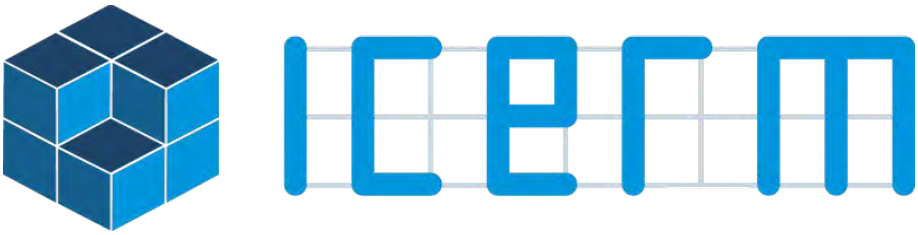

Institute for Computational and Experimental Research in Mathematics

Annual Report
May 1, 2020 – April 30, 2021

Brendan Hassett, Director, PI
Mathew Borton, IT Director
Ruth Crane, Assistant Director and Chief of Staff
Juliet Duyster, Assistant Director Finance and Administration
Sigal Gottlieb, Deputy Director
Jeffrey Hoffstein, Consulting Associate Director
Caroline Klivans, Deputy Director
Benoit Pausader, co-PI
Jill Pipher, Consulting Director Emerita, co-PI
Kavita Ramanan, Associate Director, co-PI
Bjorn Sandstede, Associate Director, co-PI
Ulrica Wilson, Associate Director for Diversity and Outreach

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Mission

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

Annual Report for 2020-2021

ICERM acknowledges that this reporting cycle is the beginning of our newest grant (DMS-1929284). However, due to the COVID-related delays in spending, all of the participant support costs we incurred in the current cycle were covered by our previous grant (DMS-1439786); we only incurred expenses for staff, directors, publicity, consulting services, and AV upgrades on the new grant. Since this is a renewal of our previous grant, and on the advice of our program officer, ICERM is reporting here scientific activity funded by DMS-1439786. When have also notated the few expenses covered by the new award. We will include any remaining participant support for scientific programs in the final report for DMS-1439786, due in December 2021.

Core Programs and Events

The following grid lists ICERM's scheduled programs and events from May 1, 2020 through April 30, 2021 supported by the core NSF award and other grants. All programs and events were virtual. The grand total of "Unique Visits" during this timeframe was **4,121**. The "Unique Visits" total for *just ICERM's core programs* was **3,743** (not including Hot Topics – see note below the grid). "Total #" column includes individuals who attended multiple events within a set period of time. For example, long-term visitors who attended several workshops during a semester program. The public lectures list the number of people registered to attend.

TYPE	TITLE	START	END	Unique Visit #	Total #
Hot Topics Workshop	Variable Precision in Mathematical and Scientific Computing	7-May-20	8-May-20	62	62
Topical Workshop	Competitive Equilibrium with Gross Substitutes, with Applications to Problems in Matching, Pricing, and Market Design	11-May-20	12-May-20	27	27
Simons Collaboration	Workshop on Arithmetic Geometry, Number Theory, and Computation	1-Jun-20	5-Jun-20	78	78
Summer@ICERM	Summer@ICERM 2020: Fast Learning Algorithms for Numerical Computation and Data Analysis	8-Jun-20	31-Jul-20	31	31
Topical Workshop	Lattice Point Distribution and Homogeneous Dynamics (partially supported by NSF CAREER grant)	22-Jun-20	26-Jun-20	99	99
Topical Workshop	Circle Packings and Geometric Rigidity	6-Jul-20	10-Jul-20	80	81
Topical Workshop	Geometry Labs United Conference	16-Jul-20	17-Jul-20	107	108
Topical Workshop	Women in Algebraic Geometry	27-Jul-20	31-Jul-20	48	55
Topical Workshop	Free Resolutions and Representation Theory	3-Aug-20	7-Aug-20	62	64

Topical Workshop	Symmetry, Randomness, and Computations in Real Algebraic Geometry	24-Aug-20	28-Aug-20	95	102
Hot Topics Workshop	Monodromy and Galois groups in enumerative geometry and applications	31-Aug-20	2-Sep-20	39	41
Semester Program	Advances in Computational Relativity	9-Sep-20	11-Dec-20	136	136
Semester Program Workshop	Advances and Challenges in Computational Relativity	14-Sep-20	18-Sep-20	152	273
Public Lecture	Uncovering Lottery Shenanigans	22-Sep-20	22-Sep-20	182	182
Semester Program Workshop	Mathematical and Computational Approaches for Solving the Source- Free Einstein Field Equations	5-Oct-20	9-Oct-20	181	300
Public Lecture	One Person, One Vote	20-Oct-20	20-Oct-20	238	238
Semester Program Workshop	Mathematical and Computational Approaches for the Einstein Field Equations with Matter Fields	26-Oct-20	30-Oct-20	142	264
Public Lecture	Quantifying and Understanding Gerrymandering - How a quest to understand his state's political geography led a mathematician to court	28-Oct-20	28-Oct-20	289	289
Semester Program Workshop	Statistical Methods for the Detection, Classification, and Inference of Relativistic Objects	16-Nov-20	20-Nov-20	136	257
Public Lecture	Q&A with Kip Thorne, Nobel Prize-winning Theoretical Physicist	2-Dec-20	2-Dec-20	483	483
Semester Program Workshop	Introductory Workshop: Combinatorial Algebraic Geometry	1-Feb-21	5-Feb-21	281	364
Semester Program	Combinatorial Algebraic Geometry	1-Feb-21	7-May-21	93	93
Semester Program Workshop	Sage/Oscar Days for Combinatorial Algebraic Geometry	15-Feb-21	19-Feb-21	110	194
Hot Topics Workshop	Mathematical and Computational Approaches to Social Justice	8-Mar-21	10-Mar-21	173	173
Semester Program Workshop	Geometry and Combinatorics from Root Systems	22-Mar-21	26-Mar-21	103	189
Hot Topics Workshop	Safety and Security of Deep Learning	10-Apr-21	11-Apr-21	102	102
Semester Program Workshop	Algebraic Geometry and Polyhedra	12-Apr-21	16-Apr-21	174	261
Topical Workshop	USTARS	29-Apr-21	30-Apr-21	66	67

Note: The Hot Topics workshops are fully funded by a Simons Foundation Targeted Grant to Institutes.

Participant Summaries by Program Type

The tables below display breakdowns of ICERM's confirmed participants by category during the reporting period for all funded programs. Each participant is represented once per unique visit regardless of the number of programs they attended during a visit. NOTE: "funded" refers to participants who had offered funding attached to their attendance (some before COVID).

ICERM Funded Participants

	Program Type	Summer@ICERM 2020	Fall Semester '20						Spring Semester '21							Topical '20 - '21								
			Semester Program	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Semester Program	Seminar	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Workshop A	Workshop B	Workshop C	Workshop D	Workshop E	Workshop F	Workshop G	Workshop H	% of # Reporting
Gender and Ethnicity	Total Participants	26	55	25	18	18	23		25	1	11	30	24	26		18	12	35	10	17	32	27	0	
	Female	11	7	4	4	3	4	29%	7	0	0	2	4	5	22%	4	3	3	3	15	5	5	0	40%
	Other	0	0	0	0	0	0	0%	0	0	0	0	0	1	1%	0	0	0	0	0	0	0	0	0%
	# Reporting Gender	24	45	8	8	7	8		24	1	6	15	17	19		6	8	25	8	15	12	20	0	
	African American	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	1	0	0	0	0	1	0	0	2%
	American Indian	0	0	0	0	0	0	0%	1	0	0	0	0	0	1%	0	0	0	0	0	0	0	0	0%
	Asian	11	10	1	4	2	1	26%	6	0	1	1	2	3	16%	1	4	4	1	3	3	3	0	22%
	Hispanic	3	1	0	0	1	1	4%	1	0	0		0	3	5%	0	0	1	1	1	0	0	0	4%
	# Reporting Ethnicity	27	40	8	8	5	7		24	1	5	16	15	18		5	8	22	9	14	12	15	0	
Geographical Point of Origin	US - Midwest	3	4	1	3	2	2	9%	4	0	2	4	5	5	17%	0	0	0	1	3	6	3	0	9%
	US - Northeast	10	17	3	3	5	3	22%	8	1	3	5	6	7	26%	7	5	11	5	4	9	4	0	30%
	US - South	9	5	3	1	2	5	12%	2	0	4	4	7	3	17%	2	0	7	4	1	9	7	0	20%
	US - West	3	9	6	3	0	3	15%	4	0	1	4	4	3	14%	2	2	0	0	3	1	1	0	6%
	Africa	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Asia	1	4	1	1	1	1	6%	0	0	0	0	0	0	0%	0	2	4	0	0	0	0	0	4%
	Canada	0	3	1	0	1	0	4%	0	0	0	1	1	1	3%	2	0	0	0	0	0	0	0	1%
	Europe	0	10	10	7	6	8	29%	5	0	1	12	1	5	21%	5	3	13	0	4	7	12	0	29%
	Latin & South America	0	2	0	0	1	1	3%	1	0	0	0	0	2	3%	0	0	0	0	2	0	0	0	1%
	Oceania	0	1	0	0	0	0	0.7%	1	0	0	0	0	0	1%	0	0	0	0	0	0	0	0	0%

All Participants (ICERM funded and Non-ICERM funded)

	Program Type	Summer@ICERM 2020	Fall Semester '20						Spring Semester '21							Topical '20 - '21								
			Semester Program	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Semester Program	Seminar	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Workshop A	Workshop B	Workshop C	Workshop D	Workshop E	Workshop F	Workshop G	Workshop H	% of # Reporting
Gender and Ethnicity	Total Participants	31	136	152	181	142	136		93	42	282	110	104	174		27	99	80	107	48	62	95	66	
	Female	12	23	16	32	21	22	18%	32	15	60	22	25	38	22%	6	21	11	26	46	16	25	34	32%
	Other	0	0	2	0	0	1	0.5%	1	0	2	0	0	2	0%	0	0	0	1	0	1	0	4	1%
	# Reporting Gender	27	120	124	162	125	119		88	38	247	87	91	153		12	89	62	99	46	42	84	61	
	African American	0	1	1	1	0	5	1%	1	0	2	0	0	0	0%	2	1	0	3	0	3	1	10	4%
	American Indian	0	0	1	2	3	3	1%	2	0	0	0	0	0	0%	0	0	0	0	0	0	1	1	0%
	Asian	11	45	40	67	49	44	40%	29	14	68	11	21	40	28%	5	33	15	23	12	9	25	14	29%
	Hispanic	3	8	7	8	9	7	6%	2	0	18	12	9	23	10%	0	1	1	4	4	1	5	16	7%
	# Reporting Ethnicity	29	114	113	151	114	113		81	34	233	78	82	150		11	82	56	96	48	40	76	62	
Geographical Point of Origin	US Based	30	68	51	48	41	49	34%	69	30	176	52	84	89	65%	17	48	38	83	34	50	53	60	66%
	Foreign Based	1	68	101	133	101	87	66%	24	12	106	58	20	85	35%	10	51	42	24	14	12	42	6	34%

ICERM Funded Speakers

	Program Type	Summer@ICERM 2020	Fall Semester '20						Spring Semester '21							Topical '20 - '21								
			Semester Program	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Semester Program	Seminar	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Workshop A	Workshop B	Workshop C	Workshop D	Workshop E	Workshop F	Workshop G	Workshop H	% of # Reporting
Gender and Ethnicity	Total Participants	0	1	17	8	10	15		1	0	2	18	14	16		9	10	22	5	0	17	19	0	
	Female	0	0	1	2	0	1	40%	0	0	0	2	2	4	24%	2	2	3	2	0	1	3	0	33%
	Other	0	0	0	0	0	0	0%	0	0	0	0	0	1	3%	0	0	0	0	0	0	0	0	0%
	# Reporting Gender	0	1	3	2	2	2		1	0	1	8	10	13		2	7	12	3	0	2	13	0	
	African American	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	American Indian	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Asian	0	0	0	1	0	0	13%	0	0	0	0	1	2	10%	1	3	2	0	0	1	2	0	26%
	Hispanic	0	0	0	0	0	0	0%	0	0	0	2	0	3	17%	0	0	0	1	0	0	0	0	3%
	# Reporting Ethnicity	0	1	3	2	0	2		0	0	0	9	8	13		2	7	10	3	0	2	10	0	
Geographical Point of Origin	US - Midwest	0	1	1	2	0	2	12%	1	0	1	2	2	3	18%	0	0	0	1	0	3	1	0	6%
	US - Northeast	0	0	3	2	5	2	24%	0	0	0	2	4	4	20%	4	4	10	3	0	6	3	0	37%
	US - South	0	0	2	1	1	3	14%	0	0	1	2	4	1	16%	2	0	3	1	0	4	6	0	20%
	US - West	0	0	5	1	0	3	18%	0	0	0	2	3	2	14%	2	2	0	0	0	0	1	0	6%
	Africa	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Asia	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	2	3	0	0	0	0	0	6%
	Canada	0	0	1	0	1	0	4%	0	0	0	1	1	1	6%	0	0	0	0	0	0	0	0	0%
	Europe	0	0	5	2	2	5	27%	0	0	0	9	0	3	24%	1	2	6	0	0	4	8	0	26%
	Latin & South America	0	0	0	0	1	0	2%	0	0	0	0	0	2	4%	0	0	0	0	0	0	0	0	0%
	Oceania	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%

All Speakers (ICERM funded and Non-ICERM funded)

	Program Type	Summer@ICERM 2020	Fall Semester '20						Spring Semester '21							Topical '20 - '21								
			Semester Program	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Semester Program	Seminar	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Workshop A	Workshop B	Workshop C	Workshop D	Workshop E	Workshop F	Workshop G	Workshop H	% of # Reporting
Gender and Ethnicity	Total Participants	5	3	19	11	16	22		3	4	5	18	15	16		9	10	27	13	15	17	20	21	
	Female	1	0	1	4	2	3	40%	0	1	1	2	2	4	25%	2	2	5	5	15	1	3	10	51%
	Other	0	0	0	0	0	0	0%	0	0	0	0	0	1	3%	0	0	0	0	0	0	0	1	1%
	# Reporting Gender	3	2	3	4	8	8		2	3	3	8	11	13		2	7	15	9	15	2	14	20	
	African American	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	3	4%
	American Indian	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Asian	0	0	0	1	0	0	4%	1	2	0	0	1	2	16%	1	3	3	1	3	1	3	2	22%
	Hispanic	0	0	0	0	0	0	0%	0	0	0	2	0	3	13%	0	0	0	1	2	0	0	4	9%
	# Reporting Ethnicity	2	2	3	4	6	8		1	4	2	9	9	13		2	7	14	9	15	2	11	17	
Geographical Point of Origin	US Based	5	3	12	7	11	13	65%	3	4	5	8	14	10	72%	8	6	15	12	12	13	12	20	74%
	Foreign Based	0	0	7	4	5	9	35%	0	0	0	10	1	6	28%	1	4	12	1	3	4	8	1	26%

ICERM Funded Postdocs

	Program Type	Summer@ICERM 2020	Fall Semester '20						Spring Semester '21							Topical '20 - '21								
			Semester Program	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Semester Program	Seminar	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Workshop A	Workshop B	Workshop C	Workshop D	Workshop E	Workshop F	Workshop G	Workshop H	% of # Reporting
Gender and Ethnicity	Total Participants	0	11	0	1	1	3		7	0	1	4	5	4		0	2	3	0	2	6	4	0	
	Female	0	2	0	0	0	0	15%	3	0	0	0	1	3	35%	0	2	0	0	1	2	0	0	42%
	Other	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	# Reporting Gender	0	10	0	1	1	1		7	0	1	3	5	4		0	2	3	0	1	3	3	0	
	African American	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	American Indian	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Asian	0	2	0	0	0	0	17%	2	0	1	1	2	2	40%	0	2	1	0	1	0	2	0	50%
	Hispanic	0	1	0	0	1	0	17%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	# Reporting Ethnicity	0	9	0	1	1	1		8	0	1	3	4	4		0	2	3	0	2	3	2	0	
Geographical Point of Origin	US - Midwest	0	1	0	0	0	0	6%	1	0	0	0	1	0	10%	0	0	0	0	0	1	0	0	6%
	US - Northeast	0	5	0	0	0	1	38%	4	0	1	2	3	3	62%	0	0	1	0	1	3	2	0	41%
	US - South	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	1	0	0	6%
	US - West	0	2	0	1	0	1	25%	1	0	0	0	1	0	10%	0	0	0	0	1	0	0	0	6%
	Africa	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Asia	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	1	1	0	0	0	0	0	12%
	Canada	0	1	0	0	0	0	6%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Europe	0	1	0	0	1	1	19%	0	0	0	2	0	0	10%	0	1	1	0	0	1	2	0	29%
	Latin & South America	0	1	0	0	0	0	6%	1	0	0	0	0	1	10%	0	0	0	0	0	0	0	0	0%
	Oceania	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%

All Postdocs (ICERM funded and Non-ICERM funded)

	Program Type	Summer@ICERM 2020	Fall Semester '20						Spring Semester '21							Topical '20 - '21								
			Semester Program	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Semester Program	Seminar	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Workshop A	Workshop B	Workshop C	Workshop D	Workshop E	Workshop F	Workshop G	Workshop H	% of # Reporting
Gender and Ethnicity	Total Participants	0	21	27	27	23	19		24	8	45	26	19	28		0	28	13	14	16	13	14	2	
	Female	0	4	2	4	5	3	16%	10	3	13	11	4	9	38%	0	8	2	3	15	3	4	2	41%
	Other	0	0	1	0	0	0	1%	0	0	0	0	0	1	1%	0	0	0	0	0	0	0	0	0%
	# Reporting Gender	0	20	24	27	23	17		24	7	40	22	18	22		0	24	13	14	15	10	13	2	
	African American	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	2	2%
	American Indian	0	0	0	0	0	0	0%	1	0	0	0	0	0	1%	0	0	0	0	0	0	0	0	0%
	Asian	0	7	8	5	2	3	23%	7	4	10	6	5	12	36%	0	7	2	3	4	1	5	2	27%
	Hispanic	0	2	1	2	4	1	9%	0	0	3	1	1	0	4%	0	0	0	0	1	0	1	1	3%
	# Reporting Ethnicity	0	19	23	26	25	17		22	7	35	20	15	24		0	23	11	13	16	10	12	5	
Geographical Point of Origin	US Based	0	12	10	10	8	8	41%	18	6	18	9	14	12	51%	0	12	5	7	10	9	7	2	52%
	Foreign Based	0	9	17	17	15	11	59%	6	2	27	17	5	16	49%	0	16	8	7	6	4	7	0	48%

ICERM Funded Graduate Students

	Program Type	Summer@ICERM 2020	Fall Semester '20						Spring Semester '21							Topical '20 - '21								
			Semester Program	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Semester Program	Seminar	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Workshop A	Workshop B	Workshop C	Workshop D	Workshop E	Workshop F	Workshop G	Workshop H	% of # Reporting
	Total Participants	4	13	2	4	0	5		1	0	0	0	0	0		0	0	4	0	0	1	0	0	
Gender and Ethnicity	Female	0	3	1	2	0	1	33%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Other	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	# Reporting Gender	3	12	2	4	0	3		1	0	0	0	0	0		0	0	4	0	0	1	0	0	
	African American	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	American Indian	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Asian	1	2	0	2	0	0	24%	0	0	0	0	0	0	0%	0	0	1	0	0	0	0	0	20%
	Hispanic	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	1	0	0	0	0	0	20%
	# Reporting Ethnicity	3	9	2	4	0	2		1	0	0	0	0	0		0	0	4	0	0	1	0	0	
Geographical Point of Origin	US - Midwest	0	0	0	0	0	1	4%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	US - Northeast	2	5	0	0	0	2	29%	1	0	0	0	0	0	100%	0	0	1	0	0	0	0	0	20%
	US - South	0	1	0	0	0	0	4%	0	0	0	0	0	0	0%	0	0	1	0	0	1	0	0	40%
	US - West	1	0	0	1	0	0	4%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Africa	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Asia	1	3	0	1	0	0	17%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Canada	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Europe	0	4	2	2	0	2	42%	0	0	0	0	0	0	0%	0	0	2	0	0	0	0	0	40%
	Latin & South America	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%
	Oceania	0	0	0	0	0	0	0%	0	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0%

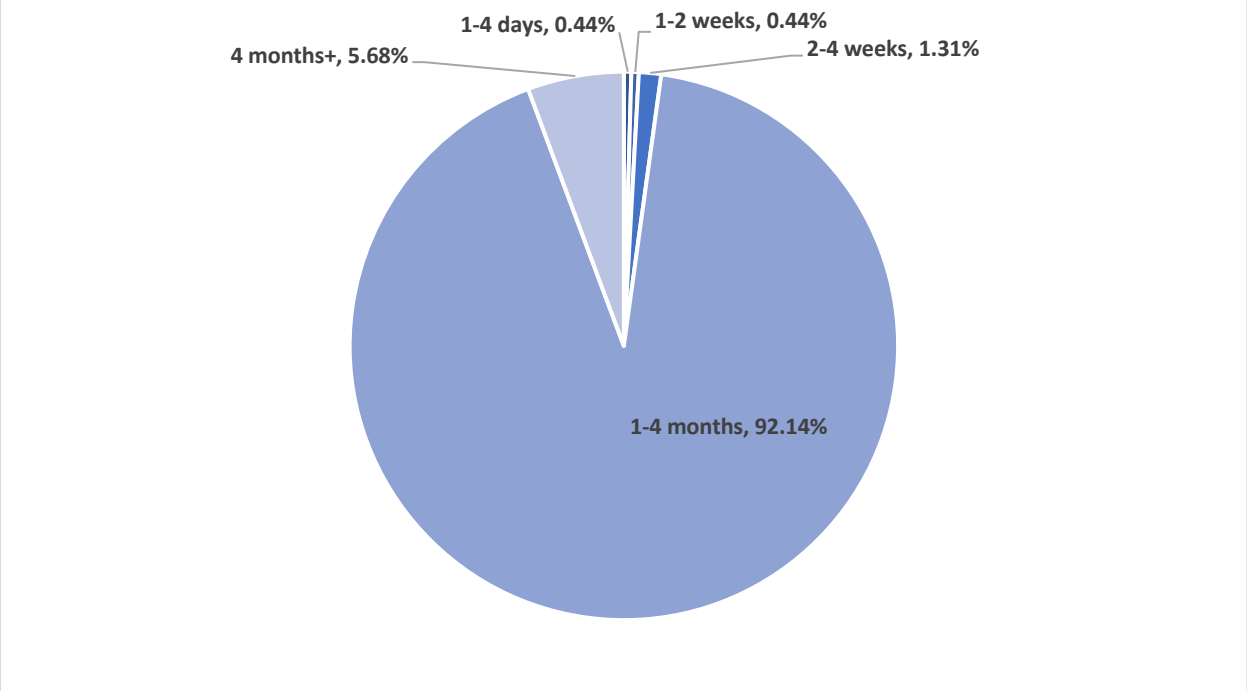
All Graduate Students (ICERM funded and Non-ICERM funded)

Program Type		Summer@ICERM 2020	Fall Semester '20						Spring Semester '21							Topical '20 - '21								
			Semester Program	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Semester Program	Seminar	Workshop 1	Workshop 2	Workshop 3	Workshop 4	% of # Reporting	Workshop A	Workshop B	Workshop C	Workshop D	Workshop E	Workshop F	Workshop G	Workshop H	% of # Reporting
Gender and Ethnicity	Total Participants	4	48	63	65	51	51		26	13	119	29	27	58		4	26	12	10	14	9	42	35	
	Female	0	11	9	14	10	10	20%	11	4	22	5	7	11	24%	1	5	2	3	14	4	12	19	40%
	Other	0	0	1	0	0	0	0%	1	0	0	0	0	0	0%	0	0	0	0	0	1	0	2	2%
	# Reporting Gender	3	47	58	62	48	49		24	13	104	27	27	55		3	26	11	9	14	9	42	35	
	African American	0	1	0	1	0	1	1%	1	0	0	0	0	0	0%	1	1	0	1	0	1	0	2	4%
	American Indian	0	0	0	0	1	1	1%	0	0	0	0	0	0	0%	0	0	0	0	0	0	1	1	1%
	Asian	1	19	18	29	22	21	45%	11	5	29	3	7	12	29%	1	8	6	3	6	3	16	8	35%
	Hispanic	0	2	3	3	3	3	6%	0	0	8	6	4	13	13%	0	1	1	0	1	0	4	7	10%
	# Reporting Ethnicity	3	45	50	57	41	47		22	10	98	23	25	54		3	26	10	9	16	8	41	32	
Geographical Point of Origin	US Based	3	21	13	9	5	17	23%	23	8	74	13	23	26	61%	2	18	7	9	13	9	27	34	78%
	Foreign Based	1	27	50	56	46	34	77%	3	5	45	16	4	32	39%	2	8	5	1	1	0	15	1	22%

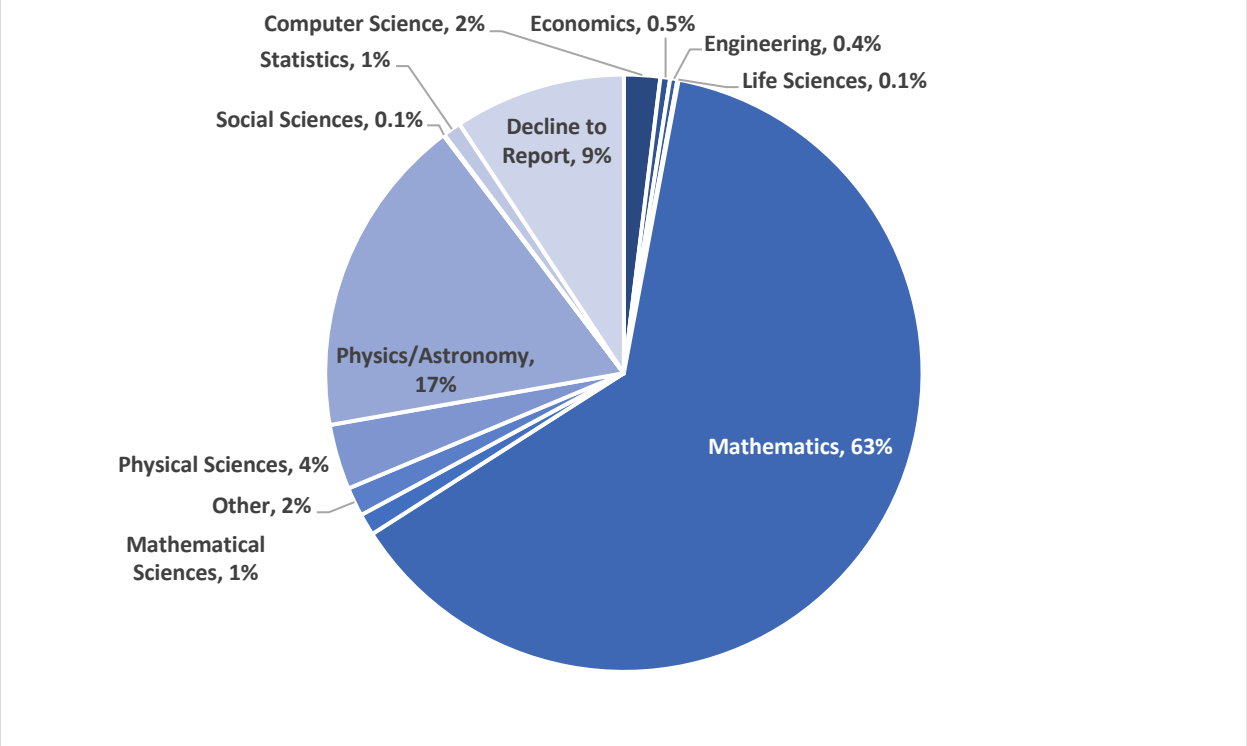
Additional Participant Data

The charts below display breakdowns of ICERM's confirmed NSF-funded participants by category during the reporting period for all funded programs. Each participant is only reflected once per chart regardless of the number of programs they attended.

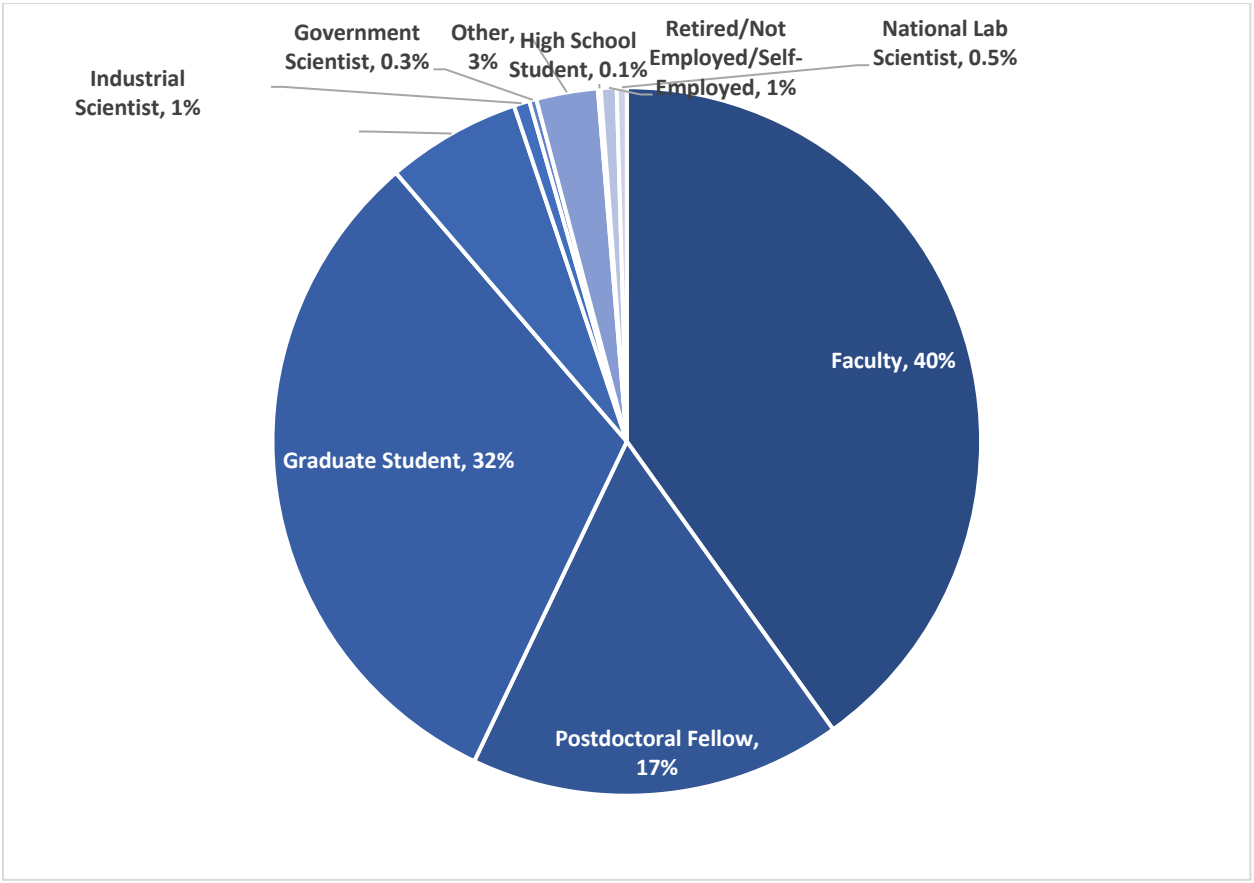
Semester Program Length of Stay



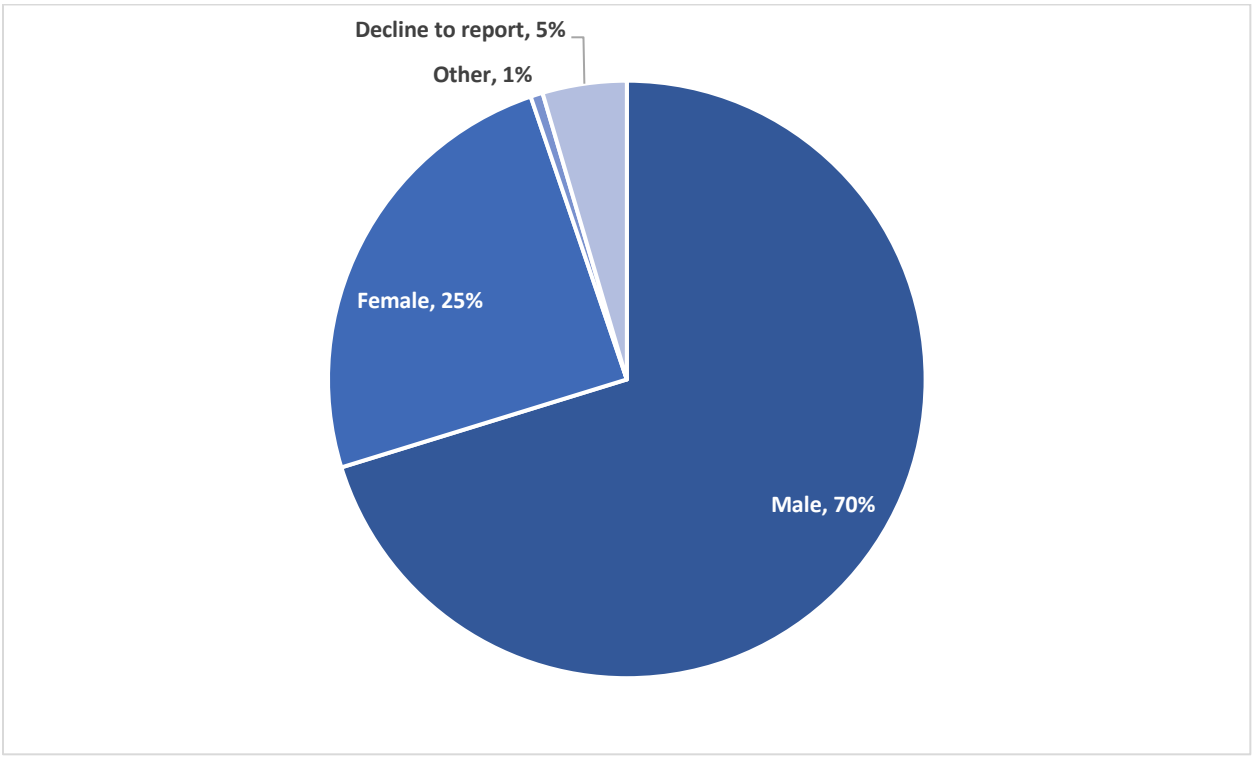
Primary Field of Interest



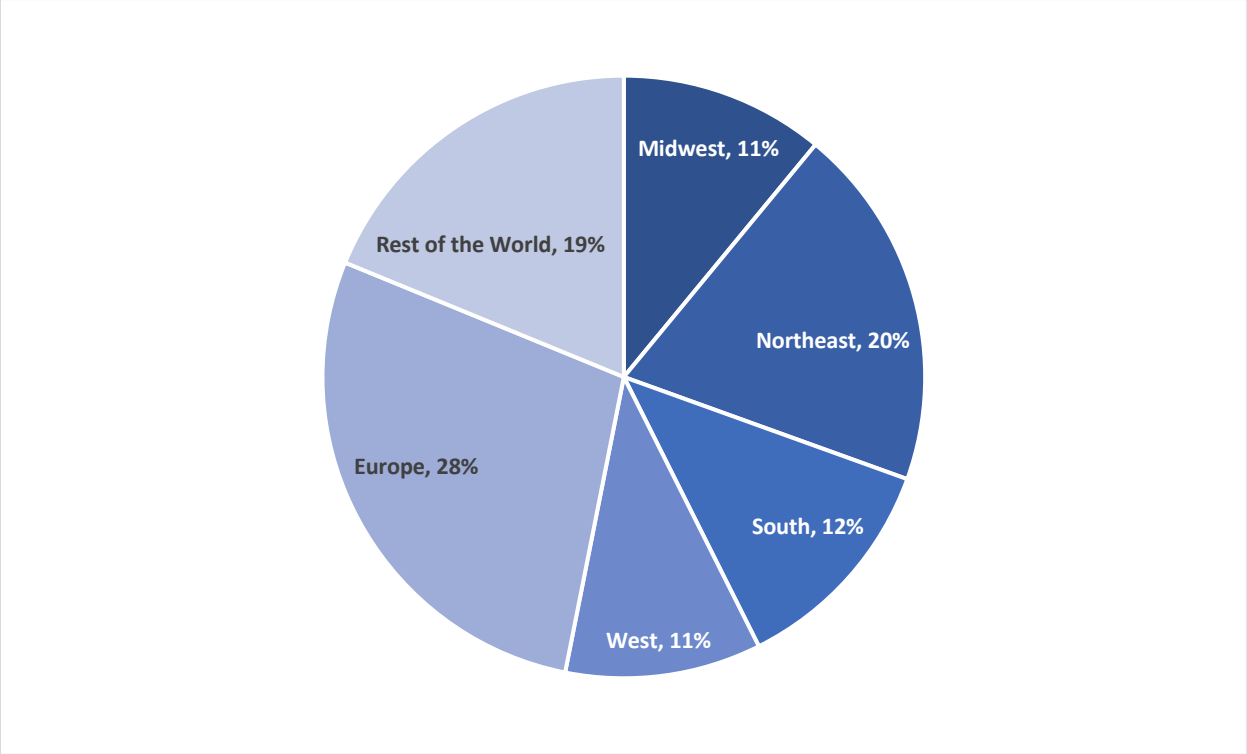
Position



Gender

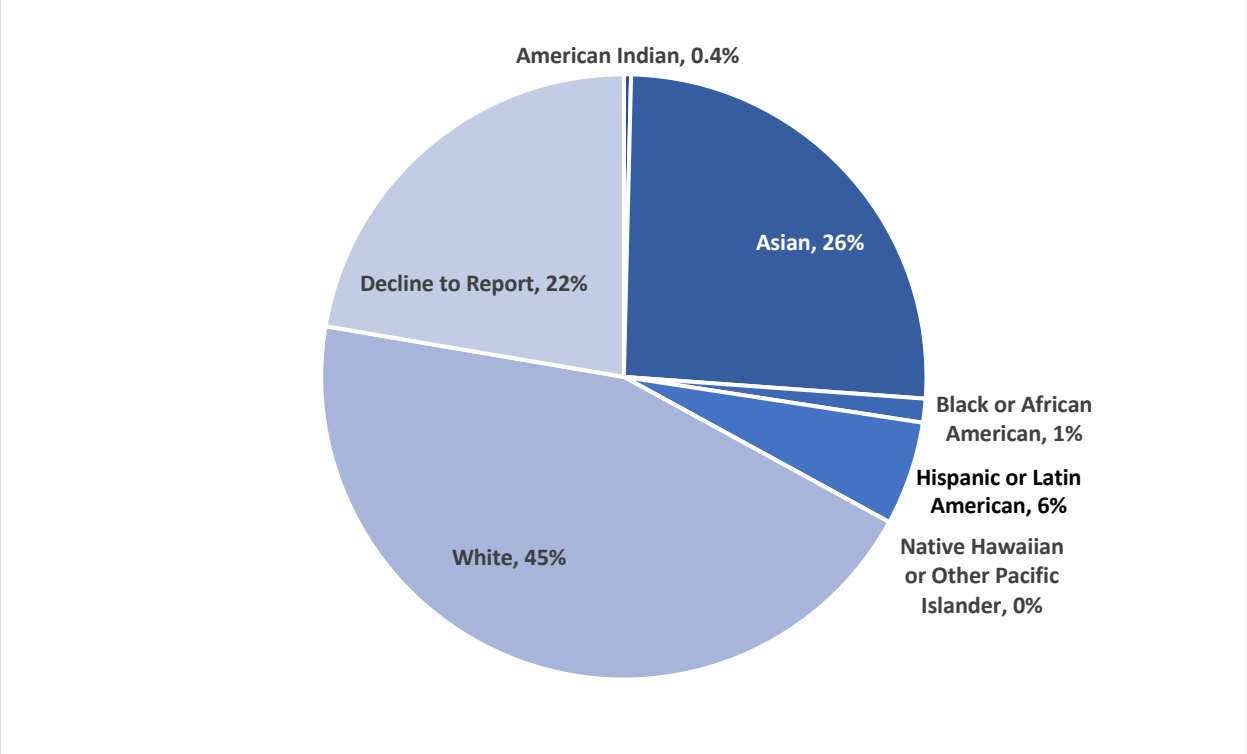


US vs Foreign Based Participants



Rest of the World includes: Africa, Asia, Canada, Latin & South America, and Oceania.

Ethnicity



Note: Participants can select multiple ethnicities so some are reflected in this pie chart more than once.

Impact of the Pandemic on 2020-2021 Programming

Due to the COVID-19 pandemic, all programming was converted to a virtual platform during this reporting cycle.

Since moving programs and workshops to a virtual format, ICERM has made some changes to its application, selection, and offer processes. For applications, a checkbox indicating "I wish to attend this program virtually" has been added to all applications. This option removes some of the previously required uploads such as statements of support for graduate students, making virtual participation more accessible. As in past years, ICERM continues to rely on the input of program and workshop organizers for participant selection. ICERM also streamlined its invitations, removing travel funding offers and highlighting code of conduct and export control guidelines.

Outside of these processes, ICERM also made great strides in creating opportunities for virtual collaborations. Zoom and Gathertown are used to enhance specific types of scheduled events; more scientific content is hosted using Zoom meeting, and more informal and social events are hosted in Gathertown. Gathertown allows for floorplan redesign, and ICERM took advantage of this feature to reflect the institute's physical space. In this way, though deliberate, these virtual opportunities enable collaboration. ICERM has worked with organizers to ensure that time is scheduled so that participants can juggle various timezones and the myriad of competing priorities that come with participating from home.

It is important to note that the institute's applicant pool increased significantly since there were fewer barriers to participating with the availability of virtual programming. Where ICERM previously accepted 70-80 applicants per program, it often accepted 300+ applications. Many participants were selective in the talks they attended, so attendance was quite variable.

Semester Programs

Since its inaugural semester program in September 2011, a large portion of the Institute's activity has taken place in the context of semester long thematic programs together with their associated workshops. ICERM encourages proposals for programs that support its mission "to foster and broaden the relationship between mathematics and computation". The institute is open to proposals from any area of the mathematical sciences. Both pure and applied fields may benefit from the positive feedback between computation and theory that ICERM seeks to promote. ICERM Directors help proposers flesh out their ideas within the context of our mission; it is an iterative process, involving many conversations with ICERM Directors and proposal drafts in response to feedback from Directors and ICERM's boards, and fine-tuning after the event is publicly announced.

Semester Program Process

ICERM's Scientific Advisory Board SAB meets annually in November, and schedules conference calls as needed throughout the year. The fall 2020 annual meeting and a subsequent conference call in June resulted in the selection of semester programs and topical workshops through Fall 2023.

The semester program selection process follows these steps:

1. Solicitation of Proposals

ICERM hosts two semester programs per year. Each has organizers and long-term participants who are expected to be in residence for the majority of the semester. Semester programs typically incorporate three week-long associated workshops.

Semester Program Full Proposal Requirements

A semester program proposal should be 6-10 pages and contain:

- List of 5-10 organizers, including the main contact for organizing committee
- Short abstract of the program's basic goals and underlying philosophy
- Description of the program area/theme and central scientific challenges, written for a general mathematical audience
- Description of the experimental and computational aspects of the program
- Plan for ensuring the participation of underrepresented groups—As part of your plan please identify a main contact among the organizers that will take the lead in ensuring participation from underrepresented groups. The plan should also list potential participants of the program that are women and potential participants who are members of an underrepresented minority group (African American, Hispanic or Latino, American Indian or Alaskan Native).
- List of 8-10 high priority senior scientists likely to visit ICERM for a month or more
- Ranked list of 20+ potential long-term participants who will help form a critical mass for the scientific program
- Description of three proposed workshops, including potential organizers, if known
- Description of a 2-3 day opening event that will survey guiding problems or introduce key computational or experimental methodologies
- Concrete plans for involving and mentoring graduate students, postdocs, and early-career mathematicians in the program

Deadline and Review Process

Proposals are submitted to the ICERM Director. Annual target deadlines are October 1st and May 1st. ICERM Directors and the Scientific Advisory Board (SAB) review all proposals. Proposers receive feedback within a month of the SAB meeting.

2. Proposal Selection

The Science Advisory Board SAB approves the semester programs. The deadline for proposals is at least a week prior to the annual November SAB meeting. Once a proposal is accepted, a member of the ICERM Directorate and members of a SAB subcommittee are assigned to assist the organizers who are also provided with a planning timeline. The “high priority” list of senior scientists are contacted and invited to participate immediately upon SAB approval. Program dates are scheduled with details posted on the ICERM website and various on-line math organization calendars SIAM, AMS, European Mathematical Society, National Math Institutes, and Conference Service Mandl. Program and/or workshop ads are placed in appropriate publications if recommended by the organizers and Directors. ICERM reserves some funds for applicants (non-invitees) to the program.

From this point on, organizers are involved in making decisions on the following: ICERM postdoc selection; applications for long-term visitors, graduate students, and workshop participants; mentoring of students and postdocs (an institute Director assists the organizers with mentor coordination). Members of the Directorate make the final decisions on all invitations. A designated organizer assists ICERM staff by providing appropriate program images for web and print ads and will be asked to review marketing materials.

3. Selection of Long-term Visitors/Research Fellows

The organizers propose a ranked list of 20 to 30 research fellows. ICERM Directors approve and/or suggest additions or re-rankings in consultation with assigned SAB members. The standard model for long-term participation for senior faculty is through paid leaves such as sabbatical.

4. Offers to Research Fellows

Once the list of research fellows has been finalized and funding determined, an invitation is sent to each. The invitation describes the program and outlines the support to be provided. During this reporting cycle, ICERM updated all of its research fellow invitations to include language regarding Brown University's "Code of Conduct", which addresses sexual harassment, discrimination, and other unprofessional behaviors. Using its Cube database, ICERM tracks demographic information about, and all interactions with, research fellows.

5. Semester Workshops

Semester program organizers recommend organizers each of the three-to-four workshops, taking into account feedback from ICERM's Scientific Advisory Board and responsible Directors. The organizers propose an initial ranked list of 20-25 possible speakers and a list of 10 alternates. The ICERM Directorate approves and/or suggests additions or re-rankings in consultation with assigned SAB members. Formal invitations are sent by ICERM staff describing the program and outlining the support to be provided to those who indicate an interest. During this reporting cycle, ICERM updated all of its workshop invitations to include language regarding Brown University's "Code of Conduct", which addresses sexual harassment, discrimination, and other unprofessional behaviors. A designated workshop organizer assists ICERM staff by providing appropriate program images for the workshop's web and print ads, and will be asked to review marketing materials.

6. Application Process

Once the organizers and Directors agree there is enough critical mass in terms of confirmed long-term visitors and/or workshop speakers, the on-line application for that particular program is opened on the ICERM website. All applications are stored in the institute's "Cube" database (see also the "Recruiting and Selection of ICERM-Funded Postdocs" later in this report). The ICERM postdoctoral fellow applicants who were not hired via MathJobs.org are alerted that the ICERM postdoc positions have closed and that they should apply online for partial support to attend as a participant if they are still interested.

7. Applicant Selection

Program organizers can view the applicants and their supporting documents as well as prioritize them within Cube. A member of the ICERM Directorate reviews the prioritized list, re-ranks as appropriate and makes the final selections, taking into consideration the remaining space in the program, diversity, participant support requested, and whether or not the applicant is a young researcher who has an advisor already participating in the program. ICERM staff then updates the applicant about their status, and any support they are eligible for, as appropriate.

Financial Decisions for Semester Programs

Financial decisions are made by ICERM Directors based on discussions with organizers. For a typical program, ICERM provides travel and lodging support for 5-10 organizers (at least a month in residence, with some for the full semester); 20-30 long-term participants (4+ weeks); 1 Institute and 5 Semester postdoctoral fellows (salaried); 60 short-term participants (1-4 weeks); 10-15 graduate students (6+ weeks); and workshop attendees. ICERM helps essential long-term participants negotiate sabbatical leaves or teaching releases to foster their participation.

Opening, Closing, and Related Events

Semester program opening and closing events are tailored to each program. Here are some examples of planned events during semester programs.

Opening event(s)

During the first week of program and can include:

- Opening reception
- 10-15 minute introductory presentations by the postdocs and grad students, designed to get everyone acquainted
- Talks related to upcoming workshops
- IT tutorial led by ICERM's IT staff

Weekly Seminar non-workshop weeks

- The weekly seminar includes talks by visitors in residence at ICERM. Program organizers are provided with names and dates to facilitate scheduling.

Mini-Series (Optional)

- Mini-courses or other multi-session events are encouraged.

Research Clusters (Optional)

A Research Cluster takes place during a semester program and is an independently organized research group activity in a focused subfield of that semester program.

A typical Research Cluster lasts at least 10 days, and as long as 4-6 weeks, and focuses on immediate progress on a major problem or on several problems of significance in the field of the program. In addition to the invited participants, interested faculty, postdocs or graduate students in residence at ICERM may participate in the research cluster.

The activity period begins with a collection of tutorials or a short workshop. The research activities, planned by the organizers, may consist of teamwork, daily/weekly seminars, and

closing presentations. In collaboration with an ICERM Director, Research Cluster organizers develop a list of 6-15 key scientists to form the core cohort of the cluster.

Prior to each of semester workshops (optional)

- Full-day tutorials the Thursday and Friday the week before each workshop
- Tutorials are given by long term visitors to the program

During Semester Workshops

- Workshops last 1 week and usually consist of 45-50 minute talks with 10 minutes of Q&A.
- Sometimes one afternoon is left "open" for collaborations and small groups
- A poster session is scheduled early in the workshop week
- Networking opportunities within workshops and semester programs, e.g., opportunities for women to come together for lunchtime discussions (optional)

Non-workshop weeks

- Lectures occur through either mini courses, research seminars, special talks, and/or computational working group meetings
- Young Researcher Seminar, where graduate students and postdocs meet sans faculty and discuss scientific questions
- Postdocs and grad students are mentored throughout the program, both informally and with formal professional development seminars and meetings

Final Event

During the first week of the program discussion about a closing event occurs with the organizing committee. Some possible models include:

- Short talks from all long-term visitors who are still in residence
- Special Colloquium to close out the event on the last day of the program
- Time set aside for takeaways
- Closing reception

Note: Sample schedules and organizer timelines can be found in Appendix A.

2020-2021 Semester Programs

Fall 2020 Semester Program: Advances in Computational Relativity

September 9 – December 11, 2020

Organizing Committee:

Stefanos Aretakis, University of Toronto
Douglas Arnold, University of Minnesota
Manuela Campanelli, Rochester Institute of Technology
Scott Field, University of Massachusetts Dartmouth
Jonathan Gair, Max Planck Institute for Gravitational Physics
Jae-Hun Jung, POSTECH
Gaurav Khanna, University of Massachusetts Dartmouth

Stephen Lau, University of New Mexico
Steven Liebling, Long Island University
Deirdre Shoemaker, University of Texas at Austin
Jared Speck, Vanderbilt University
Saul Teukolsky, Cornell University

Program Description:
The Nobel-Prize-winning detection of gravitational waves from binary black hole systems in 2015 by the Laser Interferometer Gravitational-Wave Observatory (LIGO) and the LIGO Scientific Collaboration has opened a new window on the universe. In addition, the 2017 observation of both gravitational and electromagnetic waves emitted by a binary neutron star system marked a new era of multi-messenger astronomy. While these successes are a remarkable experimental feat, they also constitute a significant computational achievement due to the crucial role played by accurate numerical models of the astrophysical sources in gravitational-wave data analysis. As current detectors are upgraded and new detectors come online within an international network of observatories, accurate, efficient, and advanced computational methods will be indispensable for interpreting the diversity of gravitational wave signals. This semester program at ICERM will emphasize the fundamental mathematical and computational challenges in computational relativity and gravitational-wave data science.

The aim of this semester program is to bring together pure and applied mathematicians, physicists, and statisticians with the goals of fostering an environment for in-depth collaboration and cross-pollination of ideas between these communities, working towards solving the most pressing mathematical modeling and numerical simulation issues facing the gravitational wave community, and cultivating new subfields within mathematics that focus on important, pressing issues related to gravitational waves as well as providing mathematicians with new questions and problems to explore.

The program's areas of focus will be: (i) mathematical and computational approaches for solving the source-free Einstein field equations (a nonlinear, coupled, hyperbolic-elliptic PDE system) including fundamental aspects of general relativity or alternative theories of gravity, (ii) mathematical and computational approaches for the Einstein field equations with matter and magnetic fields, as well as the multi-scale, multi-physics modeling challenges for such problems, and (iii) methods for the detection, classification, and Bayesian inference of relativistic objects and gravitational-wave datasets, especially by considering under-explored techniques such as machine learning or uncertainty quantification.

The list of all long-term visitors to the fall 2020 Semester program as well as the participant list for the affiliated workshops can be found in Appendix B.

Here follows a sample of the most substantive comments from our long-term visitors:
Some Long-term Visitor Comments for “Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.”:

- *It was tremendously helpful to understand the state of the art in computational relativity. I now understand better which techniques are already used and which computational methods haven't been established yet.*
- *The semester at ICERM provided deep insights into the science of gravitational waves by bringing together world experts from a carefully chosen variety of sub-fields of relativity. This stimulating mix allowed me to extend my own skills by adapting new approaches and ideas into my own framework.*
- *I learned about some exciting new developments on the theoretical front. I especially liked the panel discussions, where important open problems were outlined, context for recent developments was provided, and tantalizing speculation about what might or might not be true/provable was provided. I also developed a further appreciation for the gap between experimental data/computational methods and rigorous theory.*
- *The workshops organized were really good and I learned a lot from them. I really liked the idea of having both lectures and hands-on workshops. I learned a lot about various software packages that are developed for research in relativity. Because of the semester program, I was able to collaborate with fellow participants (Brendan and Scott) and which also helped me learn new topics and work on a project.*

Some Long-term Visitor Comments for "Briefly describe program highlights":

- *I initiated a project on the development and analysis of radiation boundary conditions in computational relativity. In addition, I made progress on completing work on the construction of energy-stable DG methods for arbitrary regularly hyperbolic systems. Also, as a result of the workshop, I may initiate new projects related to the direct computation of singularity development for the Euler equations and the construction of mimetic finite difference schemes based on the finite element exterior calculus.*
- *I continued a project on computing first-order radiation-reaction effects occurring in compact object binaries known as extreme-mass-ratio inspirals (EMRIs). I have built the foundation for a new code that will hopefully improve the computational efficiency of these calculations in the future, enabling new explorations of resonant effects on EMRIs.*
- *During the semester program, I started a collaboration with Dr. Brendan Keith and Dr. Scott Field. We started with the idea of using Physics informed Neural Network (PINN) for gravitational waves. We are currently working on a project to use PINNs to extract dynamical models for binary black hole mergers using the waveform data. This is in a sense a reverse approach where we infer the model (differential equations for orbital parameters) using gravitational-wave data.*
- *The highlight of this program was the collaboration I started. ICERM made it possible for me to make make connections with the physics community I never otherwise would have had the chance to.*
- *In terms of theoretical understanding, I really appreciated the the following talks: "Electromagnetic-gravitational perturbations of Kerr-Newman black hole" by Elena Giorgi and "BMS-like structures in cosmology" by Beatrice Bonga. Both presented surprising results (to me). The talk "Critical Phenomena in Gravitational Collapse" by Thomas Baumgarte was extremely good, and real fun to attend. Finally, from a practical standpoint my own work and collaborations will (probably) be most affected by the tutorial "Introductory Talk to The Simulating eXtreme Spacetimes waveform catalog" and its followup by Mike Boyle.*

Workshop 1: Advances and Challenges in Computational Relativity
September 14 – 18, 2020

Organizing Committee:
Douglas Arnold, University of Minnesota
Scott Field, University of Massachusetts Dartmouth
Gaurav Khanna, University of Massachusetts Dartmouth
Deirdre Shoemaker, University of Texas at Austin
Saul Teukolsky, Cornell University
Niels Warburton, University College Dublin
Barry Wardell, University College Dubli

Program Description: This kick-off workshop will seek to provide an overview of both the state-of-the-art and open challenges drawing from multiple themes (theory, analysis of the equations, computation, and data analysis) within the broad context of Einstein's general relativity theory. We welcome participation from physics, mathematics, statistics, and astrophysics, and the speaking schedule will reflect this diversity of scientific disciplines.

The workshop will also feature a series of hands-on, computational tutorials in the afternoon. We plan to hold tutorials on (i) the SXS gravitational waveform catalog which contains important simulation outputs from the numerical relativity code SpEC, (ii) the Einstein Toolkit software platform for numerically solving the Einstein equation, the relativistic (magneto-)hydrodynamics equations, and other tools to support research in relativistic astrophysics and gravitational physics, (iii) the Black Hole Perturbation Toolkit which can be used to model gravitational radiation from small mass-ratio binaries, ringdown of black holes, and other computational tools to assist with the study of gravity within the context of perturbation theory, and (iv) xAct, an efficient tensor computer algebra framework for Mathematica. Some tutorials may also integrate relevant data analysis tutorials for working with gravitational-wave datasets. Tutorial participants will be given both an overview of the key pieces of software as well as practical instructions on installing and running example cases.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *Through the ICERM program, I learned more about the state-of-art developments in the waveform modelling of higher order GW modes, the synergy between numerical and analytical methods, and the need to fine tune analytical methods by incorporating results from numerical simulations. The talks also introduced me to the need for efficient GPU usage for GW modeling and data analysis and better algorithms that adapt to the architectural differences between supercomputers from a computer science lens. I absolutely loved the interdisciplinary approach of the program! The hands-on workshop introduced me to new computational skills (xACT, BHP toolkit, Einstein toolkit) that would help me through my graduate research.*
- *The tutorials were very helpful when trying to understand how some of the numerical relativity code work and will be important for my research in the future. I appreciate that*

they were recorded for future use as well. The lectures helped with my theoretical understanding of the code and the challenges facing the current researchers. I only wished some of the tutorials had more time.

- *The workshop was very useful in getting a broad overview of the topics of interest in computational relativity in the community. While the directions for research when it comes to waveform modeling seemed familiar, I was very intrigued by the renewed push towards simulating high mass ratio systems (Hari Sundar's talk) and developing semi-analytical methods for dealing with EMRI's in general. I also enjoyed Doug Arnold's talk on finite element exterior calculus--the idea was new to me and seems like it has a lot of potential if implemented in hydrodynamical simulations where keeping B divergence-free has been an issue.*
- *ICERM allowed me to get me in touch with several techniques that will be useful in the near future of my career. As a Ph.D. student, I gained a little more expertise (or at least a starting point) in method that are state-of-the-art which I hope will help me to expand my horizons for futures projects.*

Some Workshop Participant Comments for "Briefly describe workshop highlights":

- *Tutorials on xAct, BHP Toolkit, Einstein toolkit, talks by Adrian Ottewill, Beatrice Bonga, David Garfinkle, Maria Okounkova.*
- *The single major highlight was being able to conduct my research, expand my knowledge base, and create professional contacts especially in light of the worldwide pandemic, which threatens the continuity and communication of the global scientific community. This workshop made it posible for science to continue.*
- *The ICERM semester program - Advances in Computational Relativity, in my experience, has been a greatly effective platform in bringing together scientists from different domains - theoretical and computational physicists, gravitational wave astrophysicists, experts from cosmology, and computer scientists - while maintaining a common theme that the talks were oriented around. Every event ensured a natural transition between talks while tying back to the holistic goal of the seminar program. The seminars ranged from state-of the art detailed explanations, interdisciplinary topics, and visions general enough that there was something to take back for everybody - from professors and research scientists to graduate students. The online workshops were extremely helpful in introducing state-of-the art computational resources for anybody willing to learn!*
- *I appreciated the fact that the speakers described open challenges in many fields. The quality of the talks was very good. I also liked that 10-15 minutes were dedicated to questions, so there was a nice interaction with the attendees to the workshop.*

Workshop 2: Mathematical and Computational Approaches for Solving the Source- Free Einstein Field Equations

October 5 – 9, 2020

Organizing Committee:

Stefanos Aretakis, University of Toronto
Scott Field, University of Massachusetts Dartmouth
Jan Hesthaven, Ecole Polytechnique Federale de Lausanne
Jae-Hun Jung, POSTECH

Gaurav Khanna, University of Massachusetts Dartmouth
Stephen Lau, University of New Mexico
Steven Liebling, Long Island University
Deirdre Shoemaker, University of Texas at Austin
Jared Speck, Vanderbilt University
Helvi Witek, University of Illinois at Urbana-Champaign

Program Description:
This workshop will focus on theoretical and computational approaches to solving the vacuum Einstein field equations (the master equation of general relativity: a nonlinear, coupled, hyperbolic-elliptic PDE system) without matter field sources. A particular important special case is the simulation of two merging black holes, which will be emphasized throughout the workshop. Gravitational wave solutions will be another important aspect of this workshop, and special attention will be given to modeling techniques for the computation of these waves. The topics covered in this workshop will be relevant to both LIGO and LISA scientific efforts.
Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *Before attending this workshop, I had a very vague idea about numerical relativity and how it works to obtain waveforms as templates for gravitational wave observation and parameter estimation. The workshop has in a great way helped me gain a basic understanding of the various steps that go into the modelling of a template waveform which is then used in GW observations. Some of the talks were extremely descriptive and gave a very good introduction to these exciting numerical and analytical approaches used in GW data analysis to a beginner like me. I look forward to participating in more workshops like these in the future.*
- *Being more involved on the theoretical side, with some basic knowledge of numerical relativity, the workshop has been an opportunity to know new computational tools useful in the analysis of gravitational waves and black hole dynamics, for example, the software package NRPy+. The lectures during the workshop also provided insight into topics that have intersections with my research; it is quite likely that overall, my research will benefit from this knowledge.*
- *I am very appreciative of the opportunity to hear from such a wide variety of speakers - much wider than a traditional conference. The panel sessions were excellent. They gave me a big-picture overview of the most important challenges in the field, as seen by some top experts.*
- *I primarily work on the implications of various alternate gravity models on observations related to black hole accretion, jet, shadow, and QPOs. I have not worked directly on gravitational wave astrophysics till now. However, I am extremely keen to learn and work on various aspects of computational astrophysics, in particular, numerical relativity, and consider its application in understanding alternate gravity models. In this regard, the talks in both workshops were extremely beneficial. I really enjoyed most of the overview talks, in particular, talks by Zachariah Etienne, Harald Pfeiffer, Patricia Schmidt, Helvi Witek, to name a few.*

Some Workshop Participant Comments for "Briefly describe workshop highlights":

- *Participating "Mathematical and Computational Approaches for Solving the Source-Free Einstein Field Equations" workshop that I recently attended was a huge experience and was a great opportunity for me. I got some idea of recent problems and issues related to General relativity. I learnt how the challenges in GR motivated us in different alternatives GR, dark energy, exotic matter etc. Also, I got some deep insights into the issue of cosmic censorship. These days the numerical relativity is an active area of research which was discussed in the workshop. Particularly, I am working on compact stellar model where it is very important to show that a compact star may behave like a gravitational wave source. In this perspective, the discussions on tidal love number were very interesting for me. Hope in future we may have more workshop that will enhance my research.*
- *Harald Pfeiffer's talk: A really nice overview. Helvi Witek's talk; I found her talk really interesting. The models she has been working on involve scalar fields in strong gravity. I have been working on scalar field models of Dark Energy in context of Cosmology where I simulate then in weak perturbations' regime. I would probably approach her for a project in this regard. Zachariah Etienne's talk and the follow up tutorial on NRPy*
- *This virtual workshop gave me an opportunity to attend a very good conference from the comfort of my home (institution). Actually, it is very difficult to get funding to travel abroad and attend international conferences. So, this gave us a chace to listen to and interact with some of the leading experts of the field without imposing any financial burden on us.*
- *I liked the fact that the mathematical relativity talks were given in a way which was quite understandable to non-mathematical relativists like me. I particularly enjoyed the mathematical relativity talk by Rita Teixeira da Costa which had relevant results and was delivered in a very didactic way.*

Workshop 3: Mathematical and Computational Approaches for the Einstein Field Equations with Matter Fields

October 26 – 30, 2020

Organizing Committee:
Stefanos Aretakis, University of Toronto
Manuela Campanelli, Rochester Institute of Technology
Scott Field, University of Massachusetts Dartmouth
Jan Hesthaven, Ecole Polytechnique Federale de Lausanne
Gaurav Khanna, University of Massachusetts Dartmouth
Luis Lehner, Perimeter Institute
Steven Liebling, Long Island University
Jared Speck, Vanderbilt University

Program Description:
This workshop will focus on theoretical and computational approaches to solving the Einstein field equations (the master equation of general relativity: a nonlinear, coupled, hyperbolic-elliptic PDE system) with (fluid) matter field sources, as typical of binary neutron stars and supernovae. Simulations of these systems are targets of interest to both LIGO and telescopes such as Hubble, Fermi, and CHANDRA. In this workshop, special attention will be given to the

governing equations of relativistic (magneto-) hydrodynamics and multi-scale, multi-physics modeling challenges.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *I have now knowledge of different numerical approaches to the analysis of gravitational waves and on the data analysis; I have also gained insight into a set of theoretical topics that are of current interest in the community and are best understood using numerical simulations.*
- *The organization was neat and clever. I enjoyed and profited from talks about different topics (self-similarity in grav. collapse, boson star simulations, non-perfect fluids...) and the different approaches used. Very exiting scientific questions and review to what kind of assumptions we still need to take in order to tackle these problems computationally. Great workshop!*
- *I have gained an increased understanding of machine efficiency and sensitivity to various input, inputs that on paper are mathematically equivalent but not machine equivalent. As for the theoretical, I have become aware of areas of widespread misconception and equations and states of matter that have been insufficiently explored through mathematical analysis thus making their computational implementation extremely expensive and inefficient.*

Some Workshop Participant Comments for "Briefly describe workshop highlights":

- *I much appreciated the thoughtful review given by Thomas Baumgarte on critical phenomena in gravitational collapse, a nice balance of the basics and recent work. Cécile Huneau's talk on the high frequency limit for Einstein equations was also new and interesting for me.*
- *I often face the problem to solve these equations for modified theories or gravities where equations are too lengthy to analytically solve. I have not a good command on numerical methods so this conference provide me a chance to collaborate with other researchers who have good command on these techniques.*
- *I was impressed with the binary massive black simulation with accretion material around them. The speaker for the critical phenomenon talk also gave a nice presentation.*

Workshop 4: Statistical Methods for the Detection, Classification, and Inference of Relativistic Objects

November 16 – 20, 2020

Organizing Committee:
Sara Algeri, University of Minnesota
Sarah Caudill, Nikhef
Katerina Chatziioannou, Caltech
Alessandra Corsi, Texas Tech University
Scott Field, University of Massachusetts Dartmouth
Jonathan Gair, Max Planck Institute for Gravitational Physics
Jae-Hun Jung, POSTECH

Gaurav Khanna, University of Massachusetts Dartmouth

Program Description:
This workshop will focus on data analysis strategies for comparing model predictions to data. Special attention will be placed on comparing solutions to the Einstein field equations (as in workshops 2 and 3) with data collected from gravitational-wave or telescopes. The workshop will include (but will not be limited to) coverage of topics involving reduced-order models, surrogate models, machine learning, UQ, and Bayesian techniques.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *My future plan is to work with GW data to test GR. This workshop helped me set the perspective of my future research. I am now familiar with new research directions as well as a good understanding of the past works.*
- *ICERM showed me how to extend and generalize some of the statistical techniques I studied in my study plan. Also, it added to my knowledge some interdisciplinary connections that I didn't see before in my career.*
- *The tutorials on surrogate waveforms and Bilby were very well conducted and so were very helpful in understanding the method and implementation. Since my PhD work focusses on the study of compact binary systems using 3G detectors, I found these tutorials very useful in learning these computational tools. The lecture on Pulsar timing array was also very interesting.*
- *I am just starting in Gravitational Waves and this workshop was really helpful for me as it introduced important tools as well as frontiers being explored. Tutorials and lecture talks were really helpful and I suggest that future programs should follow a similar approach.*

Some Workshop Participant Comments for "Briefly describe workshop highlights":

- *I learned about many cutting-edge alternatives to the usual Bayesian data analysis methods, e.g., topological, machine learning, harmonic construction, etc... It would have taken me a while to learn about all these different methods on my own, so having them presented like this was very helpful.*
- *The introductory lectures were brilliant and covered what I needed to know. I hope a similar methodology is applied in future programs as well for helping beginners before going into the details. The tutorials were also a highlight for me, the lecturers were really helpful and I understand the data analysis part better now.*
- *Familiarising with the cutting-edge analysis tools in GW analysis and becoming part of the very helpful and welcoming community. This experience definitely falls within the category of collateral benefits of the unfortunate pandemic situation, as otherwise the workshop would not have been virtual and many of us would have missed out on an amazing learning opportunity.*

Spring 2021 Semester Program: Combinatorial Algebraic Geometry

Februart 1 – May 7, 2021

Organizing Committee:
Anders Buch, Rutgers University
Melody Chan, Brown University
June Huh, Stanford University
Thomas Lam, University of Michigan
Leonardo Mihalcea, Virginia Polytechnic Institute and State University
Sam Payne, University of Texas at Austin
Lauren Williams, Harvard University

Program Description:
Combinatorial algebraic geometry comprises the parts of algebraic geometry where basic geometric phenomena can be described with combinatorial data, and where combinatorial methods are essential for further progress.

Research in combinatorial algebraic geometry utilizes combinatorial techniques to answer questions about geometry. Typical examples include predictions about singularities, construction of degenerations, and computation of geometric invariants such as Gromov-Witten invariants, Euler characteristics, the number of points in intersections, multiplicities, genera, and many more. The study of positivity properties of geometric invariants is one of the driving forces behind the interplay between geometry and combinatorics. Flag manifolds and Schubert calculus are particularly rich sources of invariants with positivity properties.

In the opposite direction, geometric methods provide powerful tools for studying combinatorial objects. For example, many deep properties of polytopes are consequences of geometric theorems applied to associated toric varieties. In other cases geometry is a source of inspiration. For instance, long-standing conjectures about matroids have recently been resolved by proving that associated algebraic structures behave as if they are cohomology rings of smooth algebraic varieties.

Much research in combinatorial algebraic geometry relies on mathematical software to explore and enumerate combinatorial structures and compute geometric invariants. Writing the required programs is a considerable part of many research projects. The development of new mathematics software is therefore prioritized in the program.

The program will bring together experts in both pure and applied parts of mathematics as well mathematical programmers, all working at the confluence of discrete mathematics and algebraic geometry, with the aim of creating an environment conducive to interdisciplinary collaboration. The semester will include four week-long workshops, briefly described as follows.

- A 'boot-camp' aimed at introducing graduate students and early-career researchers to the main directions of research in the program.
- A research workshop dedicated to geometry arising from flag manifolds, classical and quantum Schubert calculus, combinatorial Hodge theory, and geometric representation theory.

- A research workshop dedicated to polyhedral spaces and tropical geometry, toric varieties, Newton-Okounkov bodies, cluster algebras and varieties, and moduli spaces and their tropicalizations.
- A Sage/Oscar Days workshop dedicated to development of programs and software libraries useful for research in combinatorial algebraic geometry. This workshop will also feature a series of lectures by experts in polynomial computations.

The list of all long-term visitors to the spring 2021 Semester program as well as the participant list for the affiliated workshops can be found in Appendix C.

Here follows a sample of the most substantive comments from our long-term visitors:
Some Long-term Visitor Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *I was a remote participant, attending from Germany. Given that Germany was in a lockdown state again for quite a bit of the time (with school kids at home in my case), it was unfortunately a lot harder for me to attend than I had planned originally. I went to fewer events than I had planned. Nevertheless, for those few which I was able to attend, I was thankful to have had the occassion. They were good and stimulating talks, and I can only regret not to have been to more. Thanks to the organizers, and to ICERM!*
- *The week-long workshops have created a unique opportunity to become acquainted with new topics that are adjacent to my field. The opening week was extremely helpful and inspirational, and facilitated many introductions. Apart from that, the weekly seminars (and how accessible and friendly they felt) were an incredible opportunity to learn and connect with other researchers.*
- *The special semester provided a great opportunity to interact with researchers, and consolidate and expand my theoretical knowledge into several directions, including cotangent Schubert Calculus, quantum K theory and semi-infinite flag manifolds, Hall-Littlewood and Macdonald theory, cohomology of Peterson, Hessenberg, and wonderful compactifications. All of this required developing code to provide experimental data supporting my interactions.*
- *I was able to discuss the results of my theoretically search with people who are proficient in use of computers hence they helped me to better understand and interpret in your ways my theoretical results*

Some Long-term Visitor Comments for "Briefly describe program highlights":

- *The reading group on invariant differential forms on moduli spaces of metric graphs organised by Melody Chan and Sam Payne.*
- *Opening week was amazing, and the Thursday 10am seminar about differential forms on the graph complex was inspirational.*
- *From a community point of view, I really enjoyed, and I was impressed by the enthusiasm and energy of the introductory workshop, where all the talks were aimed to early career participants. From a research point of view, I highly benefitted from many meetings I had with semester participants; the highlight was my actual visit, and staying in residence for 1 month at the institute. I had the best interactions with the people in residence there.*
- *The Introductory Workshop was really excellent.*

- *I enjoyed the gather hours to talk more with participants and explore research ideas.*
- *It was great to see all the good work of young people.*

Workshop 1: Introductory Workshop: Combinatorial Algebraic Geometry

February 1 – 5, 2021

Organizing Committee:
Anders Buch, Rutgers University
Melody Chan, Brown University
Thomas Lam, University of Michigan
Leonardo Mihalcea, Virginia Polytechnic Institute and State University

Program Description:
This introductory workshop in combinatorial algebraic geometry is aimed at early career mathematicians and other mathematicians looking for an entry point into the field. The workshop will feature expository lectures on some of the basic objects of interest, together with "expert" lectures discussing some current trends in the field. There will also be ample time for problem sessions and discussions.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *The workshop format was generally pretty well designed for learning the basics of a new research field within combinatorial algebraic geometry. Of course, each talk is only the beginning of a vast area of research, so they cannot all inform my future research directions, but I found it helpful to learn about many of these topics I see discussed in papers related to my own work. I am hoping this new foundation will allow me to build upon existing connections between my research and research areas that were introduced to me in the sessions.*
- *Did not advance experiment/computation, but did do a great job of introducing the foundations of exciting new topics, providing ways to go further during the semester.*
- *The program served to both fill in gaps in my knowledge (for example, concerning Schubert Calculus and Cluster algebras), while at the same time introduced me to areas that I am not very familiar with but very much want to know more (Hodge theory, quantum cohomology...). I expect that more computational aspects of the program are to appear in the 2nd workshop.*
- *First of all, the way the workshop is designed is excellent. Unlike the other virtual conferences I attended, we had a chance to communicate with other participants. Especially, during the problem sessions. I met new people and kind of got the feeling how distant collaboration might be. Most of the areas are quite new to me, and the area I am doing research is not close to computational algebraic geometry. The introductory workshop helped me to have exposures in different areas of the computational/theoretical algebraic geometry.*

Some Workshop Participant Comments for "Briefly describe workshop highlights"

- *Mark Shimozono's talks. Sarah Billey's talks. Tried to attend all of them and all were very good. Most of all I think that the workshop did a great job of using Gather.Town and feeling very interactive, alive.*
- *The problem sessions were definitely extremely helpful in digesting the material of the lectures. Between the two, I came away with some ideas of some problems that I had known little about, and with a better idea about some problems that I had been exposed to before.*
- *One highlight was to understand the wonderful compactification described by Chris Eur -- both his talk and a follow-up conversation with one of the TAs was very helpful. I also got a lot out of Sam Payne's talk, especially his diagrams of the stable tropical cuves of genus g and the associated complex. I also finally understand cluster algebras -- Lauren Williams talks were wonderful and I met with a group of grad students and young faculty via Zoom to work on problems.*

Workshop 2: Sage/Oscar Days for Combinatorial Algebraic Geometry

February 15 – 19, 2021

Organizing Committee:
Anders Buch, Rutgers University
Wolfram Decker, Technische Universität Kaiserslautern
Benjamin Hutz, Saint Louis University
Michael Joswig, TU Berlin & MPI Leipzig
Julian Rüth, None
Anne Schilling, UC Davis

Program Description:
This workshop will focus on the development of software to facilitate research in combinatorial algebraic geometry, based on the SAGE Mathematical Software System and the OSCAR Computer Algebra System. Special attention will be given to efficient computations with multi-variate polynomials, which is a critical part of many algorithms in combinatorial algebraic geometry. Aside from development of software, the workshop will feature a series of talks about polynomial computations, as well as introductory lectures about Sage and Oscar.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *The scope of the meeting was rather broad and hence talks did not always go into depth, but they highlighted the main threads and important developments, so that it was up to the participants to then jump into conversations on selected topics to go further into depth. I quickly identified those people I needed to talk to and we had very fruitful discussions on several topics of talks.*
- *My knowledge of OSCAR and of parallelization went from 0 to something meaningful. My knowledge of Sage gained a similar amount.*

Some Workshop Participant Comments for "Briefly describe workshop highlights":

- *Presentation of new tools and the discussion around parallel computing architectures and software for doing algebraic/symbolic computations. Talks by Arvind*
- *The multipolynomial bases package is really useful for my own research!*
- *I was able to attend a talk given by my advisor as well as a collaborator of his and this was helpful to learn and grow in my research area as a PhD student.*

Workshop 3: Geometry and Combinatorics from Root Systems

March 22 – 26, 2021

Organizing Committee:
David Anderson, Ohio State University
Angela Gibney, Rutgers University, New Brunswick
June Huh, Stanford University
Thomas Lam, University of Michigan
Leonardo Mihalcea, Virginia Polytechnic Institute and State University

Program Description:
The purpose of the workshop is to bring together a diverse group of researchers working on combinatorial and geometric aspects related to spaces with symmetries. The workshop will cover problems arising from various flavors of Schubert Calculus and enumerative geometry on flag manifolds, and problems from geometric representation theory and combinatorial Hodge theory. The topics covered include the study of Littlewood-Richardson coefficients, quantum cohomology and quantum K theory of flag manifolds, Maulik-Okounkov stable envelopes and characteristic classes, conformal blocks, and combinatorics related to moduli spaces, Macdonald theory, and quiver polynomials, Soergel bimodules, Hodge theory of matroids. These are trends in a rapidly developing area, and our aim is to facilitate interactions among researchers who work on different problems but employ similar techniques, at the intersection of algebraic geometry, combinatorics, and representation theory.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *The workshop talks and especially the related discussions after generated several new ideas. For instance, the shape of certain formulas appearing in geometric representation theory (such as formulae for local intersection forms in Elias's talk, or counts over finite fields using q-Catalan numbers) suggest similarities to phenomenons in cotangent Schubert Calculus. Experimentation on the "cotangent side" will be required to make this precise, including finding the correct objects for which the formulae match. On the theoretical side, I am particularly interested in Kato's theory of semi-infinite flags, as well in the mixed Hodge module results relating open Richardson varieties to knot theory.*
- *By participating in the conference, I have learned some new approaches to problems in Schubert calculus, some of which are focused on computational methodologies.*
- *I attended a talk (on K-theory of affine grassmannians, a topic I don't know very much about) and saw in it a formula which looked extremely reminiscent of a formula I had conjectured for certain compositions of morphisms in representation theory (a completely*

different topic). Afterwards, I had a long discussion with about 5 experts on the topic, and we tried to figure out why the formulas were the same. It was illuminating and productive, and I imagine we will attempt to collaborate in the future. It would be a surprising and powerful new tool if one could prove results in modular representation theory using these formulas from K-theory.

Some Workshop Participant Comments for "Briefly describe workshop highlights":

- *There were many interesting talks, but I was genuinely surprised about the liveliness of the discussions after the talks. Most of these discussions took place on Zoom, and workshop participants could jump in at any time.*
- *Great variety of interesting talks. I am no expert in any of the areas presented in the workshop, but am tangentially close enough to enjoy and learn a great deal from the talks.*
- *Most of the talks were spectacular and the social experiences in Gather.town were the best I've had during the pandemic.*

Workshop 4: Algebraic Geometry and Polyhedra

April 12 – 16, 2021

Organizing Committee:
Federico Ardila, San Francisco State University
Man-Wai Cheung, Harvard University
Yoav Len, University of St Andrews
Sam Payne, University of Texas at Austin
Lauren Williams, Harvard University

Program Description:
combinatorial structures such as graphs, polytopes, and polyhedral complexes. In particular, the workshop will foster dialogue among groups of researchers who use similar combinatorial geometric tools for different purposes within algebraic geometry and adjacent fields. The topics covered will include Newton-Okounkov bodies, Ehrhart theory, toric geometry, tropical geometry, matroids, and interactions with mirror symmetry.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *There were several topics that had the potential for partial experimental/computational methodologies, but the speakers did not highlight those aspects. The conference was organized around several themes. Many speakers were close collaborators and were presenting very closely related results (many were not complementary). I would have preferred a wider selection of topics, rather than a focused conference.*
- *The event that I took at ICERM showed me a great variety of problems relate with Phd thesis, this allows me to try reach new people for their advice. Also, it guided me to construct new communication channels between my advisor, the others participants and me.*

- *Of course, attending this online event helped to increase my own knowledge (mostly) in recent theoretical developments on a field that is close to mine. The ICERM provided all the tools to facilitate this and I am very grateful for this.*

Some Workshop Participant Comments for "Briefly describe workshop highlights":

- *I liked that in all the talks, the speakers have given strong motivations for the development of the exposed theory. In the same way, I would like to highlight that the topics they presented were of great interest.*
- *The biggest highlight was connecting with the community again, after the pandemic hiatus. This was my first experience using gathertown, and to connect with people I already knew this worked fairly well (though only a small fraction of attendees participated in the coffee breaks). From a mathematical point of view, I enjoyed Monday's and Friday's talks.*
- *The workshop was very accessible. Speakers were really putting so much effort in making the attendees understand their research topics. This is remarkable, both for scientific progress as well as the development of community (algebraic geometry).*

Note: for a list of upcoming semester programs, see Appendix D.

Topical Workshops

ICERM's topical workshops run over 5 weekdays and focus on a timely and exciting theme that aligns with the institute's mission of supporting and broadening the relationship between mathematics and computation. ICERM hosts several topical workshops each year. They are typically scheduled in December, January, and May through August (around the dates of the semester programs).

1. Solicitation of Topical Workshop Proposals

A topical workshop proposal should be 2-4 pages and contain:

- List of 3-6 organizers, and the main contact for the organizing committee
- Description of the program area/theme, written for a general mathematical audience
- Description of the experimental and computational aspects of the program
- Plan for ensuring the participation of underrepresented groups—As part of your plan please identify a main contact among the organizers that will take the lead in ensuring participation from underrepresented groups. The plan should also list potential participants of the program that are women and potential participants who are members of an underrepresented minority group (African American, Hispanic or Latino, American Indian or Alaskan Native).

2. Topical Workshop Selection

Proposals are submitted to the ICERM Director. The Science Advisory Board (SAB) approves the topical workshops. The deadline for proposals is October 1, prior to the annual November SAB meeting, and May 1, prior to a mid-May conference call.

Approved program dates are scheduled and the workshop's lead organizer will assist ICERM staff by providing appropriate program images for web and print ads, and will be asked to review

marketing materials. Details are posted on the ICERM website and various on-line math organization calendars SIAM, AMS, European Mathematical Society, National Math Institutes.

3. Recommendation of Speakers

The organizers propose a ranked list of 20-25 speakers, which the ICERM Directors approve and make additional suggestions as needed.

4. Invitations to Speakers

Once the list of workshop speakers has been finalized and funding determined, an invitation is sent to each. The invitation describes the program and outlines the support to be provided. During this reporting cycle, ICERM updated all of its topical workshop invitations to include language regarding Brown University's "Code of Conduct", which addresses sexual harassment, discrimination, and other unprofessional behaviors.

5. Application Process

Once the organizers and Directorate agree there is enough critical mass in terms of confirmed speakers, applications are opened and accepted on-line for that particular workshop on the ICERM website. All applications are stored in the institute's "Cube" database.

6. Applicant Selection

Program organizers can view the applicants and their supporting documents as well as prioritize them within Cube. A member of the ICERM Directorate reviews the prioritized list, re-ranks as appropriate and makes the final selections, taking into consideration the remaining space in the program, diversity, participant support requested, and whether or not the applicant is a young researcher who has an advisor already participating in the program. ICERM staff then updates the applicant about their status, and any support they are eligible for, as appropriate.

Financial Decisions for Topical Workshops

Financial decisions are made by ICERM Directors based on discussions with organizers. ICERM covers travel and lodging expenses of the organizers and 20-25 invited speakers/lead participants; some applicants to the workshop may also be supported.

Topical Workshops in 2020-2021

ICERM hosted seven topical workshops from May 1, 2020 to April 30, 2021. These workshops focus on topics of current interest in the mathematical sciences.

The list of participants for each of ICERM's 2020-2021 Topical Workshops can be found in Appendix E.

Topical Workshop 1: Competitive Equilibrium with Gross Substitutes, with Applications to Problems in Matching, Pricing, and Market Design

May 11 – 12, 2020

Organizing Committee:
Gabrielle Demange, Paris School of Economics

Alfred Galichon, New York University
Robert Mccann, University of Toronto
Larry Samuelson, Yale University

Workshop Description:
A short history of equilibrium computation. The computation of economic equilibrium is making a spectacular comeback in economics, mathematics and computer science. The availability of massive real-time datasets and the affordability of computing power, including parallel computation, has made it possible to implement and build on an effort that had been stalled since the end of the 1970s. But even more than the new technical possibilities, it is the novel applications to online platforms and market design tools that led to the surge of interest in computation. Pricing engines like Uber's, matchmakers like OkCupid, allocation mechanisms like those that are used by public school districts – all need to compute an equilibrium problem.

While the problem of equilibrium computation is hard in general, a particular instance of the problem, namely the gross substitutes property, makes it analytically tractable and computable in practice, while able to cover a large number of applications including optimal transport, multinomial choice models, matching, hedonic models, and trade equilibrium problems. The goal of this workshop is to bring together researchers working on the frontier of the current knowledge in this topic, consolidate the theory, present state-of-the-art applications, and present the latest algorithms. It will connect several different mathematical fields:

1. Optimal transport
2. Stable marriage problem and lattice theory
3. Systems of nonlinear equations on networks, M-maps
4. Discrete convexity

It will also include an important algorithmic component and thus touch upon computer science and operations research.
A number of introductory lectures will set the stage before moving on to the presentation of research papers.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *I learned some new ideas regarding the characterization of gross substitutes preferences. I am excited about doing further research on this topic based on these ideas.*
- *I have a computer Applications background. Attending these sessions gave me new ideas towards many topics in Mathematics and Economics.Thank you*
- *I learned about the latest variations on gross substitutes and their importance. Gave me some ideas about future research, and I received good comments on my talk.*

Some Workshop Participant Comments for "Describe the highlight of this workshop":

- *I had expected the virtual to be a pale shadow of an `in-person' workshop. While not a perfect substitute, I still learnt from the speakers and the Q&A. I was pleasantly surprised at the level of engagement of other participants.*

- *Weinstein's talk on how to think about complementarity and substitutability of goods was very interesting and, I think, a nice contribution to demand theory.*

Topical Workshop 2: Lattice Point Distribution and Homogeneous Dynamics
June 22 – 26, 2020

Organizing Committee:
Dubi Kelmer, Boston College
Alex Kontorovich, Rutgers University
Min Lee, University of Bristol

Workshop Description:
In the last decade, there have been several important breakthroughs in Number Theory, where progress on long-standing open problems has been achieved by utilizing ideas originated in the theory of dynamical systems on homogeneous spaces, and their application to lattice point counting and distribution.

The aim of this workshop is to expose young researchers to these fields and provide them with the necessary background from dynamics, number theory, and geometry to allow them to appreciate some of the recent advancements, and prepare them to make new original contributions.

The workshop will include four mini-courses on the topics

> 1) Dynamics and lattice point counting 2) Thermodynamic formalism 3) Diophantine approximation 4) Fine-scale statistics in number theory and dynamics

In addition, there will be a number of research and expository talks. The talks will emphasize the role that computation and experiment have thus far played in stating key conjectures and establishing key results.

The mini-courses will be aimed primarily at non-experts and will benefit graduate students and early career researchers in related areas, who are particularly encouraged to apply to participate in the workshop.

This workshop is partially supported by NSF CAREER award DMS-1651563.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":
- *I learnt a lot about dynamics and its links to Diophantine approximation. A gentle introduction to this field was exactly what I needed for my research.*
- *The workshop topics were adjacent to, but not directly in line with, my research area. Therefore, the workshop helped promote a slightly different perspective on material that I am familiar with, as well as expanded my understanding of the greater context adjacent to my own work.*

- *Experimental/computational methodologies: I became aware of the work by Bandtlow, Pohl, Schick, Weisse on calculating resonances that improves above the approach by Borthwick, etc. Although this new work was discussed only in the questions after Dyatlov's talk, it made a deep impact on me and my understandings of the available methods and results. theoretical development: The lecture series by Dyatlov, Lim, Marklof and the research talks discussed new theoretical developments in the field and presented or hinted at open problems that are important to be solved.*
- *ICERM helps me to understand some basic facts about applying of dynamical systems to number theory, Diophantine approximation. Moreover, I leaned some interesting things about finer structure of some random/deterministic sequence. Many thanks indeed!!*

Some Workshop Participant Comments for "Describe the highlight of this workshop":

- *All mini courses were extremely interesting. I particularly enjoyed Semyon Dyatlov's course about spectral gaps and Dmitry Kleinbock's talk.*
- *I especially enjoyed the talks by professors Dyatlov and Merrill, which were not only interesting, but also very clearly presented.*
- *I loved the mini-courses. They quickly brought me up to speed on a myriad of current research topics.*

Topical Workshop 3: Circle Packings and Geometric Rigidity

July 6 – 10, 2020

Organizing Committee:
John Bowers, James Madison University
Philip Bowers, The Florida State University
Robert Connelly, Cornell University
Steven Gortler, Harvard
Miranda Holmes-Cerfon, CIMS
Anthony Nixon, Lancaster University

Workshop Description:
This workshop brings together two distinct streams of mathematics - on the one hand, the classical rigidity theory of bar-joint frameworks in combinatorics and discrete geometry, and on the other the theory of generalized circle packings that arose from the study of 3-manifolds in geometric topology.

Combinatorial and Geometric rigidity theory is concerned with the local and global uniqueness of congruence classes of frameworks as solutions to their underlying geometric constraint system.

The focal point of circle packing theory is the Koebe-Andre'ev-Thurston Theorem that gives conditions that guarantee the existence and rigidity of circle packings on closed surfaces in the pattern of a given triangulation of the surface.

A scattering of results in recent years has started to forge connections between these research areas. The main aim of the workshop is to develop a cross-fertilization of such ideas, with particular emphasis on the rigidity of inversive distance packings. As well as presentations on cutting edge research, the workshop will be an opportunity for new collaborations to emerge. Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *ICERM workshops have enabled me to create new research collaborations and learn more theoretical and computational aspects of my research area as well as connections to other areas of research.*
- *As a graduate student, the ICERM conference was a great way to learn about open problems and network for future research.*
- *It has made me more aware of the common techniques and tools used by rigidity theorists. As a researcher in discrete conformal geometry where rigidity is a focal point, this is relevant to my work. I've also had the advantage of seeing what other software tools people are using for experimental verification of theoretical concepts and for visualization, which I will take into account going forward.*

Some Workshop Participant Comments for "Describe the highlight of this workshop":

- *The highlight was certainly being able to meet the many participants working in rigidity theory. I am new to the field and so this was an important opportunity to make connections and meet people.*
- *Talks by Kaie Kubjas and Shin-Ichi Tanigawa, and the Spacial Chat sessions*
- *I gave my first talk as a PhD graduate here, in front of a research community that readily welcomed me and gave me great ideas for my research moving forward.*
- *Great variety of topics across disciplines, from mechanical problem to purely geometric problems. Great interaction between combinatorial/discrete methods and classical continuous problems. The organizers did great in providing options for virtual interaction.*

Topical Workshop 4: Geometry Labs United Conference

July 16 – 17, 2020

Organizing Committee:
William Goldman, University of Maryland
Sean Lawton, George Mason University
Jack Love, George Mason University
Anton Lukyanenko, George Mason University

Workshop Description:
Experimental geometry labs create an environment ripe for students and faculty to treat mathematics as a laboratory science. Visualization and computational pattern discovery help guide research, formulate conjectures and develop ideas in proofs. In addition to research, experimental geometry labs foster community engagement via grassroots outreach activities in local schools, libraries, and museums. These activities spread the wonder and excitement of mathematics to people both within and outside the academy.

This workshop is partially supported by the Department of Mathematical Sciences and the College of Science at George Mason University.

For this workshop, ICERM welcomes applications from undergraduates, graduates, postdocs, and faculty who wish to participate. Undergraduate students and graduate students who apply should ask their advisor to submit a statement of support by July 3. We will ask students to present their work.

Some Workshop Participant Comments for "Describe the highlight of this workshop":

- *This program was great for exposing me to the various visualization techniques employed by other labs. It was also great for exposing me as an incoming director of a geometry lab to the programs being run at all of the labs. It also helped me see, particularly through Professor Dumas's talk how the lab's work can be related to active research programs.*
- *This conference was very helpful to me and helped me understand how my existing experimental research lab might fit into the existing Geometry Labs system. It was very useful to see what the Labs are working on, especially the student projects.*
- *This conference was extremely beneficial for strengthening the Geometry Labs community and helping some of us (including myself) who are just starting geometry labs get our labs up and running.*
- *Please host this meeting again! It was a great mix of people from lots of disciplines and the student talks were great! Esp in the virtual format it was nice having participants from other countries, that we might not have had in a normal year.*
- *The talk of David Dumas, which synthesized some beautiful experimental projects, and the pedagogical and organizational challenges that arose.*
- *Moira Chas' presentation on inclusivity in mathematics. I really like how she incorporates live feedback from participants. I'd like to do something similar in my online classes this coming fall semester.*
- *I hadn't been aware that the Geometry Labs United network had grown to 13 labs! It was amazing to see how far they had grown and come and all the excitement that surrounds their founding. It was also good to hear about people excited for Girls' Angle, the program I am involved with, and interested in thinking of ways to interface between the two organizations.*

Topical Workshop 5: Women in Algebraic Geometry

July 27 – 31, 2020

Organizing Committee:
Melody Chan, Brown University
Antonella Grassi, University of Pennsylvania and Università di Bologna
Rohini Ramadas, Brown University
Julie Rana, Lawrence University
Isabel Vogt, Stanford University

Workshop Description:

The Women in Algebraic Geometry Collaborative Research Workshop will bring together researchers in algebraic geometry to work in groups of 4-6, each led by one or two senior mathematicians. The goals of this workshop are: to advance the frontiers of modern algebraic geometry, including through explicit computations and experimentation, and to strengthen the community of women and non-binary mathematicians working in algebraic geometry. This workshop capitalizes on momentum from a series of recent events for women in algebraic geometry, starting in 2015 with the IAS Program for Women in Mathematics on algebraic geometry.

Successful applicants will be assigned to a group based on their research interests. The groups will work on open-ended projects in diverse areas of current interest, including moduli spaces and combinatorics, degenerations, and birational geometry. Several of the proposed projects extensively involve experimentation and computation, which will increase the likelihood that concrete progress is made over the course of five days and provide useful training in computational mathematics.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *I found it very interesting that a topological idea was transformed in an AG conjecture; and I am now thinking about its homological interpretations.*
- *By promoting the workshop, ICERM firstly have me the opportunity to get to know a researcher working in a different field than mine (tropical geometry) with whom I co-lead a group. The workshop week served as a catalyst for our research in the proposed theme. I learned a lot by discussing with my group and preparing background for them. I also got to be in touch with state-of-the-art research through the mini-talks.*
- *My group had participants working on both the computational and theoretical sides of our problem, and the collaboration between the two sides allowed us all to learn about both methods.*
- *We worked, in small groups and under supervision of senior experts, on new research projects. I learned a lot of new theory through this. We also did some computations using techniques which I had seen before, but feel more comfortable with now.*

Some Workshop Participant Comments for "Describe the highlight of this workshop":

- *It was wonderful to work with so many other women - I've never had that experience outside of this conference. The group leaders did an amazing job preparing the topic and getting us started.*
- *Prior to this workshop, I was not familiar with Del Pezzo surfaces. This workshop gave me an opportunity learn about them. I also met several other mathematicians who I expect to collaborate with in the future.*
- *I appreciated the opportunities to chat about math and momming, and different kinds of US-based academic jobs with women in algebraic geometry. I also thought the gather platform worked well, although I missed the chaos that comes from being in person.*
- *Work with experts and junior researchers at the same time - Focus on a concrete problem, with precise questions and interesting research perspectives - Discuss with the group*

- *Strengthening the sense of community and belonging as a female mathematician; providing wonderful collaboration opportunities with other women mathematicians that would be otherwise impossible.*

Topical Workshop 6: Free Resolutions and Representation Theory
August 3 – 7, 2020

Organizing Committee:
Lars Christensen, Texas Tech University
Claudia Miller, Syracuse University
Steven Sam, University of California, San Diego
Jerzy Weyman, University of Connecticut and Jagiellonian University, Cracow, Poland

Workshop Description:
The structure of free resolutions plays an important role in analyzing singularities of varieties of low codimension. Codimension 2 Cohen-Macaulay varieties (resp. codimension 3 Gorenstein varieties) come from rank conditions on an n x (n+1) matrix (resp. a skew-symmetric (2n+1) x (2n+1) matrix).

This workshop seeks to push such results to Cohen-Macaulay varieties of codimension 3 and Gorenstein varieties of codimension 4.

This problem turns out to be related to the classification of semi-simple Lie algebras. These new methods allow one to create a 'map' of free resolutions of a given format. The calculations that arise are very demanding and require new computational methods involving both commutative algebra and representation theory.

The organizers have shared two sets of notes for attendees to review before the workshop.

Some Workshop Participant Comments for "Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.":

- *Prior to the workshop I was familiar with the general ideas of the topics discussed while after the workshop I was much more knowledgeable of the specifics of these topics, of how the different areas of math used worked together, and of the computations required. My background and interest are mostly in theoretical aspects, however. I now better appreciate the use of calculations in developing theoretical insight and I better understand how Macaulay2 can be used to handle the specific calculations for what we discussed. I have a much better idea about the future avenues of research discussed and what are potential questions and methods to look into.*
- *Great introduction to current work in this area, I have a connection with it through some past work and was able to be useful by supplying some notes and a 1-page response to a question asked me. Learned about these connections.*
- *I have learned so much during the workshop! Zulip platform was great. I liked the talks and the pace. I have a lot of materials to investigate for my research now. Already contacted couple people from the participants. Looking forward to working with them!*

Some Workshop Participant Comments for "Describe the highlight of this workshop":

- *Learning about the connection between commutative algebra and representation theory, as well as meeting many mathematicians working in those areas.*
- *The online format worked really well. At first, I was skeptical of why we needed to use Zulip for group discussion instead of just having various Zoom meetings, but then the Zulip forum and hashtags helped to separate topics, share content, and it was easy to follow the discussions.*
- *Using Zulip to keep track of discussions is a good idea.*
- *I really enjoyed the problem sessions in the afternoons, and found them a great way to learn, collaborate, and make connections (especially during the pandemic).*

Topical Workshop 7: Symmetry, Randomness, and Computations in Real Algebraic Geometry

August 24 – 28, 2020

Organizing Committee:
Saugata Basu, Purdue University
Antonio Lerario, SISSA (International School for Advanced Studies)
Annie Raymond, University of Massachusetts, Amherst
Cordian Riener, UiT The Arctic University of Norway

Workshop Description:
Real algebraic (and semi-algebraic) geometry studies subsets of R^n defined by a finite number of polynomial equalities and inequalities. Such sets occur ubiquitously in practice both inside and outside of mathematics. While being easy to define, semi-algebraic sets can be complicated topologically, which restricts the application of many algorithms. In recent years, there has been progress in proving much stronger results – both quantitative and algorithmic -- when the problem under consideration involves the invariance under some group action.

In this workshop, we plan to focus on two situations where this phenomenon happens.

The first one is the statistical study of the topology of random real algebraic varieties as well as semi-algebraic sets, where the polynomials defining these objects are picked from a distribution invariant under the action of a certain group (usually the orthogonal group) acting on the space of variables. The behavior of the set of zeros (or more generally level sets) of such random polynomial systems is an extremely active topic with deep connections with classical enumerative problems in algebraic geometry (over real as well as complex fields), theoretical computer science, statistical physics, and machine learning.

The second one is the deterministic behavior of the topology of semi-algebraic sets admitting a group action (say a finite reflection group or a Lie group). The cohomology modules of such symmetric semi-algebraic sets then acquire the structure of a finite-dimensional representation of the corresponding group. This added structure is extremely useful in studying the topology as well as developing algorithms for computing topological invariants of such sets. The study of symmetric semi-algebraic sets has promising connections with several other areas, including

representational and homological stability, sums-of-squares proofs and lower-bound questions in theoretical computer science.

Some Workshop Participant Comments for “Please describe how ICERM has (or has not) added to your knowledge of experimental/computational methodologies and/or theoretical developments within this topic.”:

- *I mostly learned about theoretic developments in algebraic geometry. It gave me some new ideas about random polynomials and how their analysis is simpler than that of specific polynomials.*
- *It helped me to gain deep insights to use computational methods in the field of theoretical astrophysics and General Relativity.*
- *During this workshop, I have been introduced several topics in mathematics (viz. tropicalization, rigid continuation path, p-adic integral geometry etc.) which were not in my knowledge at all. These will help and promote my research work. I would like to think about the topics:"sequence of symmetric ideals", "p-adic integral geometry" as my future research areas.*

Some Workshop Participant Comments for “Describe the highlight of this workshop”:

- *I found exciting to learn about the new applications of invariant theory to problems coming from statistic. These were covered in the talks by Harm Derksen and Visu Makam. In the brakes, using the gather software, it was even possible to have discussions. One of those is likely to initiate new research.*
- *Mentoring session for graduate students, Greg Blekherman's talk. Coffee times, though I wasn't able to make them all.*
- *The great opportunity to learn from experts around the world without having to move from home. Likewise, sharing with mathematicians that otherwise would be very hard to meet personally.*
- *One of the highlights was the series of lectures by Henry Cohn, and even though it's still in its infancy, the connections to gauge fields seems fascinating.*

Collaborate@ICERM (C@I)

Collaborate@ICERM offers teams of 3-6 researchers the opportunity to spend five days at the institute during the summer (May-August) or during the month of January. The team research project should have a computational or experimental component. ICERM provides access to a variety of software packages as well as to high performance computing through Brown's Center for Computation and Visualization.

Proposals involving research projects that continue a collaboration fostered at one of the past ICERM semester programs are encouraged. Collaborate@ICERM provides limited funding for travel to the institute and local accommodations for six nights. The majority of participants must be from U.S. institutions. The entire team should be present for the week at ICERM.

No Collaborate@ICERM programs were held during this reporting period due to the COVID-19 pandemic. All of the approved meetings were rescheduled to run starting in summer 2021.

TRIPODS Workshops

Brown University's Data Science Initiative partners with ICERM on public events, included workshops supported by the TRIPODS grant from the National Science Foundation.

No TRIPODS programs were hosted during this reporting period due to the COVID-19 pandemic.

Hot Topics Workshops

ICERM is the recipient of one of the Simons Foundation Targeted Grants to Institutes. The Simons funding, totaling nearly $1 million over 5-years (2017-2021), enhances and expands ICERM's efforts to bring top scholars to the institute to explore big questions in mathematical research.

ICERM uses the additional funding to improve financial support for the academic leaders of the institute's semester-long topical conferences and workshops.

In this reporting year, ICERM also started using these funds to launch its "Hot Topics" workshop program. Hot Topics workshops are designed to allow ICERM to move quickly in order to start the public exploration of breakthroughs and emerging mathematical areas. They run 2-3 days and are organized on a few months' notice. They can originate through suggestions from ICERM boards or the community. The Simons Foundation Targeted Grant provides financial support of around $50K for each Hot Topics workshop, including honoraria to attract key speakers and organizers.

The institute welcomes suggestions for Hot Topics Workshops and encourages researchers to contact the ICERM Director with ideas. The Director and a SAB Hot Topics subcommittee considers proposals for such workshops, which should include:

- List of potential organizers
- Description of the program area/theme (1 paragraph)
- Explanation about why it is a "Hot Topic" (1 paragraph)
- List of 8-10 high-level speakers/participants, their research areas, and how they connect to the goals of the workshop.

Hot Topics suggestions are accepted on a rolling basis. Suggestions are considered by the ICERM Directors, and a sub-committee of ICERM's Scientific Advisory Board that decides which ideas are developed into workshops. ICERM responds to all Hot Topics suggestions within two weeks.

Hot Topics Workshop 1: Variable Precision in Mathematical and Scientific Computing

May 7 – 8, 2020

Organizing Committee:
David Bailey, University of California, Davis
Neil Burgess, Arm, UK
Jack Dongarra, University of Tennessee

Alyson Fox, Lawrence Livermore National Laboratory
Jeffrey Hittinger, Lawrence Livermore National Laboratory
Cindy Rubio-González, University of California Davis

Workshop Description:
From its introduction in the 1980s, the IEEE-754 standard for floating-point arithmetic has ably served a wide range of scientists and engineers. Even today, the vast majority of numerical computations employ either IEEE single or IEEE double, typically one or the other exclusively in a single application. However, recent developments have exhibited the need for a broader range of precision levels, and a varying level of precision within a single application. There are clear performance advantages to a variable precision framework: faster processing, better cache utilization, lower memory usage, and lower long-term data storage. But effective usage of variable precision requires a more sophisticated mathematical framework, together with corresponding software tools and diagnostic facilities.

At the low end, the explosive rise of graphics, artificial intelligence, and machine learning has underscored the utility of reduced precision levels. Accordingly, an IEEE 16-bit "half" precision standard has been specified, with five exponent bits and ten mantissa bits. Many in the machine learning community are using the "bfloat16" format, which has eight exponent bits and seven mantissa bits. Hardware such as NVIDIA's tensor core units can take advantage of these formats to significantly increase processing rates.

At the same time, researchers in the high-performance computing (HPC) field, in a drive to achieve exascale computing, are considering mixed-precision, such as in iterative refinement calculations where initial iterations are performed using half- or single-precision. Along this line, recognizing that for many simulations much of the data stored in a IEEE 64-bit double precision variable has low information content, researchers are exploring the use of lossy floating point compression, not only for I/O, but also for storing solution state variables.

Exascale computing has also exposed the need for even greater precision than IEEE 64-bit double in some cases, because greatly magnified numerical sensitivities often mean that one can no longer be certain that results are numerically reliable. One remedy is to use IEEE 128-bit quad precision in selected portions of the computation, which is now available via software in some compilers, notably the gfortran compiler. As a single example, researchers at Stanford have had remarkable success in using quad precision in multiscale linear programming applications in biology.

There has also been a rise in the usage of very high precision (hundreds or even thousands of digits). For example, numerous new results have been discovered by computing mathematical expressions to very high precision, and then using integer relation algorithms such as the "PSLQ" algorithm to recognize these numerical values in terms of simple mathematical formulas. Among the results that have been discovered in this fashion are new formulas connecting mathematical constants and the elucidation of polynomials connected to the Poisson potential function of mathematical physics (the latter requiring up to 64,000-digit precision). Such computations are most efficiently performed using a dynamically varying level of

precision, doing as much computation as possible with standard precision and only invoking very high precision when necessary.

In summary, although the IEEE 754 floating-point standard has served the mathematical, scientific and engineering world very well for over 30 years, we now are seeing rapidly growing demand for reduced precision (machine learning, neural nets, graphics, etc.), a growing need for mixed 32-64-bit precision, and also a need for greater than 64-bit, all typically varying within a given application. To the extent that IEEE-754 fails to adequately meet new demands such as these, researchers are considering completely different alternatives, for which a flexible precision level is a fundamental feature of the design, and are exploring new mathematical and software frameworks to better understand and utilize such facilities.

This workshop is fully funded by a Simons Foundation Targeted Grant to Institutes.

Hot Topics Workshop 2: Monodromy and Galois groups in enumerative geometry and applications

August 31 – September 2, 2020

Organizing Committee:
Alexander Esterov, National Research University Higher School of Economics
Jose Rodriguez, University of Wisconsin-Madison
Frank Sottile, Texas A&M University

Workshop Description:
Galois groups encode the internal structure of field extensions. Less well-known is that (families) of systems of polynomial equations or geometric problems also have Galois groups that encode the internal structure of the equations or geometric problems. During the 2018 Fall program at the ICERM on Nonlinear Algebra, different groups of researchers who were studying or using Galois groups in their work became more aware of their related interests. This common thread connects recent work in enumerative geometry, statistics, computer vision, number theory, and numerical nonlinear algebra. Further connections have subsequently been realized to arithmetic enhancements of intersection theory and to random real algebraic geometry. This workshop will bring representatives of these research groups together to deepen these interactions and chart new research goals.

This workshop is fully funded by a Simons Foundation Targeted Grant to Institutes.

Hot Topics Workshop 3: Mathematical and Computational Approaches to Social Justice

March 8 – 10, 2021

Organizing Committee:
Veronica Ciocanel, Duke University
Nancy Rodriguez, University of Colorado at Boulder
Chad Topaz, Institute for the Quantitative Study of Inclusion, Diversity, and Equity

Workshop Description:

Social justice refers to fair relations between individuals and society, including issues such as equity, diversity, and inclusion. While the study of social justice historically has been rooted in the social sciences and humanities, mathematics and computation provide complementary and powerful approaches. Tools from dynamical systems, network science, applied topology, stochastic processes, data mining, and more have been applied to issues ranging from voting to hate speech.

This Hot Topics workshop seeks to promote new areas of research on quantitative approaches to social justice. We will bring together mathematical and computational scientists who are equipped with tools and methodologies that could be applied to social justice, as well as those who already have expertise with social justice work. We aim to showcase research at the intersection of mathematics, computing, and social justice, as well as build community among scientists interested in quantitative social justice research.

This workshop is fully funded by a Simons Foundation Targeted Grant to Institutes.

Hot Topics Workshop 4: Safety and Security of Deep Learning

April 10 – 11, 2021

Organizing Committee:

Ben Adcock, Simon Fraser University
Simone Brugiapaglia, Concordia University
Anders Hansen, University of Cambridge
Clayton Webster, University of Texas

Workshop Description:

Deep learning is profoundly reshaping the research directions of entire scientific communities across mathematics, computer science, and statistics, as well as the physical, biological and medical sciences. Yet, despite their indisputable success, deep neural networks are known to be universally unstable. That is, small changes in the input that are almost undetectable produce significant changes in the output. This happens in applications such as image recognition and classification, speech and audio recognition, automatic diagnosis in medicine, image reconstruction and medical imaging as well as inverse problems in general. This phenomenon is now very well documented and yields non-human-like behaviour of neural networks in the cases where they replace humans, and unexpected and unreliable behaviour where they replace standard algorithms in the sciences.

The many examples produced over the last years demonstrate the intricacy of this complex problem and the questions of safety and security of deep learning become crucial. Moreover, the ubiquitous phenomenon of instability combined with the lack of interpretability of deep neural networks makes the reproducibility of scientific results based on deep learning at stake.

For these reasons, the development of mathematical foundations aimed at improving the safety and security of deep learning is of key importance. The goal of this workshop is to bring together experts from mathematics, computer science, and statistics in order to accelerate the exploration of breakthroughs and of emerging mathematical ideas in this area.

This workshop is fully funded by a Simons Foundation Targeted Grant to Institutes.

Program Promotions

ICERM programs and events are typically marketed through a variety of outlets: its website, dedicated Facebook page, Twitter, Instagram, and LinkedIn accounts, targeted blast emails, posters mailed to purchased targeted university and college lists, placement of advertisements in mathematical journals and newsletters, ICERM directorate participation in conferences and exhibits, upcoming program fliers and announcements made available to all ICERM participants, and various on-line math organization calendars (researchseminars.org, SIAM, AMS, NAM, European Mathematical Society, National Math Institutes, and Conference Service Mandl). No posters were printed or mailed during this reporting cycle due to the pandemic.

ICERM's email database is made up of former and upcoming participants, ICERM board members, academic and corporate sponsors, and the department managers from higher education math departments in both the US and overseas. It currently has over 5,000 contact emails.

During the 2020-2021 reporting cycle, ICERM hosted a virtual booth with several of the NSF mathematical sciences institutes at the Joint Mathematics Meeting (JMM) during Winter 2021. It was very well-attended, with many early career researchers taking the opportunity to speak with ICERM's Director about ICERM's postdoc opportunities.

All program advertising emphasizes diverse participation and uses language encouraging minority and under-represented students to apply. More details about this can be found in the "Outreach/Diversity" section of this report.

Communications Plan

ICERM's frequent social media postings, quarterly newsletters, funder acknowledgements, and presence on Brown's fundraising page have helped ICERM remain relevant and maintain contact with recent, current and upcoming program participants, board members, corporate and academic sponsors, and the general population. Brown is still committed to supporting ICERM's Provost-approved fundraising goals, and Brown's Foundation Relations continues to help ICERM build relationships with corporations and foundations. There was little-to-no fundraising activity during this reporting cycle due to the pandemic.

Organization/Infrastructure

ICERM's governing body is a Board of Trustees (BOT). The Scientific Advisory Board (SAB) oversees all scientific activities of the Institute and selects the scientific programs. The Education Advisory Board, or EAB coordinates the oversight of educational activities at all levels at ICERM.

Board of Trustees (BOT)

The Board of Trustees oversees all institute activities. This includes being responsible for reviewing the budget for the coming year, developing policies and procedures, advising on the

appointment of new Directors and actively recruiting for the position as needed, and taking a leadership role in fundraising and public awareness. The Board of Trustees has a face-to-face meeting at ICERM for one day each year (usually in late spring), and one or two conference-call meetings if needed.

Board of Trustee member appointments are for four years. Chairs from the Scientific Advisory Board (SAB) and the Education Advisory Board (EAB), as well as the ICERM Directors and co-PIs, are invited to sit in.

Board of Trustee Members:

Name	Institution
Ron Buckmire	Occidental College
Charles Epstein (Chair)	University of Pennsylvania
Anna Gilbert	Yale University
Leslie Greengard	Flatiron Institute & NYU Courant Institute of Mathematical Sciences
Bruce Hendrickson	Lawrence Livermore National Laboratory
Julia Kempe	New York University
Stéphane Mallat	Collège de France
Jonathan Mattingly	Duke University
Jill Mesirov	University of California, San Diego
Karen Smith	University of Michigan

The following people rotated off the BOT at the end of June 2020: John Ball, Jennifer Chayes, Peter Jones, David Keyes, and Jill Pipher.

Note: The minutes from the May 28, 2020 annual Board of Trustees meeting can be found in Appendix F.

Scientific Advisory Board (SAB)

The Scientific Advisory Board (SAB) is responsible for approving the programs and scientific activities of the Institute. In addition, through direct communication with the Directors, Science Board members will be involved in shaping the direction of the scientific enterprise through specific suggestions of thematic programs, program organizers.

Terms are three years. The ICERM Directors act as ex officio members of this committee.

Scientific Advisory Board Members:

Name	Institution
Liliana Borcea	University of Michigan
Henry Cohn (Chair)	Microsoft Research
Ivan Corwin	Columbia University
Jesús De Loera	University of California, Davis
Anne Gelb	Dartmouth College
William Goldman	University of Maryland
Misha Kilmer	Tufts University
Sven Leyffer	Argonne National Laboratory
Anna Lysyanskaya	Brown University
Mauro Maggioni	Johns Hopkins University

Rosa Orellana	Dartmouth College
Joseph Silverman	Brown University
Rachel Ward	University of Texas
Jon Wilkening	UC Berkeley

The following people rotated off the SAB at the end of June 2020: Jeffrey Brock, Vanja Dukic, Rachel Kuske, Kavita Ramanan, Bjorn Sandstede, Rachel Ward, and Carol Woodward.

Note: The minutes from the May 8, 2020 mid-year SAB conference call and the November 15-16, 2020 SAB annual meeting can be found in Appendix G.

Education Advisory Board (EAB)

The Education Advisory Board 1) oversees the undergraduate research programs, and helps to develop and identify successful proposals, 2) helps to develop proposals for outreach programs and events that are aligned with the mission of the institute, and 3) helps to identify sources of funding for education and outreach activities.

Terms are three years. The ICERM Directors act as ex officio members of this committee.

Education Advisory Board Members:

Name	**Institution**
Tarik Aougab	Haverford College
Cathy Boutin	West Warwick School Department (Math)
John Ewing	Math for America
Thomas Garrity	Williams College
Ryan Hand	University of Pennsylvania
Rachel Levy (Chair)	AMS/AAAS Congressional Policy Fellow
Katharine A. Ott	Bates College
Javier Rojo	Oregon State University
Jessica Sidman	Mount Holyoke College
Ulrica Wilson	Morehouse College

The following people rotated off the EAB at the end of June 2020: Karen Haberstroh, Lynn Rakatansky, and Sergei Tabachnikov.

Note: The minutes from the September 11, 2020 annual Education Advisory Board meeting can be found in Appendix H.

Mathematics Institute Directors Meeting (MIDs)

The April 24, 2021 MIDs meeting minutes can be found in Appendix I.

ICERM's Early Career Training and Mentorship

A special focus of the operations of the institute is the training and mentorship of younger and early career mathematicians, through specific outreach programs and directed opportunities for connections between mathematicians at different stages in their career. This includes ICERM's postdoctoral program, integration and support of graduate students in the context of semester programs, and summer research programs for undergraduates (Summer@ICERM). The addition

of postdoctoral fellows (as described above) and graduate students is essential to the success of ICERM's programs.

Postdoctoral Program

ICERM's postdoctoral program brings early career mathematicians to the institute in order to support and expand their research and to create lasting career collaborations and connections. ICERM supports postdoctoral researchers in two salaried categories: "Semester" postdoctoral fellows who participate in a single semester-length program, and a smaller number of "Institute" postdoctoral fellows, who stay at ICERM for an academic year.

Recruiting and Selection of ICERM-Funded Postdocs

ICERM's postdoctoral positions are widely advertised using MathJobs.org, print and online publications of the Society for Industrial and Applied Mathematics News, Notices of the American Mathematical Society, the Association of Women in Mathematics, the Society for the Advancement of Chicanos and Native Americans in Science, and on the ICERM website. These positions are also advertised at the NSF Institute Reception at the Joint Mathematics Meeting. ICERM collects applications via Mathjobs.org, an online job application service provided by the American Mathematical Society.

In all written material sent out, it is emphasized that Brown is an EEO/AA Employer and that ICERM encourages applications from women and minority candidates.

ICERM sets an early-January deadline for postdoctoral applications. Application review begins immediately and continues until the positions are filled.

The Postdoctoral Fellow Search Committee consists of the ICERM Semester Program organizers for the upcoming programs with input for the Directorate.

The program organizers review all of the applications and provide a rank-ordered list to the ICERM Directors for each of the two types of positions (Semester and Institute postdocs). The Directorate reviews the ranked lists, and may suggest changes to ensure diversity and field balance. The Director approves all offers, and Brown University's Dean of the Faculty oversees postdoctoral offers and appointment terms.

2020-2021 ICERM Postdoctoral Cohort

ICERM Postdoctoral Fellows (4 months w/benefits; funds for travel to and from institute)

Name	**Previous Institute**	**ICERM Semester Program**
Martin Licht	University of California, San Diego	Fall 2020
Jacob Lange	Rochester Inst of Technology	Fall 2020
Caroline Mallary	UMass Dartmouth	Fall 2020
Zachary Nasipak	University of North Carolina	Fall 2020
Brendan Keith	TU Munich	Fall 2020
Sunita Chepuri	University of Michigan	Spring 2021
Netanel Friedenberg	Yale University	Spring 2021
Sean Griffin	University of Washington	Spring 2021
Gleb Nenashev	Brandeis University	Spring 2021

ICERM Institute Fellows (9 months w/benefits; funds for travel to and from institute)

Name	Previous Institute	ICERM Semester Program
Stefan Czimek	University of Toronto	2020-2021: focus on Fall 2020
Daoji Huang	Cornell University	2020-2021: focus on Spring 2021

Based on available information, the ICERM stipend-supported postdocs for 2020-2021 break down as follows:

	Male		Female	
Black	0		0	
Hispanic	0		0	
American Indian/Alaskan Native	0		0	
Asian/Pacific Islands	0		2	
White	8		1	
Other (specify)	0	+	0	
	8		3	= 11 Total

Tracking Former Postdocs (Institute and Semester)

ICERM Research Fellows are supported with a salary for one semester. We expect that these postdoctoral fellows will be on leave from, or have deferred the start of, another position. The institute makes every effort to keep in touch with its postdoctoral alums in order to track their professional growth.

ICERM-funded postdocs ***(to date)***	**Period of Stay**	**Where are they as of Spring 2021?**
Emre Esenturk	Fall 2011	University of Warwick
Jeffrey Haack	Fall 2011	Los Alamos National Laboratory
Andong He	**Fall 2011**- Spring 2012	Passed away in 2016
Ahmed Kaffel	Fall 2011	Marquette University
Daniela Tonon	Fall 2011	Università degli Studi di Padova
Dongming Wei	Fall 2011	RBC Capital Markets
Cecile Armana	Spring 2012	University of Franche-Comté
Anupam Bhatnagar	Spring 2012	Facebook
Alon Levy	Fall 2011 – **Spring 2012**	Transit Writer at the Marron Institute
Bianca Viray	Spring 2012	University of Washington
Xiaoguang Wang	Spring 2012	Zhejiang University
Daniel Cargill	Fall 2012	Lockheed Martin
Arnab Ganguly	Fall 2012	University of Wisconsin-Madison
Peng Hu	Fall 2012	Huazhong University of Science & Tech
Hao Ni	Fall 2012	Alan Turing Institute
Aaron Smith	**Fall 2012** - Spring 2013	University of Ottawa
Julio Andrade	Fall 2012 - **Spring 2013**	Universty of Exeter
Kwangho Choiy	Spring 2013	Southern Illinois University
Zajj Daugherty	Spring 2013	CUNY
Martina Lanini	Spring 2013	Università di Roma Tor Vergata
Ben Salisbury	Spring 2013	Central Michigan University
Ryan Greene	Fall 2013	The Ohio State University

BoGwang Jeon	Fall 2013	POSTECH
Rodolfo Rios-Zertuche	Fall 2013	Toulouse School of Economics
Giulio Tiozzo	**Fall 2013** – Spring 2014	University of Toronto
Anastasiia Tsvietkova	Fall 2013	Rutgers University
Kyle Fox	Spring 2014	University of Texas at Dallas
Danupon Nanongkai	Spring 2014	University of Copenhagen
Amanda Redlich	Spring 2014	UMASS Lowell
Charalampos Tsourakakis	Spring 2014	Boston University
Grigory Yaroslavtsev	Fall 2013 - **Spring 2014**	George Mason University
Ali Ahmed	Fall 2014	Information Technology University (Lahore)
Ulas Ayaz	**Fall 2014** – Spring 2015	JP Morgan Chase & Co.
Jacqueline Davis	Fall 2014	Data Scientist at Carvana
Pawel Siedlecki	Fall 2014	Polish Academy of Science
Li Wang	Fall 2014	University of Illinois
Tyler Helmuth	Spring 2015	Durham University
Marcin Lis	Spring 2015	University of Vienna
Emily Russell	Fall 2014 – **Spring 2015**	Google
Xuan Wang	Spring 2015	Data Scientist at Databricks
Samuel Watson	Spring 2015	Brown University/DSI
Olga Balkanova	Fall 2015	Steklov Mathematical Institute
Sandro Bettin	Fall 2015	University of Genova
Edgar Costa	Fall 2015	MIT
Anna Medvedovsky	**Fall 2015** – Spring 2016	Boston University
James Weigandt	**Fall 2015** – Spring 2016	Freelancer
Abel Farkas	Spring 2016	Alfréd Rényi Institute of Mathematics
Marta Canadell Cano	Fall 2015 – **Spring 2016**	Wallapop
Nishant Chandgotia	Spring 2016	Tata Institute
Zhiqiang Li	Spring 2016	Peking University
Polina Vytnova	Spring 2016	University of Warwick
Hannah Alpert	**Fall 2016** – Spring 2017	University of British Columbia
Chaim Even-Zohar	Fall 2016	University of California, Davis
Isaac Mabillard	Fall 2016	Google
Greg Malen	Fall 2016	Union College
Jose Alejandro Casas	Fall 2016	PUC-Chile
John Wiltshire-Gordon	Fall 2016	Williams College
Sergey Dyachenko	Fall 2016 – **Spring 2017**	University of Buffalo
Seok Hyun Hong	Spring 2017	Pohang University
Cecilia Mondaini	Spring 2017	Drexel University
Olga Trichtchenko	Spring 2017	Western University
Xeucheng Wang	Spring 2017	Tsinghua University
Xiaoqian Xu	Spring 2017	Duke University
Mario Bencomo	**Fall 2017** – Spring 2018	Rice University
Wei Li	Fall 2017	DePaul University
Shixu Meng	Fall 2017	Chinese Academy of Sciences
Yimin Zhong	Fall 2017	Duke University
David de Laat	Spring 2018	Delft University of Technology
Maria Dostert	Spring 2018	Royal Institute of Technology

Philippe Moustrou	Spring 2018	University of Tromsø
Yuguang Wang	Spring 2018	University of New South Wales
Wei-Hsuan Yu	Fall 2017 – **Spring 2018**	National Central University in Taiwan
Daniel Bernstein	Fall 2018	MIT
Papri Dey	Fall 2018	University of Missouri
Mareike Dressler	Fall 2018	University of California - SD
Kathlén Kohn	Fall 2018	KTH/Stockholm
Sara Lamboglia	Fall 2018	Goethe-Universität
Dane Wilburne	Fall 2018	Illinois Institute of Technology
Marilyn Vazquez	Fall 2018 – **Spring 2019**	Postdoc at MBI
Shubhendu Trivedi	Fall 2018 – **Spring 2019**	MIT CSAIL
Guangyao Zhou	Spring 2019	Vicarious AI
Gabriel Dorfsman	Fall 2019	UC Berkeley
Alba Málaga Sabogal	**Fall 2019** – Spring 2020	Maître de Conferences, Lorraine University
Michael Musty	Fall 2019	ERDC-CRREL
Martin Skrodzki	Fall 2019	TU Delft
Steve Trettel	Fall 2019	Stanford University
Gregory Darnell	Fall 2019 – **Spring 2020**	Apple
Davide Palitta	Spring 2020	Max Planck Institute
Jemima Tabeart	Spring 2020	University of Edinburgh
Michael Schneier	Spring 2020	Naval Nuclear Laboratory
Min Wang	Spring 2020	Duke University
Stefan Czimek	**Fall 2020** – Spring 2021	Extended ICERM Institute Postdoc
Martin Licht	Fall 2020	Postdoc at University of Texas at Austin
Jacob Lange	Fall 2020	Rochester Institute of Technology
Caroline Mallary	Fall 2020	UMass Dartmouth
Zachary Nasipak	Fall 2020	NASA Goddard Space Flight Center
Brendan Keith	Fall 2020	Lawrence Livermore National Lab
Sunita Chepuri	Spring 2021	Postdoctoral Assistant Professor at the University of Michigan
Netanel Friedenberg	Spring 2021	Georgia Tech
Sean Griffin	Spring 2021	Krener Assistant Professor at UC Davis
Daoji Huang	Fall 2020 – **Spring 2021**	Postdoc at University of Minnesota
Gleb Nenashev	Spring 2021	Brandeis University

Graduate Students

Support for Graduate Students

The research semester program budget typically includes partial support for a cohort of graduate students. Applicants include graduate students working with visitors to the program, as well as students who intend to attend without an advisor. Graduate students must arrange for a letter of recommendation from their advisor to be sent separately. The graduate student applications prioritized by the semester program organizing committee (1 - Would make a contribution to this program; 2 - Desirable for this program but not high priority; 3 - High priority, important for the success of the program). The prioritized list is subsequently reviewed by the Deputy Director overseeing the development of that particular program. Final decisions are made by the Directors. The ability to provide a mentor for each graduate student in residence is a factor in the decision.

Training and Mentoring Programs

Before a semester program starts, ICERM attempts to assign a mentor to all postdocs and graduate students. The institute provides all senior mentors with written guidelines that spell out their responsibilities and the responsibilities of mentees. Currently, the assigned ICERM Deputy Director coordinates these efforts and works with the members of the Program Organizing Committee assigned to be responsible for mentorship.

It was extremely challenging to match mentors virtually with graduate students and postdocs. ICERM was, however, able to assign mentors to its hired (paid) postdocs.

The mentoring program for the Institute Postdoctoral Fellows necessarily includes a plan for the "off semester" when these postdocs are "in residence" at ICERM while there is no active research program in their area. In most cases, postdocs are matched with mentors at Brown in Math, Applied Math, or Computer Science in order to continue their ICERM research. During this reporting cycle, Fall Institute Postdocs Stefan Czimek was mentored by Jared Speck (Vanderbilt). The spring Institute Postdoc, Daoji Huang, was mentored by both Melody Chan (Brown) and Thomas Lam (University of Michigan).

ICERM Postdoctoral Participant and Mentor list by Semester Program

Postdoc	**Mentor**	**Program/How Supported**
Stefan Czimek	Jared Speck	Fall 2020 Institute Postdoc (NSF Funds)
Brendan Keith	Mark Ainsworth	Fall 2020 Semester Postdoc (NSF Funds)
Jacob Lange	Deirdre Shoemaker	Fall 2020 Semester Postdoc (NSF Funds)
Martin Licht	Jae-Hun Jung	Fall 2020 Semester Postdoc (NSF Funds)
Caroline Mallary	Rob Coyne	Fall 2020 Semester Postdoc (NSF Funds)
Zachary Nasipak	Gaurav Khanna	Fall 2020 Semester Postdoc (NSF Funds)
Sunita Chepuri	Lauren Williams	Spring 2021 Semester Postdoc (NSF Funds)
Netanel Friedenberg	Dan Abramovich	Spring 2021 Semester Postdoc (NSF Funds)
Sean Griffin	Leonardo Mihalcea	Spring 2021 Semester Postdoc (NSF Funds)
Daoji Huang	Melody Chan, Thomas Lam	Spring 2021 Institute Postdoc (NSF Funds)
Gleb Nenashev	Anders Buch	Spring 2021 Semester Postdoc (NSF Funds)

Roundtable Discussions

To prepare graduate students and postdocs better for their future careers, the institute also organizes regular roundtable discussions with long-term visitors, Brown faculty, and Directors, that in the course of each semester, cover the following topics:

- Preparing job applications
- Writing and submitting papers
- Writing grant proposals
- Ethics in research as required by NSF – mandatory, attendance is taken
- Job opportunities in industry and government labs

Peer-to-Peer Discussions

During semester programs, there are regularly scheduled postdoc-graduate student seminars, expressly limited to junior researchers. This gives participating postdocs and graduate students an opportunity to discuss research topics and any other issues openly, without senior people present. The format is completely flexible. For example, it could feature talks by postdocs or graduate students on their current research or provide an opportunity to read and report on papers, or give an introduction to upcoming talks in other seminars. The group could even ask a senior participant to give a tutorial lecture and then follow up with a discussion session afterwards.

ICERM makes all of its resource materials for its Graduate Students and Postdoctoral Fellows available to the general public on its website, which can be found at:
https://icerm.brown.edu/pds/

Summer Undergraduate Research Program

Summer@ICERM is an eight-week summer research program for 16-20 undergraduates. Students work in small groups, typically in pairs, supervised by faculty advisors and assisted by TAs. In addition to research projects, the program includes topical mini-courses and colloquium-style lectures given by invited speakers. Students present their findings at a symposium at the end of the program.

1. Solicitation of Proposals

ICERM solicits and recruits proposals from faculty nationwide. Faculty organizers and TAs are required to be in residence for a minimum of six of the eight weeks, especially the first and last week of the program.

2. Future Proposal Selection

Programs are selected from proposals submitted to ICERM in an open competition. Successful programs typically have a significant computational component. Summer research programs which pair with the semester programs are especially encouraged, but not required. A subcommittee of the EAB and an Associate Director, vet proposals. External evaluations of proposals are solicited. Preliminary decisions on summer programs are made by the Directors and must be approved by the Education Advisory Board.

3. Application Process

Undergraduates apply to the program through MathPrograms.org and participants are selected from a talented pool of students currently enrolled in U.S. universities and colleges. A small number of international participants may also be admitted.

4. Applicant Selection

Undergraduate participants are selected by the Summer@ICERM faculty organizers and the selections are finalized by ICERM Director(s). At all stages of recruitment, solicitation, and selection, the organizers are instructed about the diversity goals of the National Science

Foundation, and ICERM in particular. To ensure a diverse group of applicants, ICERM advertises and recruits from minority serving organizations.

Financial Decisions for Program

Faculty and TAs receive a stipend and travel support, and faculty also get partial or full support for lodging. Undergraduate participants funded by ICERM receive a stipend, travel funds within the United States, meals, and accommodation in a Brown dormitory.

Summer 2020: Summer@ICERM – Fast Learning Algorithms for Numerical Computation and Data Analysis

June 8 – July 31, 2020

Organizing Committee:
Yanlai Chen, University of Massachusetts, Dartmouth
Akil Narayan, University of Utah
Minah Oh, James Madison University

Program Description
The 2020 Summer@ICERM program at Brown University is an eight-week residential program designed for a select group of 18-22 undergraduate scholars.

The faculty advisers will present a variety of interdisciplinary research topics utilizing large-scale linear algebra, model reduction, randomized algorithms, and deep learning. Participants will have the opportunity to learn the theoretical underpinnings of these research topics in applied and computational mathematics and will help develop open-source software tools that accomplish data-driven scientific predictions.
The faculty will begin the program with brief introductory talks. Throughout the eight-week program, students will work on assigned projects in groups of two to four, supervised by faculty advisors and aided by teaching assistants. Students will meet daily, give regular talks about their findings, attend mini-courses, guest talks, and professional development seminars, practice coding, version control, and Tex typesetting. Students will learn how to collaborate mathematically, and they will work closely in their teams to write up their research into a poster and/or paper by the end of the program.

ICERM provides an excellent research environment, and the students and their faculty and TA mentors will have access to shared offices and collaborative space throughout the institute. They also will have access to ICERM's computer facilities and specialized software. ICERM staff will provide logistical support for students and will help build community through fun activities and events.

This program is partially funded by a grant from the National Security Agency.

2020 Proposed Research Project Topics

1. Iterative methods for electromagnetic problems
2. Randomized singular value decomposition and its applications
3. Efficient eigensolvers and their applications

4. Theoretical and computational aspects of expressive power of deep neural networks
5. Graph spectral clustering and sparsification
6. Random projections and dimension reduction

2020 Summer@ICERM Cohort

The Summer@ICERM 2020 program had a cohort of 19 students. All of them were funded through the NSF.

Student Name	Institute	Funding Source
Rishi Advani	Cornell University	NSF Core Grant
William Barton	University of Massachusetts	NSF Core Grant
Madison Crim	Salisbury University	NSF Core Grant
Trevor Crupi	Purdue University	NSF Core Grant
Max Daniels	Northeastern University	NSF Core Grant
Jordan Fox	Western Carolina University	NSF Core Grant
Catherine Huang	Berkeley	NSF Core Grant
Ryan Jeong	University of Pennsylvania	NSF Core Grant
Katie Keegan	Mary Baldwin University	NSF Core Grant
Yuqing Liu	University of Michigan	NSF Core Grant
Chloe Makdad	Butler University	NSF Core Grant
Shubham Makharia	Brown University	NSF Core Grant
David Melendez	University of Central Florida	NSF Core Grant
Yonah Moise	Yeshiva University	NSF Core Grant
Sean O'Hagan	University of Connecticut	NSF Core Grant
Hannah Odom	University of Texas at Austin	NSF Core Grant
Maricela Ramirez	University of Mary Hardin-Baylor	NSF Core Grant
Kelly Rivera	St. Thomas University	NSF Core Grant
Jennifer Zheng	Emory University	NSF Core Grant

Here follows a sample of the most substantive comments from our Summer@ICERM participants.

Some Participant Comments for “Describe the highlight of this workshop”:

- *The highlight of this virtual program was seeing just how much progress we all made from the first to the final week. A second highlight was being able to make new math inclined friends and witness just how passionate everyone was about this beautiful subject.*
- *The research component. It was so incredibly rewarding, especially to see the final results and have everything come together. It made all of the frustration, late nights, and hair pulling worth it. Also, my group members. They were incredibly helpful and our collaboration was so easy, fun, and rewarding. They are amazing people and I’m so glad I got to meet them, albeit virtually.*
- *The speakers definitely stand out; they all gave me a new way to look at mathematics that definitely helped to renew my passion for it. In addition, the connections that I was able to create even through a virtual platform were quite surprising, but I am very happy that they were made.*

- *The learning experience in so many different areas - research, presentations, scientific writing, etc - was very big. I am also very excited to have gotten to know people who will be in the same profession as I will be in soon.*
- *The highlight of this program was working in my group meetings, and staying in contact with my group members throughout each day. We were in constant communication, both via video chat in the morning and primarily through text into the afternoon and night. I feel like the three of us got along very well and I both made friends, learned a lot about them, and learned a lot about myself through this experience.*

Summer@ICERM 2020 Scientific Outcomes to Date

Final Student Presentations

- T. Crupi, H. Odom, Y. Moise, Iterative methods for electromagnetic problems.
- K. Keegan, D. Melendez, J. Zheng, Randomized SVD and Its Applications.
- K. Rivera, J. Fox, E. Liu, Efficient eigensolvers and their applications.
- M. Daniels, C. Huang, C. Makdad, S. Makharia, Graph Spectral Clustering.
- R. Advani, S. O'Hagan, M. Crim, Random projections and dimension reduction.

The Evaluation Process: Measure to Evaluate Progress

Current Program Evaluation

ICERM continues to work with Strategic Research Group (SRG), an external evaluation company, to build upon its current survey data.

ICERM automates its survey reporting, using templates that display particular variables of interest across participants and over time. In this way, ICERM can easily recognize a pattern of program strengths in certain areas and may be able to tailor aspects of its programs to successfully equip individuals for a thriving and influential research career.

ICERM also successfully creates two and five-year follow-up surveys that are customized to a single participant instead of distributing a broad and generalized survey to all participants. An example of how customized surveys are being used at the institute is the generation of publication lists for each participant. When the survey is sent, Qualtrics reads the unique identification number of the participant stored in the panel database and generates a list of publications previously collected by ICERM staff and assigned to that specific identification number. Then, the surveyed participant is able to identify the publications that can be attributed to his or her time at ICERM. This novel incorporation of a participant-specific generated publication list has been useful in understanding how influential ICERM programs are to one's research career long-term.

COVID-19 and its impact on survey response rates

ICERM strives to get the highest response rate for its surveys. The Director informs participants that they will receive a survey during the welcoming remarks. In addition, the institute explains within the body of every survey how it handles responses confidentially and why it collects

gender and ethnicity data. Reminders are sent one or two weeks after each survey is first sent out.

During this reporting cycle, the institute's applicant pool increased significantly since there were fewer barriers to participating with everything being available virtually. Where ICERM previously accepted 70-80 applicants per program, it often accepted 300+ applications. Many participants were selective in the talks they attended, and many more did not respond to the exit surveys. Therefore, ICERM's average response rate of 66% for all exit surveys was significantly lower this year, averaging only 28%.

Measure impact across subgroups

Qualtrics cloud-based software not only aids in creating customizable surveys for participants, but also serves as a platform for analyzing data according to different subgroups of participants e.g., gender, job title, race/ethnicity.

SRG continues to assist ICERM with using the Qualtrics data analysis tools to better understand how the institute's programs impact different subgroups of researchers in both the immediate i.e., program exit surveys and intermediate-/long-term i.e., two- and five-years after program participation. Qualtrics also provides the opportunity to analyze longitudinal data, which will be helpful in the analysis of certain programs over time. Ultimately, these analyses will provide information as to how ICERM can alter programs to benefit different types of participants who may be at various points in their research career.

Measure long-term outcomes

Since 2014, ICERM has been administering an intermediate - i.e., two-year follow-up survey to past semester program participants. Using the unique identification numbers and in-survey data analyses as described above, these surveys measure the attributable impact of participation in ICERM research programs by gathering data on published papers, invited talks, and funded or pending grant proposals. These follow-up surveys help us understand the far-reaching impact of ICERM's research programs over time.

To boost survey response rates during this reporting cycle, the SAB suggested the program organizers send a "heads up/please respond" email to their program's long-term participants prior to putting the follow-up surveys in the field. This request resulted in an increased response rate (from our average of 50% for the two-year-follow-up and 36% for the five-year-follow-up to 52% and 55%, respectively.

A central tenet of ICERM is that networking, collaboration, and engagement with computational tools promote career growth that would not be possible without engagement with our programs.

With SRG's help, the institute developed a longitudinal comparison report using a program's exit survey, as well as its 2 and 5-year follow-up survey. In this way, ICERM can connect participant data across surveys (with the use of unique IDs) and generate a more holistic narrative of ICERM's impact over a longer period of time. The results from this report are meant to showcase ICERM's long-term impact on participant careers and their continued perceptions of their time at the institute. Notably, this report examines:

- trends in employment over time
- professional talks
- grant funding submitted and received
- collaborations

The challenge, of course, is having high enough response rates for the collected data to draw meaningful conclusions.

The SAB is interested in seeing details about a program's long-term impact. The challenge in the coming year is to pare down the massive quantity of information we collect to something more concise. ICERM will endevour to simplify and streamline our survey instruments, with a view toward what we need for formative evaluation (in our director-manager meetings) and summative evaluation (led by our boards).

ICERM continues to play a large role in gathering and updating participant information for the two and five-year follow-up surveys. Specifically, one question provides participants with a list of their papers, pre-prints, or reports published since their participation at ICERM (or, in the case of the five-year follow-up, since their initial two-year survey). Participants then have the opportunity to include/update publications resulting from their participation in an ICERM program or event. ICERM is responsible for finding and compiling these publications for each participant. Additionally, before implementing each survey, ICERM continues to be involved in editing and testing the survey in order to have an end product that will most effectively provide data aligned with its goals.

It is important to note here that although ICERM has hired SRG as its external evaluation company to aid in reaching their evaluation goals, the institute still plays a vital role in the data collection and survey distribution process. In addition, at weekly management meetings, survey results are reviewed and discussed so that improvements can be made as appropriate.

Note: Links to exit survey summaries for core programs run during this reporting cycle (May 1, 2020 through April 30, 2021) can be found in Appendix J.

Reported Scientific Outcomes/Projects Initiated

In the past, the Director sent a request to all long-term participants asking for updates on their research projects and/or publications that arose during, or were enhanced by, participation in an ICERM program. With the advent of ICERM's 2-year and 5-year follow-up survey for each of its semester programs, scientific outcomes have begun to be collected much more systematically and consistently. In the coming year ICERM will work with its boards to determine what data they find most informative in terms of scientific outcomes and develop a standardized report.

In general, the response rate for all survey types has remained steady over the past four years, when ICERM first began tracking response rates.

Note: a list of research projects (publications, code, software) initiated at ICERM during the Fall 2020 and Spring 2021 semester programs can be found in Appendix K.

Corporate and Academic Sponsorship

Several math institutes currently funded by the NSF employ corporate and university-sponsored programs with tiered memberships. ICERM launched its own unique corporate and academic sponsorship programs in 2011.

The Corporate Sponsorship program has a $5,000 annual membership fee. To date, ICERM has received $92,500 in corporate sponsorship funds.

Our current corporate sponsors are:

- Microsoft Research
- Schlumberger

The Academic Sponsorship has an annual membership fee of $1,500 for domestic memberships with small graduate student programs, $3,000 for domestic membership with large graduate student programs, and $5,000 for international membership. To date, ICERM has received $99,375 in academic sponsorship funds.

Academic sponsors include:

- Cornell University, Department of Mathematics
- Indiana University, Bloomington, Department of Mathematics
- Korea Advanced Institute of Science and Technology, Dept. of Mathematical Sciences
- Michigan Tech, Department of Mathematical Sciences
- Worcester Polytechnic Institute, Mathematical Sciences Department

External Support

The institute staff works to develop new sources of support for its programs. Assistant Director of Finance and Administration, Juliet Duyster, has duties which include managing both public and private grants, managing the proposal process and ensuring that follow-up reporting is completed. Assistant Director Ruth Crane manages relations with the institute's sponsoring corporations and serves as a liaison to Brown's Division of Advancement, which unites Alumni Relations, Development, Corporate and Foundation Relations in a single, focused organization.

In addition to the funding provided by the NSF, ICERM receives substantial in-kind financial support from Brown University. The Director is released from teaching, and two Deputy Directors are released from half of their teaching responsibilities. In addition, ICERM is not charged for the use of its building or for custodial care which Brown values at $670,500. This year Brown gave ICERM $75,000.

Other Funding Support received in 2020-2021

Additional Grants	*Amount*
American Mathematical Society Epsilon Fund *(for GirlsGetMath@ICERM)*	$ 3,000.00
JetBlue Foundation *(for expanding the GirlsGetMath program nationally)*	$ 50,000.00
Sub-total	**$ 53,000.00**

University Funding Support	
University Research Committee	$ 75,000.00
Sub-total	**$ 75,000.00**
Sponsor Support	
Academic Sponsors	$ 5,000.00
Corporate Sponsors	$ 5,000.00
Individual Sponsors	$ 1,150.00
Sub-total	**$ 11,150.00**
TOTAL	**$139,150.00**

"Mathinstitutes.org" Supplemental Funding

ICERM handles ongoing basic maintenance for the www.mathinstitutes.org website. This entails hosting the website on Brown servers, providing technical assistance to other institutes uploading data, keeping the diversity program pages and other resources current, and adjusting the video search interface as needed.

ICERM requested this supplement because the institute had been covering the costs of this work through its core grant. The supplement allows ICERM to be more active in keeping the site current and responsive to our peers as they request changes.

The main advantages of this supplement are that: 1) the NSF can quantify the ongoing cost to maintain the site; 2) ICERM staff are able to take on larger and more complex updates to the video search interface; and 3) ICERM can facilitate improvements to the presentation and organization of the diversity program webpages.

The www.mathinstitutes.org site serves an important role for the Mathematical Institutes program as a whole. This supplement ensures that it evolves to meet the changing needs of each of the institutes and allows ICERM to be pro-active in responding to suggestions from program leadership on how institute activities may best be promoted. ICERM technical staff continues to provide routine maintenance and end user support.

From May 2020 through April 2021, $13,738.23 was spent on staff time and hosting costs. This time was focused on making incremental changes to page layout, such as adjusting the way upcoming events are displayed, modifying content based on feedback from the Institutes Directors, and fixing bugs to improve the accuracy of search results. During this time ICERM staff also updated the underlying software for the joint media database and the website as a whole in order to stay within vendor support parameters.

Diversity and Outreach

Ulrica Wilson, an Associate Professor of Mathematics at Morehouse College, is also ICERM's Associate Director of Diversity and Outreach. Ulrica provides leadership in meeting institutional diversity goals: ensuring diversity throughout ICERM's programs, assisting in the development of policies and procedures, participating in national meetings and conferences, and helping to identify and obtain funding for programs and activities. She chairs the overarching diversity

committee of the Mathematical Sciences Institutes Diversity Initiative (MSIDI). In addition, she leads the program 'Research Experiences for Undergraduate Faculty' (REUF), a collaboration of ICERM and the American Institute of Mathematics that supports faculty at four-year institutions that would like to lead research experiences for undergraduates.

ICERM strongly supports the National Science Foundation's goals of expanding the numbers and diversity of individuals engaged in mathematical sciences through increased participation. Through its membership in the Math Institutes Diversity Committee, the institute actively seeks best practices for securing the participation of women and under-represented minorities in ICERM's governing bodies and in all scientific programs, workshops and events. Specifically, ICERM policy includes the following:

In consultation with Dr. Wilson and members of the Scientific Advisory Board (SAB), ICERM's Directors reach out to women and underrepresented minorities to encourage them to submit proposals for workshops and semester programs. When we receive program sketches and pre-proposals, Directors routinely ask organizers to consider women as organizers. When invitations are issued to speakers or long-term program participants, Directors push back if the proposed slates include few women. Similar guidance is offered as postdocs and undergraduate students are evaluated. Directors review each shortlist to ensure it takes ICERM's diversity goals into account.

Directors also promote networking opportunities within workshops and semester programs, e.g., opportunities for women to come together for lunchtime discussions. During this reporting cycle ICERM hosted the Women in Algebraic Geometry workshop.

ICERM typically hosts or co-sponsors special events or conferences that serve women and under-represented minorities in the mathematical sciences, including diversity workshops, Blackwell-Tapia conferences, Society for Advancement of Chicanos and Native Americans in Science (SACNAS) conferences, Association for Women in Mathematics (AWM) workshops and events, and is building relationships with academic institutions that serve large minority populations. None of these events were held, or ICERM chose not to participate, during this reporting cycle due to the pandemic.

ICERM states its commitment to diversity on all informational and promotional materials, and broadly advertises its activities and opportunities for funding.

Other Activities

- Continue to share funds among NSF Mathematics Institutes available for rotating programs like Modern Math Workshop and Blackwell-Tapia
- ICERM is a member of the NSF Institute-wide diversity committee
- ICERM co-supporter the AWM mentor network
- GirlsGetMath@ICERM high school math camp (outside funding)
- ICERM has a subcommittee to support Brown University's diversity and inclusion action plan

Outreach Activities

Public Lectures

ICERM has gained a reputation for providing the Brown community and the general public with an excellent public lecture series. These lectures attract a broad audience, from high school students on up.

During this reporting cycle, four virtual public lectures were held:

- Uncovering Lottery Shenanigans, with Skip Garibaldi (September 2020)
- One Person, One Vote, with Sharad Goel (October 2020)
- Quantifying and Understanding Gerrymandering, with Jon Mattingly (October 2020)
- Q&A with Kip Thorne, Nobel Prize-winning Theoretical Physicist (December 2020)

GirlsGetMath@ICERM

For seven years, ICERM has been able to secure funding to run its well-received GirlsGetMath@ICERM program. Unfortunately, it was not feasible to run the program in the summer of 2020 due to the pandemic.

Because GirlsGetMath incorporates so many interactive, hands-on experiences, and the participants benefit from meeting peers with shared interests, we determined that a virtual version of the program this summer would lose its impact.

We worked with the founding program organizers (Katharine Ott and Amanda Tucker) to come up with an alternate plan that provided meaningful and engaging content in keeping with the spirit of the program. A very abbreviated, asynchronous version of GirlsGetMath was made available to every applicant as well as the general public. Two-to-three videos of Katy and Amanda presenting a selection of modules related to the GirlsGetMath curriculum (as well as some downloadable activities) are still posted on ICERM's GirlsGetMath website.

GirlsGetMath was designed to address the underrepresentation of women in STEM fields, seeks to motivate young women to consider careers in mathematics, computation, and quantitative fields, and provides an affirming environment that encourages participants to explore, and invites them to excel in, the mathematical sciences.

The program inspires 20-25 participants to love math by:

- demonstrating through hands-on activities, games, and computer simulations that the study of mathematics can be exciting, fun, and useful;
- introducing the high school participants to a variety of career opportunities for which sophisticated mathematical ability plays a key role, with an emphasis on the central role mathematics plays for success in STEM careers; and
- providing the participants with a support group of like-minded peers and mentors.

GirlsGetMath Broader Impact

The mentorship provided to the participants has been specifically designed by those with experience in outreach to meet a key set of needs identified by research as being most likely to make a difference in the way the girls view mathematics and STEM disciplines. The program

content is created by mathematicians who collectively have many years of experience as researchers and educators. It is crafted to be at the appropriate level for the participants, but at the same time challenging and practical. The topics are selected to showcase the beauty and depth of mathematics.

Thanks to funding from the JetBlue Foundation in 2018, ICERM developed a train-the-trainer opportunity for nine faculty who were interested in replicating a GirlsGetMath program at their home institutions. The observational training occurred during ICERM's summer 2019 GirlsGetMath program. The train-the-trainer participants were then given the opportunity to apply for start-up seed funds to run their own programs. Six out of the nine trainees applied for the four available seed grants. Through the seed grants, GirlsGetMath programs will now be developed at the University of Delaware, the University of Central Oklahoma, Boston University, and Stonehill College in summer 2020 (delayed by one year due to the COVID-19 pandemic).

ICERM has developed methodologies for tracking GirlsGetMath alumnae annually in order to follow their educational interests – specifically, how many will go on to seek a college degree and if they choose to major in a STEM field. We are already aware that two GirlsGetMath alumnae (from 2014 and 2015) are currently matriculating at Brown University. One has already declared her concentration in Computer Science.

EPSCoR

ICERM supports the National Science Foundation's EPSCoR mission: "to assist the NSF in its statutory function "to strengthen research and education in science and engineering throughout the United States and to avoid undue concentration of such research and education." EPSCoR goals are:

1. to provide strategic programs and opportunities for EPSCoR participants that stimulate sustainable improvements in their R&D capacity and competitiveness;
2. to advance science and engineering capabilities in EPSCoR jurisdictions for discovery, innovation and overall knowledge-based prosperity.

Accepted ICERM participants from EPSCoR States

(May 1, 2020 through April 30, 2021)

EPSCoR State	# of ICERM Participants
Alabama	10
Arkansas	2
Delaware	6
Hawaii	4
Idaho	4
Iowa	12
Kansas	11
Kentucky	19
Louisiana	29

Maine	4
Mississippi	3
Missouri	13
Nebraska	3
Nevada	1
New Hampshire	7
New Mexico	15
North Dakota	5
Oklahoma	12
Rhode Island	109
South Carolina	3
Tennessee	27
Utah	18
Vermont	3

Administration and Staff

The ICERM Directors who received funding from the NSF core grant during this reporting cycle were Carolyn Klivans, Benoit Pausader, Jill Pipher, Kavita Ramanan, Bjorn Sandstede. Brendan Hassett commits 100% time. Note that Directorate and staff effort during this reporting cycle was split between ICERM's pervious grant (DMS-1439786), and its renewal grant (DMS-1929284).

ICERM Staff

Finance Team

Nina Succi, Coordinator of Finance and Administration, hired February 2016: reports to the Financial Manager. Serves as fiscal liaison and primary point of contact for ICERM staff, program organizers, visitors, postdocs, students, customers, and vendors for all financial transactions and related issues. Processes all participant reimbursements and payments made to vendors; assists with human resources and administrative support.

Events Team

Jenna Sousa, Program Manager hired May 2014: reports to the Assistant Director. Provides project management and logistical oversight for ICERM's complex portfolio of research programs and events. This includes the oversite of all applications, invitations, housing, program schedules, special events, and exit surveys. Manages the event staff.

Teresa Fitzenry, Program Coordinator, hired October 2016: reports to Program Manager. One of two Program Coordinator positions. Coordinates all logistical aspects of the fall semester/later summer programs and workshops. Acts as the main point of contact and customer support for ICERM visitors; sends and tracks speaker invitations, coordinates visitor housing, orders office supplies, and enters participant data into ICERM's Cube database. Assist the Program Manager and Assistant Director with other activities, such as social media and other marketing, as needed.

Kellie Shaughnessy, Program Coordinator, hired February 2017: reports to Program Manager. One of two Program Coordinator positions. Coordinates all logistical aspects of the spring

semester/early summer programs and workshops. Acts as the main point of contact and customer support for ICERM visitors; sends and tracks speaker invitations, coordinates visitor housing, orders office supplies, and enters participant data into ICERM's Cube database. Assist the Program Manager and Assistant Director with other activities, such as social media and other marketing, as needed.

IT Team

Brian Lavall, Senior Systems Administrator, hired April 2014: reports to the Director of IT. Oversees support and administration of all ICERM A/V technologies, hardware and software systems. Coordinates the development of ICERM's website and video database. Monitors and actively controls the Echo 360 lecture capture system and provides first level support for technical issues such as wireless connectivity and printing.

Bernadette McHugh, IT Customer Experience Manager, hired in September 2012: reports to the Director of IT. Updates and maintains website content, web-based applications, and social media used to support and promote ICERM and its activities. Provides A/V support for the institute's workshops and events.

Tori Santonil, Senior Application Developer, hired October 2017: reports to the Director of IT. One of two Application Developer positions. Performs project management, application testing, development, and maintenance, including development/coding, testing, and ongoing maintenance of the department's front-end applications, back-end applications, java application servers, and databases.

Zachary Hyman, Application Developer, hired March 2020: reports to the Director of IT. One of two Application Developer positions. Performs application testing, development, and maintenance, including development/coding, testing, and ongoing maintenance of the department's front-end applications, back-end applications, java application servers, and databases.

ICERM PI and Director Biographies

Brendan Hassett (Director) joined the Brown faculty the summer of 2015 as a Professor of Mathematics. He assumed the directorship of ICERM in July 2016. Brendan received his Ph.D. from Harvard in 1996 and then spent four years at the University of Chicago before joining the faculty at Rice University in 2000. He was the chair of the mathematics department at Rice from 2009 to 2014. He has also held visiting positions at the Mittag-Leffler Institute in Stockholm, the Chinese University of Hong Kong, and the University of Paris. Brendan's research focus is algebraic geometry - the study of geometric objects that are defined as solutions to polynomial equations. Brendan has written more than 60 research papers and has authored or co-edited seven books. His work has been recognized with a Sloan Research Fellowship, a National Science Foundation CAREER award, and the Charles W. Duncan Award for Outstanding Faculty at Rice. He is a Fellow of the American Mathematical Society.

Mathew Borton was one of ICERM's first employees, hired in December 2010. As the IT Director, he brings big-picture, strategic development skills to the institute. He oversees all daily IT/technology related operational activities and ensures IT security and stability. He acts as the

liaison to the Brown University's IT community. Besides supporting the scientific activities within the institute, his responsibilities include overseeing the support of administrative IT and A/V equipment, and the development and support of key web interfaces and databases. Mat received his BS in Information Technology and his MS in Technology – Information Security, both from Purdue University.

Ruth Crane, Assistant Director, joined ICERM in November 2010 as the institute's first employee. She has over 35 years of communications and management experience, ranging from corporate training, health care, and academia. She uses her broad range of experience in order to act as chief-of-staff and oversees the coordination and administrative aspects of all the research programs of the institute. She is the liaison for the institute's fundraising activities and coordinates grant proposals, including proposal writing. Ruth manages all ICERM marketing and oversees ICERM's web content as well as community outreach activities. She works closely with the Director and the institute's boards. Ruth received her BS from Emerson College.

Juliet Duyster, Assistant Director of Finance and Administration, was hired in August 2011. She has 15+ years experience in higher education. She is responsible for directing the long-range and day-to-day financial and administrative activities that support ICERM's 18-20 mathematical conferences and 1,000+ international scientific researchers annually. She supervises the financial staff, works closely with the Directorate, is involved in management planning sessions for the Institute, and serves as the primary financial advisor and administrative risk manager. Juliet received both her BS and her MBA from Nova Southeastern University.

Sigal Gottlieb is a Deputy Director at ICERM, and a Chancellor Professor of Mathematics and founding co-Director of the Center for Scientific Computing and Visualization Research (CSCVR) at UMass Dartmouth. She is a Fellow of the Society of Industrial and Applied Mathematics (SIAM, 2019) and the Association for Women in Mathematics (AWM, 2021). Sigal graduated from the Division of Applied Mathematics at Brown University (ScB'93, ScM'95, PhD'98). Her research interests include numerical analysis, scientific computing, and high-performance computing. Specifically, the high-order numerical methods for simulation of hyperbolic PDEs with shocks. These methods include WENO, spectral, and pseudo spectral methods, as well as strong stability preserving time discretizations. She is best known for her contributions to the field of high order time-stepping for hyperbolic PDEs, and her research in this area has been funded by the AFOSR continually since 2006. Sigal is also interested in reduced basis methods for solving PDEs with many parameters, and on gravitational wave simulations, and is funded by the NSF for projects in this area. Recently, Sigal led a team of computational scientists at the CSCVR to obtain a $643,899 DURIP grant from the ONR to fund a new shared cluster at UMass Dartmouth.

Jeffrey Hoffstein is a Professor of Mathematics at Brown University, and an ICERM Consulting Director. He received his PhD in mathematics from MIT in 1978. After holding postdoctoral positions at the Institute for Advanced Study, Cambridge University, and Brown University, Jeff was an Assistant and Associate Professor at the University of Rochester. He came to Brown as a full professor in 1989. His research interests are number theory, automorphic forms, and cryptography. Jeff has written over seventy papers in these fields, co-authored an undergraduate

textbook in cryptography, and jointly holds 10 patents for his cryptographic inventions. He was a co-founder of Ntru Cryptosystems, Inc., which was recently acquired by Qualcomm.

Benoit Pausader is an Associate Professor of Mathematics at Brown University and a co-PI on the ICERM grant. Benoit received his Ph.D. from the University of Cergy-Pontoise. He's held appointments at New York University, the Centre National de la Recherche Scientifique in France, and at Princeton. His current position at Brown marks his second appointment to the Brown faculty; from 2008-2011 he was appointed as a Tamarkin Assistant Professor. Benoit studies partial differential equations, especially equations coming from physics such as the nonlinear Schrodinger equation, the Euler-Maxwell system, the Water Wave system. He has been the recipient of two grants from the National Science Foundation, was named a Sloan Research Fellow in Mathematics in 2014 and a Simons Fellow in 2021.

Jill Pipher is the Elisha Benjamin Andrews Professor of Mathematics at Brown University and ICERM's founding Director Emerita. She is Brown University's Vice President for Research, and also serves as president of the American Mathematical Society (AMS). Jill served as Chair of the Mathematics Department 2005-2008. Jill received her Ph.D. from UCLA in 1985 and came to Brown as an Associate Professor in 1990 from the University of Chicago. Her research interests include harmonic analysis, partial differential equations and cryptography. She jointly holds four patents for the NTRU encryption and digital signature algorithms and was a co-founder of Ntru Cryptosystems, Inc., now named OnBoard Security. Her awards include an NSF Postdoctoral Fellowship, Presidential Young Investigator Award, Mathematical Sciences Research Institute Fellowship, and an Alfred P. Sloan Foundation Fellowship. She served as President of the Association for Women in Mathematics in 2011-2013, was a National Women's History Month 2013 Honoree, and and also served as president of the American Mathematical Society from 2019-2020. She was honored to deliver the 2014 ICM lecture, and the 2016 Brown University Presidential Faculty Award lecture. Jill is a Fellow of the American Mathematical Society, a SIAM Fellow, and a member of the American Academy of Arts and Sciences.

Caroline Klivans is an Associate Professor of Applied Mathematics at Brown University and an ICERM Deputy Director. As Deputy Director, her responsibilities include: overseeing semester programs and other institute activities such as summer programming and special events, assisting in solicitation and development of programs and workshops and with grant proposals to support institute activity. Previously she served as an ICERM Associate Director from 2015-2020, where her focus was on the Institute's mentoring and professional development programs for students and postdoctoral fellows. Caroline received a BA degree in mathematics from Cornell University and a PhD in applied mathematics from the Massachusetts Institute of Technology. Before coming to Brown, she held positions at MSRI and the University of Chicago. Her research is in algebraic, geometric and topological combinatorics.

Kavita Ramanan is the Roland George Dwight Richardson University Professor of Applied Mathematics at Brown University, also serving as Associate Chair. She served as Deputy Director of ICERM in 2020, and is currently an Associate Director. Kavita works on probability theory, stochastic processes and their applications. She has made fundamental contributions to the study of reflected processes, large deviations theory, high-dimensional probability and applications to asymptotic convex geometry. She has also developed novel mathematical

frameworks for the analysis of stochastic networks, Markov random fields and interacting particle systems, which arise as models in a variety of fields ranging from operations research and engineering to statistical physics and neuroscience. Her work combines tools from several fields including discrete probability, stochastic analysis and partial differential equations. She also has four patents to her name. Kavita is an elected fellow of multiple societies including the AMS, SIAM and AAAS. She has received several honors for her research. She was awarded the Erlang prize in 2006 for "outstanding contributions to applied probability" by the INFORMS Applied Probability Society, and a Medallion from the Institute of Mathematical Sciences in 2015. She was a recipient of a Simons Fellowship in 2018, a Guggenheim Fellowship in 2020, a Distinguished Alumna Award from IIT Bombay in 2020, the Newton award in 2020 from the Department of Defense for "transformative ideas" during the COVID-19 pandemic, and a Distinguished Research Achievement Award from Brown University in 2021. She was also named a member of the American Academy of Arts and Sciences in 2021.

Bjorn Sandstede is Professor of Applied Mathematics, the Department Chair of the Division of Applied Mathematics, and an ICERM Associate Director. He studied mathematics at the University of Heidelberg and received his PhD in 1993 from the University of Stuttgart. After holding postdoctoral positions at the Weierstrass Institute in Berlin and at Brown University, he was a faculty member at the Ohio State University from 1997-2004, before moving in 2004 to the University of Surrey in England. In 2008, he joined the Division of Applied Mathematics at Brown University. Bjorn received an Alfred P Sloan Research Fellowship in 2000, was awarded the first JD Crawford Prize of the SIAM Activity Group on Dynamical Systems in 2001, received a Royal Society Wolfson Research Merit Award in 2004, the Elsevier Jack Hale Award, and Brown's Philip Bray Award for Teaching Excellence and the Graduate School Faculty Award for Advising and Mentoring. He was selected as a Fellow of the Society for Industrial and Applied Mathematics.

Ulrica Wilson is an Associate Professor of Mathematics at Morehouse College. As ICERM's Director of Diversity and Outreach, she provides leadership in meeting institutional diversity goals: ensuring diversity throughout ICERM's programs, assisting in the development of policies and procedures, participating in national meetings and conferences, and helping to identify and obtain funding for programs and activities. Ulrica's primary research has been in noncommutative ring theory and combinatorial matrix theory. Throughout her career, she has integrated opportunities to address diversity issues in the mathematical workforce. A decade of experience includes directing the Enhancing Diversity in Graduate Education EDGE Program and Research Experience for Undergraduate Faculty REUF workshops at AIM and ICERM. Ulrica was recently named as a 2019 AWM Fellow for her work supporting the professional development of women pursuing careers in the mathematical sciences.

Facilities

ICERM is located on the 10th and 11th floors of 121 S. Main Street, in a Brown owned building in downtown Providence, RI. Visitors to ICERM are within a 10-minute walking distance of the Brown campus, the train station, major hotels, and a variety of restaurants and historic sites.

The space includes a 120-seat lecture hall, a 20-seat seminar room, a 20-seat conference room, an administrative suite, office space for 40-45 visitors, two kitchens, and three large collaborative areas.

IT Resources

ICERM's information technology group's mission is to provide the necessary tools for research, collaboration, and information dissemination required by the institute's participants and to support the administrative staff. This is accomplished by providing flexible systems that can be quickly reconfigured to meet research needs and efficient administrative tools that allow the institute's staff to maintain operational excellence.

Work Stations

ICERM provides virtual desktop systems to all semester program participants using a custom VNC connection to the Center for Computation and Visualization. The host operating system is Redhat Linux Server, the guests use Redhat Linux workstation, and the client machines are thin clients using a thin version of Debian. Applications are distributed based on the needs of the current program and researcher requests. Applications are distributed as needed. Application needs differ from program to program and researcher to researcher. Individuals have administrative control over their own virtual desktops. Researchers are also free to provide their own equipment or use their own laptop. The majority of the applications provided to users will leverage existing Brown license agreements.

Web Based Tools

ICERM provides an evolving suite of web-based tools for collaboration and to assist research. ICERM uses Zoom Meeting to facilitate virtual workshops and the software is available for smaller presentations and participant working groups. They also have access to a dedicated Slack workspace for text-based messaging. ICERM offers participants licensed access to Overleaf, a collaborative web based LaTeX editor. Access to Jupyter notebooks and CoCalc are available on request.

All previous talks and papers generated in the course of semester programs are archived and available for download and review via the website.

Multimedia Resources

ICERM has state of the art audio/visual capabilities. The 120-seat lecture hall features dual projection screens, a centrally controlled AV system capable of displaying multiple media types, and a lecture capture system with an auto-tracking camera for recording presentations and streaming to the web. A smaller meeting room is equipped with a video conferencing system and includes a digital media projection system. The video conferencing system can also be leveraged to communicate with the lecture hall. A seminar room on the 10th floor provides basic multimedia presentation capability. Digital signage screens throughout the institute are used to display important information to visitors and can be independently used as a peripheral display from a laptop.

Live Streaming

ICERM provides live, real-time video streaming of all Workshop talks, special events, and tutorial sessions given in the lecture hall.

Video Archives

ICERM digitally records semester and topical workshop talks and special lectures in High Definition using the Panopto lecture capture system. Presentations are then archived and made available for viewing on our website along with a PDF copy of the presenter's slides, when available.

Data Collection and Reporting

ICERM has a visitor management system called CUBE to collect and report on participant data. This system will become a central point of data management for both staff and participants as new feature sets are added.

ORCID ID

ICERM collects ORCID iDs from NSF-funded participants. The following message is conveyed: *In order for the NSF's Division of Mathematical Sciences to effectively evaluate math institutes, it requires that funded participants provide their Open Researcher and Contributor ID (ORCID) identifier. Only those participants who furnish their ID to ICERM may be supported with award funds.*

Brown Computing Resources

ICERM participants are encouraged to use other IT resources available at Brown. Chief among these is the high-performance computing cluster hosted by the Center for Computation and Visualization. ICERM provides premium access accounts upon request to all long-term participants and to workshop participants on an as needed basis with approval from the Director.

Participants are also welcome to use the Digital Scholarship Lab at the Rockefeller Library. This room incorporates a high-definition video wall for large-scale visualization and collaboration.

CCV makes other services available to ICERM participants, including access to consultants for code creation and optimization and an immersive display environment.

APPENDIX:

Appendix A: Sample Semester Schedule & Organizer Timeline
Appendix B: Fall 2020 Semester Program and Workshop Participant Lists
Appendix C: Spring 2021 Semester Program and Workshop Participant Lists
Appendix D: Upcoming Programs and Events
Appendix E: 2020-2021 Topical Workshops: Participant Lists
Appendix F: Minutes from Board of Trustees Meeting
Appendix G: Minutes from Scientific Advisory Board Meetings
Appendix H: Minutes from Education Advisory Board Meeting
Appendix I: MIDs Meeting Minutes
Appendix J: Survey Summaries May 1, 2020-April 30, 2021

Appendix K: Projects Initiated at ICERM 2020-2021
Appendix L: ICERM Income and Expenditure Report (NSF Required)