Department of Mathematics

The Department of Mathematics is a world class leader in mathematical research, education and outreach, and is the top-ranked mathematics department in the United States. It is unique among elite departments in its dedication to teaching and mentoring, and the scope of its program is a key part of MIT's educational mission at all levels. Our graduates are sought after, both in industry as highly trained problem solvers, and in academics as young researchers. Key to the department's success is recruitment of the very best junior and senior faculty and graduate students in an ever-more competitive environment. The department strives for diversity in all its appointment and admission levels, and is committed to fostering greater diversity in earlier grades through its numerous outreach programs to high school and middle school students.

Our award-winning faculty are leaders working in many central fields in pure and applied mathematics and statistics. We have specialists in analysis, geometry, topology, algebra, and number theory; physical applied mathematics, computational science, computational biology, theoretical computer science (including quantum computing, optimization, machine learning, and computational complexity), combinatorics, probability, and statistics. Because of the department's breadth, our faculty interact with researchers in other MIT departments, including the Departments of Electrical Engineering and Computer Science; Biology; Physics; Mechanical Engineering; Civil and Environmental Engineering; the Institute for Data, Systems, and Society; as well as the Broad institute.

Awards and Honors

The faculty received numerous distinctions this year.

Professor Frank Thomson Leighton was inducted into the National Inventors Hall of Fame for the content delivery network methods he invented with his graduate student Daniel Lewin. Professor Scott Sheffield and former Schramm and National Science Foundation (NSF) Fellow Jason P. Miller received the 2017 Clay Research Award for their work on the geometry of the Gaussian free field and its application to the solution of open problems in the theory of two-dimensional random structures. Professor Sheffield was also selected for a 2016 Aisenstadt Chair from the University of Montreal.

Professor Bonnie Berger was appointed the next Simons Professor of Mathematics. Professor Tobias Colding was awarded the Carlsberg Foundation Research Prize for ground-breaking research in differential geometry and geometric analysis, and Professor Gigliola Staffilani received the 2017 Guggenheim Fellowship. Professors Tomasz Mrowka, Colding, and Staffilani received the 2017 Simons Fellowship.

Professor Hung Cheng was honored with the 2017 Distinguished Achievement Award in Technology and Humanity/Humanities by the Chinese Institute of Engineers, San Francisco Bay Chapter. Professor Paul Seidel was appointed distinguished visiting professor at the Institute for Advanced Study for the academic year. Professors David Jerison and Gigliola Staffilani, with Postdoctoral Associate Jennifer French and MITx

Fellow Karene Chu, made up one of three groups that received the inaugural MITx Prize for Teaching and Learning in MOOCs (massive open online courses).

Among the department's assistant professors, Professor Ankur Moitra received the Packard Fellowship in Science and Engineering. He was also appointed the Rockwell International Career Development Assistant Professor of Mathematics. Professsor Jörn Dunkel was recognized as a 2017 Outstanding Referee by the American Physical Society. Professors Semyon Dyatlov and Aaron Pixton each received a Sloan Research Fellowship.

Two faculty members, Professors Vadim Gorin and Philippe Rigollet, were selected by the MIT research support committee for support from the NEC Corporation Fund for Research in Computers and Communication for AY2017.

CLE Moore Instructor Roger Casals received the Vicent Caselles Mathematical Research Award of the Banco Bilbao Vizcaya Argentaria (BBVA) Foundation and the Royal Spanish Mathematical Society (RSME). He also received the RSME's José Luis Rubio de Francia Award and the BBVA Research Fellowship.

Lectures

John Bush delivered a Sectional Lecture in Fluid Dynamics at the 24th International Congress of Theoretical and Applied Mechanics in Montreal, August 2016.

Tobias Colding gave a one-hour American Mathematical Society (AMS) invited address at the Joint Mathematics Meetings in Atlanta, GA, in January 2017.

David Jerison presented the Zhu Kezhen Distinguished Lectures at Zhejiang University, Hangzhou, China, in January 2017.

William Minicozzi gave the 2017 Ritt Lectures at Columbia University in March 2017. He also gave a talk at the 2016 Clay Research Conference and Workshops at Oxford University, UK, in September 2016.

Scott Sheffield presented the Aisenstadt Chair Lectures at the Center for Mathematical Research at the University of Montreal in September 2016. In July 2016, he gave the Doob Lecture at the World Congress of Probability and Statistics at the Fields Institute for Research in Mathematical Sciences in Toronto, and he was a Saint-Flour summer school lecturer in Auvergne, France.

Peter Shor delivered the Viterbi Lecture in the Department of Electrical Engineering at the University of Southern California in March 2017.

Gigliola Staffilani gave a one-hour AMS invited address at the Joint Mathematics Meetings in Atlanta, GA, in January 2017.

Gilbert Strang delivered the Alan Tayler Lecture at Oxford University in November 2016.

David Vogan gave two of the 18th Takagi Lectures at the University of Tokyo in November 2016.

New Faculty and Promotions

Elchanan Mossel joined the department faculty as full professor with a joint appointment in the MIT Institute for Data, Systems, and Society. He comes from the University of California, Berkeley, where he was professor of statistics and computer science. Since 2014 he was also professor of statistics at the Wharton School, University of Pennsylvania, on leave from Berkeley. Professor Mossel works in applied probability whose program strongly impacts statistics. His research has resolved open problems in computational biology, machine learning, social choice theory, and economics. One of his projects led to the proof of the "Majority is Stablest" conjecture and confirmed the optimality of the Goemans-Williamson MAX-CUT algorithm. Professor Mossel received his PhD from Hebrew University in 2000 studying under Yuval Peres. Before joining the faculty at UC Berkeley in 2003, he was a fellow at the Microsoft Theory Group and a Miller Research Fellow.

Andrew Lawrie joined the faculty as assistant professor from the University of California, Berkeley, where he was an NSF Fellow and member of the Mathematical Sciences Research Institute. Professor Lawrie is an analyst. His program focuses on the asymptotic dynamics of solutions to various geometric dispersive equations, such as the wave map equation. He received his PhD from the University of Chicago in 2013 studying under Wilhelm Schlag.

Associate Professor Philippe Rigollet was awarded tenure.

Assistant Professor Jared Speck was promoted to associate professor without tenure.

Assistant Professor Gonçalo Tabuada was promoted to associate professor without tenure.

In Memoriam

Bertram Kostant

Bertram Kostant, professor emeritus of mathematics at MIT, died at the Hebrew Senior Rehabilitation Center in Roslindale, MA, on February 2, 2017, at the age of 88.

Professor Kostant joined the mathematics faculty at MIT in 1962. His field was in group representations and Lie theory. In the early 1960s he began to develop the method of co-adjoint orbits and geometric quantization, relating symplectic geometry to infinite-dimensional representation theory. Geometric quantization provides a way to pass between the geometric pictures of Hamiltonian mechanics and the Hilbert spaces of quantum mechanics. In the early 1960s Kostant proved a purely algebraic result about tridiagonal matrices. In the 1970s he used that result and the ideas of geometric quantization to study Whittaker models (which are at the core of the theory of automorphic forms), and the Toda lattice (a widely studied model for one-dimensional crystals). Kostant's work ultimately touched almost every corner of Lie theory: algebraic

groups and invariant theory, the geometry of homogeneous spaces, representation theory, geometric quantization and symplectic geometry, Lie algebra cohomology, and Hamiltonian mechanics.

Over the years he supervised more than 20 PhD students, among them the differential geometer James Simons, and served as a mentor to many postdoctoral researchers and young faculty members. He worked with great energy and success to build MIT's faculty in Lie theory and representation theory.

Professor Kostant retired from MIT in 1993 but maintained his very active life in research, travel, and lecturing at universities and conferences around the world. He continued as an active participant in the department's weekly seminars in Lie theory.

Kostant received many awards and honors. He was a 1959–1960 Guggenheim Fellow and a 1961–1963 Sloan Fellow. He was elected to the American Academy of Arts and Sciences in 1962 and to the National Academy of Sciences in 1978. He was awarded the 1990 Steele Prize of the American Mathematical Society in recognition of his 1975 paper "On the existence and irreducibility of certain series of representations." In 2001 Kostant was a Chern lecturer and Chern visiting professor at UC Berkeley. He received honorary degrees from the University of Córdoba in Argentina in 1989, the University of Salamanca in Spain in 1992, and Purdue University in 1997.

In May 2008, the Pacific Institute for the Mathematical Sciences hosted a conference, "Lie Theory and Geometry: The Mathematical Legacy of Bertram Kostant," celebrating Kostant's 80th birthday. In 2012, he was elected to the inaugural class of fellows of the American Mathematical Society. In June 2016, Professor Kostant received the prestigious Wigner Medal, "for his fundamental contributions to representation theory that led to new branches of mathematics and physics."

Bertram Kostant was born on May 24, 1928, in Brooklyn, NY. After studying chemical engineering for two years at Purdue University, he switched to mathematics, earning a bachelor's degree with distinction in 1950. At the University of Chicago, he received his MS in mathematics in 1951 and, under Irving Segal, his PhD in 1954. Between 1953 and 1956 he was a member of the Institute for Advanced Study, and in 1955–1956 he was a Higgins lecturer at Princeton University. From 1956 to 1962, Professor Kostant was a faculty member at UC Berkeley, becoming a full professor in 1962. He was a member of the Miller Institute for Basic Research from 1958 to 1959.

A memorial was held at the MIT chapel on May 11, 2017. A conference in his honor will be held in the spring 2018 term.

Administration

Professor Michel X. Goemans will follow Tomasz Mrowka as interim department head while Professor Mrowka is on sabbatical.

For AY2018, John Bush will continue as associate department head, Tobias Colding as chair of the pure mathematics committee and Peter Shor as chair of the applied

mathematics committee. Davesh Maulik and William Minicozzi will continue as co-chairs of the graduate committee in pure mathematics, and Jonathan Kelner as chair of the committee in applied mathematics. Steven Johnson and Philippe Rigollet will continue as co-chairs of the committee of undergraduate advisors.

Development

The Department of Mathematics had another successful year in reaching out and engaging alumni and friends of the department. We hosted events and faculty talks for alumni, parents, and friends, as well as stewardship events for donors.

The department successfully raised funds for student fellowships and for the renovation of Building 2, now renamed the Simons Building, with a symposium and dedication of the building held in October. In addition, the department has increased the number of donors to the Program for Research in Mathematics, Engineering, and Science (PRIMES), and is now looking to raise funds for MathROOTS, the newest addition to the PRIMES outreach program (see PRIMES section below). The department will continue to publish its annual newsletter, *Integral.*

The Simons Building

The renovation of Building 2 and its renaming as the Simons Building has brought a renewed sense of purpose to the department. The past two years have seen an uptick in graduate recruitment, and our recent faculty recruitment efforts have been quite successful, with the new and wonderful space no doubt playing a role.

On October 7, 2016, Building 2 was officially renamed the Simons Building in a day-long dedication hosted by the Institute and the department. Attendees included James and Marilyn Simons, the building project team, additional donors who made the renovation possible, colleagues, friends, and members of the MIT community. The day's events began with a symposium, "Celebrating Math at MIT," with opening remarks by Tomasz Mrowka, followed by talks by James Simons, Tom Leighton, Professor John Milnor (co-director of the Institute for Mathematical Sciences at Stony Brook University), Professor Daniel Spielman (the Henry Ford II Professor at Yale University), and Institute Professor Isadore M. Singer. Following a luncheon and building tour, the formal dedication took place under a tent in Lowell court. MIT Chairman Robert M. Millard and President L. Rafael Reif delivered opening remarks, thanking James and Marilyn Simons and the many donors for their generosity and support. Professors Bonnie Berger and Tomasz Mrowka, and graduate student Gweneth McKinley followed with talks on how their work and the department's community life had been impacted by the new spaces. Michael Sipser, former Mathematics department head and current dean of the School of Science, who had initiated and overseen the renovation, closed the dedication with lively stories of the design process.

The Simons Building then opened its spaces to all of the MIT community for an evening of refreshments, games, and entertainment. A central feature of the Simons Building is the art piece, CHORD, by Sir Antony Gormley: a beautiful polyhedral steel structure spiraling from the ground floor to the 4th floor skylight in the main lobby stairwell. It was first unveiled in March 2016.

The Department is grateful to the Institute to have been given the opportunity to honor James and Marilyn Simons, the many generous donors, talented project team, senior administration, and all who contributed to the monumental success of the renovation of Building 2.

Ann Beha Architects, the project architect, was named one of the top 50 firms of the year by *Architect Magazine* for the seventh year in a row. It was also announced this year that the Building 2 renovation was awarded the LEED Gold certification by the U.S. Green Building Council.

Simons Lecture Series

Yuval Peres, principal researcher at Microsoft Research and adjunct professor at UC Berkeley, and Martin Hairer, the Regius Professor of Mathematics at the University of Warwick in Coventry, UK, were the distinguished 2017 Simons Lecturers. The lectures began on April 24 and concluded on May 3, followed by a department dinner honoring the speakers at the Kimpton Marlowe Hotel in Cambridge.

Yuval Peres is known for his research in probability theory, ergodic theory, analysis, theoretical computer science—particularly on topics such as fractals and the Hausdorff measure—random walks, Brownian motion, percolation, and Markov chain mixing times. He holds numerous distinctions, including the Rollo Davidson Prize, the Loève International Prize in Probability, and the David R. Robbins Prize. He is a fellow of the American Mathematics Society, and was elected foreign associate of the National Academy of Sciences. Dr. Peres's Simons lecture series, titled "Surprises in Discrete Probability," focused on the partition of spheres, the geometry of high-dimensional spanning forests, and mixing times in Ramanujan graphs and random graphs.

Martin Hairer's research program lies as at the interface of probability theory and analysis. He has done major breakthrough work in developing the theory of regularity structures in the study of nonlinear stochastic partial differential equations (PDEs) and in designing analytic tools for rigorous study of the phenomenon of "universality." Professor Hairer's distinctions include the Whitehead Prize and the Philip Leverhulme Prize, the Wolfson Research Merit Award of the Royal Society, the Fermat Prize, the Fröhlich Prize, and the 2014 Fields Medal. He is a fellow of the Royal Society and a member of the Austrian Academy of Sciences, the German National Academy of Sciences (Leopoldina), and the Berlin-Brandenburg Academy of Sciences and Humanities. Professor Hairer's Simons lectures series, titled "Singular Stochastic PDEs," covered topics on bridging microscopic dynamics and macroscopic laws, quantum field theory, and a renormalization scheme for stochastic PDEs.

Building Diversity

The diversity committee, headed by Faculty Diversity Officer Gigliola Staffilani, met to discuss initiatives and review ongoing practices throughout the year. MLK Visiting Assistant Professor Ryan Hynd was a participant throughout.

Women and Minorities Profile, AY2017

	AY2016		AY2017	
	Women	Minorities	Women	Minorities
Faculty	11%	0%	8%	0%
Instructors	11%	3%	9%	6%
Graduate students*	18%	4%	18%	5%
Math majors*	32%	14%	32%	15%

*Registrar figures from the fifth-week of fall term.

During the year, the department offered a tenured faculty appointment to an outside woman faculty member. If she accepts during AY2018, it will increase our percentage of women faculty. The department will also appoint a woman scholar, Giulia Saccà as assistant professor to begin AY2018. Our postdoctoral instructorship program was at 9% women in AY2017, but saw a slight increase in underrepresented minorities from 3% to 6% from the year before. Our student women and minority percentages are the same for women, with 1% increases in minorities among our graduate students and mathematics majors between AY2016 and AY2017.

As indicated in the department's diversity statement, the department sees mathematical potential to be independent of ethnicity, gender, sexual orientation, religious beliefs, and socio-economic background. It is fully committed to increasing diversity among our faculty, postdoctoral researchers and students. The department carefully reviews applicants for these positions. In addition to participating in the MIT Summer Research Programs (MSRP), the department has long recognized the need to build a pipeline from earlier academic grades. To this end, we support numerous outreach programs geared toward women and underrepresented minorities at the high school and middle school levels, as described below.

The Mathematics Major

With nearly all MIT students taking core mathematics subjects their first two years, the department continued to explore formats to inspire more women and underrepresented minority students to consider the mathematics major, either as their primary or secondary major. The "Meet-the-Mathematician" event, held in the spring term 2016, was seen by the diversity committee as too infrequent to be effective. For AY2017, the committee decided to take advantage of the department's daily tea (for faculty, postdocs, and graduate students) and designated two teas per month as a "Tea with Mathematicians." The undergraduate attendance rate at these events continued to be low, however. For AY2018, Professor Staffilani has decided to open the department's daily teas twice per week to all undecided undergraduates and declared math majors. The main goal is for more undergraduates—in particular women and underrepresented minority students—to become acquainted with the mathematics community in a social setting and discover the community's commitment and interest in one-on-one mentoring for both academic and career development.

The Graduate Program

In summer 2016, department faculty mentored two students in the MSRP program. Susan Kemboi, an African American student at the University of Texas at Arlington, was mentored by Professor Vogan; Antonio Ruiz, a Hispanic student at Florida International University, was mentored by Professors Tabuada and Clark Barwick. Both students expressed interest in pursuing a PhD in mathematics. Ms. Kemboi mastered the background in group actions and Galois theory for her project, and Professor Vogan recommended her highly. She will enter the doctoral program in mathematics at Cornell University in fall 2017. Mr. Ruiz, who knew little about algebraic topology at the beginning of the program, came away understanding "virtually everything there is to know about delooping machines," according to Professor Barwick. He described Ruiz's mathematical development as "stunning" and provided him a recommendation for graduate study.

The MSRP program is an integral step in the consideration of women and minority students for mathematics graduate study at MIT. Through contact with our prior and current visiting MLK faculty, we continue to network with outside math faculty to identify potential undergraduates who, with additional training, might be eligible to apply to leading math graduate programs. The department would invite these candidates to the MSRP program and—for those who demonstrate strong capability—recommend them to leading programs of their choice (including MIT). For those admitted to the MIT mathematics graduate program, accommodations could be made to offer courses in the first year to fill in any potential gaps.

MathROOTS

From June 18 through July 2, 2017, the Department of Mathematics hosted its third MathROOTS summer camp program. MathROOTS offers an accelerator summer camp experience for high school students who show strong math potential and come from underrepresented minority backgrounds or underserved communities. In total, 20 African American and Latino high school students were selected nationally. The goal of the program is to expose students to beautiful yet accessible mathematics, immerse them in the MIT academic culture, and create a friendly social environment of like-minded peers and mentors.

The second MathROOTS program during summer 2016 proved effective in bringing underrepresented minority students to MIT. One African American student in MathROOTS 2015 reinvigorated his high school math club using MathROOTS problems. Thus far, 13 MathROOTS participants have enrolled at MIT in AY2017.

PRIMES Circle for High School Students

The Program for Research in Mathematics, Engineering, and Science successfully ran its PRIMES Circle section for the fifth year in a row. The program teaches a mathematical enrichment curriculum to students with underprivileged backgrounds from the Boston area. A total of 13 students from urban public high schools, including two African Americans, one Latino, and 10 female students, participated in the 2017 program. They studied advanced topics in group theory, number theory, combinatorics, and knot

theory; prepared expository papers, and delivered presentations at a mini-conference at MIT in May 2017.

The PRIMES Circle section has been very successful. In a 2016 survey of PRIMES Circle students, participants commented: "My experience in MIT PRIMES Circle has allowed me to appreciate mathematics from a new perspective and become fascinated by how beautifully simple a complex idea can become. The best part was walking out of the program with better developed critical thinking skills and a mathematical toolbox that I could apply to the real world." Another participant wrote, "To me, PRIMES Circle is a wonderful opportunity to learn what is it like to be a real mathematician."

Women in Mathematics

For the sixth consecutive year, the department hosted the annual Advantage Testing Foundation Math Prize for Girls, a national mathematics contest for middle and high school students (held September 10, 2016). Young women from the United States and Canada competed for cash prizes, resulting in 14 top-ranked students, followed by 21 highly ranked participants, from a field of 271 contestants. Hosting the Math Prize competition at MIT exposes these young women to the Institute and the mathematics department early in their academic careers. The department will continue to support hosting the Math Prize for Girls for the foreseeable future.

Girls' Angle

Women mathematics majors, graduate students, and academic staff continue to participate as mentors in Girls' Angle—a nonprofit math club in Cambridge, MA, for young women in middle school. Girls' Angle was started by one of our doctoral alumni.

Building Community for Women

The department fosters a sense of community for our female faculty, postdocs, and students through special dinners, lectures, and other events. Professor Staffilani hosts a popular Women in Math dinner at her home each year for women of the math department and women mathematicians in the greater Boston area. Approximately once a month, the department also hosts the Women in Math Luncheon, in which a senior woman mathematician is invited to talk about her career and research. Prior to AY2017, women graduate students, postdocs, and faculty were invited. This year we opened the luncheon to undergraduate female math majors. Attendance of women math majors was strong, and we anticipate continued interest.

Martin Luther King Program

Ryan Hynd of the University of Pennsylvania joined our faculty in AY2017 as an MLK visiting faculty member. Hynd is an analyst who studies PDE methods in control theory, finance, and fluid mechanics. An excellent teacher and mentor, Professor Ryan taught an analysis undergraduate seminars and co-instructed a projects laboratory. With his experience attracting more underrepresented students to the graduate program at the University of Pennsylvania, he was active on the department's diversity committee, advising members on best outreach and mentoring practices, both at MIT and at outside

institutions. The department is presently considering an MLK faculty member for AY2019.

Directed Reading Program

The department's Directed Reading Program began in January 2011 with funding from a National Science Foundation Research Training Group grant. It has been regularly offered during the Independent Activities Period in January. Modeled on a program at the University of Chicago (and other institutions), an undergraduate is paired with a graduate mentor to work through one or more mathematics texts. Underrepresented minority students are especially encouraged to apply. The overall number of participants steadily increased, from 22 participants in 2014 to 38 in 2016 to 26 in 2017, with 23% of the 2017 participants underrepresented minority and 35% female students. These percentages increased from 2016, which had 11% underrepresented minority and 29% female student participants. Funding from the NSF Research Training Group grant ended in 2016, but given its success, the Directed Reading Program will continue to be funded from the department's budget.

Ongoing Initiatives

The department maintains funding support for the Undergraduate Society of Women in Mathematics, which assists in welcoming new women mathematics majors and brings speakers on campus to describe how mathematics relates to their work both in academics and industry. The department also continues its funding support of the MIT Black Women's Alliance and the MIT Black Graduate Student Association's Ebony Affair. The department additionally provides funds to the MIT Chapter of the Society of Hispanic Professional Engineers.

The department encourages faculty and staff to attend diversity-related events. Graduate student Peter Haine and staff member Dennis Porche attended the Advancing Chicanos/Hispanics and Native Americans in Science (SACNAS) conference in fall 2016 in Long Beach, CA. This conference is now the main diversity conference for all American ethnic groups in academic and research laboratory settings. Peter and Dennis were active at the MIT booth, and Peter reviewed poster exhibits and engaged with participants who wanted to learn more about the department's graduate program. Dennis will participate again in the SACNAS 2017 conference in Salt Lake City, UT.

Education

Curriculum Updates

The department added a new version of 18.100 Real Analysis, an important introductory course in pure mathematics. Previously there were three versions, 18.100A, 18.100B, and 18.100C, where 18.100A was a less abstract version of 18.100B, while 18.100C was a version of 18.100B that included expanded instruction in mathematical writing and so allowed students to satisfy the Institute's communication requirement in mathematics (CI-M). Owing to the attraction of the CI-M credit, many students who should have taken 18.100A took 18.100C, and found themselves out of their depth academically. In

order to avert this problem, the department created a new CI-M version of 18.100A, numbered 18.100P, and renumbered 18.100C to 18.100Q.

The ongoing reform of the core 18.0N courses is being done with a view to raisnig the level of mathematical literacy across the Institute among students in science and engineering. Some five years ago, Lecturer Jeremy (Jerry) Orloff, Professor Haynes Miller, and CLE Moore Instructor Jonathan Bloom, with the support of the Davis Educational Foundation, revised 18.05 Introduction to Probability and Statistics with a view to making it more effective and relevant. The subject is now taught in the "flipped" style, using MIT's special technology-enhanced active learning classrooms. This year, Dr. Orloff revised the curriculum of 18.04 Complex Analysis with Applications, but preserved the traditional classroom style.

This year also saw the release of Professor Strang's new course, 18.065 Matrix Methods in Data Analysis, Signal Processing and Machine Learning, which attracted more than 100 students from across the Institute. 18.642 Topics in Mathematics with Applications in Finance has been expanded to include increased instruction in mathematical communication, thus allowing it to be added to our list of communication intensive offerings. In response to student demand, we have added recitations to a number of our classes, including our basic sequence in probability and statistics: 18.600 Probability and Random Variables and 18.650 Fundamentals of Statistics. Links to MIT's Institute for Data, Systems, and Society will soon result in a number of cross-listed course offerings.

The development of 18.01x represents the first step toward online versions of many of the department's core undergraduate offerings (18.01–18.06). The next course to be released onto edX is 18.03 Differential Equations, a course for which the online platform has already been developed for MITx by David Jerison, Haynes Miller, Gilbert Strang, Bjorn Poonen, Jennifer French, and Jerry Orloff, with original funding from a d'Arbeloff Grant in AY2013 and current funding from the MITx Grant Program. The department now uses the 18.03 notes on MITx as the textbook for its regular 18.03 class. The first of the three modules of 18.03 Differential Equations, specifically 18.031x Introduction to Differential Equations, was released in January 2017, and the second module is scheduled for release in the spring of 2018. After the completion of 18.03x, 18.02 Multivariable Calculus will be next in line for addition to the open online courses.

Graduate Students

There were 130 graduate students in mathematics in 2016–2017, all in the PhD program. A total of 19 students received their doctoral degrees between September 2016 and June 2017.

Following completion of their degrees, most of these graduates advance to postdoctoral positions in mathematics and related departments at other universities, which this year included positions at Boston University, Brandeis University, the University of Chicago, Columbia University, Harvard Medical School's Department of Biomedical Informatics, the University of California at Los Angeles, University of Paris XIII, the University of Michigan, and the University of North Carolina Chapel Hill. One graduate will join

MIT's Department of Electrical Engineering and Computer Science as an instructor and another will be a visitor at the Mathematical Sciences Research Institute.

Only a few members of this year's graduating class have chosen non-university jobs, with one graduate working for Amazon Research, one as a fellow at the Broad Institute, and one as a trader at Five Rings Capital.

There will be 19 new students entering the mathematics doctoral program in September 2017, including one student transferring into our fourth-year class accompanying a new incoming professor. This entering class includes four women. The department continues the policy of offering all first-year students fellowship support.

Awards

Graduate students Gus Lonergan, Jonasz Slomka, and Lucas Tambasco each received the Charles and Holly Housman Award for Excellence in Teaching for their exceptional skill and dedication to undergraduate teaching. PhD candidate Sylvain Carpentier received the Charles W. and Jennifer C. Johnson Prize for an outstanding research paper accepted in a major journal. (Sylvain was also the featured piano soloist at Tech Night at the Pops in June 2017, the first MIT PhD graduate to be the featured artist at Tech Night's 120-year history.)

Majors

The mathematics major is the third largest major at MIT, and the largest within the School of Science. During AY2017, 356 students listed mathematics as their major at the official "fall fifth week," but enrollment increased to more than 400 undergraduates by the spring term. Of these, 136 students graduated with degrees in mathematics: 97 with a first major in mathematics and 39 with a second major in mathematics. Responses to our senior survey were only partial, but of the 64 whose post-graduate plans are known, 14 will continue in graduate programs in mathematics, 10 in programs in computer science, seven in programs in physics, and another four will pursue graduate work in other fields (primarily economics). Somewhat fewer than half will be pursuing non-academic opportunities, with seven entering jobs in software engineering, three in consulting services, 10 in the financial sector, and the rest in education, engineering, and other domains. A few plan to travel or explore opportunities before deciding on next steps.

Awards

The Jon A. Bucsela Prize in Mathematics, given in recognition of distinguished scholastic achievement, professional promise, and enthusiasm for mathematics by a mathematics major, was awarded to Yibo Gao '17.

The Hertz Foundation Fellowship was won by Ofer Grossman '17, and the 2017 AMS-MAA-SIAM Frank and Brennie Morgan Prize (for outstanding research in mathematics by an undergraduate) was awarded to David Yang '17.

Putnam Triumphs

The 2016 MIT team placed fourth in the William Lowell Putnam Mathematical Competition, with one MIT student placing among the top five individual scorers, designated as Putnam Fellows. This year's Putnam team consisted of seniors Bobby Shen and David Yang and sophomore Yunkun Zhou, who was also a Putnam Fellow.

MIT students accounted for 11 of the top 25 individual scorers, and 21 of the 68 who received Honorable Mention (34% of all honorable mentions and above). Students benefited from excellent coaching by Professor Bjorn Poonen.

Undergraduate and High School Summer Research Programs

Summer Program in Undergraduate Research

In summer 2016, the department hosted its 20th Summer Program in Undergraduate Research (SPUR), a six-week intensive mathematical research experience for MIT undergraduates in which each undergraduate pursues an individual or team project with a graduate student mentor. Twelve MIT undergraduates participated in the 2016 SPUR program, mentored by eight graduate students. Lingfu Zhang and his mentor Hong Wang shared the Hartley Rogers Jr. Prize for best project.

Research Science Institute

Summer 2016 was the 24th year of the department's participation in the Research Science Institute program for gifted high school students. In all, nine graduate students mentored 10 selected high school students in the six-week program. The students came from six different states in the US as well as from Bulgaria, India, and Poland. For their research projects, students won four semifinalist awards at Siemens 2016, and two were named national scholars at the 2017 Regeneron Student Talent Search. Dona-Maria Ivanova from Bulgaria won the 4th Award in Math at the 2017 Intel International Science and Engineering Fair.

Undergraduate Research Opportunities Program

In summer 2016, the department offered math majors an enhanced type of Undergraduate Research Opportunities Program (UROP): Supervised UROP, or UROP+. Under this program, UROP+ students work on research projects full time for three summer months, meeting with their mentors individually twice a week. Fourteen students participated, mentored by 12 graduate students, producing research and expository papers posted on the UROP+ website.

Program for Research in Mathematics, Engineering and Science

In calendar year 2017, the department is participating in the seventh year of the Program for Research in Mathematics, Engineering, and Science. Locally, 25 gifted high school students from Greater Boston are working with 15 graduate student mentors on research projects or participating in reading groups in the mathematical section of PRIMES. Additionally, in the expanded PRIMES-USA math section, 19 exceptional out-of-state students selected from a national pool are conducting research projects

under the supervision of 18 graduate students, postdocs, and outside faculty via telecommunication channels.

Another section of PRIMES, PRIMES Circle, teaches mathematical enrichment curriculum to 13 promising students from Boston's urban high schools. (See the Diversity section for a more complete description.)

In May 2017, PRIMES held its seventh annual conference at MIT, where all student research projects were presented. The well-attended event demonstrates the solid success of the program. Several projects will likely lead to publication in professional journals and will be strong contenders at national science competitions for high school students. Several PRIMES students will enter MIT as undergraduates in fall 2017, and will likely continue their research through UROP.

In fall 2016, PRIMES and PRIMES-USA math students successfully completed 23 individual and group math research projects that they had worked on during calendar year 2016. Louis Golowich and Richard Zhou won 4th Prize in the 2016 Siemens Competition in Math, Science, and Technology. Aaron Yeiser won 2nd place, and Laura Pierson 6th place in the 2017 Regeneron Science Talent Search Competition; two students were finalist, and eight were national scholars. Matthew Hase-Liu won the 3rd Award and Sathwik Karnik the 4th Award in math at the 2017 Intel International Science and Engineering Fair.

Professor George Lusztig donated a significant portion of his 2014 Shaw Prize in Mathematical Sciences to establish the George Lusztig PRIMES mentorships. These are awarded each year to continuing PRIMES mathematics mentors for exceptional mentoring service in past years. The 2017 Lusztig PRIMES mentors were graduate students Lucas Mason-Brown, Andrew Rzeznik, and Guangyi Yue.

Research Highlights

Below are some of the research highlights achieved by mathematics faculty and their research groups in AY2017.

Victor Guillemin works in analysis and geometry, and has made important contribution to microlocal analysis, symplectic group actions, and spectral theory of elliptic operators on manifolds. He has authored many texts with colleagues, including Semi-Classical Analysis, with Shlomo Sternberg in 2013, which has been widely referenced.

Among recent projects, Guilllemin, along with Alejandro Uribe and Zuoqin Wang, has developed a semiclassical version of the theory of Fourier integral operators of Hermite type. Their first paper, describing the basic properties of these objects, has already appeared, and they are currently exploring applications—in particular trying to understand from this perspective the recent work of Laurent Charles and Leonid Polterovich on dislocation theorems in symplectic geometry.

Guillemin has also collaborated with Susan Tolman and Catalin Zara on equivariant cohomology. They are attempting to generalize on the Goresky-Kottwitz-MacPherson

results to torus actions that have the property that at each fixed point at most two isotropy weights are collinear.

Lawrence (Larry) Guth has been doing research in harmonic analysis using the polynomial method. The polynomial method is a tool that comes from computer science and combinatorics. He has been adapting it to the setting of restriction theory in Fourier analysis. The restriction problem is an important open problem in Fourier analysis which was raised by Elias Stein in the 1960s and intensively studied by Jean Bourgain, Thomas Wolff, Terence Tao, and others. Using the polynomial method, Guth was able to improve on the best-known bounds. This year, in joint work with Xiumin Du and Xiaochun Li, he used this approach to solve a related problem, the 2d case of Carleson's problem about pointwise convergence for solutions of the Schrödinger equation. Last year, Guth, with Jean Bourgain and Ciprian Demeter, used ideas related to the restriction problem to prove the Vinogradov mean value conjecture, a problem in analytic number theory dating back to the 1930s. As an application, this result gives sharper information about the number of solutions to diophantine equations.

Professor David Jerison is an analyst whose program includes a number of ongoing projects. In joint work with Douglas Arnold, Guy David, Marcel Filoche, and Svitlana Mayboroda (Physical Review Letters, Vol. 116, 2016), he has produced an explanation of the mechanism by which the landscape function of Filoche-Mayboroda predicts the exponential decay of eigenfunctions in disordered media. This point of view has led to improvements (by a factor of 1000) in algorithms designed to compute the behavior of light emitting diodes.

Jerison's main focus is on free boundary regularity. His work in 2015 with Ovidiu Savin developed a new method for free boundary regularity with a strong connection to the major work of James Simons on stable minimal surfaces. He has also made significant progress, joint with Nikola Kamburov, on non-energy minimizing free boundaries with a strong analogy to theorems of Colding and Minicozzi on compactness of families of minimal disks and annuli (International Mathematics Research Notices, no. 19, 2016). In January 2017, at a workshop at the Mathematical Sciences Research Institute, he gave a series of lectures unifying a wide range of variational problems, including ones that lead to free boundaries and others that lead to minimal surfaces. He also introduced a family of new conjectures that, for the first time, connect work of Simons and of Colding-Minicozzi with the KLS conjecture in high dimensional convex geometry and the "hot spots" conjecture of Jeff Rauch.

In the latest paper, just submitted for publication in an ongoing collaboration with Alessio Figalli, Jerison proves the higher dimensional analogue in Euclidean space of a fundamental one-dimensional stability estimate in additive number theory due to Freiman. Surprisingly, unlike the situation with many stability inequalities, the optimal exponent is the same in higher dimensions as it is in dimension one.

Steven Johnson is an applied mathematician who works on the influence of complex geometries (particularly in the nanoscale) on the solutions of PDEs, especially for wave phenomena and electromagnetism. These includes analytical theory, numerics, and

design of devices and phenomena. He is also known for his work in high-performance computing.

His research group works to invent and design several new types of devices and discover mathematical insights in classical nanophotonics. Among many projects, they recently proved a "diameter-bandwidth product" scaling bound for invisibility "cloaking" of objects. They also predicted a new type of embedded eigenvalue (anomalous localized state) in electromagnetism that was validated experimentally.

They have also made major strides in the theoretical modeling of electromagnetic phenomena arising from quantum and thermal fluctuations: Casimir (and van der Waals) forces, near-field thermal radiation, fluorescence, and laser linewidths. They proved exciting new analytical upper bounds for the strength of light-matter interactions. Given only the material properties (the index of refraction), independent of the shape, they can bound the potential for light scattering, absorption, spontaneous emission, and thermal radiation. In some cases, they were able to provide geometries that reach the upper bound (within a small constant factor), e.g., to obtain provably optimal nanoparticles for light absorption (which were subsequently fabricated experimentally). In the case of near-field thermal radiation, where until recently computational exploration was limited to planar structures, they showed that planar structures fall orders-of-magnitude short of the bound, which offers tantalizing possibilities for dramatic improvements via computational design, with potentially important implications for future generations of thermophotovoltaic devices.

Andrew Lawrie studies the dynamics of solutions to nonlinear wave and dispersive equations in geometric settings where the nonlinear structure is intimately tied to classical geometric notions such as curvature. In these equations, solitons (coherent solitary waves) are the basic building blocks of both global-in-time dynamics and singularity formation.

In a 2017 preprint with Jacek Jendrej, Lawrie was able to control the revolution of solutions to the critical wave maps equation near a pure 2-soliton (a superposition of two concentrating harmonic maps). Their work gave a complete classification of the dynamics, including the precise rates of concentration, for solutions with twice the energy of a harmonic map. This is the first result of its kind and it pairs naturally with the one-bubble classification obtained by Lawrie in earlier work with Cote, Kenig, and Schlag (American Journal of Mathematics, 2015). In a 2017 preprint with Casey Rodriguez, Lawrie proved that the Adkins-Nappi-Skyrme model, a physically relevant dispersive PDE, admits asymptotically stable solitons, and moreover that a conditional version of the stable soliton resolution conjecture holds. This builds on Lawrie's initial proof of the conditional large perturbation stability of the vacuum solution (Communications in Mathematical Physics, 2014), and uses techniques inspired by Lawrie's work with Kenig and Schlag (Geometric and Functional Analysis, 2014), which gave the first proof of the stable soliton resolution conjecture for a non-integrable PDE.

Elchanan Mossel is developing a theory that bridges additive combinatorics and noise stability. Additive combinatorics analyzes arithmetic structures such as arithmetic

progressions, while noise stability studies robustness of geometric structures to random perturbations. In constructing a common theory that bridges these two existing theories, Mossel is able to analyze quantitative questions which come up naturally in application areas and do not belong to any one of the specific areas. In particular, the new theory implies a strengthening of the famous theorem of Arrow in social choice, showing the impossibility of rational ranking of three or more alternatives.

As part of his work at the MIT Institute for Data, Systems, and Society, Mossel studies a number of questions in combinatorial statistics regarding the inference of seeds of randomly growing trees. He introduced a new model that sheds light on the failure of classical inference algorithms and the success of deep learning inferences for data that is generated from hierarchal models.

Andrei Neguț's research mainly concentrates on problems in geometric representation theory, an area that overlaps studies in algebraic geometry and representation theory. His results connect to areas in mathematical physics, symplectic geometry, combinatorics, and probability theory.

Over the past year, Neguț has been following two main research avenues. The first is a joint project with Eugene Gorsky and others which seeks to find algebro-geometric incarnations of Khovanov homology and related categorifications of knot invariants. The second is a project that he has undertaken, to understand how W-algebras in conformal field theory relate to moduli spaces of semi-stable sheaves on smooth surfaces. The case when the surface is A2 has been submitted for publication. The case of an arbitrary projective surface is a generalization that he has worked out more recently, and it has spawned many interesting new constructions that he plans to study in the near future.

Professor Philippe Rigollet's research focuses on understanding the fundamental limitations associated with high-dimensional statistical problems, and to develop methodology that performs optimally within these limits. Rigollet's faculty appointment is joint with MIT's Institute for Data, Systems, and Society. Rigollet's group seeks to develop methods with provable guarantees that blend tools from discrete and continuous optimization, statistical modeling, information theory, and computational complexity. Recent research areas include:

- Learning determinantal point processes: Determinantal Point Processes (DPPs) are a family of probabilistic models that arise from the study of quantum mechanics and random matrix theory found in numerous applications in machine learning, bioinformatics, and neuroscience. Rigollet's group has developed the first statistical algorithms with provable guarantees for learning DPPs.

- Optimal Transportation for Statistics: The theory of optimal transportation, introduced in the 18th century, has found new applications in computer imaging (to compute distances between images). Integrated with newfound uses of entropic regularization, Rigollet's team is investigating using entropy for statistical regularization, akin to its use in aggregation.

- Causal inference: While machine learning algorithms have been successfully employed in a wide range of applications, they seldom rely on modeling assumptions, but instead focus on optimizing prediction performance. Thus, understanding of the underlying prediction process is lacking, which is critical to fields such as biology, medicine, and sociology.

Rigollet's group is currently advancing on this problem on two fronts:

- Introducing new, average case, statistical models for causal inference producing unprecedented advances in the context of learning causal models from observational data only
- Learning from interventional data; Rigollet's group has identified a set of necessary and sufficient conditions for interventions to uniquely determine a causal system, potentially with cycles.

Professor Paul Seidel's research interests focus on studies in symplectic topology, mirror symmetry, homological algebra, and string theory. His latest program is concentrated on Lefschetz fibrations and how they might provide key information about the symplectic topology of their fibres (ample hypersurfaces). This crystallized into a conjectural description of Fukaya categories, centered on a particular nonlinear Schwartzian differential equation (a formal one with respect to the Novikov parameter). The main achievement of 2016 is that he obtained a geometric derivation of this equation, which is the main step towards proving the conjecture. If true, this would be the first nontrivial, and yet quite general, structural result about Fukaya categories.

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