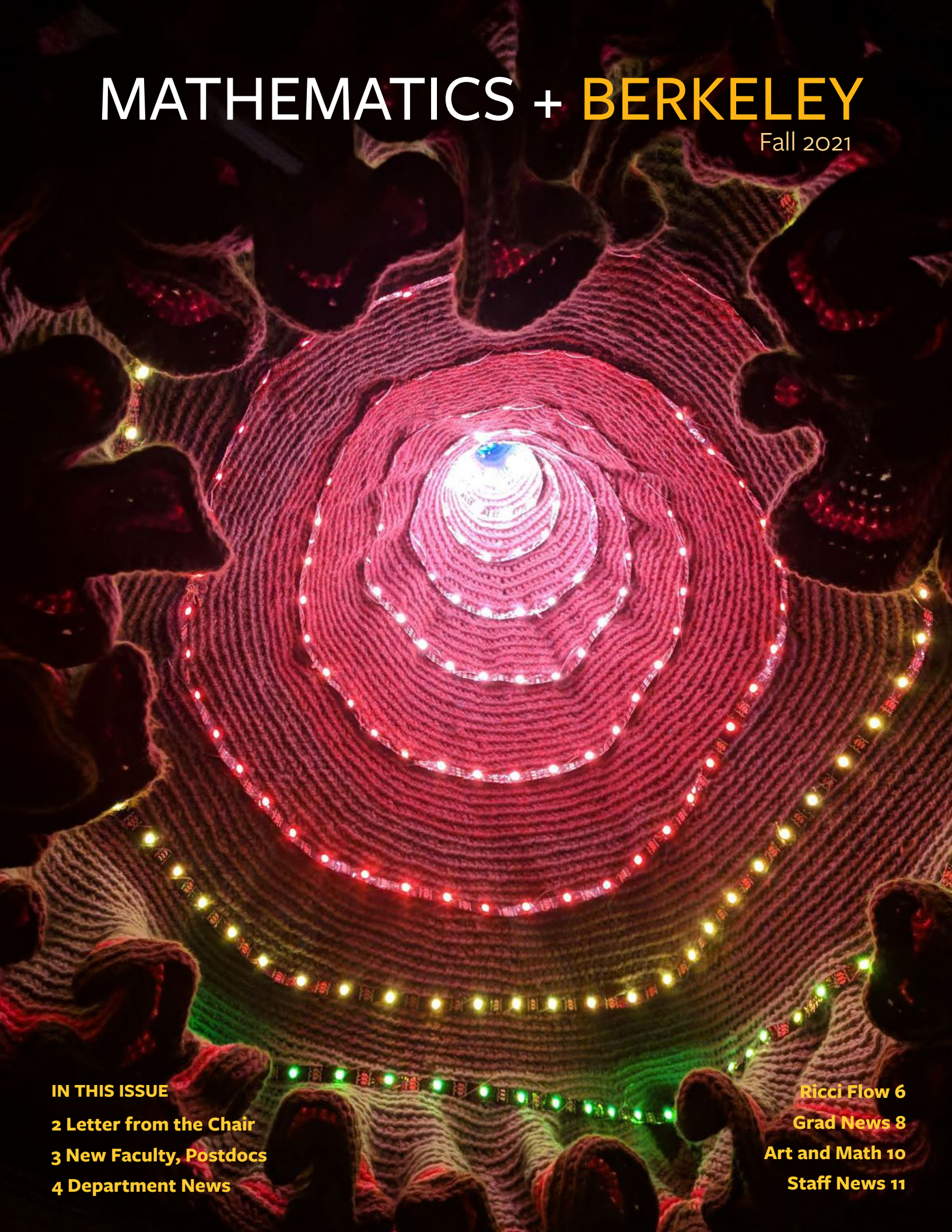
# MATHEMATICS + BERKELEY

Fall 2021



IN THIS ISSUE

*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,

"Excuse me, do you know where Evans Hall is?" The excitement was palpable as we returned to in-person activities this fall. Not only the first-year students, but also most second-year students had never been to campus before. Our classes are now almost all in person, although we continue to hold some online seminars in order to more easily connect with the international mathematical community. Everyone on campus is required to be vaccinated against Covid-19, except for those with medical or religious exemptions. Just to be extra safe, for the time being we are holding our department teas outside on the ninth floor patio, weather permitting.

During the last academic year almost all of our activities were online, but everyone continued their research, teaching, and service as best as they were able to, sometimes in very creative ways. For example, Richard Borcherds created a wonderful series of YouTube lectures on a wide variety of topics in mathematics, which provide an invaluable resource for advanced undergraduates and graduate students both in and outside of the department. Kelli Talaska and Alexander Paulin received UC Berkeley's Extraordinary Teaching in Extraordinary Times award, for their work developing the Pre-Calculus Essentials online course and summer program, to better prepare incoming undergraduates for their first math courses.

Our faculty received a number of new honors for their research accomplishments. To list a few examples: Mina Aganagic, Richard Bamler, Bernd Sturmfels, and Sug Woo Shin will be Invited Speakers at the 2022 International Congress of Mathematicians in St. Petersburg, Russia. Lin Lin and collaborators won the 2022 Association of Computing Machinery Gordon Bell Prize. Nikhil Srivastava recieved the 2021 Michael and Sheila Held Prize. Alan Hammond was elected a Fellow of the Institute of Mathematical Statistics, and Nicolai Reshetikhin was selcted as a 2022 Fellow of the American Mathematical Society.

We were fortunate to recruit two outstanding new faculty, who will start in summer 2022. Yunqing Tang, who works in arithmetic geometry and number theory, will join the department as an Assistant Professor. And — stop the presses! — Andrei Okounkov, who works in representation theory, algebraic geometry, probability theory, and mathematical physics, will re-join the department as a Professor (he was briefly on our faculty around the turn of the century).

We are currently actively recruiting more faculty in order to maintain the research excellence and meet the teaching needs of the department. For the same reason we are also working to increase the number of Morrey Visiting Assistant Professors (three-year teaching postdocs) in the department, with plans to have twelve Morreys in the department next year, and hopefully even more in the future.

Although there was a bit of a dip during the pandemic, we continue to teach an enormous number of undergraduate students. In spring 2021 we had over 750 mathematics majors, and we awarded 397 undergraduate degrees in pure and applied mathematics. The total enrollment in our courses for the year 2020-21 (the sum over all math courses of the number of students in the course) was more than 17,500. This includes a record summer enrollment of over 1,850 students in summer 2021.

Our world-class graduate program was once again ranked in a tie for second place by US News & World Report. This year we weclomed a diverse incoming class of 23 graduate students, 12 of whom are international.

As always, our department could not function without the tireless dedication of the staff. Among several arrivals and sad departures, we are happy to welcome back Vicky Lee in the new role of Director of Student Services.

In other news, plans to move the department to a new building on the North Field site have been temporarily put on hold, but we are still expected to move out of Evans Hall by 2030 — stay tuned!

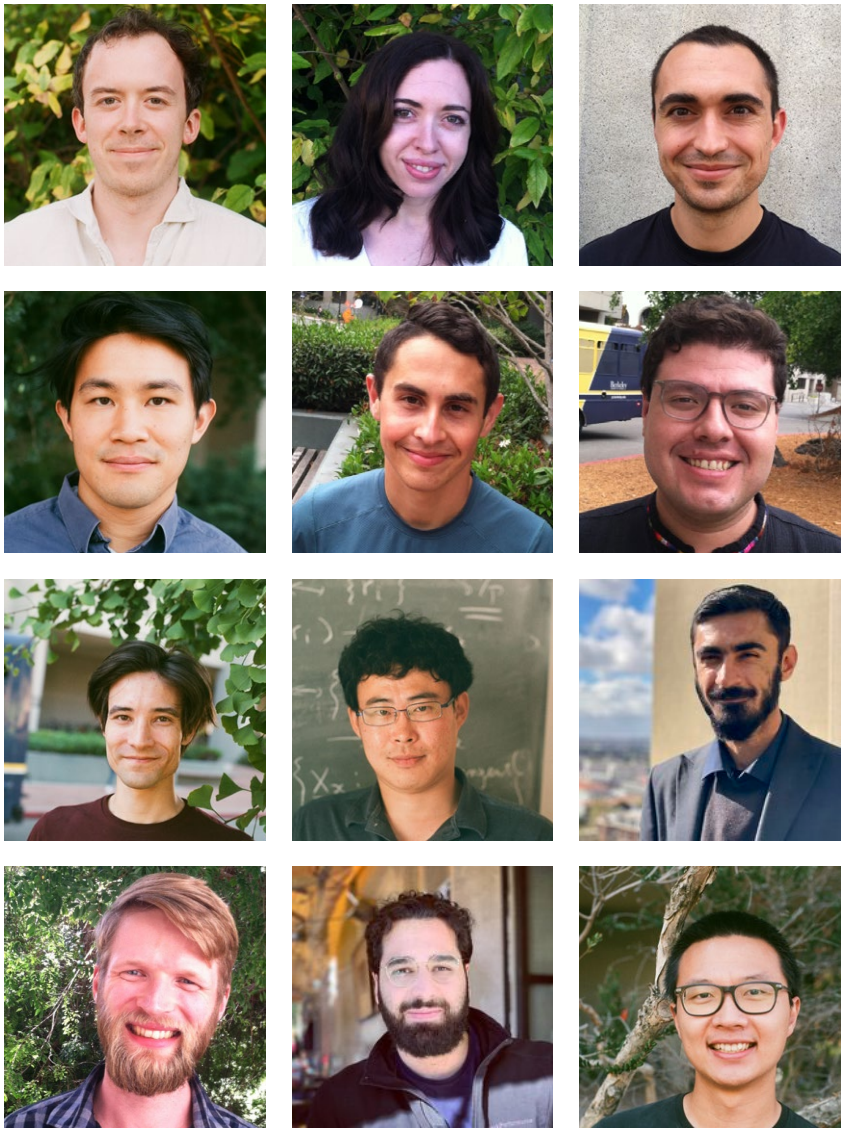
I want to acknowledge the donors who have supported the department over the years and express, on behalf of the Department of Mathematics, our heartfelt gratitude. Simply put, we could not sustain our level of excellence in research and teaching without your support!

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.


*Scary Textbooks, Halloween Tea, October, 2021 (Photo: Brittany Hosea-Small).*

## New Postdocs

- Owen Barrett (Morrey), PhD Chicago. Algebraic and arithmetic geometry
- Lea Beneish (Morrey), PhD Emory. Number theory, representation theory.
- Jackson Morrow (RTG), PhD Emory. Number theory, arithmetic geometry.
- Eric Chen (NSF), PhD Princeton. Geometric analysis and differential geometry.
- Peter Haine (NSF+President's Postdoc), PhD MIT. Homotopy theory and algebraic geometry.
- Andrés R. Vindas Meléndez (NSF), PhD Kentucky. Algebraic and geometric combinatorics.
- Nilin Abrahamson (Simons Fellowship), PhD MIT. Quantum computation.
- Shaosai Huang, PhD Stony Brook. Differential geometry, geometric analyisis.
- Subhayan Roy Moulik, DPhil Oxford. Quantum theory, quantum computation.
- Dino Rossegger, PhD TU Wien. Computability theory.
- Nima Moshayedi, PhD Zurich. Mathematical physics, symplectic geometry.
- Xin Xing, PhD Georgia Tech. Numerical analysis, quantum chemistry.



*Right: the twelve new postdocs postdocs pictured in the order above.*

Yunqing Tang will join the faculty as an Assistant Professor in Fall 2022. Tang obtained her Ph.D. from Harvard in 2016 under the supervision of Mark Kisin. Tang was a a member of the Institute for Advanced Study from September 2016 to June 2017, an instructor at Princeton University from July 2017 to January 2020, and a junior researcher (Chargé de recherche) at CNRS/Université Paris-Sud from February 2020 to June 2021; she is currently an assistant professor at Princeton University. Tang's research is in arithmetic geometry and number theory. Her main interest lies in studying the arithmetic of abelian varieties via the geometry of their moduli spaces and generalizing arithmetic algebraization theorems to tackle various problems in number theory.

Ruixiang Zhang joined the department as an Assistant Professor in Fall 2021. Zhang won a gold medal at the IMO in 2008 before going to Peking University for his undergraduate education. He obtained his Ph.D. from Princeton in 2017. During the years 2017-2018 and 2020-2021 he was a member of the Institute for Advanced Study and in 2018-2021 he was a Van Vleck Visiting Assistant Professor at University of Wisconsin-Madison. Zhang is interested in a lot of problems broadly related to Harmonic analysis, including problems in Euclidean Fourier analysis, incidence geometry, analytic number theory and additive combinatorics. Among them a good example is the Kakeya conjecture which predicts that in every Euclidean space, a set containing a unit line segment in every direction must have full dimension. Outside of mathematics, he enjoys playing board games and several sports. He was a competitive Pokemon TCG player before the pandemic.

## New Faculty Profiles

## DEPARTMENT NEWS

### Faculty Honors

- Jennifer Chayes received the 2020 Distinguished Service Award of the Association for Computing Machinery.
- Alan Hammond was named a Fellow of the Institute of Mathematical Statistics.
- Olga Holtz received the MUSA Distinguished Teaching Award.
- Lin Lin was named a Simons Investigator, and with collaborators received the 2020 ACM Gordon Bell Prize.
- Alex Paulin and Kelli Talaska were awarded the UC Berkeley Teaching Extraordinary Teaching in Extraordinary Times Award.
- Nicolai Reshetikhin delivered a plenary talk at the International Congress of Mathematical Physicists.
- Kenneth Ribet was elected to the Council of the National Academy of Sciences.
- Nikhil Srivastava and collaborators were awarded the 2021 NAS Michael and Sheila Held Prize.
- Mina Aganagic, Richard Bamler, Bernd Sturmfels, and Sug Woo Shin are invited speakers at the 2022 International Congress of Mathematicians.

*Department Alumni Greg Kemnitz '86 and Tiffany Yeh '14 at a Berkeley Connect Career Panel, October 2021. (Photo: Brittany Hosea-Small)*

### Graduate Student Honors

- The 2020-21 Herb Alexander Prize was awarded to Julian Chaidez, David Keating, and Yi Lai.
- The 2020-21 Bernard Friedman Memorial Prize in Applied Mathematics was awarded to Dong An, Zixi Hu, Angxiu Ni, and Madeleine Weinstein.
- Ian Gleason, Melissa Sherman-Bennett, and German Stefanich received the Kenneth Ribet & Lisa Goldberg Award in Algebra.
- Abdulrahman Bin Omar, David Casey, Christine Chow, Amrit Daswaney, Rachel Fitzpatrick, Ritwik Ghosh, Andrew Gitlin, Grace Gordon, Yafei Li, Larsen Linov, Michelle Lui, Mark Macerato, Xianglong Ni, Mohandas Pillai, Ritvik Ramkumar, Alexander Sherman, Leah Stephens, Yiling You, and David Zhao received 2020-21 Outstanding Graduate Student Instructor Awards.

### Undergraduate Student Honors

- The 2020-21 Department Citation was awarded to Junhao Fan.
- The 2020-21 Paul Chernoff Memorial Prize in Mathematics was awarded to Junhao Fan.
- Reuben Drogin, Mason Haberle, Nathan Kenshur, Casey Perdue, Eunice Sukarto, and Huanning Zhang received the Dorothea Klumpke Roberts Prize in Mathematics.
- Matin Ghavamizadeh, Kyle Huang, Reid Johnson, Rohan Joshi, Xiaoyu Niu, Mark Olson, Kai Shaikh, Shengze Wang, and Sixian Yu received the Percy Lionel Davis Award for Excellence in Scholarship in Mathematics.
- Eunice Sukarto was the Runner-up for the Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman.

### Undergraduate Life

This past year 397 undergraduates (70% Applied Math, 30% Pure Math) received their undergraduate mathematics degrees from UC Berkeley. With all but the largest classes taught in-person this fall and the students back on campus, the lively undergraduate mathematics community is thriving. Our student groups organize many events including distinguished lecture series for undergraduates, mathematics DeCal classes, directed reading courses with graduate students and faculty, and peer tutoring to name a few. For more information about our undergraduate program see https://math.berkeley.edu/programs/undergraduate

## Richard Borcherds: YouTube Sensation

I started my math YouTube channel largely by accident: I had to record my graduate lectures anyway because of covid, and figured that I might as well put them on YouTube. I was surprised to find that the number of viewers per day is not a Poisson process: most of the time there is a steady trickle, but a few times a year the numbers briefly shoot up, because of people mentioning the channel on reddit or twitter (or maybe math department newsletters).

In case anyone else wants to try starting a YouTube math channel, the easiest setup I found (after some experimentation) is to use a document camera directed at what I am writing, together with another camera directed at me. You can combine these into a single video using the (free, easy) program OBS Studio. A front ring light, a background light, and a lapel microphone improve things. Editing videos is a massive time sink so I try to avoid it: if I make a bad mistake it is faster to re-record everything than to edit out the mistake.

Finally I'll answer the question that everyone is secretly wondering about: how much money does my YouTube channel make? The answer is that YouTube pays about a tenth of a cent per ad viewed, which is so little that I keep ads turned off, as such a tiny amount of money is not worth the annoyance to students. With ads turned on, channels of this size would bring in about a dollar or two a day. This would be about a tenth of minimum wage for the time I spend, so I advise anyone planning to get rich on YouTube to pick a topic other than graduate math lectures.

*Judges of the Halloween Costume Contest, including Prof. Borcherds, October 2021. (Photo: Brittany Hosea-Small)*

## Faculty Retirements

Professors L. Craig Evans, John Strain, and Nicolai Reshitikhin (pictured above) retired this year and remain affiliated with our department as emeriti. These colleagues made distinguished contributions to mathematics and to our department, and were among its friendliest members. A joint retirement party was held for Craig and Kolya on Zoom on May 25, 2021. We wish them all well and hope to see them often.

## Distinguished Lectures

- The 2021-22 Bowen Lectures were given in October, 2021 by Richard Kenyon of Yale University, on *"Multinomial random tilings and other models."*
- The 2021-22 Serge Lang Lecture was given on November 15, 2021 by Stephon Alexander of Brown University, with a lecture entitled *"The Jazz of Physics: The Link Between Music and The Structure of the Universe."*
- The 2021-22 DiPerna Lecture will be given on December 3, 2022 by Felix Otto of the University of Bonn, on *"A Variational Regularity Theory for Optimal Transportation."*
- The 2021 Alfred Tarski Lectures will be given in April, 2022 by Zoé Chatzidakis of the École Normale Supérieure.

*Cover*: "The Fabric of Spacetime", by Gabriel Dorfsman-Hopkins and M. Maynard. See p.10-11 for more on how it was made.

## Faculty Research Highlight:

### *Ricci Flow and its Topological Applications*

*Associate Professor Richard Bamler*

About 20 years ago, Grigori Perelman published a series of papers in which he proved two famous conjectures: the Poincaré Conjecture (a Millennium Problem!) and the Geometrization Conjecture. While these conjectures were of topological nature, their solution relied on a technique from geometric analysis called *Ricci flow*. Ever since Perelman's discoveries, geometric analysts have been intrigued by the question of whether Ricci flow can be used to prove further conjectures in topology. In this article, I will give a short overview on this topic and discuss two recent advances — the first one has already led to some topological applications and the second one may do so in the future.

A Ricci flow is a process that can be used to improve, or homogenize, a given geometry. To motivate this process using a real life example, suppose that we have two inflatable beach toys: a beach ball and an inner tube. When deflated, the surfaces of both toys have very irregular, crumpled geometry and it may be hard to tell them apart. But, as the toys are inflated, these crumples are smoothened — convex and concave regions cancel each other out — and we obtain a geometry that depends on the topology (the loose underlying structure) of each beach toy: the beach ball becomes completely round and the inner tube develops its own rotationally symmetric geometry. So through inflation, both objects attain a certain *inherent geometry* and, therefore, they become easily distinguishable from one another.

In mathematical terms, a Ricci flow is described by a manifold $M$ (a loose topological structure) equipped with a family of Riemannian metrics $g(t)$, depending on a time parameter $t$, that describes the evolving geometry by assigning a notion of length to every tangent vector of $M$ at every time $t$. The evolution of the metrics $g(t)$ is governed by the Ricci flow equation:

$$\partial g(t) = -2\mathrm{Ric}[g(t)]$$

Here $\mathrm{Ric}[g(t)]$ denotes the *Ricci curvature* of the metric at time $t$ — a term that roughly measures the second variation of the area of hypersurfaces under normal deformations. Under the Ricci flow equation, directions of positive Ricci curvature contract, while directions of negative Ricci curvature expand. The equation also implies that the curvature of the metric $g(t)$ evolves according to a non-linear heat equation. This suggests that — at least in some cases —the metric becomes "smoother", similar to the evolution of a heat equation, under which regions of high and low heat cancel each out after some time.

In dimension 2, this is indeed the case: if we start the Ricci flow from an arbitrary metric, then the flow always converges, after rescaling, to a metric of constant curvature, which is inherent to the topology of the underlying manifold. In dimension 3 and above, however, the flow may develop singularities "too soon" and then cease to exist. Figure 1 shows three rotationally-symmetric examples, in which the flow starts from a "dumbbell-shaped" geometry (two round spheres of radii $r_1$, $r_3$ that are connected by a "neck" of width $r_2$). Its singularity depends on the choice of the radii $r_1, r_2, r_3$. For example, in the case in which $r_1 \approx r_2 \approx r_3$, the geometry becomes rounder and rounder and shrinks to a point, while in the case $r_2 \ll r_1, r_3$, the flow develops a cylindrical neck singularity.

One of Perelman's key findings was that, in fact, *any* (not necessarily rotationally symmetric) singularity in dimension 3 falls into one of the three types of Figure 1. This allowed him to perform a so-called *surgery construction*, under which the almost singular part of the manifold was removed by discarding spherical components and cutting away cylindrical regions. This results in a "less singular" geometry, from which the flow can be restarted until we reach another singularity, where another surgery is necessary, and so on (see Figure 2). Note that a surgery potentially changes the topology of the manifold (for example, it may disconnect it), but this change is controlled and fits into a good topological framework. Perelman could argue that such a *Ricci flow with surgery* will eventually "improve" the metric to an extent that it allows conclusions on the underlying topology, which lead to the resolution of the Poincaré and Geometrization Conjectures.

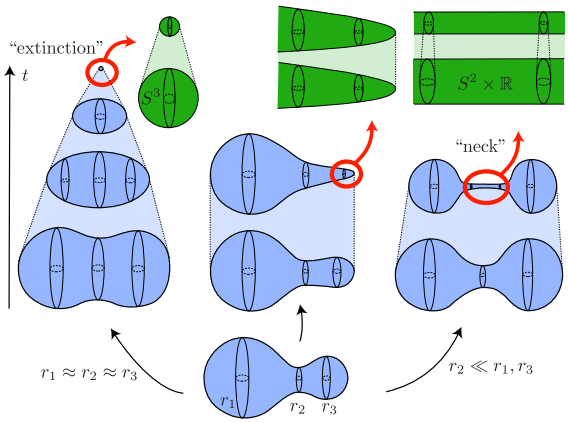



*Fig 1. Different types of singularities*

While Ricci flows with surgery have proven to be extremely powerful, they still have one drawback: They are not canonical. This is because there are many ways of performing surgeries at each step of the construction — for example at a different scale or position. As a result, there are often infinitely many different Ricci flows with surgery starting from a single initial metric To address this drawback, Bruce Kleiner and John Lott (a UC Berkeley faculty) introduced a different type of flow, called *Ricci flow through singularities* (see Figure 3), which seems to resolve singularities "on its own" at an infinitesimal scale.

This intuition was verified later in work of Bruce Kleiner and myself, where we showed that such a flow is indeed *uniquely* determined by its initial metric. So given an initial metric $g_0$, there is a *canonical* Ricci flow through singularities $M(g_0)$ starting from $g_0$.

Our proof had an important byproduct: It established continuous dependence of the flow $M(g_0)$ on its initial condition $g_0$. So a similar initial condition leads to a similar Ricci flow through singularities, though changes in the types of singularities may occur. This allowed us to use Ricci flow to improve continuous *families* of initial metrics (see Figure 4) and led to the first topological applications of Ricci flow since Perelman's work.

Let me briefly describe one of these applications. Consider the set of all diffeomorphisms $\varphi: S^2 \to S^2$ from the 2-dimensional sphere to itself (i.e., $\varphi$ is smooth and invertible and its inverse is smooth as well). An old result of Smale (a UC Berkeley emeritus) states that it is possible to continuously deform all of these diffeomorphisms, at once, to basic rotations of the sphere. Our work implies that the same is true if we replace the 2-dimensional sphere by a 3-dimensional sphere or by similar manifolds that arise as quotients. In our proof we exploit a relationship between the set of diffeomorphisms and the set of Riemannian metrics. So a uniform deformation of Riemannian metrics implies a uniform deformation of diffeomorphisms.

Now that we have obtained a satisfactory understanding of the Ricci flow in dimension 3, it is natural to move to higher dimensions. Unfortunately, many of the previous techniques break down in dimensions 4 and above. Recently, however, I have developed an alternative approach, which sheds some light on the possible singularity formation in all dimensions. It roughly asserts that "most" singularities are modeled on certain geometries called *gradient shrinking solitons (GSS)*. In dimension 3, the only GSS are (quotients of) the round sphere $S^3$ or the cylinder $S^2 \times R$, i.e., the models in the first and third singularity of Figure 1. By contrast, classifying GSS in higher dimensions seems like an intimidating task. However, we have some partial information in dimension 4, which suggests that there should be some kind of 4-dimensional "Ricci flow through singularities". In this flow, topological change should occur along cylinders of the form $S^3 \times R$ or $S^2 \times R^2$ or along cones. A construction of such a flow would be spectacular, in my opinion, as it would show that Perelman's surgery construction was not just a lucky coincidence in dimension 3, but that topological change is deeply encoded in the Ricci flow equation. In addition, there may be some interesting topological applications. One potential candidate would be the "11/8-Conjecture", which predicts an inequality between certain topological invariants and which is the missing piece in the classification of smooth, simply-connected 4-dimensional manifolds up to homeomorphy.

*Undergraduate Students at a MUSA/Berkeley Connect Event, October 2021. (Photo: Brittany Hosea-Small)*

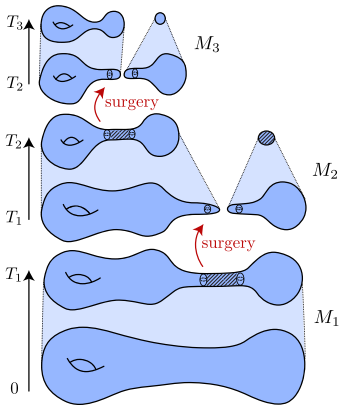



*Fig 2. Ricci flow with surgery*

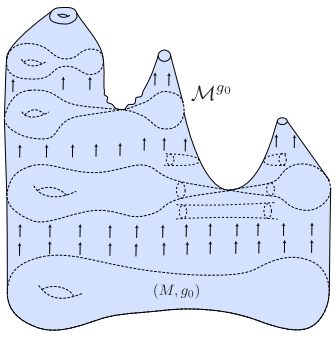



*Fig 3. Ricci flow through singularities*

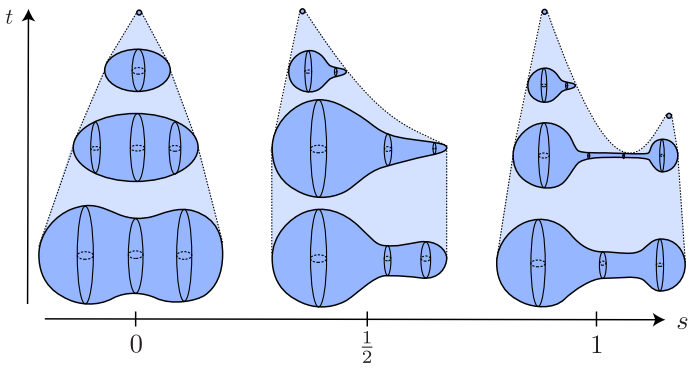



*Fig 4. A continuous family of Ricci flows through singularities*

## Congratulations to our students who received their PhDs this past academic year!

Dissertation chair is indicated in parentheses

Dong An (Lin Lin)

Paula Burkhardt-Guim (Richard Bamler)

Benjamin Castle (Thomas Scanlon)

Julian Chaidez (Michael Hutchings)

Michael Christianson (Martin Olsson)

Charles Cifarelli (Song Sun)

Rahul Dalal (Sug Woo Shin)

Yifeng Ding (Wesley Holliday)

Daniel Erdmann-Pham (Yun Song/Steven Evans)

Anningzhe Gao (Martin Olsson)

Ian Gleason (Sug Woo Shin)

Milind Hegde (Alan Hammond/Shirshendu Ganguly)

Zixi Hu (James Sethian)

Yanhe Huang (Jon Wilkening)

David Keating (Nicolai Reshetikhin)

Donghyun Kim (Lauren Williams/Sylvie Corteel)

Michael Klug (Robion Kirby/Peter Teichner)

Yi Lai (Richard Bamler)

*Graduate Students, October 2021. (Photo: Brittany Hosea-Small)*

Pen Long (Antonio Montalban)

Patrick Lutz (Theodore Slaman)

Noble Macfarlane (Per-Olof Persson)

Thomas Mack-Crane (Sug Woo Shin)

Calvin Mcphail-Snyder (Nicolai Reshetikhin)

Jeremy Meza (Mark Haiman)

Satyaki Mukherjee (Nikhil Srivastava)

Angxiu Ni (John Strain)

Eugene Rabinovich (Peter Teichner)

Mario Sanchez (Lauren Williams/Federico Ardila/Sylvie Corteel)

Isabelle Shankar (Jon Wilkening/Serkan Hosten)

Melissa Sherman-Bennett (Lauren Williams/Sylvie Corteel)

Benjamin Siskind (John Steel/Paolo Mancosu)

Michael Smith (Richard Bamler)

German Stefanich (David Nadler)

Mariel Supina (Federico Ardila)

Peter Vinella (Lawrence Evans)

Jian Wang (Maciej Zworski)

Madeleine Weinstein (Bernd Sturmfels)

Liyu Xia (Anne Collins/James Pitman)

Kentaro Yamamoto (Wesley Holliday)

Zhewei Yao (Ming Gu/Michael Mahoney)

Dongxiao Yu (Daniel Tataru)

Leon Zhang (Bernd Sturmfels)

Xinyu Zhao (Jon Wilkening)

*An Oedipus Complex, Halloween Tea, October 2021. (Photo: Brittany Hosea-Small)*

## Graduate Student Profile

Theo McKenzie is a fifth-year graduate student advised by Nikhil Srivastava and Luca Trevisan. He is originally from New York City and obtained his undergraduate degree from Harvard University.

Theo's research is on the spectral theory of graphs and random matrices. A broad current goal of his is to deduce the relationship between the statistics of eigenvectors of infinite sequences of finite graphs converging to an (infinite) limit graph and the spectral statistics of the limit graph. For his work, he employs tools from spectral theory, probability theory, and combinatorics.

Theo was supported by a Chancellor's Fellowship in 2017-2019. This allowed him to dedicate himself to his research. Specifically, he could participate fully in the Bridging Continuous and Discrete Optimization program at the Simons Institute for the Theory of Computing in 2017, and he remained fully funded during a month-long summer research trip to Rome in 2019. In addition to this, the award allowed him to increase his outreach. At Berkeley he mentors Black undergraduates interested in STEM, planning with them career paths in academia and technical fields; for this, Theo won the Math and Physical Sciences Mentorship Award in 2018. Outside of campus, Theo has been an instructor for the associate degree program at San Quentin State Prison since 2018.

Theo is planning on starting a postdoctoral position in Fall 2022, with the eventual goal of a tenure-track position at a research institution.

## Graduate Program News

Despite the COVID situation, we continued to host a weekly departmental tea time on Gather Town through the year 2020-21, in a virtual room that mimicked (the real) Evans 1015.

In Spring 2021 the department hosted its first Advise-a-thon series (on Zoom), which connected first and second year graduate students with potential advisors and more senior graduate students in their research area. Feedback was very positive — one student wrote: "I found it quite friendly and it showed a strong intention on the part of the department to be more transparent and helpful about the advising process, which is extremely important for me." This is going to become a new annual tradition.

COVID-19 brought about quite a few changes in our admissions process. The number of applications went up by more than 30% from the previous year. We waived the GRE score requirement and hosted our annual open house for new admits on Zoom.

We had an unusually small graduating cohort in Spring 2020 due to COVID, so our Spring 2021 cohort was much larger than usual (42 students, as seen on the facing page). Many students delayed graduation due to the difficulty of traveling/moving for post-doc positions as well as hiring freezes and slowdowns. We are glad to see that essentially all those students that deferred in 2020 were able to graduate and obtain positions in 2021.

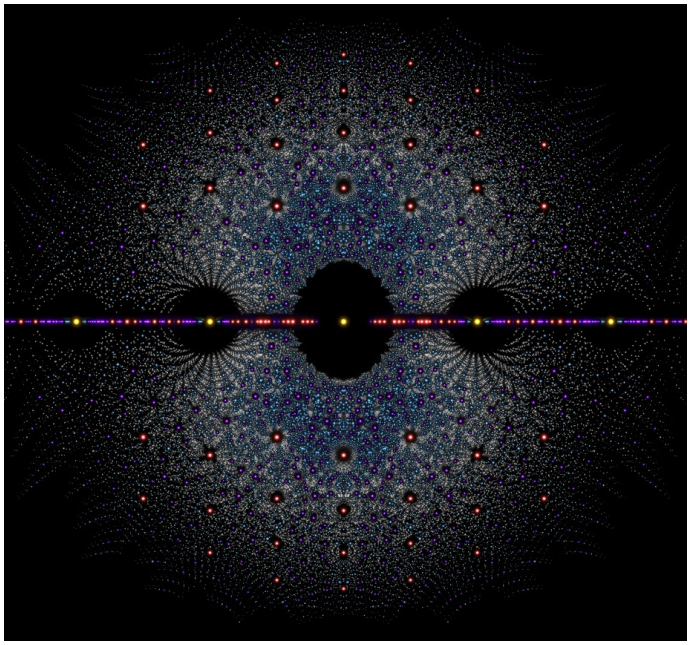
*—Sug Woo Shin (Vice chair for graduate affairs) , Jon Phillips (Graduate advisor) , and Isabel Seneca (Graduate advisor) .*

*Tea in the Ninth Floor Courtyard, September 2021.*

## Postdoc Profile : Gabriel Dorfsman-Hopkins
*on Art and Math*

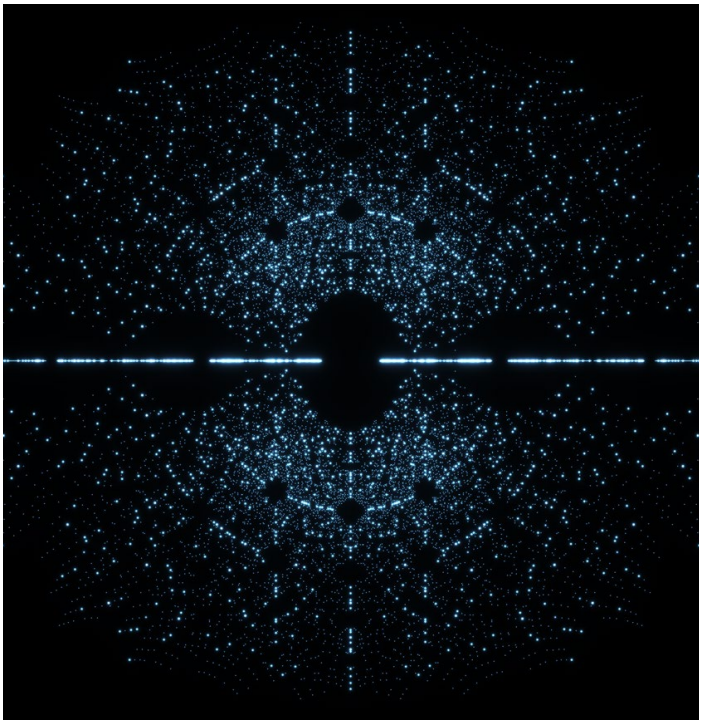
There are two primary branches to my research. On one hand, I work in $p$-adic geometry, studying algebraic varieties over the $p$-adic numbers and their reductions mod $p$, as well as certain infinitely ramified covers known as perfectoid spaces. On the other hand, I explore an interdisciplinary approach to research, teaching, and learning, using various media (from computational to textile) to create mathematical art and artistic mathematics. These avenues come together beautifully in many unexpected ways, and I want to take this opportunity to talk about the latter.

I think about the role of illustration and art in mathematics as multifaceted, spanning pedagogy, research, and outreach. A good illustration can help solidify understanding and insight, and often highlight new ideas that demand explanation and further study. It can also be an invitation to a broader community to explore the mysteries lying in the mathematical world. But even further, the act of creating an illustration demands a deep and explicit understanding of the behavior of whatever it is you are trying to illustrate, and this connection has been a jumping off point for collective learning experiences I've shared with students, mentors, and colleagues alike.



I recently had the pleasure of working with a talented Berkeley student (now alumnus) Candy Xu on a project exemplifying each of these aspects. It started as their senior thesis, and progressed to a research collaboration at the intersection of algebraic number theory and computer graphics. The project revolved around creating and studying images called algebraic starscapes: plots of algebraic integers, that is, complex numbers which arise as zeroes of monic polynomials with integer coefficients. The production of these types of images has a rich and collaborative history, bringing together mathematicians and digital artists to create beautiful and mysterious images which invite the viewer to explore the mysterious patterns arising in number theory.

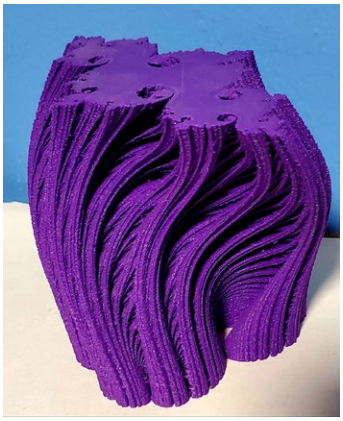
Our approach was to size the algebraic integers according to invariants arising in Galois theory, exposing previously hidden patterns. In particular, our methods emphasized so called rigid numbers: those which have fewer than the expected amount of arithmetic symmetries (more specifically, algebraic integers whose Galois group is not the full symmetric group). This had the effect of bringing hidden patterns to the forfront. As a toy example, the algebraic starscape of integers of degree 3 shows that the rigid ones are concentrated on the real axis. In fact, it is not hard to see why (hint: first show the Galois group of a rigid cubic is $\mathbb{Z}/3\mathbb{Z}$, then use the intermediate value theorem!). For rigid quartics, more interesting patterns arise. I'll leave you with the following image of quartic algebric integers, with rigidity emphasized.



Searching for explanations for the patterns arising in these images inspired routes of theoretical research in the geometry of rigid numbers, and our progress so far appears in a collaborative paper: Searching for Rigidity in Algebraic Starscapes.

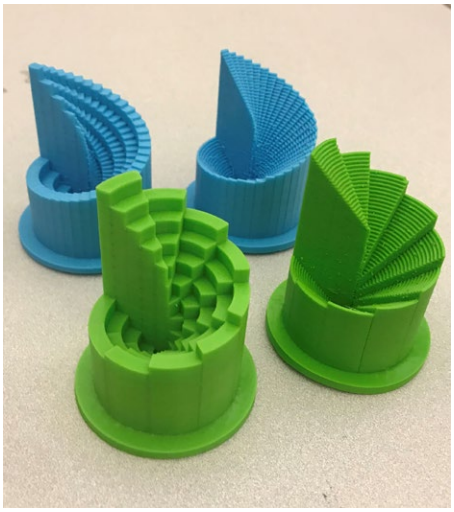
I also create art that allows a non-mathematical audience to interact with and understand mathematical explorations and ideas. In collaboration with artist M. Maynard I crocheted an interactive model of the universe titled the Fabric of Spacetime, implementing the method of Daina Taimina to make the 8 foot tall hyperbolic manifold shown the cover. The technique involves adding stitches in such a way that the circumference

grows exponentially, introducing negative curvature to illustrate rapid expansion of an early universe (fractions of a second from the Big Bang). We then wired it with hundreds of LEDs, 6 motors, and a motion sensor to create a moving, breathing, interactive space for visitors to observe and engage with the geometric consequences of the rapid exponential expansion, responding to visitors as they walk into the space, and inviting them to gaze into the geometric consequences of exponential expansion.



The art of mathematical illustration is central to my practice as a working mathematician. It forms the foundations of collaborations with students and connections with the broader community, while providing evidence or inspiration for avenues of theoretical research. It blends the art of mathematics with the art of making, and I feel lucky to be supported by Berkeley to pursue this exploration.

To see more feel free to visit my website: www.gabrieldorfsmanhopkins.com. The two images in this column show samples of other projects. Above: deformations of Julia sets. Bottom: Riemann sums in polar coordinates.



## Staff News

With the start of the Fall Semester, most of our staff returned to campus for the first time in nearly 18 months with many working flexible schedules allowing them to split their time between campus and their home office while supporting the needs of our community both in-person and remotely. A special "thank you" to our Building Coordinator & Facilities Manager Jasan Fujii for his tireless support keeping Evans Hall operational and accessible throughout the pandemic.

*Top to Bottom: Fujii (upper left), Tobolski, Sixt, Kim, Mendoza, Vela, Gallegos, Lee.*

There were three departures among our department staff in the last year. Christine Tobolski, Director of Student Services, resigned in June 2021. Jennifer Sixt, Curriculum Analyst & Honors Program Advisor, retired in July 2021 after more than 23 years at UC Berkeley, including 16 years in the Math Department. Michael Kim, Research Administrator - ChaMPS, retired in August 2021 after nearly 32 years of UC Service, including 20 years with the Math Department.

This past year we welcomed one former staff member back and three new staff members to the Math Department. Arryanna Mendoza joined us in February 2021 as our HRIS & Payroll Administrator, replacing Yue Liu (retired 2020). This is Arryanna's first appointment with UC Berkeley. Janet Vela joined us in August 2021 as our Research Administrator - ChaMPS, replacing Michael Kim. Janet previously worked with the Space Sciences Lab. Zhanara Nauruzbayeva Gallegos, PhD, joined us in September 2021 as our Curriculum & Course Manager, replacing Jennifer Sixt. Zhanara formerly worked for the School of Information. Lastly, Vicky Lee returned to the Math Department as our new Director of Student Services, replacing Christine Tobolski. Vicky previously served in the Math Department as a Grad Advisor from 2016 to 2019 before taking a position with the Graduate Division as their Director of Student Funding.

*— Brian Underwood, Department Manager*

University of California, Berkeley
Department of Mathematics
970 Evans Hall #3840
Berkeley, CA 94720-3840



# MATHEMATICS + BERKELEY

FALL 2021 NEWSLETTER

*Entering class of graduate students in Mathematics and Logic, 2021 (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 tremendous 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.*

Newsletter Contributors: *Editors:* Martin Olsson and Nikhil Srivastava. Thanks to Michael Hutchings, Melanie VandenBerghe, Isabel Seneca, Jon Phillips, and Brian Underwood. *Photography:* Brittany Hosea-Small and George Bergman.

Berkeley

MATHEMATICS + BERKELEY

*The Department of Mathematics wishes to thank all alumni, parents, students, faculty, staff and friends who support the department.*

**You may return this form to:**

UC Berkeley Foundation
University of California, Berkeley
Donor and Gift Services
1995 University Avenue, Ste 400
Berkeley, CA 94704-1070

## Your Gift Is Welcome!

❑ Enclosed is my gift of $_____
*Please make your tax deductible gift for the Department of Mathematics payable to "UC Berkeley Foundation."*
❑ $5000 ❑ $1000 ❑ $500 ❑ $250 ❑ $100 ❑ Other $_____
In addition, (company name) _____ will match my gift. The company matching gift form ❑ is enclosed ❑ will be mailed

❑ Please direct my gift to the Department of Mathematics Annual Fund, to be used for the Department's greatest need at the Chair's discretion (Fund #N7221).

❑ I prefer to designate my gift for undergraduate scholarships (Fund #N7284).

❑ I prefer to designate my gift for graduate student fellowships (Fund #N7398).

❑ Send me information on charitable estate and gift planning or on establishing an endowment.

Print Name Signature
Date

Address

E-mail*

Please provide your e-mail address so we can send you future issues of this newsletter.

You can also donate to the Department of Mathematics online at:

**https://math.berkeley.edu/donate**

The information you provide will be used for University business and will not be released unless required by law. A portion of all gifts is used to defray the costs of administering the funds. All gifts are tax-deductible, as prescribed by law.

# *Thank You For Your Gifts!*