



From the Chair

I would like to extend my sincerest congratulations to the class of 2021, as well as those graduate students who will complete their final public orals over the next few months. While the past two years have presented some unusual obstacles, I am proud to see our students continue to thrive academically as they rally towards their goals. I am also happy to welcome the undergraduate classes of 2019 and 2020, as well as those graduate students who have completed their PhDs since our last publication, as new members of our distinguished alumni.

Much has changed on a global scale in recent times, and the Princeton University Math Department holds no exemption. But while we find ourselves in a time of unique challenges, it is also proving to be a time of exceptional achievements. Last spring, when the university transitioned to online teaching and research in response to the COVID-19 pandemic, we found ourselves in largely unfamiliar territory. Despite this, I am pleased to report that the math department was able to leverage academic, administrative, and technological resources to swiftly orchestrate the framework for this new way of learning, which continued to improve over the 2020-2021 academic year. In addition to the facilitation of online classes, the department has also kept its seminar program active with an online schedule that matches that of previous years, and continues

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Teaching During a Pandemic

"The first indication we had of the coming disruption was at the very beginning of the spring 2020 semester when junior faculty who'd spent the winter abroad were having difficulty getting back into the country.

"Big restrictions kicked in suddenly during midterm week. At that point everyone was trying to be hopeful that life would return to normal in a few weeks, but it rapidly became clear that optimism might not be the best strategy." Dr. Jennifer Johnson, Senior Lecturer and Associate Director of Undergraduate Studies oversees the department's large, multi-section calculus and linear algebra courses, and as it became clear that the spring term would have to transition to an online format she began work with our dedicated faculty to ensure the spring semester was able to carry on and to prepare for the likelihood of a full year of virtual teaching.

Going Virtual

The immediate move online in the spring of 2020 naturally led to experimentation with teaching styles, com-

binning live lectures and office hours with pre-recorded content. Instructor Dr. Andrew Yarmola taught MAT201: "The lecture itself contained basic examples, the pre-recorded problems were usually more detailed and allowed students to focus on specific topics (and review as they saw fit). All-in-all, my sense is that the students saw more worked-out problems in live Zoom precepts and pre-recorded problems vs. a usual non-virtual year."

A variety of approaches gave us a better idea of what was and was not working. "We saw through student feedback that higher production videos did not necessarily equate to a better learning experience for the students; they much preferred videos that felt more 'real' to them, for example videos recorded at a chalkboard" recalls Dr. John Fickenscher, Associate Research Scholar and Lecturer.

While recorded course materials worked well as supplementary material to the courses, Dr. Johnson saw in mid-semester feedback that stu-

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From the Chair

from the Chair

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to cultivate academic collaboration as we adapt to these unexpected changes. It is inspiring to witness the unwavering perseverance, enthusiasm, and camaraderie of our faculty, students, and staff as they rise to meet the challenges of such an unprecedented chapter in our university's history.

This year, we welcomed one new Assistant Professor, four new instructors, and four new researchers to the department. We are also pleased to report that seven new instructors and assistant professors have accepted offers to join our junior faculty over the next couple of years. During this academic year, we were honored to have Chenyang Xu join our department as a Professor of Mathematics. We welcomed Jacob Rasmussen of the University of Cambridge, as our Minerva Distinguished Visitor in the spring of 2020, and James Maynard of the University of Oxford delivered an online series of three Minerva Lec-

tures.

The department also created a new Climate and Inclusion Committee this year. Chaired by Professor Peter Sarnak, this committee of faculty, students, alumni, and staff has begun the hard work of addressing important issues to our community. In addition to town hall meetings and directed mentorship programs, a new Horizons Lectures series began this year, where speakers are invited to give both a research talk and host a seminar on the societal impacts of mathematics with respect to diversity, inclusion, and mentorship. Our inaugural Horizons Lecturer was Trachette Jackson of the University of Michigan, who hosted a compelling panel discussion.

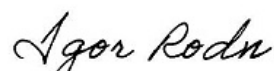
Since the last publication of *Fine Letters*, the department lost two stellar mathematicians. Professor Emeritus Goro Shimura, internationally renowned within the fields of modern number theory, arithmetic geometry and automorphic forms, passed away in May of 2019. We also lost Professor Emeritus John Conway, who passed last April. A prolific and imaginative thinker, Conway's enormous mathematical contributions will leave a lasting mark on current and future generations of mathematicians.

At the end of the 2019-2020 academic year, we celebrated the retirement of Professor Robert Gunning, who has been a member of the department since 1956. Among his many contributions to the university, Robert served as Chair of the Mathematics Department, Chief Marshall for University Convocations, and Dean of the Faculty. An extraordinary teacher, he also received the President's Award for Distinguished Teaching in 2003. He transitioned to Emeritus status last year.

This July, Yakov Sinai will also retire to Emeritus status after twenty-eight years with the department. Among his many professional achievements, Sinai's extensive work in mathematical physics and probability theory earned him the Abel Prize in 2014. He has also made a significant impact as a teacher, and has advised over 50 students throughout his career.

Members of the department have continued to receive accolades and awards in the field of mathematics. To highlight a few of many notable achievements, Aleksandr Logunov was named both a Packard Fellow and a Sloan Research Fellow, and received the New Horizons Prize; and Tristan Buckmaster received a Clay Research Award (joint with Philip Isett '13 and former Assistant Professor Vlad Vicol). Our alumni have also continued a tradition of success, with Hillel Furstenberg '58 receiving the Abel Prize, and Alex Eskin '93 taking home the Breakthrough Prize.

In closing, allow me to express my disappointment that alumni weekend events, and many end-of-year activities, are once again canceled as a result of the pandemic. The department's Alumni Reception is an important tradition, and I count myself among the many members of the department who look forward to reconnecting with alumni during this exciting time of year. Despite this set back, I know that many of you will continue to stay in touch with members of the Fine Hall family, and I look forward to welcoming you all at future events.



Igor Rodnianski
Department Chair

Department Administration

Chair

Igor Rodnianski

Associate Chair

János Kollár

Departmental Representative

János Kollár

Director of Graduate Studies

Mihalis Dafermos
Evita Nestoridi

Senior Advisors

John Pardon

Junior Advisor

Mark McConnell

Placement Officer

Ana Menezes

Faculty Appointments

Professor Chenyang Xu



The department is pleased to announce the appointment of Chenyang Xu as a Professor of Mathematics.

A leader in Algebraic

Geometry with a focus on birational geometry, Professor Xu completed his PhD here at Princeton in 2008 under the supervision of Professor János Kollár. Xu was a CLE Moore Instructor at MIT from 2008-2011, after which he took positions as an assistant professor at the University of Utah before joining Peking University as a research fellow and then a professor. Most recently Xu was a professor at MIT.

Professor Xu has received numerous awards, including the 2016 Ramanujan Prize, the 2019 New Horizons Prize in Mathematics, and the 2021 Frank Nelson Cole Prize in Algebra. Xu was elected to the 2020 class of Fellows of the American Mathematical Society for his "contributions to algebraic geometry, in particular the minimal model program and the K-stability of Fano varieties."

Senior Faculty Appointments

Two new Professors of Mathematics will join the department for the 2021-2022 academic year, June Huh and Emmy Murphy. Huh was previously the Fernholz Visiting Professor in our department and a Visiting Professor at the IAS, and Murphy was previously a Professor at Northwestern University.

2019-20 Academic Year

Daniel Álvarez Gavela
Instructor
Symplectic Geometry

Jacob Carruth
Postdoctoral Research Associate
Analysis

Duncan Dauvergne
Instructor
Probability

Michele Fornea
Postdoctoral Research Associate
Number Theory

Yusuf Bariş Kartal
Instructor
Symplectic Topology

Ben Krause
Postdoctoral Research Associate
Analysis

Nicholas Marshall
Postdoctoral Research Fellow
Harmonic Analysis

Joaquín Moraga
Instructor
Algebraic Geometry

Takumi Murayama
Postdoctoral Research Fellow
Algebraic Geometry

Eden Prywes
Postdoctoral Research Associate
Functional Analysis

Ary Shaviv
Postdoctoral Research Associate
Analysis

Sophie Spirkl
Instructor
Graph Theory

Maxime van de Moortel
Instructor
PDEs, Mathematical Physics

Jingwei Xiao
Veblen Research Instructor
Number Theory

2020-21 Academic Year

Allen David Boozer
Instructor
Topology

Alan Chang
Instructor
Analysis

Evra Shai
Instructor
Number Theory

Tristan Leger
Postdoctoral Research Associate
Analysis

Sarah Peluse
Veblen Research Instructor
Combinatorics, Number Theory

Hannah Schwartz
Postdoctoral Research Associate
Topology

John Sheridan
Postdoctoral Research Associate
Algebraic Geometry

Fan Wei
Postdoctoral Research Associate
Combinatorics

Ruobing Zhang
Assistant Professor
Differential Geometry

Faculty Retirements

Robert Gunning

Robert C. Gunning was born in Longmont, Colorado, in 1931. He is actually a sixth generation Coloradan, where his family lived long before Colorado became a state, and some of his New England ancestors date back to the Mayflower. He received his undergraduate degree in mathematics from the University of Colorado-Boulder in 1952, and went on to complete his graduate work and Ph.D. in mathematics at Princeton in 1955 under the guidance of Salomon Bochner.

Robert has been affiliated with the Department of Mathematics at Princeton for nearly his entire career. After a year as an NSF postdoctoral fellow at the University of Chicago, he joined the Princeton math department as a Higgins Lecturer in 1956. He went on to serve as an assistant professor, Sloan Fellow, and associate professor, before being appointed as a professor in 1966.

His excellence in undergraduate and graduate teaching culminated in the conferral of the President's Award for Distinguished Teaching in 2003. While the



colleagues and students who nominated him for the award praised his superb lecturing skills and profound insight into the subject matter, as one would expect, they also highlighted his sense of humor, math jokes, and positive disposition. One student in particular summarized Professor Gunning as "an inspirational combination of all the qualities that make up an excellent teacher."

In addition to his faculty appointments and teaching accomplishments, Robert has contributed extensive service to the University, and to the mathemati-

cal community as a whole. He served as the chair of the mathematics department from 1976-79, and chief marshal for University convocations for a decade before becoming dean of the faculty from 1989-1995. He was a member of the editorial board for Princeton University Press from 1969-73, and holds fellowships in the American Mathematical Society and the American Association for the Advancement of Science. Additionally, he co-chaired the AMS Summer Institute on Theta Functions (1987) and the AMS Summer Institute on Several Complex Variables (1974).

Robert has contributed greatly to the field of function theory of one and several variables, and is known for authoring many books in this area. Among other accomplishments, he introduced indigenously bundles, and found a solution to the Schottky problem in the theory of Riemann surfaces. He transferred to emeritus status last year after more than six decades of tremendous contributions to Princeton's mathematics department.

Yakov Sinai

Yakov Sinai was born on September 21, 1935 in Moscow, Russia. Raised in an academic family, Sinai was strongly influenced by his grandfather, Veniamin Kagan, who served as the head of the Department of Differential Geometry at Moscow State, where Yakov would complete his Ph.D. in 1960 under the advisement of Andrey Kolmogorov.

Sinai's professional mathematical career began in 1960 at his alma mater, Moscow State, where he served as a Scientific Researcher for the Laboratory of Probabilistic & Statistical Methods. In 1971, he was promoted to the role of Professor, which he held for over twenty years. In the same year, he also accepted a position as a Senior Researcher with the Landau Institute of Theoretical Physics at the Academy of Sciences of Russia, a position he held concurrently with his teaching roles throughout his career. Yakov's affiliation with Princeton University began in 1993, when he joined the department as a Professor of Mathematics. He also served as the Thomas



Jones Professor during the 1997-98 academic year. A prolific teacher and advisor, Sinai is known for his engaging and respectful interactions with students, and has had over 50 advisees throughout his career.

Among his many awards, Sinai received the Abel Prize in 2014, which is considered the highest mathematical honor. The Norwegian Academy of Sciences and Letters, which governs these awards, described Yakov as "one of the most influential mathematicians of the 20th century," and went on to

applaud his "numerous groundbreaking results in the theory of dynamical systems in mathematical physics and in probability theory." His other accolades include the Wolf Prize in Mathematics, the Nemmers Prize, the Henri Poincaré Prize, and the Leroy P. Steele Prize for Lifetime Achievement.

Professor Sinai is known for his work in mathematical physics and probability theory, and has an extensive list of publications in these areas, including several with his wife, Elena B. Vul, a mathematician and physicist. He is also known for the many mathematical processes and equations that are named after him, including Kolmogorov-Sinai entropy, Sinai's billiards, Sinai's random walk, Sinai-Ruelle-Bowen measures and Pirogov-Sinai theory. He transitioned to emeritus status this year after 60 years of outstanding contributions to the mathematical community as a whole, and nearly thirty years of service to Princeton University.

Faculty Memorials

Goro Shimura 1930—2019 *by Liz Fuller-Wright, Office of Communications*



Photo by Orren Jack Turner, 1964

Goro Shimura, Princeton's Michael Henry Strater University Professor of Mathematics, Emeritus, died on Friday, May 3, 2019 in Princeton, New Jersey. He was 89.

"Goro Shimura was a major research mathematician, creative and original and inspiring," said Robert Gunning, a fellow math professor. "He was a quiet presence around the department and we will miss him deeply."

He was "a true giant in the fields of modern number theory, arithmetic geometry and automorphic forms, whose pioneering papers and ideas have shaped these fields in unmistakable and enduring ways," said Jonathan Hanke, a visiting lecturer in mathematics at Princeton who was Shimura's last graduate student. "He established many deep and surprising connections between these fields and often seeded research directions with his own pioneering and foundational work."

The Shimura varieties, generalizing elliptic functions with complex multiplication, are at the center of geometric theory, said Peter Sarnak, Princeton's Eugene Higgins Professor of Mathematics. "Fundamental mathematical truths have long shelf lives, and this is especially true for Shimura's works," Sarnak said.

Shimura once said that his guiding philosophy was that many geometric

objects have a natural way of being presented other than the conventional mathematical expressions. This thinking led him to solve many longstanding problems and raise new areas of inquiry. In 1964, he formulated an important conjecture, building on the work of his friend Yutaka Taniyama, that suggested a surprising relation between elliptic and modular curves.

That conjecture turned out to be key to then-Princetonian Andrew Wiles' solution of Fermat's Last Theorem.

"Shimura was a man of the highest standards for research as well as for life in general," Gunning said. "I remember many discussions of possible appointments to the Princeton mathematics department in which a major question was whether the appointment was up to Shimura's standards."

Hanke echoed those sentiments: "He was a tireless champion of the highest standards of professional conduct for research papers and mathematical communication — a truly principled person of integrity who cared deeply about the literature, academia and the impact that compromising standards could have on the next generation of young researchers," he said. "While I have known many Fields medalists (and co-authored several papers with one), it is the highest privilege of my academic life to have been his student and to grow under the tutelage of a master like Goro Shimura. I have never met his equal and deeply treasure the time we have spent together — as adviser, then colleague and later as a friend."

Born Feb. 23, 1930, in Hamamatsu, Japan, Shimura studied at the University of Tokyo, obtaining his B.A. in 1952 and D.Sc. in 1958. He taught at the University of Tokyo and Osaka University before coming to Princeton in 1962 as a visiting professor and then joining the regular faculty in 1964. He transferred to emeritus status in 1999.

Many of Shimura's advisees have

become leading figures in their fields. "I was his last graduate student, which made our mathematical levels maximally mismatched — he was at the height of a monumental career in number theory and I was a beginning graduate student," said Hanke, a 1999 graduate alumnus. "He advised me to 'find my own problems' — difficult advice to follow, but clearly what led him to his greatness. He was willing to explore questions regardless of whether there was a pre-existing formalism there to support him."

Among many honors and awards, Shimura received a Guggenheim Fellowship in 1979, the Cole Prize for number theory in 1976, the Asahi Prize in 1991 and the Steele Prize for lifetime achievement in 1996. He is a member of the American Mathematical Society and the Mathematical Society of Japan, and he was a visiting member of the Institute for Advanced Study five times. He wrote more than 100 scholarly papers and books, including his 2008 autobiography, "The Map of My Life," and a coffee-table book about the Imari porcelain that he spent 30 years collecting: "The Story of Imari: The Symbols and Mysteries of Antique Japanese Porcelain."

"I recall him showing me around his home once," Sarnak said. "He had two desks there, one at which he worked in the morning on new research, and a second one which was devoted to polishing and preparing for publication papers, and I think this was used in the afternoons. After making a breakthrough and completing a draft of a new paper, he would put it in a drawer in the second desk for a period of a year or so to let it mature, before returning to it and presenting it to the mathematical community. Given his striking publication record, it is clear that this technique was very effective."

Shimura is survived by his wife, Chikako, his daughter, Tomoko, and his son, Haru.

Faculty Memorials

John Horton Conway 1937—2020 *by Catherine Zandonella, Office of the Dean for Research*

John Horton Conway, a legendary mathematician who stood out for his love of games and for bringing mathematics to the masses, died on Saturday, April 11, 2020 in New Brunswick, New Jersey, from complications related to COVID-19. He was 82.

Known for his unbounded curiosity and enthusiasm for subjects far beyond mathematics, Conway was a beloved figure in the hallways of Princeton's mathematics building and at the Small World coffee shop on Nassau Street, where he engaged with students, faculty and mathematical hobbyists with equal interest.

Conway, who joined the faculty in 1987, was the John von Neumann Professor in Applied and Computational Mathematics and a professor of mathematics until 2013 when he transferred to emeritus status.

"John Conway was an amazing mathematician, game wizard, polymath and storyteller who left an indelible mark on everyone he encountered — colleagues, students and beyond — inspiring the popular imagination just as he unraveled some of the deepest mathematical mysteries," said Igor Rodnianski, professor of mathematics and chair of the Department of Mathematics. "His childlike curiosity was perfectly complemented by his scientific originality and the depth of his thinking. It is a great loss for us and for the entire mathematical world."

Over his long career, Conway made significant contributions to mathematics in the fields of group theory, number theory, algebra, geometric topology, theoretical physics, combinatorial game theory and geometry.

"He was like a butterfly going from one thing to another, always with magical qualities to the results," said Simon Kochen, professor of mathematics, emeritus, a former chair of the department, and a close collaborator and friend.

Kochen went on to say that Conway

was a "magical genius," defined as a person who is not merely smarter than most people but whose mind works in highly advanced and unfathomable ways. The term was coined by the late mathematician Mark Kac to describe the physicist Richard Feynman.

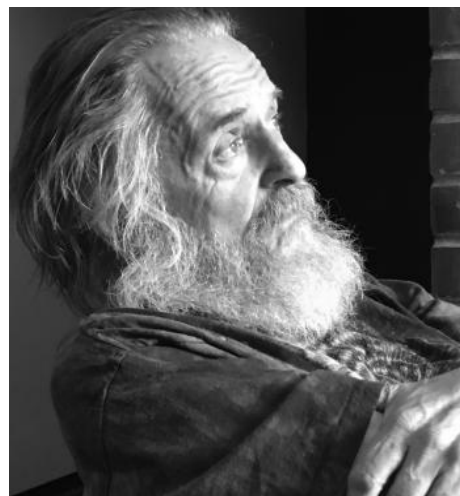
One of Conway's most well-known accomplishments was the Game of Life, which he conceived in the 1970s to describe how life can evolve from an initial state. The concept builds on ideas that trace back to John von Neumann, a pioneer of early computing, in the 1940s. Conway's game involves a two-dimensional grid in which each square cell interacts with its neighbors according to a set of rules. Over time, these simple interactions give rise to complexity.

Manjul Bhargava, who was advised by Conway during his first year as a graduate student at Princeton and who is now Princeton's Brandon Fradd, Class of 1983, Professor of Mathematics, said that Conway's love for games and magic tricks as a way to teach mathematical concepts inspired Bhargava's own approach.

"I learned very quickly that playing games and working on mathematics were closely intertwined activities for him, if not actually the same activity," Bhargava said. "His attitude resonated with and affirmed my own thoughts about math as play, though he took this attitude far beyond what I ever expected from a Princeton math professor, and I loved it."

Conway's genius led to many discoveries and accomplishments far deeper and more fundamental than the Game of Life, according to Peter Doyle, a longtime friend and collaborator, and a professor of mathematics at Dartmouth College. "People invariably describe Conway as the inventor of the Game of Life," Doyle said. "That's like describing Bob Dylan as the author of 'Blowin' in the Wind."

The achievement for which Conway



himself was most proud, according to Kochen, was his invention of a new system of numbers, the surreal numbers. This continuum of numbers includes not only real numbers such as integers, fractions and irrational numbers such as pi, but also the infinitesimal and infinite numbers.

Later, with Kochen, Conway developed and proved the Free Will Theorem in 2004 to explain principles of quantum mechanics, the branch of physics that dictates the behaviors of atoms and other elementary particles. It states that if an experimenter can freely choose what to measure in a particular experiment, then elementary particles can also freely choose their spins in order to make the measurements consistent with physical law.

The Free Will Theorem gained attention for its implication that if humans have free will, then elementary particles — like atoms and electrons — also possess free will.

Conway's numerous honors include the London Mathematical Society's Berwick Prize and Pólya Prize, Northwestern University's Nemmers Prize in Mathematics, and the American Mathematical Society's Leroy P. Steele Prize for Mathematical Exposition. Conway is a fellow of the Royal Society of London and the American Academy of Arts and Sciences.

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Faculty Awards

Noga Alon



Alon and his co-author received the 2021 Steele Prize for Mathematical Exposition. Alon also shared the 2019 Nerode Prize, given annually for a

leading paper in the field of parameterized complexity, and the ACM Paris Kanellakis Theory and Practice Award.

Daniel Álvarez-Gavela



was awarded the Vicent Castelles Prize at a ceremony October 3rd, 2019 by the BBVA Foundation and the Royal Spanish Mathematical Society.

Tristan Buckmaster



with Philip Issett *13 (now at Caltech) and former Assistant Professor Vlad Vicol (now at NYU) received a joint Clay Research Award.

Sun-Yung Alice Chang



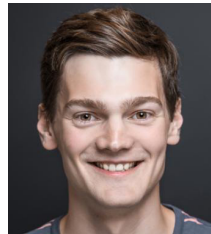
was elected as Foreign Member of Royal Swedish Academy of Sciences at its general meeting, February 12, 2020

Peter Constantin



was elected to the National Academy of Sciences in 2021.

Duncan Dauvergne



was named the 2020 Doctoral Prize Recipient by the Canadian Mathematical Society.

Shai Evra



received the 2020 SASTRA Ramanujan Prize for outstanding contributions by individuals not exceeding the age of 32.

Aleksandr Logunov



received the 2021 New Horizons Prize, was named a 2020 Sloan Research Fellow, a 2019 Packard Fellow, and received the Young

Researcher Prize from the European Mathematical Society.

Fernando Codá Marques



was named one of four 2020 Simons Investigators in Mathematics

Assaf Naor



received the 2019 Ostrowski Prize in Higher Mathematics.

Peter Sarnak



received Royal Society's Sylvester Medal for his "transformational contributions across number theory, combinatorics, analysis

and geometry."

Paul Seymour



received the Commemorative Medal from Comenius University in Bratislava

Yakov Shlapentokh-Rothman



was named a Sloan Research Fellow for 2021.

Allan Sly



received the 2019 Line and Michel Loève International Prize in Probability. Awarded every two years, it is intended to recognize out-

standing contributions by researchers in probability who are under 45 years old.

Chenyang Xu



will receive the 2021 Frank Nelson Cole Prize in Algebra.

Teaching Awards

EXCELLENCE IN TEACHING AWARDS



Gabriele Di Cerbo



Ashvin Swaminathan



Mohan Swaminathan

In 2020, Assistant Professor Gabriele Di Cerbo, and in 2021 graduate students Ashvin Swaminathan and Mohan Swaminathan were awarded the Undergraduate and Graduate Engineering Student Councils.

This student-nominated award is for a professor or TA who "was espe-

cially dedicated, taught the material clearly, and simply deserves to be recognized for the hard work he or she put into the course." These teaching awards are entirely student-run, and any professor or AI instructing an engineering, mathematics, or physics course is eligible.

Students noted that Hanselman was "approachable, clear, and genuinely caring," and "simply amazing!" They felt he "absolutely stimulated the curiosity of all the students in the class," and appreciated his discussions of more advanced topics such as the Fourier series. Students also gave him kudos on his pre-lecture videos.

Defant's students cast similar praise, saying he is "amazing at explaining the tricky material" and that "getting him as a preceptor is like winning the lottery!"

Nam's students thought him a "very dedicated, helpful, and patient" instructor, who "made multi-variable calculus about as fun as it can be."

Finally, Paz's students called him "a fantastic instructor who broke down the material before exams in a simple yet comprehensive way." They particularly noted his well-organized board work and, in the words of his students, a "true linear algebra king."

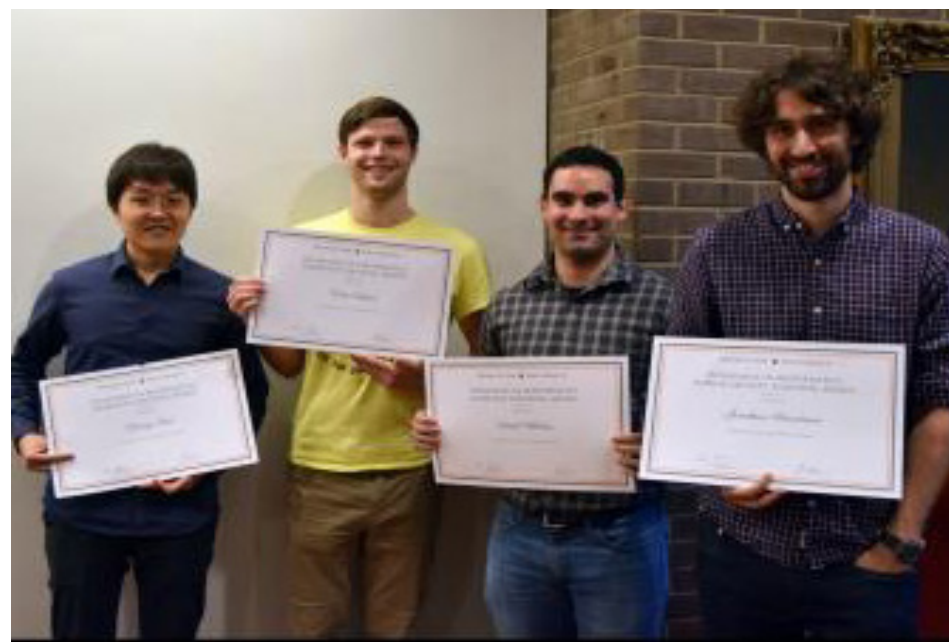
The Fall 2020 awards went to Assistant Professor Yakov Shlapentokh-Rothman and graduate student Boya Wen.

DEPARTMENT TEACHING AWARDS Graduate Student and Junior Faculty

Each year the department presents awards to junior faculty and graduate students to recognize exceptional undergraduate teaching. The awards are given by the senior faculty and are based largely on

student evaluations.

The fall of 2019 awards went to Assistant Professor Jonathan Hanselman and graduate students Colin Defant, Danny Nam, and David Villalobos Paz.



Danny Nam, Colin Defant, David Villalobos Paz, and Jonathan Hanselman received the Fall 2019 Department Teaching Awards.



Yakov Shlapentokh-Rothman and Boya Wen received the Fall 2020 Department Teaching Awards.

Climate and Inclusion

New Department Committee on Climate and Inclusion

After a series of department town hall meetings over the summer of 2020, a Climate and Inclusion Committee was formed in September 2020 to communicate, coordinate, and create activities that enhance the department's efforts to achieve its diversity and inclusivity goals.

This past fall, the committee assisted with a climate survey sent to the Department of Mathematics members to provide a confidential opportunity to share how things are going, what has worked well, and what could be better. This valuable information will give essential guidance to the department as to develop programming, provide support, and plan for the future.

A second initiative has included the Directed Reading Program. The DRP is an opportunity for Princeton undergraduates to work one-on-one with a

graduate student for a semester-long independent project. The program is open to undergraduates of any year and majors interested in exploring a mathematical topic in-depth. Students who are new to math or underrepresented in the mathematics community are especially encouraged to participate. It is an excellent way to receive personal attention and mentorship; this spring semester consisted of 22 mentorships.

This spring, the committee announced a new seminar series: The Horizons Lectures. It consists of two events, a research colloquium and a seminar discussion on the societal impacts of the mathematics profession. Speakers are invited to discuss any topic of their choice. For example, speakers might share their journey in academia, share their experiences in

mentoring students and developing curricula that meet students' needs, or discuss some efforts and challenges to building an equitable mathematical community. The inaugural Horizons Lectures were given by Professor Trachette Jackson of the University of Michigan and six panelists on April 29, 2021. To learn more about the speakers, a recorded video of the seminar discussion is available on the Climate and Inclusion webpage <https://www.math.princeton.edu/climate-and-inclusion>.

2020-2021 Committee Members

Department Chair, Ex Officio Member

Igor Rodnianski

Committee Chair

Peter Sarnak

Senior Faculty Representative

Maria Chudnovsky

Junior Faculty Representatives

Takumi Murayama

Evita Nestoridi

Graduate Student Representatives

Tara Abrishami

Shikhin Sethi

Érico Silva

Undergraduate Representative

Caoimhe Boyle

Staff Representatives

Kathleen Applegate

Lisa Giblin

Maria Mastroianni

Alumni Representative

Linh Truong *16

Alumni News

Hillel Furstenberg *58, Hebrew University of Jerusalem, and graduate student of Salomon Bochner at Princeton, received the 2020 Abel Prize "for pioneering the use of methods from probability and dynamics in group theory, number theory and combinatorics." He shares the prize with Gregory Margulis of Yale.

Alex Eskin *93, the University of Chicago's Arthur Holly Compton Distinguished Service Professor, received the 2020 Breakthrough Prize in Mathematics "for revolutionary discoveries in the dynamics and geometry of moduli spaces of Abelian differentials, including the proof of the 'magic wand theorem' with Maryam Mirzakhani."

Carolina Araujo *04, a researcher at the Institute for Pure and Applied Mathematics (IMPA) in Rio de Janeiro, Brazil, received the 2020 Ramanujan Prize for Young Mathematicians from Developing Countries.

Maggie Miller *20 and **Georgios Moschidis *18** have been named 2021 Clay Research Fellows. Four Clay Research Fellowships were awarded this year on the basis of exceptional quality of the candidates' research and their promise to become mathematical leaders.

Miller will spend her four-year fellowship at Stanford while Moschidis will return to Princeton to spend his two-year fellowship here.

Special Events

Minerva Distinguished Visitor & Minerva Lectures

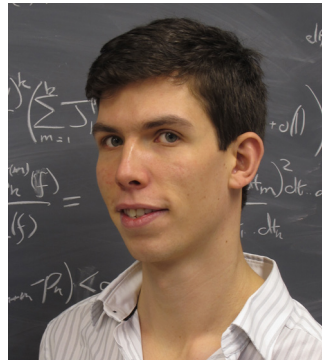
While in-person events are still restricted at Princeton, we were pleased that we were able to host both a Minerva Distinguished Visitor and Minerva Lecture series virtually this year.

Jacob Rasmussen, currently a Reader in Geometry at the University of Cambridge and member at the Institute for Advanced Study, and a former Princeton undergraduate student (class of 1998) and faculty member (Veblen Research Instructor, 2003-05; Assistant Professor, 2005-07), was appointed as our spring Minerva Distinguished Visitor. Rasmussen delivered a six-part Minerva mini-course on "aspects of the HOMFLY-PT polynomial and its categorification, with an emphasis on geometry."

We were also pleased that James



Jacob Rasmussen



James Maynard

Maynard, Research Professor at the University of Oxford, was able to deliver a series of three Minerva Lectures on his work with prime numbers, originally scheduled to happen last April in Princeton.

We regret that we were not able to host either Maynard or Rasmussen on campus this year, and we are grateful to their willingness to contribute to our research program virtually. All of their virtual talks were extremely well at-

tended, and are available to watch on the department's YouTube channel.

The Minerva programs are made possible because of the generous support of the Fernholz Foundation, and we hope we are able to continue these fantastic programs in person next year.

Watch these lectures on



Minerva Lectures
Horizon Lectures
Conference talks
Faculty profiles

math.princeton.edu/youtube

Horizon Lectures

The Horizons Lectures were founded this year as part of the department's Climate and Inclusion Committee. The series consists of two events, a research colloquium as well as a seminar discussion on the societal impacts of the mathematics profession with the following goals:

- To discuss issues of diversity and inclusion in STEM fields.
- To provide career advice to graduate students and junior faculty.
- To promote the work of mathematicians from underrepresented groups.

Speakers are invited to discuss any topic of their choice. For example, speakers might share their own journey in academia, share their experiences in mentoring students and developing curricula that meet students' needs, or discuss some efforts and challenges to building



Trachette Jackson

an equitable mathematical community.

The department was honored to have Trachette Jackson of the University of Michigan as our first Horizon Lecturer.

Professor Jackson, who specializes in Computational Cancer Research or Mathematical Oncology, delivered a PACM Colloquium on April 26, titled

"Turning cancer discoveries into effective treatments with the aid of mathematical modeling".

For the second part of her Horizons series, Professor Jackson hosted a panel discussion, "A Conversation with Thought Leaders who are Transforming Mathematics through Diversity, Equity, and Inclusion" with Ron Buckmire, Occidental College; Erika Camacho, Arizona State University and the National Science Foundation; Edray Goins, Pomona College; Suzanna Sindi, UC Merced; Talitha Washington, Clark Atlanta University; and Michael Young, Iowa State University.

Professor Jackson's panel shared their individual journeys in academia, with insights into their experiences as minority members in their academic communities.

Going Virtual

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dents found traditional live lecture time — even through Zoom — to be the most effective, “many instructors moved away from small group sessions, replacing it with the whole class working through problems all together in Zoom with the instructor serving as scribe/guide.”

The Personal Connection

A major difficulty in online teaching was recreating the personal connection with students and recognizing those that were struggling. Professor Robert Gunning retired at the end of the 2020 academic year, and that spring semester was his last time teaching an undergraduate class: “The major problem was getting the students to react and ask questions and make suggestions with the ease that was possible while in the same room. I did not try simply recording an hour lecture and leaving that to the students to follow at their leisure; but it is always surprising what difficulties in understanding the material do arise, many of which can be handled quickly

and most effectively by a bit of give and take between student and teacher.”

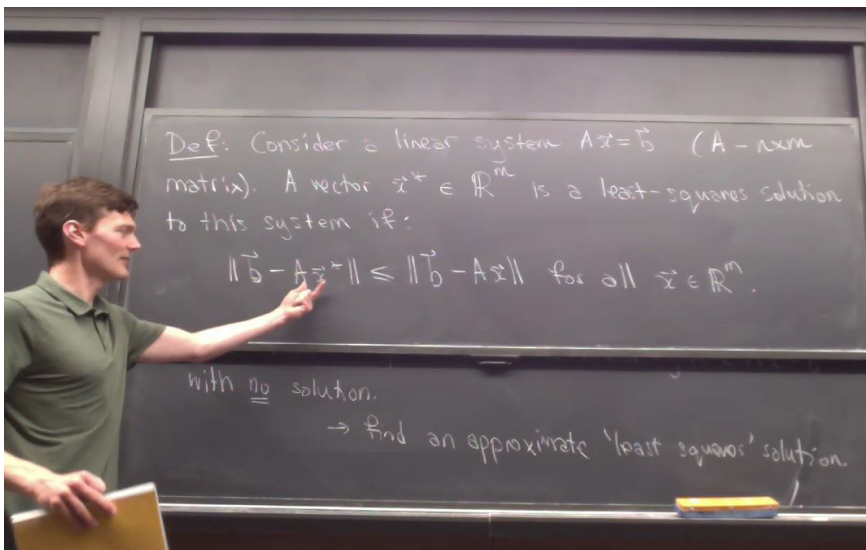
“Office hours were critical during the pandemic”, emphasized Dr. Mark McConnell, Senior Lecturer and Junior Advisor. “Teaching often uses the Socratic method, where the student asks questions, and in response the instructor asks more questions to get the student thinking in the right direction. Office hours on Zoom makes the Socratic method work, because the instructor and student can see each other's faces as they talk in real time. An added bonus was seeing the decorations and posters in the students' rooms; this broke the ice in conversation, and it gave a hint about the students' personalities.” Instructor Dr. Casey Kelleher found connecting one on one with students in office hours “gave feeling of normalcy and hanging out, and allowed me to occasionally check in about how students are doing mentally too.”

The department also expanded its summer course offerings through the Freshman Scholars Institute in 2020,

which introduced oral examinations as a supplement to written exams. Dr. Fickenscher found that “oral exams were the most surprising and rewarding experience for both students and me personally. These opportunities allowed us to connect with students in a much needed way and fostered better engagement through other course channels.” Dr. Yarmola agrees: “(1) it helped students prepare for the written portion and (2) it really helped mitigate the lack of a face-to-face contact in lecture.”

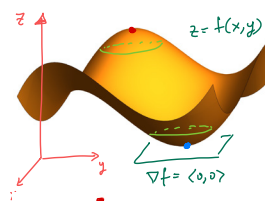
Help from our undergraduate course assistants (UCAs) was also essential, and in fall 2020 we hired a larger than usual number. The UCAs held sessions at a wide range of times every week, including times when students in Europe or Asia would be awake. And to help bridge the digital divide some UCAs volunteered to be social chairs for informal meetings outside of class with other students and took the initiative and gave an introductory workshop on LaTeX.

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Optimization of Multivariable Functions

Local Extrema & Critical Points



Goal: given $f(x, y)$ defined over a region D , find the maximum and minimum values of f over D .

Idea: First find all **local** maxima and minima.

Def: At an interior point (a, b) of D , we say that $f(a, b)$ is a

- **local maximum** if $f(a, b) \geq f(x, y)$

- **local minimum** if $f(a, b) \leq f(x, y)$

for all domain points (x, y) in a small open disk around (a, b) (called local extrema).

Observation

Local extrema occur at points where either:

- we have a horizontal tangent plane

Local extrema at non-diff pts.
 f not diff
 -> local minima

Faculty tried many ways of online teaching. Instructor Duncan Dauvergne (left) spent spring recess 2020 recording the rest of his semester's lectures alone in a Fine Hall classroom, while instructor Andrew Yarmola used an iPad to record videos for his students to watch before live classes on Zoom.

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Eager to Return

At the beginning of the spring 2020 semester no one would have dreamed of the drastic and rapid changes that would soon be necessary in the fight against the pandemic, and it is a testament to the hard work of faculty and students that our curriculum was able to carry on as it did.

While most will agree that online teaching is no substitute for the personal connections developed in Fine Hall, both in the classrooms and the common room, the past 18 months did spur pedagogical innovation that will outlast

the pandemic. For example, the department has an online exam review tool for students, and we plan to integrate video content created over the last year into the site as guided examples.

The University is committed to returning to in-person teaching in the fall of 2021, and our faculty are eager to reunite with our students and to reconnect in a way we have learned cannot be replicated through

a computer screen; as Professor Gunning put it, the “give and take between student and teacher”.



Professor Gunning, who retired last year, taught his last undergraduate classes via Zoom.

Conway

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Conway was born in Liverpool, England, on December 26, 1937. He received his B.A. from Cambridge University in 1959 and his Ph.D. from the same institution in 1964. He was a faculty member at Cambridge until he came to Princeton.

Peter Sarnak, Princeton’s Eugene Higgins Professor of Mathematics, recalls that “an extrovert by nature, John liked to be at the center of mathematical discussions and he enjoyed thinking and inventing on the spot,” Sarnak said. “To this end he gave up his regular office in the Princeton mathematics department and moved into the big common room where he could always be found holding court on the latest (often his!) mathematical development or invention. On days of little mathematical news he would be challenging others to mathematical games or puzzles and now that I think of it, I can’t recall any instance where he did not win.

“The mathematical world has lost a very special person but we are much richer for all that he gave us.”

“He was really without exaggeration a genius, absolutely” said Joseph Kohn,

professor of mathematics, emeritus, and a former chair of the department. “He knew so many things and he was interested in all aspects of mathematics and science. He was an enthusiastic teacher; he liked to share his knowledge and discuss things. He was very playful, and always ready to have a game, many of which he invented himself.”

“He moved into the common room where he could always be found holding court”

Kohn related a time when Conway had committed to giving a large public lecture and on the way to the lecture, asked his companions what topic he should cover. Upon deciding on the topic in the car, Conway successfully gave the lecture without any additional preparation.

Conway combined playfulness with a mastery of esoteric information, several who knew him commented.

Conway’s wife, Diana, first met Conway in 1996 in a coffee shop on Witherspoon Street in Princeton where they were both regular morning customers.

The two discovered that they shared a love of games and became friends. At the time, Diana worked at the University bookstore and though not a mathematician, enjoyed math and later became an accountant. They married in 2001.

“John was the most fascinating human being I’ve ever met,” said Diana Conway. “He was not only interested in math, he was interested in everything.”

Diana Conway described John Conway’s willingness to talk to anyone interested in mathematics, whether another university professor or a hobbyist with an interesting theory or discovery.

“There were always strange characters showing up at our house, joining us for dinner, or sitting with John out in the back garden,” said Diana Conway. “He would get buckets and buckets of fan mail.”

Conway is survived by Diana Conway and son Gareth. He is also survived by sons Alex and Oliver from his second marriage to wife Larissa; and daughters Susie, Rosie, Ellie and Annie from his first marriage to wife Eileen Howe. He is also survived by three grandchildren and six great-grandchildren.

Undergraduate Program

Program updates

Course Placement

Beginning in the 2019 academic year all placement into calculus and linear algebra courses was consolidated into a new 2-day placement and orientation workshop series, MAT INFO.

Dr. Jennifer Johnson, Associated Director of Undergraduate Studies describes that, "students in these workshops work through example problems with instructors so that they have a better understanding of how each class works, how they differ from high school classes, and how their preparation compares to other students so that they can accurately place themselves. This has been a very successful program, and would not have been possible without the extensive efforts of Michelle Matel, Undergraduate Administrator, and the dedicated instructors leading these workshops."

Exam Archive

Over the last several years the department has developed an online database of exam problems, along with answers, hints, and fully detailed solutions. This archive is searchable and allows students to work independently to review and synthesize the ideas and techniques they are learning in class. The archive is fully established for single variable calculus and has been a much appreciated study tool. We are currently expanding the archive to include multivariable calculus this summer and will soon work on incorporating linear algebra material.

Adding video content to this system had been planned well before the past difficult year, and we are working to incorporate the large video library created for classes into this system.

Sophomore Open House

In the spring the department usually hosts a special tea to welcome sophomores interested in the math major.

As Junior Advisor Dr. Mark McConnell had to recreate this tradition online. "I made a video summarizing what I would have said at the tea, and Michelle Matel, our Undergraduate Administrator, created a very informative document on the major including post-graduate paths for math students. The Open House was a live Zoom meeting for sophomores. Michelle Matel and I shared information about the department, and two older math majors spoke."

While this online material is no substitute for the connections we can make in person, Dr. McConnell notes that "the website has proved valuable for Princeton Preview, the recruiting event for high-schoolers who have been accepted to Princeton, as well."

Alice Lin '20



has been selected as one of this year's Churchill Scholars and has been selected as an Honorable Mention of the 2020

AWM Alice T. Schafer Prize.

Lin is one of 15 Churchill Scholarship winners this year who will spend a year studying at the University of Cambridge while living at Churchill College, which focuses on STEM subjects. She plans to complete Part III of the Mathematical Tripos, which confers a Master of Advanced Study in mathematics. The Churchill Scholarship pays for a year of tuition and fees, living expenses,

travel, and at times provides a research grant. The program is administered by the Winston Churchill Foundation of the United States.

The AWM's Alice T. Schafer Prize was established in 1990 and is named for AWM former President and one of its founding members, Alice T. Schafer, who contributed a great deal to women in mathematics throughout her career. Lin's citation for this award notes that through her research, she has demonstrated "great potential to become a successful mathematician in the future."

Isabella Khan '21



Undergraduate math major Isabella Khan has been awarded a Goldwater Scholarship, an annual award for

outstanding undergraduates interested in careers in mathematics, the natural sciences and engineering.

One- and two-year Goldwater Scholarships cover tuition, fees, room and board up to a maximum of \$7,500 per year. Khan was one of the 396 winners for 2020, selected from a field of 1,343 nominees. The scholarship program honoring Sen. Barry Goldwater was created as part of the Barry Goldwater Scholarship and Excellence in Education Foundation, a federally endowed agency instituted by an act of Congress in 1986.

Graduate Program

Graduate Student Profile: John Anderson



My interests lie in hyperbolic partial differential equations, which often arise when modeling things that exhibit wave-like phenomena. Examples include

the compressible Euler equations describing gas dynamics, Maxwell's equations describing electromagnetic radiation, and the Einstein equations of general relativity. During my time as a graduate student here, I have mostly studied stability properties of special solutions to hyperbolic equations. I was also an undergrad here, and returned for grad school after two years in Switzerland. I first learned about hyperbolic equations in a class taught by my senior thesis advisor, Sergiu Klainerman, who went on to be my PhD advisor as well. Since very early on, I have been particularly captivated by the connections between hyperbolic equations and other areas of math, such as harmonic analysis and differential geometry.

I'm very lucky to have been able to study here because of the vibrant community focused on hyperbolic equations led by Mihalis Dafermos, Sergiu, and Igor Rodnianski. I learned a great deal from being able to meet and work with the people in this community. I also made countless other friends among the students, faculty, and staff in Fine Hall, and also among the many visitors who would come through in pre-pandemic times. All of these factors contributed to an outstanding experience at Princeton. My time was more productive, more enjoyable, and ran much more smoothly than I could have imagined, and I am grateful for all of the fond memories I will leave Princeton with. I will without a doubt be on the lookout for excuses to return and visit in the future.

Director of Graduate Studies — Mihalis Dafermos



Another pandemic year has come and gone. It has been a difficult year for all members of our department, but especially

for our graduate students, whether they be first-years having to adjust to Princeton graduate-student life without actually being in Princeton, post-generals students trying to get their research off the ground without the usual stimulating intellectual climate of Fine Hall, or students towards the end of their Ph.D., who had to face the prospect of applications in a very uncertain world. It is reassuring that, despite these difficulties, we have done our best to carry on. As the academic year draws to a close, let us hope that the recent glimpses of normality are indeed a signal of a fully in-person Fall 2021.

In this unusual year where we have had to learn to do things a little bit differently, let me single out for special thanks our graduate student committee, in particular, for their essential assistance in putting together the virtual open house we held in March. One of the reasons that we will be welcoming such a large class of incredibly talented new students next year, from a wide variety of backgrounds from all over the world, is undoubtedly due to the effort graduate students made to engage with the prospectives at our two-day online event, which included both scientific and social interactions with students and faculty over zoom and gathertown, and collaborative games and other activities. Faculty pitched in too of course, but I think the success of

the event is primarily due to the initiative of our own graduate students.

This past year in fact saw a record number of applications to our graduate program. (Many thanks to those faculty who participated in the Committee that read through all these additional applications...) The increase in applications may in part be due to the fact that, in view of the pandemic, we waived the usual GRE requirement (both subject and general). In our highly selective program, the GRE has never been the primary criterion for admission, and there is a lot of lively discussion in the department, among both faculty and graduate students, about its merits, with a variety of opinions having been expressed concerning its pros and cons. In the end, we have decided to continue to not require the GRE in our admissions process for this coming year—and for a suitable period in the future—so as to better understand how to make our graduate selection process the best possible. Faculty and students are always welcome to discuss with me their thoughts on this issue!

In closing, on behalf of myself, our Assistant DGS Evita Nestoridi, and our Graduate Program Administrator Jill LeClair, let me end with a special congratulations to all our finishing graduate students: We very much hope that the memories of Princeton that remain with you are not of the empty Fine Hall of this past year, but of the lively Fine Hall that you got to know in the first years of your graduate studies here. It is to that Fine Hall which we hope to be able to welcome you back often; you should always consider it as your academic home!

Ph.D.s Awarded 2019–2021

Levent Alpöge

“Points on Curves”, advised by Bhargava
Columbia University/NSF Postdoctoral Research Fellow

John Anderson

“Stability results for nonlinear hyperbolic equations”, advised
by Klainerman
Stanford University/Postdoctoral Scholar

Eric C. Chen

“Some regularity properties for two equations arising from flows”,
advised by Chang
UC Santa Barbara/Postdoctoral Research Assistant

Irving Dai

“Involutive Heegaard Floer homology and homology cobordism”,
advised by Szabó
MIT/NSF Postdoctoral Research Fellow

Amitesh Datta

“On the Burau representation of the braid group B_4 ”, advised
by Ozsváth
Princeton University/Lecturer

Alexandros Eskenazis

“Geometric inequalities and advances in the Ribe program”, advised
by Naor
Trinity College, Cambridge/Junior Research Fellow

Fabian Gundlach

“Parametrizing extensions with fixed Galois group”, advised
by Bhargava
Harvard University/Benjamin Peirce Fellow

Michael Jemison

“Polyfolds of Lagrangian Floer theory in all genera”, advised
by Hofer (IAS)
Center of Mathematical Research, Montreal/Canada Research Fellow

Zhaorong Jin

“On certain families of special cycles on Shimura varieties”, advised
by Skinner
Citadel Securities/Quantitative Researcher

Joonhyun La

“On the models of the fluid-polymer systems”, advised by Constantin
Stanford University/Szego Assistant Professor

Holden Lee

“MCMC algorithms for sampling from multimodal and changing
distributions”, advised by Arora (COS)
Duke University/Philip Griffiths Research Assistant Professor

Lena Ji

“Topics on algebraic varieties in arbitrary characteristic p ”, advised
by Kollár
University of Michigan/Assistant Professor and Research Fellow

Maggie Miller

“Extending fibrations of knot complements to ribbon disk complements”,
advised by Gabai
MIT/NSF Postdoctoral Research Fellow

Dong Hoon (Danny) Nam

“Phase transition of epidemics on random graphs”, advised by Sly
Quantitative Researcher

Zipei Nie

“On (1,1)-knots and L-space conjecture”, advised by Szabó
HiSilicon (of Huawei Technologies, China)/Senior Researcher

Federico Pasqualotto

“Nonlinear waves in general relativity and fluid dynamics”,
advised by Constantin & Dafermos
UC Berkeley/Morrey Visiting Assistant Professor

Congling Qiu

“The Gross-Zagier-Zhang formula over function fields”, advised
by Zhang
Yale University/Gibbs Assistant Professor

Akash Sengupta

“Geometric invariants and geometric consistency of Manin’s
conjecture”, advised by Kollár
Columbia University/Ritt Assistant Professor

Antoine Song

“In search of minimal hypersurfaces”, advised by Codá Marques
UC Berkeley/Clay Fellow

Daniel Stern

“Variational theory and asymptotic analysis for the Ginzburg-
Landau equalities and p -harmonic maps”, advised
by Codá Marques
University of Toronto/Postdoctoral Fellow

Jun Su

“Coherent cohomology of Shimura varieties and automorphic
forms”, advised by Taylor (IAS)
University of Cambridge/Research Associate

Maya Thackeray

“A Birch and Swinnerton-Dyer formula for high-weight modular
forms”, advised by Skinner
University of Pretoria, SA/Lecturer; Postdoctoral Research Fellow

Siyi Zhang

“Some problems in four-dimensional conformal geometry”,
advised by Chang
University of Notre Dame/Visiting Assistant Professor

Fan Zheng

“Long term regularity of some periodic nonlinear dispersive
equations”, advised by Ionescu
University of Madrid/Postdoctoral Research Assistant

Ziquan Zhuang

“Birational superrigidity and K-stability”, advised by Kollár
MIT/CLE Moore Instructor