mathematics and science. Classical examples include point groups in crystallography, Noether's theorem relating differentiable symmetries and conserved quantities, and the classification of fundamental particles according to irreducible representations of the Poincaré group and the internal symmetry groups of the standard model. However, in some quantum settings, the notion of a group is no longer enough to capture all symmetries. Important motivating examples include Galois-like

symmetries of von Neumann algebras, anyonic particles in condensed matter physics, and deformations of universal enveloping algebras. The language of tensor categories provides a unified framework to discuss these notions of quantum symmetry.

Within the framework of studying the various guises of quantum symmetries, and their interactions, the program focused on the following seven areas.

1. Tensor categories, fusion categories, module categories, and applications to representation theory.
2. Braided, symmetric, and modular tensor categories.
3. Hopf algebras, their actions on rings, and classification of semisimple and of pointed Hopf algebras.
4. Subfactors, planar algebras, and analytic properties of quantum symmetries.
5. Quantum invariants of knots and 3-manifolds, and local topological field theories.
6. Conformal nets, vertex algebras, and their representation theories.
7. Topological order and topological quantum computation.

Workshops associated with the *Quantum Symmetries* program:

Workshop 1: Connections for Women: Quantum Symmetries
January 23, 2020 – January 24, 2020
*Organizers: Emily Peters (Loyola University), * Chelsea Walton (University of Illinois at Urbana-Champaign)*

This workshop featured several talks by experts, along with numerous 5-minute presentations by junior mathematicians, on topics related to Quantum Symmetry. Such topics will include tensor categories, subfactors, Hopf algebras, topological quantum field theory and more. There was also a panel discussion on professional development. The majority of the speakers and panelists for this event were women and gender minorities, and members of these groups and of other underrepresented groups were especially encouraged to attend. This workshop was open to all mathematicians.

Workshop 2: Introductory Workshop: Quantum Symmetries
January 27, 2020 – January 31, 2020
*Organizers: Vaughan Jones (Vanderbilt University), Victor Ostrik (University of Oregon), Emily Peters (Loyola University), *Noah Snyder (Indiana University)*

This workshop consisted of introductory minicourses on key topics in Quantum Symmetry: fusion categories, modular tensor categories, Hopf algebras, subfactors and planar algebras, topological field theories, conformal nets, and topological phases of matter. These minicourses were introductory and were

aimed at giving semester participants exposure to the main ideas of subfields other than their own.

Workshop 3: Tensor Categories and Topological Quantum Field Theories (this workshop was moved online due to COVID-19)
March 16, 2020 – March 20, 2020
*Organizers: Scott Morrison (Australian National University), Eric Rowell (Texas A & M University), *Claudia Scheimbauer (TU München), Christopher Schommer-Pries (University of Notre Dame)*

The workshop covered the latest developments in the mathematical study of quantum field theories. It focused on the interplay among topics such as higher category theory, as illustrated by the cobordism hypothesis, conformal field theory, tensor categories describing the quantum symmetries, and the relation to topological phases of matter.

Program 4: Higher Categories and Categorification
January 21, 2020 – May 29, 2020
Organizers: *David Ayala (Montana State University), Clark Barwick (University of Edinburgh), David Nadler (University of California, Berkeley), *Emily Riehl (Johns Hopkins University), Marcy Robertson (University of Melbourne), Peter Teichner (Max-Planck-Institut für Mathematik), Dominic Verity (Macquarie University)*

Though many of the ideas in higher category theory find their origins in homotopy theory — for instance as expressed by Grothendieck's "homotopy hypothesis" — the subject today interacts with a broad spectrum of areas of mathematical research. Unforeseen descent, or local-to-global formulas, for familiar objects can be articulated in terms of higher invertible morphisms. Compatible associative deformations of a sequence of maps of spaces, or derived schemes, can putatively be represented by higher categories, as Koszul duality for E_n-algebras suggests. Higher categories offer unforeseen characterizing universal properties for familiar constructions such as K-theory. Manifold theory is natively connected to higher category theory and adjunction data, a connection that is most famously articulated by the recently proven Cobordism Hypothesis.

In parallel, the idea of "categorification" is playing an increasing role in algebraic geometry, representation theory, mathematical physics, and manifold theory, and higher categorical structures also appear in the very foundations of mathematics in the form of univalent foundations and homotopy type theory.

A central mission of this semester was to mitigate the exorbitantly high "cost of admission" for mathematicians in other areas of research who aim to apply higher categorical technology and to create opportunities for potent collaborations between mathematicians from these different fields and experts from within higher category theory.

Workshops associated with the Higher Categories and Categorification program:

Workshop 1: Connections for Women: Higher Categories and Categorification
February 06 2020 – February 07, 2020
*Organizers: Emily Riehl (Johns Hopkins University), *Marcy Robertson (University of Melbourne)*

This two-day workshop surveyed notable developments in the foundations and applications of higher category theory. It ocnsisted of two mini-courses given by emerging female leaders in the subject: Claudia Scheimbauer and Nathalie Wahl. This paired with a problem sessions lead by selected "TA's", themselves experts in higher structures. Each lecture series was tailored to a diverse audience and accessible to graduate students and non-expert researchers with some background in homological algebra.

The majority of the speakers and panelists for this event were women and gender minorities, and members of these groups and of other underrepresented groups were especially encouraged to attend. This workshop was open to all mathematicians.

Workshop 2: Introductory Workshop: Higher Categories and Categorification
February 10, 2020 – February 14, 2020
*Organizers: *David Ayala (Montana State University), Emily Riehl (Johns Hopkins University), Christopher Schommer-Pries (University of Notre Dame), Peter Teichner (Max-Planck-Institut für Mathematik)*

This workshop surveyed notable developments and applications of higher category theory; it was a venue for end-users to share their vision of how to apply the theory, as well as developers to share technical advancements. It consisted of 6 series of 3 lectures, each given by instrumental end-users & developers of higher category theory, together with a few question-answer sessions. Each lecture series was tailored to a diverse audience, accessible to graduate students and non-expert researchers with some background in homological also algebra. The content of these lecture series concerned the following topics.

- K-theory: categorification, non-commutative motives, trace methods;
- TQFT: functorial field theories, factorization homology.
- Parametrized higher category theory: stratifications, equivariant homotopy theory, operads, deformation theory and Koszul duality.
- Synthetic higher category theory: model-independent characterizations, cosmoi.

Workshop 3: (∞, n)-Categories, Factorization Homology, and Algebraic K-Theory (this workshop was moved online due to COVID-19)
March 23, 2020 – March 27, 2020
*Organizers: *Clark Barwick (University of Edinburgh), David Gepner (University of Melbourne), David Nadler (University of California, Berkeley), Marcy Robertson (University of Melbourne)*

This workshop focused on recent developments in factorization homology, parametrized homotopy theory, and algebraic K-theory. These seemingly disparate topics are unified by a common methodology, which leverages universal properties and unforeseen descent by way of higher category theory. Furthermore, they enjoy powerful and complementary roles in application to the cyclotomic trace. This workshop was a venue for experts in these areas to present new results, make substantive connections across fields, and suggest and contextualize outstanding questions and problems. It consisted of 4 two-part lecture series and 10 one-hour talks. The lecture series was given by Thomas Nikolaus, Akhil Mathew, David Ben-Zvi and a split Martina Rovelli and Viktoriya Ozornova.

Program 5: Complementary Program (2019-20)
August 12, 2019 – May 29, 2020
The Complementary Program had a limited number of memberships that were open to mathematicians whose interests were not closely related to the core programs; special consideration was given to mathematicians who were partners of an invited member of a core program.

B. Hot Topics Workshop

Hot Topics: Optimal Transport and Applications to Machine Learning (this workshop was moved online due to COVID-19)
May 04, 2020 – May 08, 2020
*Organizers: Luigi Ambrosio (Scuola Normale Superiore), Francis Bach (École Normale Supérieure), *Katy Craig (University of California, Santa Barbara), Carola-Bibiane Schönlieb (University of Cambridge), Stefano Soatto (University of California, Los Angeles)*

The goal of the workshop was to explore the many emerging connections between the theory of Optimal Transport and models and algorithms currently used in the Machine Learning community. In particular, the use of Wasserstein metrics and the relation between discrete models and their continuous counterparts was presented and discussed.

III. PARTICIPATION SUMMARY

B. All MSRI Members

The table below indicates the number of participants for the major programs and workshops that took place at MSRI during the 2019-20 academic year.

DATES	ACTIVITY TYPE	TITLE	PARTICIPANTS
6/10/19-8/2/19	Summer Research	2019 Summer Research for Women in Mathematics (SWiM)	46
6/10/19-8/2/19	Summer Research	2019 African Diaspora Joint Mathematics Workshop	12
6/15/19-7/28/19	MSRI-Up	MSRI-UP 2019: Combinatorics and Discrete Mathematics	18
6/3/19-6/14/19	Summer Graduate School	Commutative Algebra and its Interaction with Algebraic Geometry	27
6/10/19-8/2/19	Summer Graduate School	Random and Arithmetic Structures in Topology	30
6/24/19-7/5/19	Summer Graduate School	Representation Stability	42
7/1/19-7/12/19	Summer Graduate School	Geometric Group Theory	15
7/1/19-7/13/19	Summer Graduate School	Séminaire de Mathématiques Supérieures 2019: Current Trends in Symplectic Topology	31
7/8/19-7/19/19	Summer Graduate School	Polynomial Method	34
7/22/19-8/2/19	Summer Graduate School	Recent Topics on Well-posedness and Stability of Incompressible Fluid and Related Topics	43
7/29/19-8/9/19	Summer Graduate School	Mathematics of Machine Learning	35
7/29/19-8/9/19	Summer Graduate School	H-Principle (INdAM, Cortona Italy)	12
7/29/19-8/9/19	Summer Graduate School	Toric Varieties (National Center for Theoretical Sciences, Taipei)	27
Fall 2019	**Scientific Program**	**Microlocal Analysis**	**63**

8/29/19-8/30/19	Programmatic Workshop	Connections for Women: Microlocal Analysis	49
9/3/19-9/6/19	Programmatic Workshop	Introductory Workshop: Microlocal Analysis	107
10/14/19-10/18/19	Programmatic Workshop	Recent Developments in Microlocal Analysis	115
Fall 2019	**Scientific Program**	**Holomorphic Differentials in Mathematics and Physics**	**65**
8/15/19-8//16/19	Programmatic Workshop	Connections for Women: Holomorphic Differentials in Mathematics and Physics	59
8/19/19-8/23/19	Programmatic Workshop	Introductory Workshop: Holomorphic Differentials in Mathematics and Physics	93
11/18/19-11/22/19	Programmatic Workshop	Holomorphic Differentials in Mathematics and Physics	112
Spring 2020	**Scientific Program**	**Quantum Symmetries**	**43**
1/23/20-1/24/20	Programmatic Workshop	Connections for Women: Quantum Symmetries	75
1/27/20-1/31/20	Programmatic Workshop	Introductory Workshop: Quantum Symmetries	149
3/16/20-3/20/20	Programmatic Workshop	Tensor Categories and Topological Quantum Field Theories (Moved Online)	108
Spring 2020	**Scientific Program**	**Higher Categories and Categorification**	**47**
2/6/20 – 2/7/20	Programmatic Workshop	Connections for Women: Higher Categories and Categorification	100
2/10/20-2/14/20	Programmatic Workshop	Introductory Workshop: Higher Categories and Categorification	169
3/23/20-3/27/20	Programmatic Workshop	(∞, n)-categories, factorization homology, and algebraic K-theory (Moved Online)	97
3/11/20-5/22/20	Workshop	Critical Issues in Mathematics Education 2020: Today's Mathematics, Social Justice, and Implications for Schools (Moved Online)	128
8/12/19-5/29/20	**Scientific Program**	**Complementary Program 2019-20**	**10**
5/4/20-5/8/20	Workshop	Hot Topics: Optimal Transport and Applications to Machine Learning and Statistics (Moved Online)	206

C. NSA supported Postdoctoral Fellows

There were 32 postdoctoral fellows who participated in the 2019-20 programs. The NSA grant, H98230-19-1-0120, funded four out of the 32 postdoctoral fellows. As outlined in the grant budget, we funded two postdoctoral fellows in the fall and two in the spring with an average stipend of $6,300 per month for five months. Since the provisional Indirect Cost rate increased from the proposed 20.32% to 22.96%, we reduced the stipend charged to the grant for one of the post docs.

Brian Collier participated in the fall 2019 program, *Holomorphic Differentials in Mathematics and Physics.*

Collier, Brian

Name: Brian Collier
Year of Ph.D.: 2016
Institution of Ph.D.: The University of Illinois (UIUC)
Dissertation title: Finite order automorphism of Higgs bundles: theory and application
Ph.D. advisor: Steven Bradlow

Mentor while at MSRI: Yair Minsky

Pre-MSRI Instituton: University of Maryland
Position: NSF postdoc
Mentor (if applicable): Richard Wentworth

Post-MSRI Institution (or company): UC Irvine
Position: Assistant Professor
Anticipated length: Tenure-track

Postdoctoral fellow's comments:
During the semester at MSRI I started working on two projects, one with Richard Wentworth and Laura Fredrickson on conformal limits for parabolic Higgs bundles and another with Wentworth on a universal deformation theory for Higgs bundles. I continued to work on a joint paper with Bradlow, Garcia-Prada, Gothen and Oliveira, and it was very helpful that most of the collaborators were at MSRI for various amounts of time. I also had many interesting and useful conversations with Anna Wienhard which may lead to a future collaboration. The working conditions at MSRI were wonderful and I found the atmosphere at MSRI intellectually stimulating.

Oran Ganot participated in the fall 2019 program, *Microlocal Analysis.*

Gannot, Oran

Name: Oran Gannot
Year of Ph.D.: 2016
Institution of Ph.D.: UC Berkeley
Dissertation title: Quasinormal modes of anti-de Sitter black holes
Ph.D. advisor: Maciej Zworski

Mentor while at MSRI: Michael Hitrik & Maarten de Hoop

Pre-MSRI Institution: Northwestern University
Mentor (if applicable): Jared Wunsch

Post-MSRI Institution (or company): Unknown at this time

Postdoctoral fellow's comments:
The MLA program provided me with an excellent opportunity to discuss new ideas with researchers from all over the world, including collaborators I do not often meet face-to-face. I was able to continue thinking about projects I began during my previous postdoc. Many of the people I met at MSRI (including one of my mentors) were eager to assist me in securing postdoc positions at their universities.

Andrew Schopieray participated in the spring 2020 program, *Quantum Symmetries.*

Schopieray, Andrew

Name: Andrew Schopieray
Year of Ph.D.: 2017
Institution of Ph.D.: University of Oregon
Dissertation title: Relations in the Witt Group of Nondegenerate Braided Fusion Categories Arising from the Representation Theory of Quantum Groups at Roots of Unity
Ph.D. advisor: Victor Ostrik

Mentor while at MSRI: David Evans

Pre-MSRI Institution: University of New South Wales
Mentor (if applicable): Pinhas Grossman

Post-MSRI Institution (or company): University of Alberta
Position: PIMS Postdoctoral Fellow

	Anticipated length: 2 years Mentor (if applicable): Terry Gannon **Postdoctoral fellow's comments:** My stay at MSRI during the Spring 2020 semester was highly productive and here I would like to personally thank the countless individuals who I unfortunately will not have the chance to thank in person. Despite only being at the institution for about two months before the pandemic struck, I was able to begin four separate research projects. For two of the projects I was the sole creator. One of these projects I will not pursue further, but a second resulted in a paper which will appear on the arXiv at the end of the semester: "Norm, trace, and formal codegrees of fusion categories". This paper illustrates connections between numerical invariants of fusion categories and the (classical, number-theoretic) Schur-Siegel-Smyth trace problem of identifying algebraic integers of small absolute trace. I attribute the independence I had at MSRI as the sole reason this project succeeded. Two other projects, one with Julia Plavnik and another initiated by Eric Rowell and Victor Ostrik (all three were in residence at MSRI), are producing fruitful results and will undoubtedly produce papers in the future. Of course, the pandemic disrupting the community at MSRI decelerated the progress of these projects greatly. We continue to stay in touch electronically at a much slower pace. With regard to MSRI facilities, staff, and communication, I have nothing but positive comments. The minor administrative issues which arose were fixed with single emails, promptly answered, or a simple walk to the main office. The MSRI response to the pandemic as a whole was prompt, clear, and thorough. My only suggestion is some consolidation of the emails sent to researchers in residence through official channels. Not including emails between researchers for seminars and the like, we received emails from perhaps 15 different staff/administrators. I have two separate email addresses on file, and about half of the official MSRI emails were only sent to one or the other, and the multitude of senders were all treated differently by spam filters and the like. At least one important administrative email was filtered as spam that I learned about from talking to other researchers. *MSRI Response: With the start of the COVID-19 pandemic, MSRI did experience some technical difficulties resulting in some people being inadvertently removed from email aliases. This was remedied as soon as the issue was discovered. Members do receive emails from various staff members who are in charge of different areas of operation, but the number is much smaller than 15.*

Jay Shah participated in the spring 2020 program, *Higher Categories and Categorification.*

Shah, Jay

Name: Jay Shah
Year of Ph.D.: 2017
Institution of Ph.D.: MIT
Dissertation title: Parametrized higher category theory
Ph.D. advisor: Clark Barwick

Mentor while at MSRI: David Gepner

Pre-MSRI Institution: University of Notre Dame
Position at that institution: Visiting Assistant Professor
Mentor (if applicable): Mark Behrens

Post-MSRI Institution (or company): Universitaet Muenster
Position: Postdoc
Anticipated length: 3 years
Mentor (if applicable): Thomas Nikolaus

Postdoctoral fellow's comments:
During my MSRI fellowship, I pursued my research interests in stable homotopy theory and higher category theory, while also broadening my knowledge base through participating in the many seminars and workshops held at MSRI. A central theme that organized my research activities was to understand and exploit the close relationship between concepts in (infinity,2)-category theory on the one hand, and stratified and equivariant homotopy theory on the other hand - for instance, this connection is central to the work of David Ayala, Aaron Mazel-Gee, and Nick Rozenblyum on "stratified noncommutative geometry", who were all participants in the program. Joint with Aaron Mazel-Gee and Grigory Kondyrev, I am working on a characterization of dualizable objects in right-lax limits of left-lax diagrams a la the 1-dimensional cobordism hypothesis (working title: "The cobordism hypothesis for recollements"), where the manifolds and bordisms in question ought to be stratified in an appropriate sense. In terms of equivariant homotopy theory, such a theorem has application in computing the Balmer spectrum of the equivariant stable homotopy category of a finite non-abelian group, which is a major open problem in the field (this is work in progress with J.D. Quigley). Learning the theory of the Balmer spectrum and tensor triangulated geometry was also one of my major goals during this semester. Finally, these ideas also have impact in articulating a conjectural stratified version of Tannakian duality along the lines proposed by Clark Barwick.

In my judgment, my participation in the MSRI program has been beneficial to my development as a mathematician, and the connections made will likely assist me in my future career (though

	the direct impact of my MSRI postdoc on obtaining a future position is not possible for me to evaluate at this moment in time). As a general rule, I think the wide variety of seminars and the consequent exposure to new mathematical ideas has helped me obtain a broader outlook on my particular area of research. Concentrating a large number of researchers together also served to foster collaborations that might not otherwise have occurred (c.f. my project with Aaron and Grigory). However, the impact of the building shutdown midway through the semester was undeniably (and unavoidably) deleterious to the effectiveness of the program, which for me is reliant on a lot of in-person and freeform interaction that cannot really be replicated virtually. I don't have any specific suggestions as to what could have been done differently - hopefully, this semester will be the last time such a shutdown has to occur.

PUBLICATIONS SUMMARY

The four NSA funded postdoctoral fellows worked on several projects during the program and by the end of the Spring 2020 semester, they list the following papers as direct outcomes of their fellowship at MSRI.

Member Name	Paper Titles	Co-author(s)	Paper Status
Brian Collier	(G, P)-opers and global Slodowy Slices	Andrew Sanders	Posted
Brian Collier	A Cayley Correspondence for Higher Teichmuller Spaces	Steve Bradlow, Oscar Garcia-Prada, Peter Gothern, Andres Oliveira	Rough/Draft
Andrew Schopieray	Norm, Trace and Formal Codegrees of Fusion Categories		Working Notes
Jay Shah	The Cobordism Hypothesis for Recollements	Aaron Mazel-Gee, Grigory Kondyrev	Rough/Draft