

MATHEMATICS + BERKELEY

Fall 2022

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Chair Michael Hutchings (PhD, Harvard, 1998) has been a member of the math faculty since 2001. His research is in low dimensional and symplectic geometry and topology. He became Chair in Fall 2019.

Dear Friends of Berkeley Math,

Last May was our first in-person commencement ceremony since 2019. It was a high point of the year for me to celebrate the achievements of our graduating students together with their family and friends. With the excitement of being back together after a year and a half of remote activities, our department is thriving like never before.

In order to maintain the excellent research and teaching in the department, it is essential to continually recruit new faculty. This fall, seven outstanding new faculty started – a record, at least in recent memory. In the last three years we hired an average of three faculty FTE (full-time equivalents) per year. As encouraging as this sounds, due to inevitable retirements and occasional moves (despite our best retention efforts), we estimate that we need to hire about 2.5 faculty per year in order to keep the faculty size constant, and about 3 per year to grow from the current 51.75 FTE (this is a fraction because some faculty have joint appointments with other departments) to a target of 56.0 FTE.

Our faculty continued to be recognized by many prestigious honors and awards. To list a few: Mina Aganagic, Richard Bamler, Bernd Sturmfels, and Sug Woo Shin were Invited Speakers at the 2022 International Congress of Mathematicians (held every four years). Nicolai Reshetikhin received the Weyl-Wigner award in mathematical physics. Nikhil Srivastava together with collaborators was awarded the 2022 (inaugural) Ciprian Foias

Prize in Operator Theory. New arrival Yunqing Tang won the 2022 SASTRA Ramunajan Prize.

Our Morrey Visiting Assistant Professors (three-year teaching postdocs) also make a vital contribution to both teaching and research. We have expanded this program so that starting this year there will be twelve Morrey VAPs at any given time, and we hope to be able to support even more Morreys and other postdocs in the future.

Our world-class graduate program was ranked in a tie for third place by US News & World Report, and ahead of all other public universities nationwide. This year we welcomed an unusually large and diverse incoming class of 41 graduate students, 14 of whom are international. The energy and enthusiasm of our students are infectious. Although nominally faculty teach and advise graduate students, often it seems to be the reverse!

Our undergraduate program continues to thrive with 672 Mathematics and Applied Mathematics majors. With over 8,500 enrollments in our fall undergraduate offerings, our department maintains our commitment to teaching all Berkeley students wanting to take math courses.

Encouraged by high demand, we have also enlarged our offerings of online summer courses. David Nadler has created a course on linear algebra and differential equations (W54) and Per Persson has developed a class on numerical analysis (W128A). Both classes were already taught in the Summer 2022. In terms of in-person classes, we also have a new addition: The new class Transition to Upper Division Mathematics (Math 74), created by Zvezda Stankova, focuses on reading and understanding mathematical proofs and emphasizes precise thinking and the presentation of mathematical results.

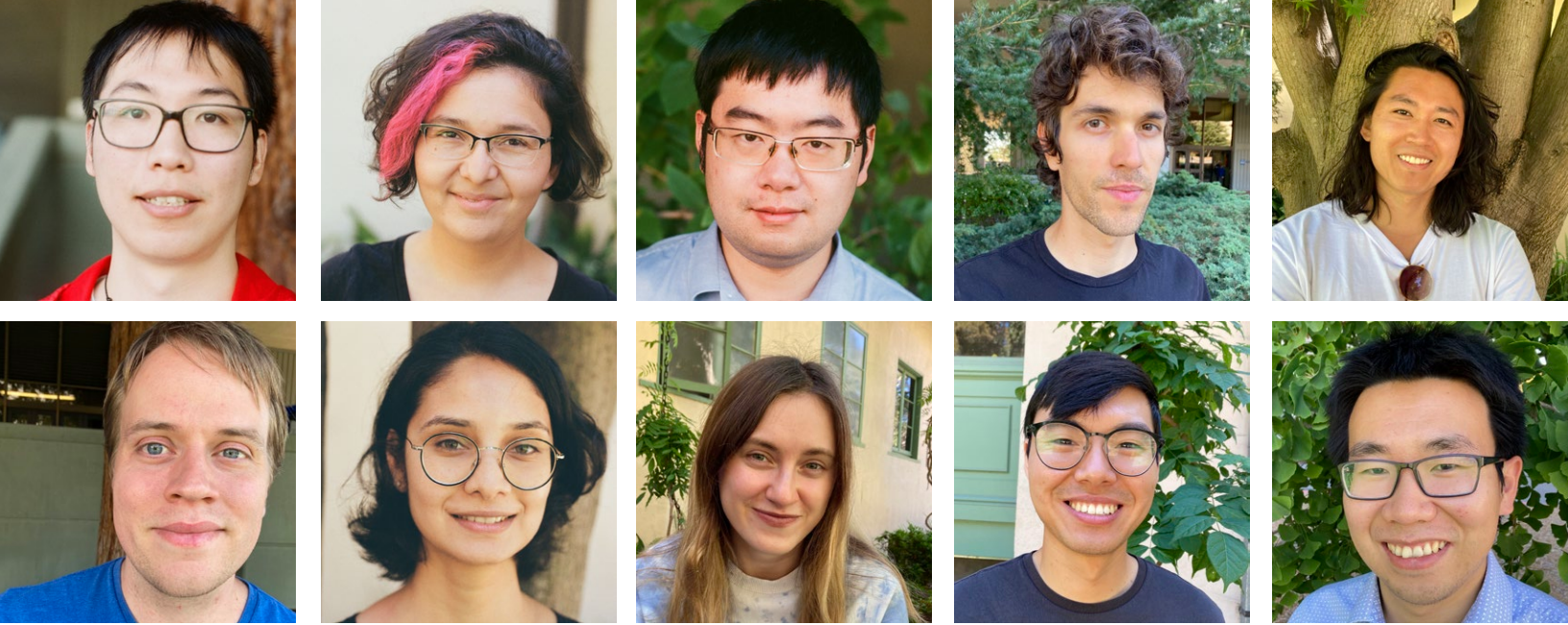
As always, our department could not function without the tireless dedication of the staff. Among several arrivals, the first new face you will probably see upon entering the department is Front Office Administrator Kathryn Mills. See page 11 for more staff updates.



In other news, we are still expected to move out of Evans Hall by 2030, and possibly quite a bit sooner – stay tuned!

I encourage you to stay connected with the department and with Berkeley. You can learn more about the many activities in the department on [our homepage](#) and the [UC Berkeley Mathematics Facebook page](#), and you can join current and former students in the [UC Berkeley Mathematics LinkedIn group](#).

Cover: “Critical Percolation” by Vilas Winstein. Each pixel represents a vertex in a square grid network, and each edge in the grid is removed independently with probability 1/2. Each connected component of the resulting network is given a different color. For more information, see: <https://youtu.be/a-767WnbaCQ>



Above: Ten new postdocs pictured in the order listed. (C. Delaney not pictured) Below: Postdoc Di Fang and Prof. Lin Lin (see page 9)

New Postdocs

Colleen Delaney (Simons Collaboration), PhD UC Santa Barbara. Mathematical physics, tensor categories, quantum topology.

Zhiyan Ding (Morrey), PhD University of Wisconsin-Madison. Numerical analysis, machine learning, quantum computing.

Nicolle González (Morrey), PhD USC. Diagrammatic categorification, representation theory, algebraic combinatorics.

Jin-Peng Liu (Simons), PhD University of Maryland. Quantum algorithms.

Borislav Mladenov (Morrey), PhD Imperial College London. Algebraic geometry.

Tobias Shin (NSF), PhD Stony Brook University. Algebraic topology.

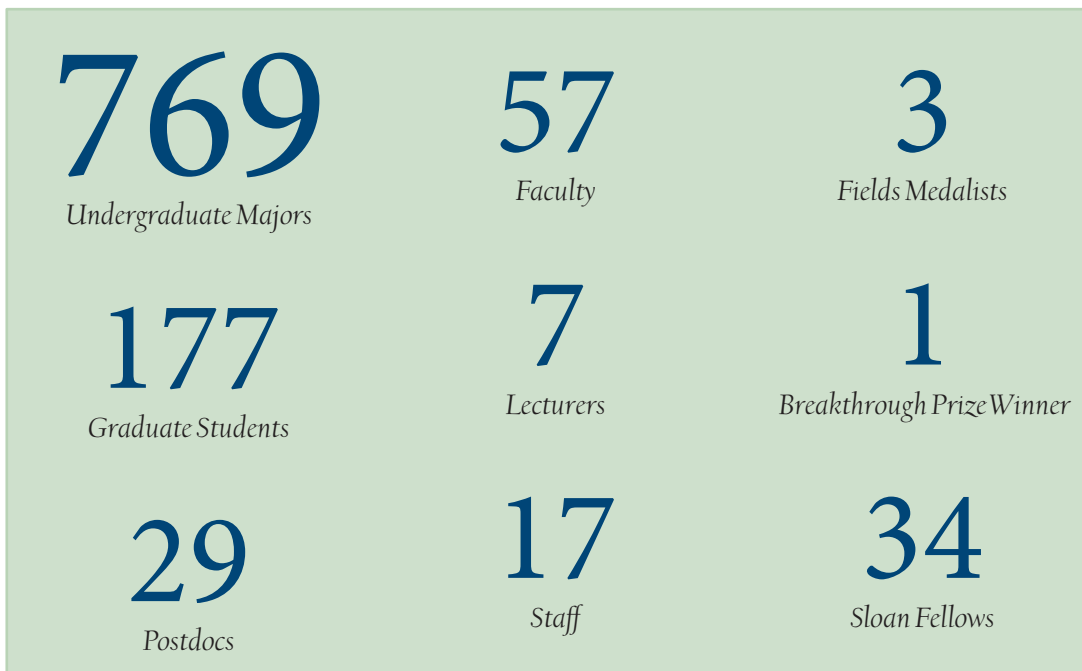
Kevin Stubbs, PhD Duke. Quantum chemistry and quantum information theory.

Krutika Tawri (Morrey), PhD Indiana University. Partial differential equations, fluid mechanics.

Aleksandra Utiralova (Morrey), PhD MIT. Representation theory and symmetric tensor categories.

Kevin Yang (NSF), PhD Stanford. Probability.

Mengxuan Yang (Morrey), PhD Northwestern University. Analysis & PDE.



Meet our new Faculty



Tony Feng graduated from Stanford in 2019 under supervision of Akshay Venkatesh. He was subsequently a C. L. E. Moore instructor at MIT and a member at IAS from 2019-2022. Tony is interested in number theory, especially aspects that have interesting interaction with

topology or representation theory. He is currently working on applying homotopical tools, such as derived algebraic geometry and cohomology operations, to problems in arithmetic geometry, and exploring the significance of quantum groups and microlocal analysis for Galois representation theory. He also enjoys playing ultimate frisbee (casually) and video games.



Michael Lindsey is joining the faculty as an Assistant Professor in Fall 2022. He grew up in suburban DC and got his PhD here at Berkeley in applied math in 2019. Most recently he was an NSF Postdoc at NYU. In his research he works on computational methods driven by numerical linear algebra, optimization, and

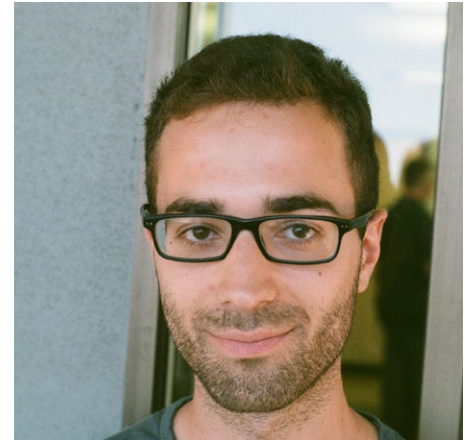
randomization, with a special focus on high-dimensional scientific computing problems. In his spare time he enjoys reading, writing, finding live music performances, walking around, and practicing the bass guitar. He is thinking about starting a math department jam band, so please contact him if interested!



Vadim Gorin is joining the departments of Mathematics and Statistics as an Associate professor. Vadim holds PhDs from Moscow State University and University of Utrecht. His US career started from a postdoc at MSRI, Berkeley, and continued with positions at MIT and University of Wisconsin-Madison before returning back to Berkeley

in Fall 2022. Vadim's research area is Integrable Probability: he studies large stochastic systems by means of exact formulas and algebraic techniques. Examples of such systems include models of two-dimensional statistical mechanics (random tilings, square ice, interface growth models), eigenvalues of random matrices, probability models underlying high-dimensional statistical hypothesis testing, and measures governing decompositions into irreducibles in the asymptotic representation theory or non-commutative harmonic analysis. Vadim enjoys playing Magic: The Gathering and various board games. Recently he tried to learn figure skating.

Gabriel Goldberg is joining the faculty as an assistant professor in Fall 2022 after spending the past three years as an NSF postdoc at UC Berkeley. He obtained his Ph.D. at Harvard for his thesis *The Ultrapower Axiom* advised by (UC Berkeley professor emeritus!) Hugh Woodin. His research is in set theory, with a focus on large cardinals (axioms of infinity), ultrafilters, inner models, ordinal definability, and the Axiom of Choice. Apart from this, he is organizing the logic colloquium and the set theory seminar and, in his free time, attempting to compose music and read novels in a foreign language.



Venkatesan Guruswami started in January 2022 as a Professor at UC Berkeley and a senior scientist at the Simons Institute for the Theory of Computing. He obtained his PhD from MIT in 2001, and was most recently a Professor of Computer Science at Carnegie Mellon. His research spans many areas of theoretical computer science and related mathematics, including error-correction, pseudorandomness, approximate optimization, and computational complexity theory. Guruswami's body of work on algebraic list decoding has yielded codes with minimum possible redundancy for correcting worst-case errors. His recent work include notable progress on polar codes, deletion-correcting codes, codes for distributed storage, and constraint satisfac-



tion problems. Guruswami has a sustained busy professional service record, including serving as the current Editor-in-Chief of the Journal of the ACM. Outside work, he enjoys listening to Carnatic (south Indian classical) music, ethnic vegetarian food (eating, not cooking), thriller movies/series, travel, and racquet sports like badminton.



Andrei Okounkov is re-joining our department in Fall 2022. He obtained his Ph.D. at Moscow State University and held positions at Chicago, Princeton, Columbia, and UC Berkeley (1999–2002). His research in modern mathematical physics and neighboring fields of mathematics, such as probability theory, enumerative geometry, and geometric representation theory, has been recognized by various prizes, including the European Mathematical Society Prize (2004) and the Fields Medal (2006). In 2018, he was a plenary speaker at the ICM. Between 2002 and now, he kept close ties with Berkeley through his active involvement in the life of the Mathematical Sciences Research Institute, where he

was a program organizer, Co-Chair of the Scientific Advisory Committee (2007-2013), and Trustee (2010-present).



Franziska Weber joined the faculty as an assistant professor in Fall 2022. As a kid, she wanted to become a marine biologist. Unfortunately, she grew up in Switzerland, far away from any reasonable-sized body of water. She has ended up working on the numerical analysis of partial differential equations related to fluid dynamics, so at least she gets to simulate some waves occasionally. Math turned out to be a fun second choice, so she went on to do a Ph.D. in Oslo, Norway, where one can buy whale meat in the supermarket. At this point, there was no hope of landing a job at Greenpeace, and so Franziska stuck with math and did a postdoc at ETH Zurich and the University of Maryland before moving to Carnegie Mellon University in 2018. When she is not doing energy estimates or cursing at a computer program, she likes to attend concerts or go running, hiking, skiing and snowboarding.

Our ICM Speakers

This year's International Congress of Mathematicians was held online. Four members of our department were speakers at the ICM: **Bernd Sturmfels** and **Sug Woo Shin** report below about their talk and experience. The other speakers were **Mina Aganagic** (who describes her research on the next page) and **Richard Bamler** (who wrote last year's research article).



Bernd Sturmfels Linear algebra is ubiquitous in the mathematical universe. It plays a foundational role for many models in the sciences and engineering. Its numerical methods are a driving force behind today's technologies. The power of linear algebra stems from our ability, honed through the practice of calculus, to approximate nonlinear shapes by linear spaces. Yet, the world is nonlinear. Nonlinear polynomial equations are a natural ingredi-

ent in mathematical models for the real world. My ICM lecture "Beyond linear algebra" challenged applied mathematicians to venture beyond linear algebra in designing models and in thinking about numerical algorithms for identifying solutions. It covered recent advances in computing critical point equations in optimization and statistics, and it explored the role of nonlinear algebra in the study of certain partial differential equations.

Sug Woo Shin I began with a motivation for studying Shimura varieties coming from a geometric and analytic approach to reciprocity laws in number theory. Then I went on to introduce the Langlands-Rapoport conjecture on points of Shimura varieties modulo primes, which can be thought of as a geometric incarnation of a general reciprocity law envisioned by Langlands. At the end I discussed my recent results with Kisin and Y. Zhu on the conjecture and related work.



I was thankful for an opportunity to give my ICM talk at a satellite conference in Singapore, where several other ICM lectures (as well as talks by others) were also delivered in person. I submitted my recording from there to be used at the ICM. While my talk was playing, I was glad to have questions on Discord, which led to an interesting conversation.

Knot Theory and Mirror Symmetry



Professor Mina Aganagic

In the long history of mathematics interacting with physics, two of the most fruitful areas are knot theory and mirror symmetry. In this

article, I will describe a new connection between them and tell the story of its discovery – a discovery in which our math department has played a key role.

This story starts in 1984, the year Vaughan Jones found a remarkable polynomial invariant of links (a link is a union of possibly “interlinked knots” in \mathbb{R}^3). The Jones polynomial $P_K(\mathbf{q})$ is defined in a simple way, by picking a projection of the link to a plane, a.k.a. a “link diagram”, and a rule for how the invariant changes as one replaces an over- with an under-crossing (see the panel on the right for more details on the Jones polynomial). Jones spent large parts of his career at Berkeley, and received a Fields medal for this discovery.

In 1988, Edward Witten explained that there is a deep connection between the Jones polynomial and theoretical physics. He showed that the Jones

polynomial arises from a three-dimensional topological quantum field theory, Chern-Simons theory (named after the late Berkeley professor emeritus Shing-Shen Chern, and his then-student Jim Simons). In doing so, he uncovered many more polynomial link invariants. Witten also received the Fields medal, the same year as Jones, in part for this work. Reshetikhin (a professor emeritus at Berkeley) and Turaev showed that one can rephrase Witten’s result in purely algebraic terms, with no reference to quantum field theory. The resulting link invariants are called *quantum group invariants*. The name reflects the fact that different invariants are labeled by a choice of a group G and its representations coloring the strands of a link. The Jones polynomial, for example, comes from taking the group to be $G=SU(2)$, and links colored by its spin $\frac{1}{2}$ representation.

Quantum link invariants are polynomials in one variable, with *integer* coefficients. A natural question is whether these integers are counting something. If so, there would be a deeper structure underlying quantum link invariants. In 1999, Khovanov showed that this is indeed the case for the Jones polynomial: He showed that to each link diagram K one can associate a collection of vector spaces $\mathcal{H}_{i,j}(K)$, labeled by a pair of integers i and j , such that a signed count of the dimensions coincides with the co-

efficients of the Jones polynomial, $P_K(\mathbf{q}) = \sum_{i,j} (-1)^i \mathbf{q}^j \dim \mathcal{H}_{i,j}(K)$. Moreover, the vector spaces $\mathcal{H}_{i,j}(K)$ turned out to be link invariants themselves.

Khovanov’s remarkable construction is part of the “categorification program”, which aims to lift integers to vector spaces and vector spaces to “categories”. A toy model of categorification comes from the Euler characteristic $\chi(M)$ of a manifold M . The Euler characteristic $\chi(M)$ is an integer, defined as an alternating sum $\sum_i (-1)^i k_i$, where k_i is the number of simplices of dimension i in a triangulation of M : k_0 is the number of vertices, k_1 of edges, k_2 the number of two-dimensional triangles, and so on. If M is two dimensional, this reduces to the familiar formula $\chi(M) = V - E + F$, where V , E and F are the numbers of vertices, edges and faces of a triangulation. The Euler characteristic can also be written as $\chi(M) = \sum_i (-1)^i \text{rk}(h_i)$, where $h_i = \ker(\partial_i) / \text{im}(\partial_{i+1})$ is the i -th homology group. The terms in this sum are now more intrinsic to M – they don’t depend on a triangulation anymore. The collection of homology groups $h_i, i=0, \dots, \dim(M)$, are said to “categorify” the Euler characteristic. The construction has a physical meaning as well. From a physics perspective, the Euler characteristic is the partition function of “supersymmetric” quantum mechanics with M as a target space: $\chi(M) = \text{Tr}(-1)^{F_e - \beta H}$. Its Hamiltonian is the Laplacian $H = dd^\dagger + d^\dagger d$, where $d = \sum_k k d_k$ is the supersymmetry operator, and one works with cohomology rather than homology.

Despite its success, Khovanov’s striking construction posed more puzzles than it solved. Unlike in our toy example of categorification of the Euler characteristic, it did not come from either geometry or physics – certainly not in any unified way. Since the vector spaces and maps between them had no geometric origin, one would like to find meaningful objects whose homology groups are the

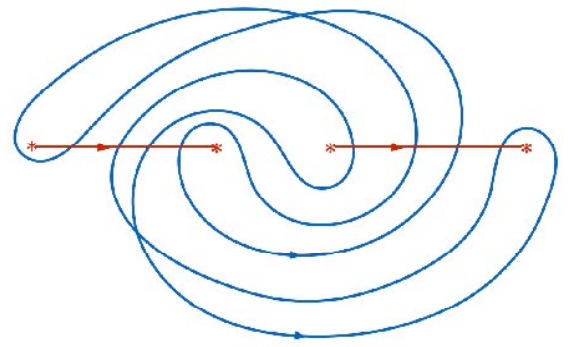
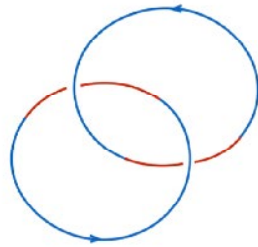


Elements of the Monster group, with some monstrous moonshine and a couple of elements of the baby monster group. Prof. Borchers on left, Okounkov middle, Agol right. Halloween Tea, October 2022.

knot homology groups $\mathcal{H}_{i,j}(K)$. The problem Khovanov initiated is to find a general framework for link homology and to explain what link homology groups are and why they exist.

The solution to the problem comes from mirror symmetry. Mirror symmetry is a duality that originates from string theory and relates a pair of “Calabi-Yau” manifolds X and Y . Its mathematical imprint are relations between very different problems in the complex geometry of X and the symplectic geometry of Y . It predicts that an uncountable set of numerical invariants of X and Y , formulated and computed in completely different ways, agree.

Kontsevich conjectured in 1994 that mirror symmetry should imply an equivalence of a pair of categories, one associated to the complex geometry of X and the other to the symplectic geometry of its mirror Y . Kontsevich’s “homological” mirror symmetry naturally produces hosts of homological invariants: For any pair of objects (known as “branes”) in the category associated to X , there is a mirror pair in the category corresponding to Y , such that the spaces of morphisms between them agree. The



A knot diagram of a Hopf link, on the left. The Jones polynomial and its categorification come from a pair of branes (colored red and blue) on the right, derived from a bi-coloring of its knot diagram.

resulting vector spaces categorify simple geometric invariants, like geometric intersection numbers of the branes on Y . I discovered a new family of mirror pairs of manifolds, in which homological mirror symmetry leads to the solution of the knot categorification problem. To a projection of a link K , a group G and a collection of its representations labeling the link components, one associates a manifold Y and a pair of branes in it. The choice of Y and the branes is determined by mirror symmetry: from the perspective of X it is easy to say which question one should study to recover homological invariants of a link; in the mirror Y , one computes them explicitly. The quantum

link invariant is obtained as the signed count of intersection points of the branes, keeping track of their grading by both i and j . The homological link invariant $\mathcal{H}_{i,j}(K)$ is the space of morphisms between them.

Many special features exist in this family, in part due to its deep connections to representation theory of quantum groups, so the categories which are usually known only abstractly can be described explicitly. One can both prove homological mirror symmetry, and compute the resulting homological link invariants from geometry. In my view, this is the most far-reaching application of homological mirror symmetry yet.

How to compute the Jones polynomial of a link

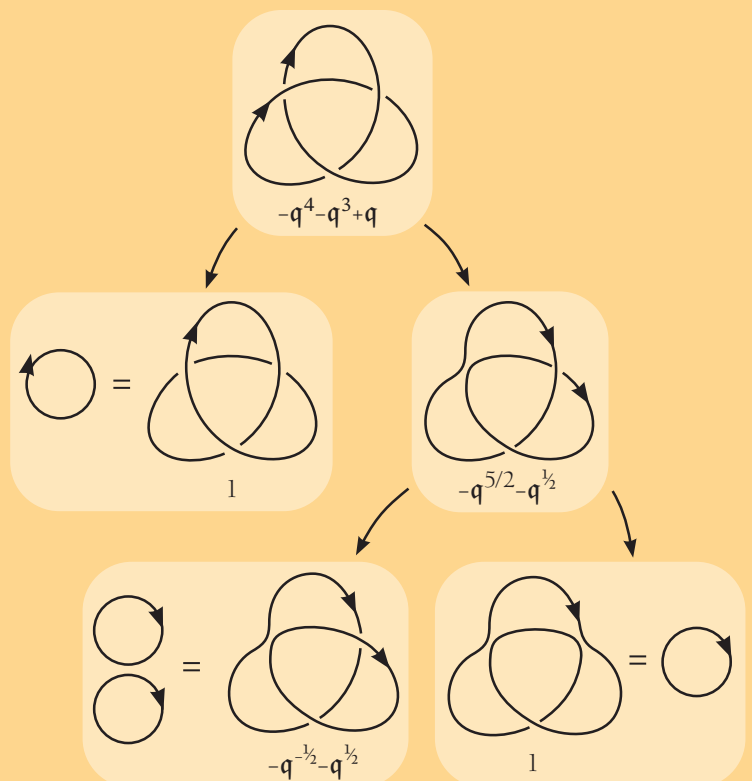
The Jones polynomial $P_K(q)$ is an invariant of an oriented link K (i.e., a union of knots). It can often be used to distinguish different knots. The Jones polynomial can be computed using a 2-dimensional link diagram (i.e., a projection of the link to the plane) via the *Skein relations*:

1. The Jones polynomial of the trivial knot is equal to 1. In fact, the Jones polynomial of the union of n unlinked trivial loops equals $(-q^{-1/2} - q^{1/2})^{n-1}$.
2. After modification of a crossing in the knot diagram, the Jones polynomials satisfy the following equation:

$$q^{-1} \times \begin{array}{c} \nearrow \\ \searrow \end{array} - q \times \begin{array}{c} \searrow \\ \nearrow \end{array} = (q^{1/2} - q^{-1/2}) \times \begin{array}{c} \curvearrowright \\ \curvearrowleft \end{array}$$

Here the arrow indicates an orientation and the first two crossing types are well defined (think of the direction in which you need to turn a screw to align both arrows).

The figure on the right shows how the Skein relations can be used to compute the Jones polynomial of the trefoil knot.



Congratulations to our 2022 Graduating PhDs!

Jess Banks "Random Matrices and Provable Algorithms for Approximate Diagonalization" under Nikhil Srivastava

Nicholas Bhattacharya "Making Sense of Protein Representation Learning in the Wild" under Yun Song and Steven Evans

Nic Brody "Groups Acting on Products of Trees" under Ian Agol

Aaron Brookner under Nicolai Reshetikhin

Marvin Castellon "Dynamics of Outer Automorphism Action on Character Varieties" under David Eisenbud

Reid Dale "Logical Interrogations of Theory and Evidence" under Thomas Scanlon and Wesley Holliday

Onyebuchi Ekenta "Spectrum-Revealing CUR Decomposition" under Ming Gu

Rockford Foster "Algorithms for Computing Highly Oscillatory Indefinite Integrals and Applications in Plasma Physics" under Jon Wilkening

Michael Franco "Efficient solvers for the implicit time integration of matrix-free high-order methods" under Per-Olof Persson

Christopher Kuo "Symplectic geometric methods in microlocal sheaf theory" under Vivek Shende

Bo Li "Numerical Algorithm in Machine Learning and Data Analysis" under Ming Gu

Jeffmin Lin "Neural Network Antisymmetries for Quantum Many-Body Simulation" under Lin Lin

Holly Mandel "Degenerations of Negative Kähler-Einstein Surfaces" under Song Sun

Theo McKenzie "Random Walks and Delocalization through Graph Eigenvector Structure" under Nikhil Srivastava and Luca Trevisan

Kyle Miller "Singularity Theory for Extended Cobordism Categories and an Application to Graph Theory" under Ian Agol



Nima Moini "Galilean Theory of Dispersion and Scattering for Kinetic Equations" under Daniel Tataru

Adele Padgett "Sublogarithmic-Transexponential Series" under Thomas Scanlon

Ritvik Ramkumar "The Geometry of Hilbert Schemes on Projective Space" under David Eisenbud

Meredith Shea "Discrete Systems in Quantum and Statistical Mechanics" under Nicolai Reshetikhin

Foster Tom "Horizontal-strip LLT polynomials" under Mark Haiman

Yu Tong "Quantum Eigenstate Filtering and Its Applications" under Lin Lin

Mariana Vicaria "Ax-Kochen/Ershov style results in model theory of henselian valued fields" under Thomas Scanlon and Pierre Simon

Weitong Wang "Distribution of Class Groups" under Melanie Wood

Haoren Xiong "Scattering resonances and the complex absorbing potential method" under Maciej Zworski

Xiaohan Yan "Quantum K-Theory of Flag Varieties and Non-Abelian Localization" under Alexander Givental

Michael Yeh "An Efficient, Tolerance-Based Algorithm for the Truncated SVD" under Ming Gu

Yiling You "Mathematical Models and Control Algorithms for Traffic Automation" under Jon Wilkening and Alexandre Bayen

Jiefu Zhang "Structure-Informed Neural Network Architecture in Regression Applications" under Lin Lin

Theodore Zhu "Some Problems on the Convex Geometry of Probability Measures" under James Pitman



Graduate Student Profile

Luya Wang is a fifth-year graduate student under the supervision of Michael Hutchings. She is originally from Hangzhou, China and obtained her undergraduate degree from Princeton University.

Luya's research interests include symplectic geometry and low-dimensional topology. She is particularly interested in exploring algebraic structures of embedded contact homology, a theory developed by Michael Hutchings. In addition, she studies knot detections through surface dynamics, and classifications of symplectic fillings through pseudo-holomorphic foliations.

Luya has been a co-organizer for the Geometric Topology Grad and Postdoc Seminar, a weekly virtual seminar for graduate students and postdocs interested in geometric topology broadly. She also co-organizes the virtual and in-person KYLEREC Workshop, an annual workshop for graduate students interested in symplectic geometry.

Luya has been supported by the Geometry and Topology Research Training Group (RTG) grant at Berkeley, and the NSF Graduate Research Fellowships Program. These fellowships have allowed her to focus on her research, as well as to help build a mathematical community for scholars from diverse backgrounds.

Mathematics and quantum computation



Associate Professor Lin Lin

Quantum computing is a new model of computation that promises to deliver a completely new level of computational power. It has received an exploding amount of attention in academia, national laboratories, and industry alike in recent years, and this has been supercharged by “quantum supremacy” experiments by Google in 2019. While the fabrication of a full-scale, fault-tolerant, universal quantum computer remains a formidable technological challenge, there has been rapid and significant progress on efficient and powerful quantum algorithms in the past decade, which can be deployed to solve tasks such as large scale linear systems of equations, eigenvalue problems, differential equations and optimization problems, whenever universal quantum computers become available. The efficient solution of such problems may impact and transform many areas such as physics, chemistry, materials science, biology, data science and even finance.

Admittedly, there are still very few mathematicians involved in quantum computing nationwide. For instance, in the Berkeley-led NSF Challenge Institute for Quantum Computation (CIQC), which includes 30+ principal investigators from 8 universities, Peter Shor (MIT; the inventor of the famous “Shor’s algorithm” for factorizing integers in polynomial time) and I are the only investigators from a mathematics department. That being said, there is fast growing interest for researchers at all levels (particularly, students and postdoctoral scholars) to develop and to apply quantum algorithms to an increasingly wide range of applications, and mathematicians naturally have an opportunity to make important contributions to this field.

This excitement is being increasingly felt in Evans hall. Together with Umesh Vazirani (Berkeley, EECS), I am currently co-mentoring three Simons Quantum Postdoctoral Scholars (Nilin Abrahamsen, Di Fang, and Jin-Peng Liu). In addition, math postdocs Zhiyan Ding (Morrey Assistant Professor) and Subhayan Roy Moulik are also primarily working on quantum algorithms and quantum information theory. Two of my former students, Dong An (PhD’2021) and Yu Tong (PhD’2022), were both awarded the Friedman Memorial Prize in Applied Mathematics for their innovative work on quantum algorithms. Di Fang, myself and several CIQC investigators are organizing a semester long program on “Mathematical and Computational Challenges in Quantum Computing” at the Institute for Pure and Applied Mathematics, UCLA in 2023.

Recently, there is also a trend of algorithmic development targeting “early fault-tolerant quantum computers” with more limited quantum resources, and these algorithms can be more



Graduate Students and Faculty in the 9th Floor Courtyard

readily used in the near to mid-future. With graduate students Yulong Dong and Yu Tong, we proposed a new algorithm called “quantum eigenvalue transformation of unitary matrices”, which can be used to perform many tasks, such as estimating the eigenvalues of a quantum Hamiltonian with unprecedented efficiency (*Physical Review X Quantum*, 2022). I think the next few years will witness an increasing amount of interest in such early fault-tolerant quantum algorithms, and quantum algorithms for scientific computation in general. This is an excellent time for exploring the interplay between mathematics and quantum computation.

Graduate Student Honors

- The 2021-22 Bernard Friedman Memorial Prize in Applied Mathematics was awarded to Jess Banks, Jorge Garza-Vargas, Mehdi Ouaki, and Yu Tong.
- Ritvik Ramkumar received the Kenneth Ribet & Lisa Goldberg Award in Algebra.
- Esme Bajo, Thomas Browning, Marvin Castellon, Fei Yu (Dennis) Chen, Daniel Chupin, Isabel Detherage, Sean Gonzales, David Gonzalez, Aubrey Gross, Haotian Gu, Michael Heinz, Erik Herrera, Eric Jankowski, Ahmee Christensen, Claire Mirocha, Zachary Stier, Mitchell Taylor, Rebecca Whitman, and Ziwen Zhao received 2021-22 Outstanding Graduate Student Instructor Awards.

Solid Foundations Project



Assistant Teaching Prof.
Alexander Paulin

Mathematics is a critical skill set needed to succeed in a wide variety of majors. At Berkeley, about 80% of undergraduate students take a course

in mathematics.

Many of these students arrive with a clear sense of what they want to study, only to find themselves underprepared and struggling through gateway math courses. This experience is often enough to deter students from pursuing scientific or technical fields. Among underrepresented students, this is an especially acute issue, with a steep STEM dropout rate of around two thirds.

To better support these students, there is a clear need to identify and address gaps in their foundational mathematical knowledge. With support from the Eustace-Kwan Family Foundation, in 2020 the department along with the Student Learning Center, developed a new program called PreCalculus Essentials. We designed it to function both as a comprehensive asynchronous online resource, available to everyone across the university, as well as the backbone of

a three-week online summer course. The program includes dozens of modules such as: algebra with inequalities, composition of functions, and properties of sine and cosine.

In the two years since then, we've run the summer course three times. These courses have been a tremendous success, with over three thousand students taking part, including those in the Pre-Engineering Program (PREP) and STEM Excellence through Equity and Diversity (SEED) honors program.

With the continued support of the Eustace-Kwan Family Foundation, we've been working to expand the scope of the program, now called the Solid Foundations Project. In Fall 2021 and 2022 we ran precalculus support workshops for students in Math 1A. We've also partnered with the Mathematics Diagnostic Testing Project at UC San Diego to strengthen the diagnostic testing process for our incoming students.

In many ways the last two years have been a learning experience, giving us a clearer sense of what support is needed and how we can best provide it. We've discovered that there is huge interest in foundational support for all lower division mathematics classes, not just our introductory calculus classes. We've found that students are at their most vulnerable during the first few weeks of these gateway courses and that's when

Undergraduate Student Honors

- The 2021-22 Department Citation was awarded to Tegan Lakshmanan.
- The 2021-22 Paul Chernoff Memorial Prize in Mathematics was awarded to Tegan Lakshmanan.
- Channing Jialu Che, Anji Dong, Lily (Qiao) Li, Corey Lunsford, Louie Putterman, Ryan Kenichi Tamura, and Tianyu Zhao received the Dorothea Klumpke Roberts Prize in Mathematics.
- Ariana Gwenyth Chin, Adrian Fan, Skye Kidd, Xinran Liang, Orion Shih Lung Ning, Jake Quinn, Digvijay Varier, Julius Vering, and Yanlai Yang received the Percy Lionel Davis Award for Excellence in Scholarship in Mathematics.
- Lily (Qiao) Li received an honorable mention for the Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman.
- Jianzhi Wang, Richard H. Wu, and Wentinn N. Liao received an honorable mention at the 82nd Annual Putnam Competition. UC Berkeley's Team received an honorable mention. Shreyas Ramamurthy, and Henry Zeng were ranked 106 and 193, respectively. Dhruva Ghosh, Ajit Kadaveru, Adam A. Khoja, Austin Lei, Axel Li, Andrew Lin, Ishaan Patkar, and Zachary Slonim were ranked 212–489.

it's the most crucial for us to be there to help. We've also learned that despite the convenience of remote instruction, students really want to learn in-person, to build community with peers and collectively work towards mastery.

With this in mind, our next focus is to shift the summer program into the beginning of the Fall semester as part of our core curriculum. We envision it as a five-week short course called *Foundations of Lower Division Mathematics*, which will run parallel to our introductory calculus classes, giving real-time support in crucial foundational topics. In the longer term, we aim to have versions of this Foundations course for each of our lower division classes. Our ultimate goal is to put in place a robust and easy to navigate support system for all students in our early mathematics classes.

Left: Women in Math at Cal Day.





Staff News

Over the past year the department welcomed several new staff members to our team. In March, **Hanh Tran** joined our department as our Undergraduate Programs Manager and Advisor. This is a new position for the department focused on supporting several undergraduate initiatives including Professor Paulin's Solid Foundations program and the recently launched MPS Scholars program. Hanh recently completed her Doctorate in Educational Leadership at San Jose State University and previously worked at San Francisco State University as an Academic Advisor. In April, **Kathryn Mills** joined us as our new Front Office Administrator after spending 17 years working in facilities management and administration with UCLA's Continuing Education of the Bar Program (CEB). Additionally, in June we welcomed Dr. **Siti Keo** as our new Finance Manager. Siti joined the department with 11 years of experience here at UC Berkeley working with a variety of different

programs, including several within the division of Mathematical and Physical Sciences. Siti holds a PhD in History from UC Berkeley and possesses a broad range of knowledge and experience in all areas of finance and administration. We are very excited to have Hanh, Kathryn, and Siti on board.

This past year we also said goodbye to several employees including **Heather Read** who retired from UC Berkeley after nearly 21 years on campus. Heather spent the last nine years working here in the Math Department as our Staff Accountant and was a highly valued co-worker and member of our math community. Congratulations to Heather on her well deserved retirement! In December we said goodbye to **Almadora Henry** who accepted a position as an Executive Officer with the School of Optometry, and in January we said goodbye to **Isabel Burle** who accepted a position with the Department of Economics as their Assistant Director of Curriculum.

— Brian Underwood, Department Manager

Left: Hanh Tran, Kathryn Mills, Siti Keo.

Below: Berkeley Connect "Meet the Faculty" Panel with Profs. Holtz, Lin, Serganova.

Summer Undergraduate Research Fellowship, 2022

The SURF Program offers undergraduates the opportunity to spend their summer working on a research question in their chosen field, in a group and under the guidance of a faculty member. The 2022 Math Team was comprised of Yuming Huang, Alexander Richardson, and Jacob Krantz, who worked on questions in nonlinear partial differential equations arising from general relativity, advised by Assistant Professor Sung-Jin Oh. Here are some of their reflections:

Y. Huang (3rd year): "It's a very fun experience! We usually meet two times a week, but we work on a real-time shared file, so one can also say we are always meeting. The most important thing I've learned is to always expect difficulties along the way and accept them positively as challenges."

A. Richardson (4th year): "Math can be a very isolating topic, so having a group like the Math Team is a very rewarding experience for discovering camaraderie and how to work around challenging problems. ... My favorite part of this project is working on a problem that might matter. Most questions we work on in class are for academic purposes, but if we can solve this, there may be some application that makes a difference somewhere. "

J. Krantz (3rd year): "Each member of our team has a different mathematical background, so working together has helped us resolve our questions quickly. My favorite part of getting to conduct math research is the opportunity to potentially discover a solution to an unsolved problem. I look forward to applying the techniques and theory I have learned in my classes to this problem."

SURF is supported by the MPS Undergraduate Research Fund



MATHEMATICS + BERKELEY

FALL 2022 NEWSLETTER



Entering class of graduate students in Mathematics and Logic, 2022 (Photo: Jon Phillips)

A Note on Strategic Priorities

The Department of Mathematics is working hard to maintain its excellence in all aspects of research and education and to bridge the resource gap that separates us from our better-funded peers. For this we continue to rely on donations from alumni and friends of the department. Here are some of the department's current top priorities:

- **Graduate Student Fellowships** are needed to enable the department to make competitive, attractive offers to the very strongest applicants to our graduate program, who are often being lured by our private peers with offers of higher stipends and lower teaching loads.
- **Endowed Faculty Chairs and Endowed Postdocs** are needed in order to improve the department's ability to make competitive offers for the recruitment and retention of world-class faculty and postdocs.
- **Research Visitor Funds** make it easier to invite high-profile visitors to come to Berkeley to deliver lectures in our department or collaborate with our faculty. These intellectual exchanges are of tre-

mendous value to our research and education.

Besides these specific goals, we welcome gifts to the department's discretionary fund, which give the Chair of the department much-needed flexibility in funding graduate student recruitment, parts of the faculty recruitment process, research travel for graduate students, and many other initiatives that make our program competitive and rewarding. Undergraduate Research Fellowships are needed to enable undergraduate students to participate in summer research groups with faculty, postdocs, and graduate students.

We invite you to join us in keeping UC Berkeley Mathematics strong through your gifts to the department. All donations, large or small, are greatly valued. You may choose whether to direct your gift toward a specific goal of your choice or to have your donation used for our most pressing needs at the department's discretion.

For further information, please contact Associate Development Director Ryan Guasco, email: rguasco@berkeley.edu or Department of Mathematics Chair Prof. Michael Hutchings, e-mail: chair@math.berkeley.edu.

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