Fine LETTERS

Spring 2018 • Issue 7

Department of
MATHEMATICS
Princeton University

Letter from the CHAIR

Congratulations to the 33 graduating members of the class of 2017 and the 9 graduate students who are now *17. Thank you for reading the 2018 edition of Fine Letters!

As I write these words, students are scrambling to finish their senior and Ph. D. theses, with graduation a distant goal, but I am looking forward to congratulating 34 new math grads, including a record 10 women, as well as 18 graduate students who are expected to complete their final public orals this spring or summer.

This year we welcomed Noga Alon (joint with PACM) as our newest professor, as well as 7 new junior faculty members and 6 postdoctoral researchers.

Professors Elliott Lieb and Gang Tian both retired this year. Giants in their fields, Prof. Lieb joined our Department (joint with Physics) in 1975 while Prof. Tian has been with us since 2003. Speaking of former faculty members, it brings me great pleasure to congratulate Robert Langlands, professor emeritus at the Institute for Advanced Study, for winning the Abel Prize. The Abel committee cited his famous letter to André Weil (precursor to what's now known as the Langlands program) written as an Associate Professor in our Department.

We were honored to host Umberto Zannier as our fall Minerva Lecturer and Laure Saint-Raymond, Demetrios Christodoulou, and Paul Seidel as our Minerva Distinguished Visitors. They

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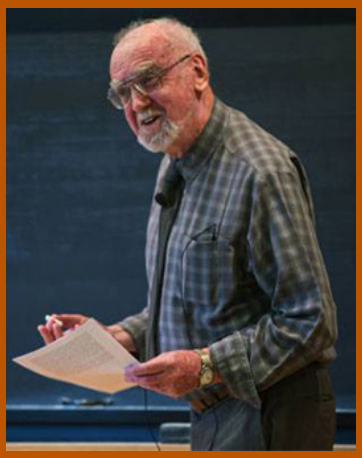
Former Faculty Member ROBERT LANGLANDS RECEIVES ABEL PRIZE

Robert P. Langlands has been awarded the 2018 Abel Prize "for his visionary program connecting representation theory to number theory;" work done while he was a 30-year-old Associate Professor at Princeton.



Previous Abel Prize recipients include professor emeritus Andrew Wiles, John Nash, and professor Yakov Sinai.

INSIDE this issue

UPCOMING...

ICM 2018
RIO DE JANEIRO
INTERNATIONAL CONGRESS OF MATHEMATICIANS

August 1–9

The Biennium of Mathematics 2017-2018, formally proclaimed by the Brazilian national parliament, encompasses a wide range of outreach initiatives throughout the country, and raised the profile of mathematics in mainstream media to totally unprecedented levels.

—Marcelo Viana
Chair, ICM 2018 Organizing Committee

Program Committee Chair:
János Kollár

Princeton Invited Speakers:

Alice Chang, Emmy Noether Lecture
Assaf Naor, Plenary lecture
John Pardon, invited section lecturer
Amit Singer, invited section lecturer
Allan Sly, invited section lecturer
Alexandr Logunov (starting Sept. 1), invited section lecturer
June Huh (IAS, Visiting Associate Research Scholar), invited section lecturer

Faculty Appointments

Department Welcomes
PROFESSOR NOGA ALON

The Department is pleased to welcome Noga Alon as our newest professor, joint with the Program in Applied & Computational Mathematics. A world leader in the field of combinatorics, Professor Alon's contributions include solutions to longstanding questions on universal graphs, epsilon-nets, and the structure of large graphs and property-testing, among many others.

Professor Alon obtained his Ph.D. in 1983 from the Hebrew University. Following a two-year postdoctoral position at MIT he joined Tel Aviv University, where he remained until coming to Princeton. He is also currently a member of Microsoft Research, Israel. He has supervised over 20 doctoral students in mathematics and computer science, many of whom are now world-leading faculty members at various institutions. He has received many honors and awards, including the Erdös prize (1989), the Feher prize (1991), tho Pólya Prize (2000), the Bruno Memorial Award (2001), the Landau Prize (2005), the Gödel Prize (2005), the Israel Prize (2008), the EMET Prize (2011) and the Dijkstra Prize (2016).

from the Chair

...continued from page 1

all gave beautiful and stimulating lectures.

Professors Igor Rodnianski and Allan Sly were named 2017 Simons Investigators in Mathematics, while professor Amit Singer was named an Investigator in Math+X, a program designed to encourage novel collaborations between mathematics and other fields. We are pleased that Andrea Bertozz '87 *91 was the other Math+X winner. Professor János Kollár won the Shaw Prize, John Pardon won a Packard Fellowship, and Assaf Naor won the Nemmers Prize. Seven of our Princeton faculty and researchers were named invited speakers for the upcoming International Congress of Mathematicians in Rio.

Instructor Hansheng Diao and graduate student Kathleen Emerson received the Excellence in Teaching Awards by the Undergraduate and Graduate Engineering Student Councils—this is the third year in a row for Hansheng! Hansheng and assistant professor Ana Menezes received this year's departmental junior faculty teaching award and our graduate student teaching awards went to Charles Stibitz and Anibal Velozo. This is the fifth year the Department has awarded these prizes highlighting and encouraging excellence in undergraduate instruction.

Our undergraduate Putnam Competition team had another outstanding year, with our team of Murilo Zanarella, Zhuo Qun (Alex) Song, and Xiaoyu Xu coming in third place overall.

With uniformly acclaimed results, Fine Hall went through its first major refurbishment since opening in 1969. Our Common Room and every office received essentially all new furniture and carpeting, though some of the beautiful and solid furniture from the old Fine Hall is still in use. Our administrative area was remodeled providing a brighter and more welcoming reception area. This project required everyone and their possessions to move out and back during a three month period. Thanks are due to Professor Igor Rodnianski for spearheading this effort. Detailed oversight, constant attention to big and little things and lots of hand holding by the staff made this all very bearable.

I close by thanking the Fernholz Foundation and the Class of 1971 Endowment for their ongoing support of the Department and thanking the Advisory Council for their valuable advice and encouragement.

I hope that all of those reading this newsletter think back on their time in Fine Hall as one of discovery and growth. I am always happy to hear from alumni and former members of the Department, so please do not hesitate to get in touch.

David Gabai *77 *80
gabai@math.princeton.edu

Faculty Appointments

Tristan J. Buckmaster

Assistant Professor

Analysis

Tristan J. Buckmaster joins the Department after three years at the Courant Institute of Mathematical Sciences, New York University, where he was an Instructor and Visiting Assistant Professor. He completed his PhD at the University of Leipzig/Max Planck Institute for Mathematics in the Sciences, Leipzig, Saxony, Germany in 2014. He is a recipient of the Leipzig Promotionspreis (PhD Prize) by the Research Academy Leipzig.

Gabriele Di Cerbo

Assistant Professor

Algebraic Geometry

Gabriele Di Cerbo joins the Department after serving as the Ritt Assistant Professor, Department of Mathematics, Columbia University, for four years. He earned his PhD in Mathematics from Princeton University in 2013 and has a Bachelor of Science degree, 2008, and Master in Mathematics degree, 2009, from the University of Rome, La Sapienza, Italy.

Jonathan Hanselman

Assistant Professor

Low-dimensional Topology

Jonathan Hanselman was an RTG Instructor at the University of Texas at Austin for three years before arriving to Princeton. He completed his PhD in 2014 at Columbia University and his MA Mathematics in 2010 and his BS in Mathematics and Physics in 2009.

Yueh-Ju Lin

Instructor

Geometric Analysis, Differential Geometry, and PDEs

Yueh-Ju Lin joined Princeton after three years as a Postdoctoral Assistant Professor, Department of Mathematics, University of Michigan. She also served as a Postdoctoral Fellow at the Mathematical Sciences Research Institute, Berkeley and as a Research Assistant at the Institute of Mathematics, Academia Sinica, Taiwan. She received her PhD and MS in Mathematics from University of Notre Dame and her BS in Mathematics from National Taiwan University. She received the Striving for Excellence in Teaching Certificate, Kaneb Center for Teaching and Learning, University of Notre Dame.

Oanh Nguyen

Instructor

Analysis, Combinatorics, and Probability

Oanh Nguyen was previously an Instructor at Yale University, where she received her PhD in mathematics. She received her MS in Applied Mathematics from Tours University, France and her BS in Mathematics and Computer Science at the University of Science, Vietnam. She is the recipient of the James D. Skinner graduate fellowship.

Yunqing Tang

Instructor

Arithmetic Geometry and Number Theory

Yunqing Tang received her PhD in Mathematics from Harvard University in 2016 and holds a BS with honors in Mathematics from Peking University. She was awarded the AWM Dissertation Prize, given for outstanding PhD dissertations by female students in the US, in 2016. Additionally, she received the New World Mathematics Award, Gold Medal for her PhD thesis, awarded for outstanding Chinese mathematics students worldwide, 2016. She received a Merit Research Fellowship at the Graduate School of Arts and Sciences, Harvard University (2015-2016).

Joseph Allen Waldron

Instructor

Birational Geometry

Joseph Allen Waldron was a Postdoctoral Researcher at Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland, 2016-2017. He received his PhD, Mathematics, July 2016 at Queens' College, University of Cambridge, UK.

Faculty Retirements

Professor Emeritus ELLIOTT LIEB

By Michael Aizenman

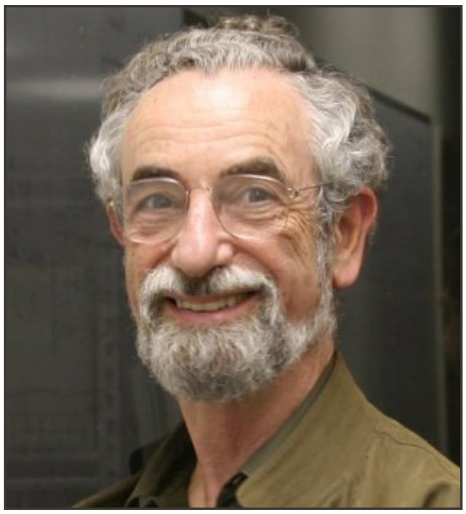
Elliott H. Lieb was born in Boston in 1932, and at the age of five moved to the Bronx where he was educated in the New York City school system, graduating from the Bronx High School of Science.

While in high school, Elliott was interested in electronics (vacuum tubes then) and amateur radio; one of his proudest achievements was being able to master Morse code sufficiently to obtain a broadcasting license, W2ZHS. Upon entering MIT in 1949 his intention was to acquire an electrical engineering degree, but thanks to the superb teaching of his first semester physics professor M. Sands (who collaborated with Feynman and Leighton on the famous "Lectures"), Elliott switched to the Physics Department.

In 1953 he took off on an NSF fellowship for Birmingham University in England, for Ph.D. studies in the Department of Mathematical Physics under Profs. R.E. Peierls, S.F. Edwards and G.E. Brown. Birmingham was one of the main centers of theoretical physics in Europe in those days. Like many young people then and now he steered towards the most advanced subject offered, quantum field theory. But after graduation in 1956 he tacked towards other directions in physics.

Throughout the rich scientific career that followed, Elliott has been guided by his drive to understand challenging physics phenomena in lucid mathematical terms. In the process he would repeatedly break new ground in physics and in mathematics. A number of active fields of research were started or invigorated that way, and some now enjoy renewed attention. His early work withstands the test of time in its clarity and reach.

Invited by J. Lebowitz, Elliott briefly held a position at the newly created Belfer Graduate School of Yeshiva Univesity, in New York. Elliott and Lebowitz became lifelong friends and collaborators, but in 1966 Elliott moved to Northeastern University in Boston. It was there that he and F.Y. Wu wrote one of the most cited papers in condensed matter physics on the one-dimensional Hubbard model. Elliott also solved the "square ice problem" and computed the entropy per atom to be (3/2)log (4/3), since known as "Lieb's ice constant". Building on the work of H.A. Bethe and C.N. Yang, and triggering subsequent papers by R. Baxter and others, this work played an important role by opening up a new area of soluble models, beyond Onsager's solution of the Ising model.



Elliott has been guided by his drive to understand challenging physics phenomena in lucid mathematical terms.

In 1968 Elliott returned to MIT, this time as a faculty member. Important scientific results from that period include the foundations of Thomas-Fermi theory and Hartree-Fock theories (with B. Simon), the Lieb-Robinson bound in condensed matter, the Hepp-Lieb maser model, and the thermodynamic limit for Coulomb systems (with J. Lebowitz). The MIT period lasted until 1974 when Elliott moved to Princeton on leave of absence. He officially came on board in 1975.

In Princeton, Elliott addressed important problems including stability of matter in magnetic fields, with J-P. Solovej and J. Yngvason, conditions for the emergence of ferromagnetism, some with M. Aizenman, and an axiomatic presentation of thermodynamics based on the concept of entropy, developed jointly with J. Yngvason.

Much of the research was directed toward understanding the quantum mechanics of atoms and the lowest energy state of the Bose gas. A significant 1987 work with I. Affleck, T. Kennedy and H. Tasaki, carried out at Princeton, was the invention and solution of the AKLT quantum spin system. This provides an early example of a system exhibiting what is nowadays referred to as a topological state of matter, which is a subject of great current interest.

Elliott's contributions were recognized, as reflected by many prizes and honors. He is a member of five national academies, including the NAS, a foreign member of the UK Royal Society, and has four honorary doctorates. He was twice president of the International Association of Mathematical Physics. For his work in physics he was awarded the Boltzmann medal, the Max Planck medal, the Norwegian Onsager prize and the Heineman prize. The American Mathematical Society recognized him with the Birkhoff and Conant prizes, and the Swedish Royal Academy awarded the Shock prize. The Austrian government awarded him the lifetime Austrian Medal of Honor for Science and Art, which can be held by no more than eighteen foreign scientists at any time.

While Elliott has retired from active professorial duties he continues to do research in mathematics and physics. We wish him many years of joy in this endeavor.

Professor Emeritus
GANG TIAN

By Alice Chang and Paul Yang

Professor Gang Tian was born in Nanjing China. He received his B.A. in mathematics from Nanjing University in 1982, his M.S. from Peking University in 1984 and his Ph.D. from Harvard University in 1988 under the direction of S. T. Yau. He served Princeton as an Assistant Professor from 1988 to 1990, returning as full Professor in 2003 after appointments at Stony Brook, NYU and MIT; he held the chair of Simons Professor of Mathematics at MIT from 1996. He was named a Eugene Higgins Professor in 2009 and became Emeritus September 1, 2017.

He currently holds the positions of Vice-President of Peking University and Professor and Director of the Beijing International Center for Mathematical Research (BICMR). He is also a member of the Scientific Council of the Abdus Salam International Centre for Theoretical Physics in Italy.

While at Princeton he strengthened the geometric analysis group. During his Princeton years, he supervised 33 Ph.D. theses from Princeton and elsewhere, as well as mentoring a large number of postdocs. Overall, he supervised over 40 Ph.D. theses from at least 11 different institutions.

Tian made fundamental contribution to geometric analysis, complex geometry and symplectic geometry. Here is a sample of his many results. He proved the existence of Kähler-Einstein metrics on compact complex surfaces with positive first Chern class. He proved what's now known as the Bogomolov–Tian–Todorov theorem for Calabi-Yau manifolds. With Ruan,

Tian made fundamental contributions to geometric analysis, complex geometry and symplectic geometry.

he established a theory of quantum cohomology and Gromov-Witten invariants on semi-positive symplectic manifolds, and in particular, symplectic manifolds of complex dimension-3 as well as Calabi-Yau spaces. This result implies the associativity of the quantum cohomology ring of semi-positive symplectic manifolds. He constructed the Gromov-Witten invariants for closed symplectic manifolds. He developed a compactness theory for high-dimensional Yang-Mills fields and found a deep connection between high-dimensional gauge fields and calibrated geometry. Tian introduced the theory of K-stability, which is central in the theory of geometric stability. He initiated the Analytical Minimal Model program through Kähler-Ricci flow, now known as Tian-Song MMP theory in complex geometry. Together with John Morgan, he gave an exposition of Perelman's proof of the Poincaré Conjecture and Thurston's Geometrization Conjecture. More recently, he solved the Yau–Tian–Donaldson conjecture, a central problem in Kähler geometry, which was independently solved by Chen, Donaldson and Sun. With Jeff Streets, he discovered new geometric flows that are now central tools in complex geometry.

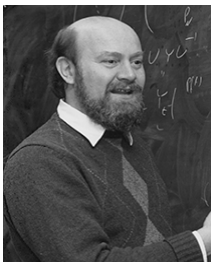
Dr. Gang Tian won the Alan T. Waterman Award in 1994 and the Oswald Veblen Prize in 1996. He gave an Invited Lecture in the Geometry section of the International Congress of Mathematics in 1990, and a Plenary Lecture at the International Congress of Mathematicians in 2002. He was elected to the National Academy of China in 2001 and the American Academy of Arts and Sciences in 2004. He has served as editor for a number of mathematical journals including the *Annals of Mathematics*, and on many mathematics advisory boards.

So far as the theories of mathematics are about reality, they are not certain; so far as they are certain, they are not about reality.

— Albert Einstein

Honors and Awards

Michael Aizenman



was presented with an honorary degree by Technion University at its June 2018 ceremony.

Javier Gómez-Serrano

was one of seven young mathematicians to receive the third annual Vicent Caselles Mathematical Research Award of the Royal Spanish Mathematical Society. The award recognizes "creativity, originality and achievement in the early years of the scientific profession," and is awarded to Spanish mathematicians around 30 years old.

János Kollár

has been awarded the 2017 Shaw Prize in mathematics. Professor Kollár shares this year's prize with Claire Voisin, professor at the Collège de France, for their "remarkable results in many central areas of algebraic geometry, which have transformed the field and led to the solution of long-standing problems."

Assaf Naor

has been named the 2018 Frederic Esser Nemmers Mathematics Prize Recipient "for his profound work on the geometry of metric spaces, which has led to breakthroughs in the theory of algorithms".

Peter Ozsváth

was elected to the Nathional Academy of Science in recognition of his distinguished and continuing achievement in original research.

John Pardon

was named a 2017 Packard Fellow. The David and Lucile Packard Foundation named 18 fellows this year, each of whom will receive $875,000 over five years to pursue their research.

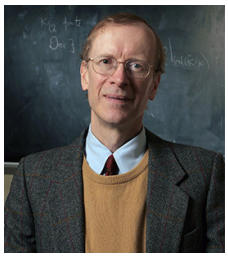
Peter Sarnak

received an honorary doctorate from King's College London in October 2017. A mini-conference to celebrate the award to Professor Sarnak was held at Goodenough College.

Allan Sly

was awarded an NSF CAREER grant. With this five-year grant Professor Sly will study "stochastic processes and embeddings on networks."

Sir Andrew Wiles



Sir Andrew Wiles, Princeton's James S. McDonnell Distinguished University Professor of Mathematics, Emeritus and a Royal Society Research Professor at the University of Oxford, was awarded the 2017 Copley Prize by the Royal Society, which included a gift of £25,000. First awarded in 1731, the Copley Medal is the Royal Society's oldest and most prestigious award.

2017 Simons Investigators

Igor Rodnianski and **Allan Sly** were named 2017 Simons Investigators in mathematics by the Simons Foundation as leaders in their fields. **Amit Singer** was named a Simon Investigator in Math +X as one of the leaders in the mathematical analysis of noisy data provided by cryo-EM. The Simons Investigators program provides a stable base of support for outstanding scientists, enabling them to undertake long-term study of fundamental questions.

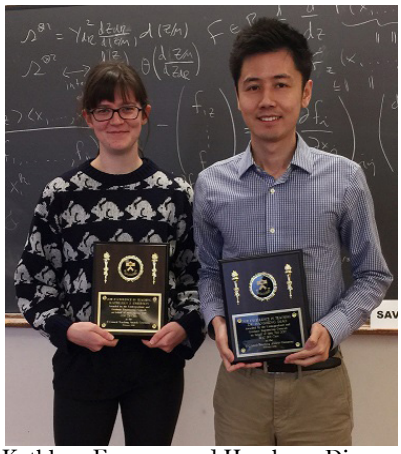
Fellows of the American Mathematical Society

Alex Ionescu, Sergiu Klainerman, Fernando Codá Marques, John Pardon, and **Peter Sarnak** were elected to the 2018 class of Fellows of the American Mathematical Society. The Fellows of the American Mathematical Society program recognizes members who have made outstanding contributions to the creation, exposition, advancement, communication, and utilization of mathematics.

Honors and Awards

DIAO and EMERSON
Honored with Excellence in Teaching Award

Mathematics Department instructor Hansheng Diao and graduate student Kathleen Emerson were awarded this year's Excellence in Teaching Award by the Undergraduate and Graduate Engineering Student Councils. This student-nominated award is for a professor or TA who "was especially 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. This is the third consecutive year that Diao has received this honor.



Kathleen Emerson and Hansheng Diao

MOSCHIDIS RECEIVES
Top Graduate Honor

Georgios Moschidis is one of four winners of this year's Porter Ogden Jacobus Fellowship, Princeton University's top honor for graduate students, along with Chantal Berman, Cole Bunzel and Matthew Edwards.

Georgios Moschidis

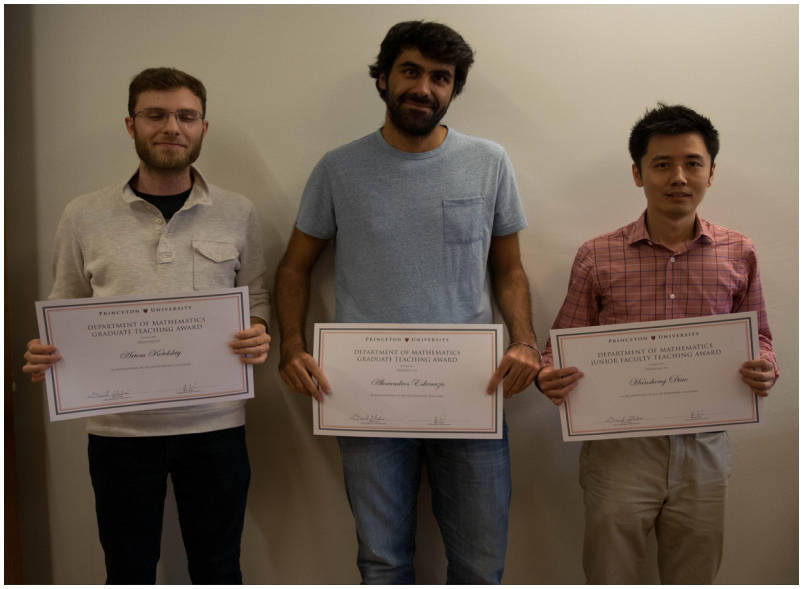
The fellowships support the final year of study at Princeton and are awarded to one Ph.D. student in each of the four divisions (humanities, social sciences, natural sciences and engineering) whose work has exhibited the highest scholarly excellence.

DEPARTMENT TEACHING AWARDS
Graduate Student and Junior Faculty

This is the fifth year the Department of Mathematics Graduate and Junior Faculty Teaching Awards have been given. The awards were created to recognize excellence in teaching at the undergraduate level. This year's graduate recipients are **Alexandros Eskenazis** and **Artem Kotelskiy**, who are current students. The Junior Faculty Teaching Award was given to Instructor **Hansheng Diao** and Assistant Professor **Ana Menezes** to recognize excellence in teaching at the undergraduate level.

Alexandros' enthusiasm for mathematics was described as inspirational, as someone who is always willing to dedicate extra time for students when needed. Artem makes sure the entire class comprehends complicated concepts and does not hesitate to put forth the effort for students who are struggling. Hansheng's lectures were described as exceptionally clear, well-organized, inspiring, informative, and challenging, and one student described him as "literally the best teacher I've had here at Princeton." Ana has been an inspiration to her students with an engaging and approachable teaching style that one student described as a "little lightbulb going off in my head."

Selection for both awards was made by a committee of faculty members.



Left to right: Artem Kotelskiy, Alexandros Eskenazis, Hansheng Diao.
Not pictured: Ana Menezes

Distinguished Visitors

The Minerva Program:
DEMETRIOS CHRISTODOULU, LAURE SAINT-RAYMOND, PAUL SEIDEL, AND UMBERTO ZANNIER

It was another productive year for the Department's Minerva Program. Umberto Zannier, this year's Minerva Distinguished Lecturer, joined us from the Scuola Normale Superiore-Pisa while Demetrios Christodoulou, Laure Saint-Raymond, and Paul Seidel came as Minerva Distinguished Visitors.

Umberto Zannier, the author of *Lecture Notes on Diophantine Analysis* and the editor of *Diophantine Geometry*, delivered a series of three Minerva Lectures on games and the Betti map: "The games of Steiner and Poncelet and algebraic group schemes"; "Torsion values for sections in abelian schemes and the Betti map"; and "Ambients for the Betti map and the question of its rank." These talks illustrated how one can vary the data of the games, obtaining families of elliptic curves and sections on elliptic schemes, for which torsion values can be sought and related to the Betti map.

Laure Saint-Raymond, who specializes in differential equations, delivered a mini-course with talks on Taylor Proudman columns: "rotation stabilizes the fluid around the 2D flow..."; Ekman pumping: "rotation stabilizes the boundary layer in the inviscid limit..."; Attractors: "when inertial waves meet topography..."; and Quasi-resonant forcing: "how generalized eigenfunctions can be observed in a bowl..."

Christodoulou, a professor emeritus at ETH Zürich who received his PhD from Princeton in 1971 and was a professor here from 1992—2001, visited the department in the Fall to collaborate with colleagues at Princeton.

Paul Seidel, professor at MIT, is visiting this Spring. While here, Seidel has lectured on the Fukaya categories of Calabi-Yau hypersurfaces.

Special Colloquium for
WEST POINT CADETS

In November of 2017, Diana Thomas, a mathematics professor at West Point Military Academy, inquired about the possibility of having a number of cadets attend the departmental colloquium. After consultations with the chair, Paul Yang organized a program of short talks about mathematical topics.

On February 17, a special mathematics colloquium was held at Princeton for West Point cadets. On the program there were three short talks given by members of our department on number theory, topology and probability. In attendance were 15 cadets and five members of the faculty from West Point Military Academy who had a brief tour of the Princeton campus prior to the colloquium.

In the colloquium, Peter Sarnak spoke about the local-to-global principle in number theory, with the interesting lead question about sums of squares and cubes. Dave Gabai gave a talk about the role of knot theory in the topology of 3-manifolds: he illustrated the topics with a number of gadgets, including his own flock of nearly impossible to manage hair. Evita Nestoridi spoke about the optimal strategy to shuffle a deck of cards and the mathematical idea behind mixing time of two distinct card shuffling models.

Mathematicians Find
WRINKLE IN FAMED FLUID EQUATIONS

By Kevin Hartnett, Quanta Magazine

Tristan Buckmaster

Vlad Vicol

The Navier-Stokes equations capture in a few succinct terms one of the most ubiquitous features of the physical world: the flow of fluids. The equations, which date to the 1820s, are today used to model everything from ocean currents to turbulence in the wake of an airplane to the flow of blood in the heart.

While physicists consider the equations to be as reliable as a hammer, mathematicians eye them warily. To a mathematician, it means little that the equations appear to work. They want proof that the equations are unfailing: that no matter the fluid, and no matter how far into the future you forecast its flow, the mathematics of the equations will still hold. Such a guarantee has proved elusive. The first person (or team) to prove that the Navier-Stokes equations will always work — or to provide an example where they don't — stands to win one of seven Millennium Prize Problems endowed by the Clay Mathematics Institute, along with the associated $1 million reward.

Mathematicians have developed many ways of trying to solve the problem. New work posted online in September raises serious questions about whether one of the main approaches pursued over the years will succeed. The paper, by Tristan Buckmaster and Vlad Vicol of Princeton University, is the first result to find that under certain assumptions, the Navier-Stokes equations provide inconsistent descriptions of the physical world.

"We're figuring out some of the inherent issues with these equations and why it's quite possible [that] people have to rethink them," said Buckmaster.

Buckmaster and Vicol's work shows that when you allow solutions to the Navier-Stokes equations to be very rough (like a sketch rather than a photograph), the equations start to output nonsense: They say that the same fluid, from the same starting conditions, could end up in two (or more) very different states. It could flow one way or a completely different way. If that were the case, then the equations don't reliably reflect the physical world they were designed to describe...

In their new paper, Buckmaster and Vicol consider solutions that are even weaker than Leray solutions — solutions that involve the same averaging principle as Leray solutions but also relax one additional requirement (known as the "energy inequality").

They use a method called "convex integration," which has its origins in work in geometry by the mathematician John Nash and was imported more recently into the study of fluids by De Lellis and Székelyhidi.

Using this approach, Buckmaster and Vicol prove that these very weak solutions to the Navier-Stokes equations are nonunique. They demonstrate, for example, that if you start with a completely calm fluid, like a glass of water sitting still by your bedside, two scenarios are possible. The first scenario is the obvious one: The water starts still and remains still forever. The second is fantastical but mathematically permissible: The water starts still, erupts in the middle of the night, then returns to stillness.

Buckmaster and Vicol prove the existence of many nonunique weak solutions (not just the two described above) to the Navier-Stokes equations. The significance of this remains to be seen.

Buckmaster and Vicol are also thinking in terms of layers, and they have their sights set on Leray solutions — proving that those, too, allow for a multitrack physics in which the same fluid from the same position can take on more than one future form.

"Tristan and I think Leray solutions are not unique. We don't have that yet, but our work is laying the foundation for how you'd attack the problem," said Vicol.

This article excerpt was reprinted from www.quantamagazine.org.

Undergraduate Program

Congratulations to the GRADUATING WOMEN

A record number of ten women will graduate with BA in mathematics this June. The ten seniors are:

Front row from left to right: Abby Hickok, Gloria Yin, Luya Wang, Iden Kalemaj, Jessica Shi, Andreea Magalie. Back row standing left to right: Daphne Yang, Boriana Gjura, Rachel Spady. Inset photo: Casandra Monroe

Boriana Gjura: Her thesis advised by Mark Zhandry of the Computer Science Department is on *Obfuscating Compute-and-Compare Programs*. Boriana will pursue a PhD in Theoretical Computer Science at Harvard.

Abby Hickok: Her thesis is on Khovanov holomogy and advised by Zoltán Szabó. Abby will start graduate school in mathematics at UC Berkeley.

Iden Kalemaj: She is working with Chun-Hung Liu on Jones' Conjecture in graph theory relating the number of minimal vertices needed to cover all cycles in a planar graph, and the maximal number of vertex-disjoint cycles that can be packed in a planar graph. Iden will be working as an Analyst at Analysis Group in Boston next fall; she plans apply to graduate school in combinatorics in a couple of years.

Andreea Magalie: She is working with Simon Levin of the Ecology and Evolutionary Biology Department on the effect of network structure on stable social groups, in particular how homophilous and targeted interactions affect the equilibrium points in a heterogenous population. Andreea will start a PhD program in mathematical biology at Georgia Tech.

Casandra Monroe: Casandra works with John Pardon for her thesis on the Volume Conjecture in knot theory. Casandra is a Mellon Mays Undergraduate Fellow mentored by Jon Fickenscher. The Fellowship's central mission is to increase diversity in the faculty ranks of higher education. As an initial step toward the Fellowship's ultimate goal, Casandra has won an NSF Graduate Fellowship to pursue doctoral studies in mathematics at the University of Illinois at Urbana-Champaign.

Jessica Shi: Her thesis, advised by Maria Chudnovsky, is on *Dominating Sets in Graphs with No Long Induced Paths*. Jessica will start a PhD program in Computer Science at MIT.

Rachel Spady: She is working with Faruk Gul of the Economics Department on market bargaining processes in the presence of intermediaries.

Luya Wang: She is working with John Pardon on the contact invariant in Heegaard Floer homology and some applications of the open book decompositions. Luya will start a math PhD program at UC Berkeley.

Daphne Yang: Her thesis on *Finite Orbits of Polynomial Automorphisms in Affine Three-Space with Applications* is advised by Peter Sarnak. After graduation, Daphne is going to work at Barclays Capital as a Trading Analyst on the US Treasuries desk.

Gloria Yin: Her thesis, advised by Fernando Codá Marques, is on Curvature on Discrete Surfaces. Gloria will take a year off before starting math graduate school at either Caltech or the University of Chicago.

MATH CLUB IMPACTS

by Matthew Tyler, Math Club President

This past year, the Math Club has continued to host social events, provide undergraduates with new opportunities to learn mathematics, and help spread mathematics and the joy of learning it to the broader community.

Roughly every two weeks, we organize a Board Game Night in the Fine Hall 3rd Floor Common Room. These gatherings are often preceded by a panel or advising session about a topic relevant to Math Club members' lives, such as applying to graduate school or choosing math courses for next semester. This May, we are also hosting our usual end-of-year banquet in the Professors' Lounge.

Additionally, we host a colloquium each week, during which a professor gives a talk for undergraduates about a topic related to mathematics. Recent talks have been on subjects as varied as minimal surfaces, modular forms, and natural algorithms, and these talks have been a great way to both gain exposure to subjects not often discussed in the classroom, and to dive deeper into a topic of interest. Moreover, we offer the Mentoring Moebius peer mentorship program, which brings together underclassmen, upperclassmen, and graduate students to meet in small groups over coffee or dinner each month to talk about math, life, or anything in between.

The Math Club after board game night

This past year, PUMaC, the math competition we run for high school students, had another successful run. Now in its 12th year, PUMaC offers high schoolers from around the country and around the globe the chance to come to Princeton and spend the day taking various mathematics tests and having fun.

RYAN CHEN named GOLDWATER SCHOLAR

By Liz Fuller-Wright, Office of Communictions

Prineton junior Ryan Chen has been awarded a one-year Goldwater Scholarship, an annual award for outstanding undergraduates interested in careers in mathematics, the natural sciences and engineering.

Chen, a mathematics major from Lawrenceville, Georgia, is planning to pursue a Ph.D. in mathematics with the goal of entering academia. "I am currently interested in studying number theory, and have been pursuing this interest in my junior independent work and summer research," Chen said. One- and two-year Goldwater Scholarships cover tuition, fees, room and board up to a maximum of $7,500 per year. Chen is one of 211 scholarship winners selected from a field of 1,280 students nationwide.

Princeton PUTNAM TEAM WINS THIRD PLACE

At the 78th annual William Lowell Putnam Mathematical Competition, organized by the Mathematical Association of America, includes the United States and Canada. In 2017, 4,638 students from 575 institutions participated and spent two 3-hour sessions solving 12 problems.

Princeton University placed third in the team competition receiving an award of $15,000 and each team member (Murilo Corato Zanarella, Zhuo Qun Song, and Xiaoyu Xu) will receive $600. Additionally, Zhuo Qun (Alex) Song and Xiaoyu Xu were recognized as part of the next ten highest ranking individuals after the Putnam Fellows, with an award of $1,000 each. Rodrigo Angelo, Murilo Corato Zanarella, Andrei Graur, and Eric Neyman received honorable mention.

The book of nature is written in the language of Mathematics.

—Galileo

Graduate Profile
GEORGIOS MOSCHIDIS

I work in the field of general relativity, which lies at the intersection of analysis, geometry and physics. Of central importance in this field is the question of stability of certain spacetime solutions of the Einstein equations under perturbations of their initial state. During my years as a graduate student at Princeton, my research has been focused on the stability properties of spacetimes modelling isolated, stationary self-gravitating systems, as well as on instability phenomena associated to the presence of a negative cosmological constant.

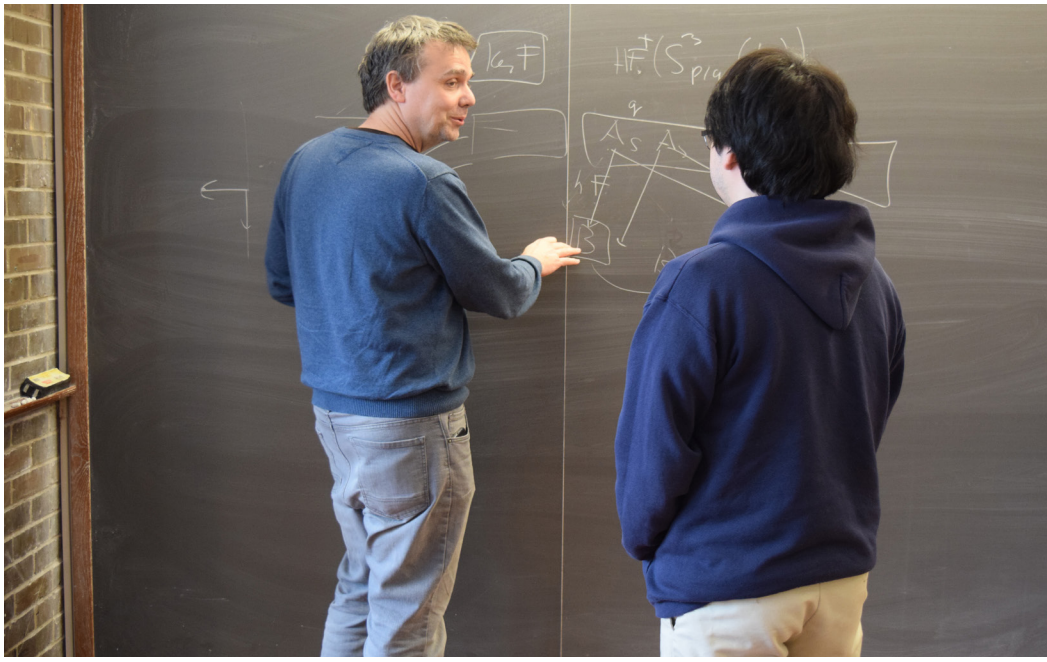
Growing up in Greece, I finished my undergraduate studies at the National Technical University of Athens. There, I had the chance to attend a talk of Mihalis Dafermos on black holes, exposing me for the first time to a subject which instantly captivated my imagination. My admission to Princeton gave me the opportunity to join the vibrant relativity community here. The close interaction between students, postdocs and professors within this community never ceased to provide me with both ideas and motivation thoughout my graduate years. I also consider myself lucky to have entered the field at the right time: Despite the century-long history of general relativity, the necessary analytical tools for addressing many prominent questions set forth already in the 60s-70s, during the so-called golden age of the theory, were only recently developed (mostly by people in Fine Hall); as a result, a plethora of interesting problems are accessible to newcomers in the field.

Looking back at my years in Princeton, I am deeply grateful for all the friends that I met here, as well as all the people who made everyday life in Fine Hall flow unobstructed. I will certainly miss all of them in the forthcoming years!

From the
DIRECTOR OF GRADUATE STUDIES: ZOLTÁN SZABÓ

Being a Director of Graduate Studies (DGS) is a rewarding job. Together with my fellow DGS, Javi Gómez-Serrano, and with the help of our excellent graduate administrator, Jill LeClair, we aim to provide guidance and support for our very talented graduate students. It is great to see them learning exciting new results and methods in Mathematics, and progressing from first year students to outstanding researchers.

One of the more challenging aspects of the job is graduate admissions. This is a multi-step process, starting with a committee of seven faculty members who meet around the end of December and read all the applications. Later it involves the full faculty and also at various points the Graduate School as well. This year we had the annual Open House in the beginning of March. Almost all of the newly admitted students visited Princeton to learn more about the Ph.D. program and talk with students and professors. This was a one-day event, with lots of interesting lectures by our own graduate students and faculty, who all helped recruit this remarkable group of students. At the end it was a great success. We are excited to welcome a large and diverse class of 16 new graduate students, who will join us in Fall 2018.



Professor Szabó, Director of Graduate Studies

Most recent Ph.D.s

Name/ Field	Undergrad	Advisor	Thesis Title	Original Placement
Gregory Gauthier *Structural Graph Theory*	Georgia Tech	Seymour	The structure of graphs with no cycles of length 0 (mod 3)	Princeton University (Math)/ Lecturer
Matthew Hernandez *PDEs*	University of North Carolina, Chapel Hill	Fefferman	Mechanisms of Lagrangian analyticity in fluids	Institute of Mathematical Sciences (ICMAT), Madrid/ Postdoctoral Researcher
Peter Humphries *Number Theory*	Australian National University	Sarnak	Equidistribution in shrinking sets and L4-norm bounds for automorphic forms	University College London/ Research Associate
In-Jee Jeong *PDEs*	Brown University	Sinai	Dynamics of the incompressible Euler equations at critical regularity	Korea Institute for Advanced Study/ Postdoctoral Researcher
Yuchen Liu *Algebraic Geometry*	Peking University	Kollár	Kähler-Einstein metrics and normalized volumes of valuations	Yale University/Gibbs Assistant Professor
Colin Sandon *Random Graphs*	MIT	Abbe	Community detection in the stochastic block model: fundamental limits	Princeton University (PACM)/Postdoctoral Research Associate
John Stogin *Hyperbolic PDEs*	Princeton University	Klainerman	Nonlinear wave dynamics in black hole spacetimes	Radix Trading, Quantitative Technologist
Mehdi Yazdi *Topology*	Sharif University of Technology	Gabai	On Thurston's Euler class one conjecture	University of Oxford/ Glasstone Fellow
Ruixiang Zhang *Harmonic Analysis and Number Theory*	Peking University	Sarnak	Perturbed Brascamp-Lieb inequalities and applications to Parsell-Vinogradov systems	IAS Member

"I feel like I won the grad school lottery. I can't imagine a better place to concentrate on math. I have made friends who came to Fine Hall from all over the world. I had the opportunity to do an internship I probably wouldn't have heard of if it weren't for my advisor, Peter Sarnak, and also got to supervise undergraduate research. The Minerva program hosting long-term visitors gave me a chance to meet my future postdoc boss, Maryna Viazovska. It's been a great experience, and I owe a big thank you to a lot of the people reading this!"

— Matthew de Courcy-Ireland

ADVISORY COUNCIL
Visits

On April 19 and 20th this year the Department's Advisory Council convened at Fine Hall. The council, composed of distinguished alumni and other mathematicians with close ties to the department, met with faculty, graduate and undergraduate students, staff, and the Dean of the Faculty over the two-day meeting.

The council meets every few years, last in 2014, to evaluate the state of the Department and to provide recommendations on how it can retain and strengthen its status as one of the world's preeminent institutions for mathematical research and instruction.

We are grateful to each of the council members for taking time out of their busy schedules to come to Princeton and provide this valuable outside review.

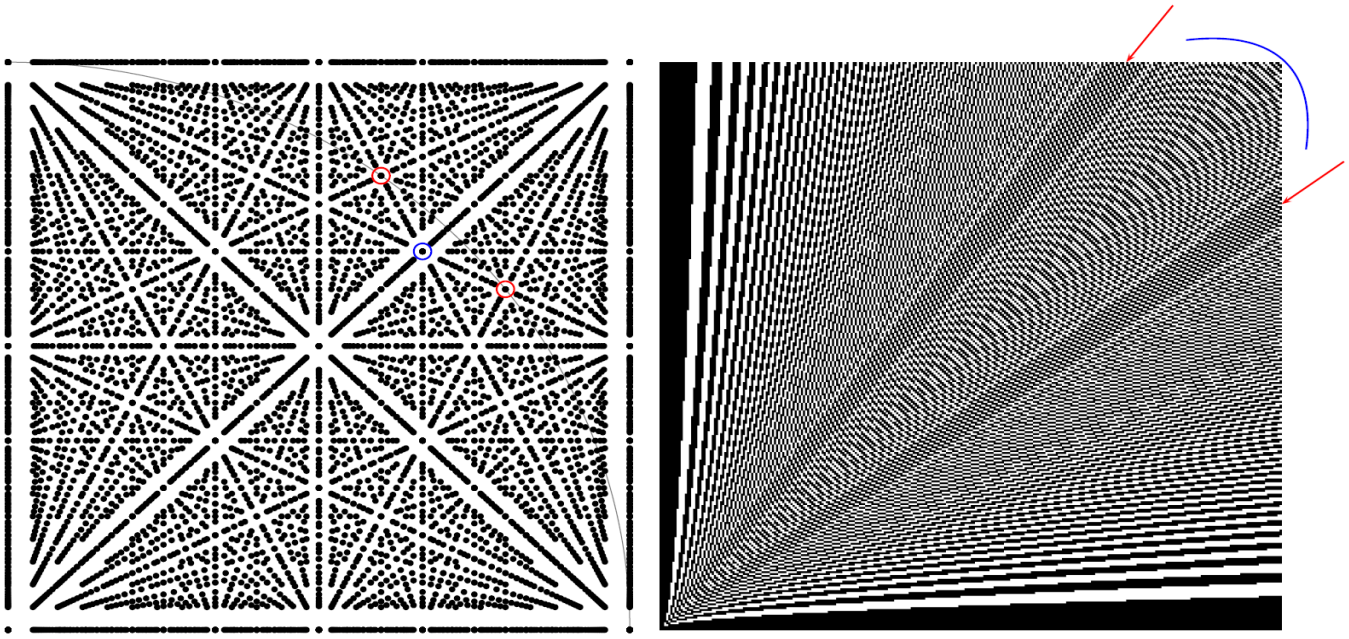
From left: János Kollár (Dept. Assoc. Chair), John Morgan, Sylvain Cappell, Jean Taylor, Luisa Fernholz (Council Chair), Flavio Bartmann, Elliott Stein, Henry Laufer, David Gabai (Dept. Chair)

TWIN Pictures

By Evan O'Dorney (G2)

It is exciting when a simple formula turns out to yield some dazzling artwork. It is even more exciting when two simple and apparently unrelated formulas give subtly connected artistic results. On the left, we have an image of the projective plane $\mathbb{P}^2(\mathbb{Q})$, made by plotting the points *(a/d,b/d)* where *a*, *b*, and *d* are integers in a bounded range. This image is relevant to the simultaneous Diophantine approximation of irrational numbers and the design of musical scales. On the right, we have colored each integer-coordinate point black or white according to whether its distance from the origin, $\sqrt{x^2+y^2}$, is above or below its closest integer.

- The striking dark bands on the right occur at points that nearly form a *3-4-5* right triangle, corresponding to the circle $x^2 + y^2 = 1$ on the left passing through the points *(3/5,4/5)* and *(4/5,3/5)* (red);
- Between those bands is a grating of elliptical arcs that can be explained by the circle's passing near the point *2/3,2/3* (blue).



Fine Hall Update

NEW LOOK
for Fine Hall

The summer of 2017 was a busy time in Fine Hall; but rather than halls filled with summer programs and conferences, the building was emptied and taken over by construction crews making improvements both seen and unseen.

Beginning the day after Commencement, every office was boxed up and emptied of the old furniture—much of it original to the building's debut in 1969. With the building emptied of persons and things, a crew of over 50 began installation of a fire sprinkler system throughout the building.

The third floor administrative area was completely renovated, including a glass wall between the reception desk and the new mail room, bringing natural light to the Department's front door.

As the major construction work was completed, all offices were outfitted with brand new carpet and furniture—a much-needed update. When the original Fine Hall—now Jones Hall—was built, Oswald Veblen insisted that the faculty have quarters more like private studies than traditional offices. We're glad to be able to keep part of this tradition alive, with all faculty offices having full sofas, creating an atmosphere conducive to individual research, collaboration, and meeting with students.

The Common Room, the Department's gathering place, was also refreshed to ensure a comfortable environment for quiet study, friendly meetings, and, of course, afternoon tea.

Many thanks are due to Professor Igor Rodnianski who spearheaded this effort, the staff who helped coordinate it, and the University's central administration for funding this project.

Department ADMINISTRATION

David Gabai
Chair

János Kollár
Associate Chair

Zoltán Szabó and Javier Gómez-Serrano
Directors of Graduate Study

János Kollár
Department Representative

Jennifer Johnson
Assoc. Department Representative

John Pardon
Senior Advisor

Mark McConnell
Junior Advisor

Vlad Vicol
Placement Officer

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Annual Alumni
OPEN HOUSE

Friday, June 1, 2018 • 2:00-3:30pm

3rd Floor Common Room, Fine Hall

Incoming Graduate Students

China • India • Israel • Korea • Spain • Caltech • Cornell Univeristy
Harvard University • MIT • NYU • UC Berkeley • University of Chicago

Undergraduate Class of 2017

11 Graduates in Graduate School

19 Employed: Education • Finance and Insurance • Health Care and Social Assistance • Information, Professional Scientific, and Technical Services