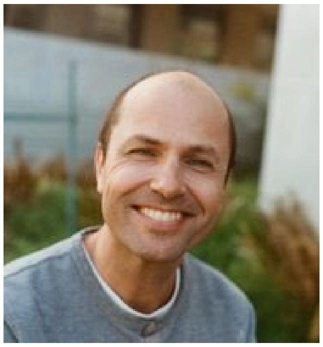
MATHEMATICS + BERKELEY

Fall 2024

IN THIS ISSUE



Chair Martin Olsson (PhD, Berkeley, 2001) has been a member of the math faculty since 2006. His research is in algebraic geometry. He became Chair in Fall 2023.

Dear Friends of Berkeley Mathematics,

I am pleased to share this edition of our annual newsletter with you. I hope you enjoy reading about the many activities in our department and accomplishments of our colleagues. A lot has been happening both on the campus as a whole as well as in the math department!

At the core of our mission is our research and teaching. While we usually discuss our achievements in these two areas separately as in this newsletter, they are, of course, tightly connected. Students at all levels benefit from interacting in both formal and informal ways with the world's very best research mathematicians, and conversely our research is invigorated by the ideas and energy of our students.

Our faculty research remains second-to-none and was recognized with a number of awards this past year, as seen on page 3. This past year we were also delighted to welcome Christian Gaetz, who works in combinatorics, as a new Assistant Professor. You can read more about Christian's work on page 5. Maintaining, and in fact increasing, our excellent faculty remains one of our very highest priorities and we will conduct more recruitments this year. In this newsletter you will also find an article by Professor John Lott about Chern-Simons theory, highlighting one of the many important contributions to mathematics and Berkeley of James Simons, who passed away in May 2024.

This past year we welcomed 35 new graduate students to our program and awarded 24 new PhDs. Our graduate program is very healthy, consistently ranked among the top graduate programs in the world.

Cover: "Sculpture of a cusp caustic, formed as the envelope of a two-parameter family of lines in R^3", by Elliot Kienzle, Graduate Student.

Our graduates go on to top postdoc positions as well as leading positions in industry. For example, on page 8 you will find an interview with Nick Ryder from OpenAI, who got his PhD with Nikhil Srivastava in 2019.

Interest in mathematics remains very high among undergraduates at Berkeley. At the lower-division level we teach students from all corners of campus, fueled by the ever increasing need for advanced mathematics in other disciplines. Even in our upper-division and graduate level offerings we have strong demand from students from other areas. And the math major itself is thriving. In May we had 914 majors, roughly divided as 621 applied and 293 pure. While serving so many students presents challenges, this incredible interest in mathematics is fundamentally terrific. On page 7 you will find an article about the MPS scholars program, which is an important mentoring program for our students.

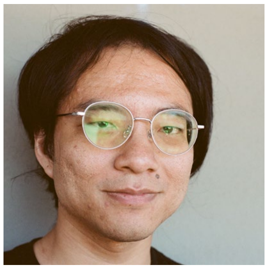
On the administrative side, a number of nontrivial challenges lie ahead. As our chancellor and others have discussed, the UC system and the Berkeley campus face significant financial issues and our department is not immune to the resulting pressures. The costs associated with almost every aspect of our operation have risen significantly without a corresponding increase in funding. The department remains fiscally strong, but these challenges lead to a healthy examination of our use of resources and appropriate adjustments to best serve our research and teaching.

With that in mind I want to extend our thanks to the Friends of Berkeley Math. Your contributions of any size have a direct impact and immediate impact, and enable us to thrive. Thank you!

Above and right: Students and faculty celebrate Pi Day

New Morrey Visiting Assistant Professors and Postdocs *(pictured right)*

Ruofan Jiang (Morrey), PhD Wisconsin. Arithmetic, geometry, and combinatorics of moduli spaces.
Jiang Hu, PhD Peking. Optimization.
Eyal Kaplan (Morrey), PhD Tel-Aviv. Logic.
Zeyu Liu (Simons Postdoc) PhD UCSD, Arithmetic geometry.
Jiaqi Leng (Simons Postdoc), PhD Maryland. Quantum algorithms.
Patrick Lutz (NSF), PhD Berkeley. Logic.
Nicki Magill (NSF) PhD Cornell. Symplectic geometry.
Ilia Nekrasov (Morrey), PhD Michigan. Representation theory.
Noah Olander (NSF), PhD Columbia. Algebraic geometry.
Robert Schippa, PhD Bielefeld. Harmonic analysis, PDE.
Michael Ragone (Morrey), PhD UC Davis. Quantum many-body physics, quantum computation.
Jasper van de Keeke, PhD Amsterdam. Mirror symmetry.
Ryan Schneider (NSF), PhD UCSD. Numerical analysis.
Felix Weilacher (NSF), PhD Carnegie Mellon. Logic.
Danielle Wang, PhD MIT. Number theory.















Faculty Honors

Svetlana Jitomirskaya received the inaugural 2023 Barry Prize of and was elected to the American Academy of Sciences and Letters, and is the 2025 JMM Colloqium Speaker
Bernd Sturmfels received honorary doctorates from the University of Bern & the University of Chicago
Venkatesan Guruswami received the ACM STOC 2024 best paper award and the Distinguished Alumnus award from IIT Madras
Ruixiang Zhang received the 2023 SASTRA Ramanujan prize
Yunqing Tang received the 2024 AWM Research Prize in Algebra and Number Theory
Michael Lindsey was a 2024 Sloan Research Fellow
Hannah Larson won the 2024 Maryam Mirzakhani New Frontiers Prize
William Kahan received the IEEE Milestone Plaque
Daniel Tataru was elected an honorary member of the Romanian Academy
Suncica Canic received the 2024 AWM-SIAM Sonia Kovalevsky Lecture Prize & was inducted into the National Academy of Arts and Sciences of Croatia
Alex Paulin was voted best professor at Berkeley by the Daily Cal, for the second year in a row
Mina Aganagic, Song Sun, and Nikhil Srivastava received 2024 Frontiers of Science Awards
Per-Olof Persson was awarded the 2024 Argyris Visiting Professorship at U. Stuttgart
Ken Ribet will receive the 2025 AMS Leroy P. Steele Prize for Seminal Contribution to Research

What is the Chern-Simons Invariant?

Professor John Lott

This note is occasioned by the passing on May 10, 2024, of Jim Simons, a mathematician, investor and philanthropist. Jim was known for his outstanding research in the 1960's and 1970's, winning the AMS's 1976 Veblen Prize in Geometry. He then took a hiatus for 30 years to set up the wildly successful Renaissance Technologies hedge fund, before returning to math research this century. I got to know Jim from our common interest in a subject called differential K-theory. Jim was so taken by a hexagon diagram appearing in the theory that he commissioned a ballet about it. Part of the diagram is shown in the picture, taken at what was then called MSRI and is now called SLMath (the Simons-Laufer Mathematical Sciences Institute).

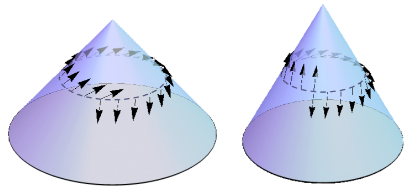
Differential K-theory is closely related to one of Jim's major achievements, the Chern-Simons invariant. This invariant appeared in a paper with Shiing-Shen Chern, a Berkeley mathematician. It can be seen as a wide-ranging extension of the notion of holonomy for a surface. Holonomy gives a way of seeing whether a surface is flat or curved, just by crawling around on the surface. As such, it arises everywhere when studying curved spaces.

To describe holonomy, let's start with an oriented surface S in $\mathbf{R}^3$, and a curve γ on S that begins and ends at a point $p \in S$, as illustrated in the figure. If we take a tangent vector v to the surface at p, there's a way to parallel transport the vector along the curve. When we come back to p, we may not get v back. Rather, we'll generally get some tangent vector to S at p, which is a rotation of v by some angle θ. Since angles are defined upto multiples of 2π, we can say that the holonomy $H_\gamma = (1/2\pi)\theta$ is defined up to integers; mathematically speaking, it is an element of $\mathbf{R}/\mathbf{Z}$. For small loops, knowing H_γ tells us how much curvature is inside of γ.

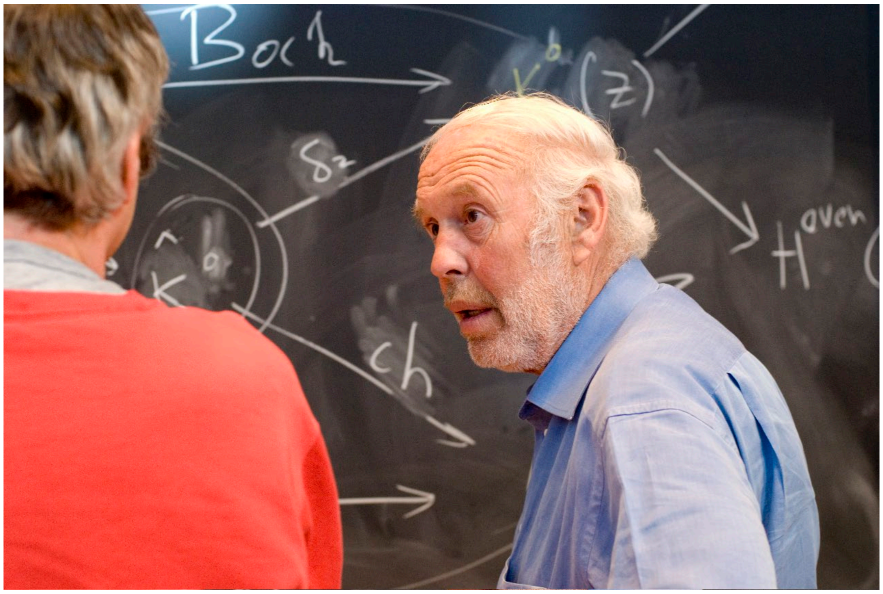
If S is intrinsically flat, for example if it is a cone, then H_γ doesn't change if we deform γ. To say this in a fancy way, assigning H_γ to γ produces an element of the cohomology group $H^1(S; \mathbf{R}/\mathbf{Z})$, and tells us something about the global geometry of the surface. In the Chern-Simons version, the surface S is replaced by a "manifold" M of arbitrary dimension. Loops are replaced by submanifolds of M. The Chern-Simons invariant associates to each appropriate submanifold an element of $\mathbf{R}/\mathbf{Z}$. In effect, it's a notion of holonomy along submanifolds of M, rather than just along loops.

One of the early successes of the theory was the proof by Chern and Simons that there are 3-dimensional compact Riemannian manifolds that can be topologically embedded in $\mathbf{R}^4$, but cannot be conformally embedded. Here "conformally" means that angles are preserved under the embedding. This contrasts with what happens one dimension down, since any compact "Riemann surface" can be conformally embedded in $\mathbf{R}^3$.

The mathematically precise way of studying parallel transport is through the notion of a connection, also called a gauge field in physics. Key to the proof of Chern and Simons is the Chern-Simons functional CS on a certain space of connections, which is derived from the Chern-Simons invariants. In mathematics, the biggest impact of the Chern-Simons functional is from the work of the Berkeley mathematician Andreas Floer. Floer defined new topological invariants of a 3-dimensional manifold by studying the profile of CS on its space of connections. The resulting Floer homology groups have become major tools in low dimensional topology.



Gauge fields arise in many branches of physics, such as electromagnetism and the standard model of particle physics. The Chern-Simons functional measures a sort of topological energy in a gauge field. As such, it can arise as a long-distance "Lagrangian" for a physical system. In one example from condensed matter physics, in the presence of a background gauge field A, performing a Feynman integral over matter fields gives an expression of the form $\exp(2\pi i r\, CS(A))$, where r is a parameter. Because CS(A) is defined up to an integer ambiguity, the expression makes sense when r is "quantized" to be an integer; this is related to the quantization of resistance in the quantum Hall effect, whose discovery earned the Nobel Physics Prize in 1985.



Jim Simons and Prof. John Lott at MSRI in 2007. Photo: David Eisenbud

Easier Than it Sounds?

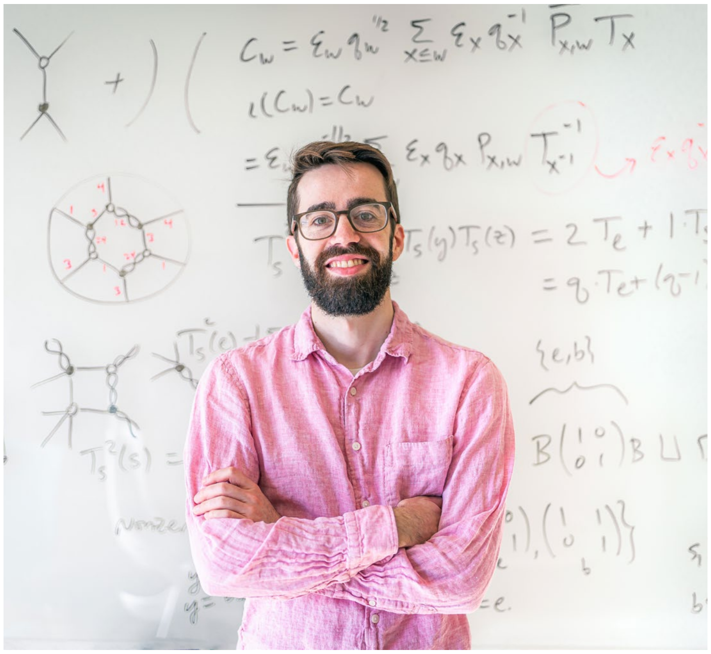
Avi Rosenzweig, Science Communications Manager, MPS Division

Pure mathematics and theoretical physics have long had a P.R. problem. People think that they are pursuits exclusively for long-haired wizards with thick accents who stay cooped up under the eaves covered in chalk dust. Math takes the worst of the stereotypes because physics at least has a wow factor—billions of lightyears or thousands of suns worth of heat can outshine a lot of eccentricities, but what do mathematicians have to reveal? And how can anyone besides other mathematicians appreciate their accomplishments?

Christian Gaetz rejects the notion that math is in a different category than other pursuits. He joined the Berkeley Mathematics Department faculty in 2024 and is quite vocal in his insistence that math should "not be daunting to anyone." It isn't just for "rarefied geniuses" but for anyone who puts in the time to build good foundations and exercise the right muscles in their head. His specialization is in algebraic combinatorics and its connections with geometry.

Combinatorics is "relatively hands-on" compared to what a lot of Berkeley faculty are working on, muses Gaetz. It focuses on the relationships between certain kinds of polynomials or graphs or matrices rather than on their contents. Imagine a map that shows several towns connected by roadways. Rather than worry about what is in each town, combinatorics looks at how the connections relate to each other. In higher-level algebra, these relationships and patterns are often studied using combinatorial methods, and if these methods give the same result regardless of how you label or organize parts, it's called combinatorial invariance. A common way of explaining this to younger students is to consider two LEGO structures that have the same arrangement of connections: they are essentially the same, even if the individual blocks are different colors or sizes. The LEGO picture is also helpful because combinatorics users often talk about 'edges' and 'vertices' when describing how parts relate.

Logic, algebraic topology, and other areas of mathematics involve more layers of abstraction than algebraic combinatorics, so Professor Gaetz feels himself to be on somewhat firmer ground. There is an especially puzzling problem called the Combinatorial Invariance Conjecture that "too many mathematicians to name" have been trying to solve since the 1980s which was first proposed by Lusztig and by Dyer. This one involves eponymous and appropriately titled Kazhdan-Lusztig polynomials. A group of investigators abbreviated BBDVW (Blundell, Buesing, Davies, Veličković, and Williamson) have recently been reconsidering the Conjecture using machine language (ML) algorithms. ML is usually associated with practical applications like image recognition or language translation, but BBDVW feed tons of descriptions of shapes and equations into ML to see if it can find invariants that will resolve the Conjecture.



Prof. Christian Gaetz. Photo: Johnny Gan Chong

Gaetz believes that he has a contribution to make towards the solution that adds perspective from other angles of approach, ones that he happens to be fluent with. He explains that the ML approach has found combinatorial structures called "hypercube decompositions" that might assist in proving the Combinatorial Invariance Conjecture, but the ML itself can't prove anything. Gaetz and his colleague Grant Barkley have proven new pieces of the puzzle, and they are working on proving the full Conjecture. He sums it up this way: the Combinatorial Invariance Conjecture states that Kazhdan--Lusztig polynomials, which are important in several areas of mathematics like algebraic geometry and representation theory, can be determined using only information contained in certain graphs called Bruhat graphs. The challenge is to figure out how to extract this information from the very complicated graphs. BBDVW employed ML to write down a recipe for extracting this information that they believe gives the correct answer, but they weren't able to prove that their recipe works. "Grant Barkley and I have proven that the recipe does work in many cases, and we are working on proving the full conjecture."

Christian Gaetz caught the math bug early, so he has a solid foundation. He insists that mathematicians, like most professionals, are built rather than born. Maybe basketball players have either got it or they don't, but the rest of us acquire expertise the hard way – layer by layer, hour by hour, of devoted learning and practice. The lucky part is connecting with good mentors. Gaetz's summa cum laude B.S. (2016) from the University of Minnesota was under Victor Reiner, a sage for the ages. At MIT for his Ph.D., Alex Postnikov (former Miller Fellow here at UC Berkeley) lit the flame of algebraic combinatorics that serves as Professor Gaetz's guiding light. After a productive postdoc at Harvard *(continues on page 6)*

The 2023-24 undergraduate prizewinners at commencement in May

where he worked with former UC Berkeley professor Lauren Williams, he won a fellowship at Cornell ('22-'24) where he connected with MIT alums from the decade previous. He gives Karola Mészáros and Allen Knutson (also a former UC Berkeley professor) due credit for mentorship in that period. This is what explains his expertise, Gaetz says. "When someone says, 'I'm not a math person' it's because they didn't have the opportunities or the right kind of exposure at the start," he believes. A good math education makes it "natural" to be a math person.

Professor Gaetz comments that math sits at a special position among the arts and sciences. Like artists, mathematicians employ a lot of creativity along the way to a solution. But a piece of art is finished when the artist decides to stop; it depends on the creator's subjective impulses. Mathematical solutions are clearer: everyone agrees when you've reached the 'right' conclusion. The solution seems like it was discovered rather than made.

That combination of creativity and confirmation is part of why Christian Gaetz is happy with his choice of career. He wasn't aiming for it from the start but he's glad he made it here. The tools and methods math uses aren't objects of worship. Gaetz keeps a computer by his desk to run examples of what he's thinking about only as a "sanity check" to help stay on track. He recalls an article by esteemed physicist Eugene Wigner. The article notes that mathematicians are often guided by an aesthetic sense, rather than potential applications. "Yet the ideas they produce very often eventually find application in science," Gaetz marvels. "I think that mathematicians have developed a remarkable collective aesthetic by which ideas that mathematicians find interesting, and well-motivated, and beautiful very often get at something deep about the way that the universe works. And that such ideas often are found later to be important in natural science." With the right foundation, these are accomplishments that everyone can appreciate.

Undergraduate Student Honors

Christopher Ying received the 2023-24 University Medal (awarded to UC Berkeley's most distinguished graduating senior).

The 2023-24 Department Citation was awarded to Zachary Slonim

The 2023-24 Paul Chernoff Memorial Prize in Mathematics was awarded to Zachary Slonim

Alex Bouquet, Sean Guan, Rhea Kommerell, Fangyuan Lin, Wade McCormick, Siddharth Menon, Lakshay Patel, and Richard Wu received the Dorothea Klumpke Roberts Prize in Mathematics

Aaron Agulnick, Maxwell Black, Alex Fu, Alec Li, Henry Purcell, Vibhu Ravindran, Zain Shields, Hui Sun and Isadora White received the Percy Lionel Davis Award for Excellence in Scholarship in Mathematics

Theodore Lysek, Noah Mart, Jianzhi Wang N. Liao ranked in the top 200 at the 84th Annual Putnam Competition. Yash Aggarwal, Daniel Ao, Aditya Baireddy, Ralph Cao, Preston Fu, Andrew Huang, Aathreya Kadambi, Andrew Lee, Bradley Louie Saito, Justin Park, Youngmin Park, Shreyas Ramamurthy, Robin Sharif, Brian Sui, Dylan Xu and Robert Yang placed in the top 500

MPS Scholars helps math students reach their potential

Claire-Marie Kooi, Associate Director, MPS Scholars Program

This summer, incoming UC Berkeley mathematical and physical sciences (MPS) majors, were welcomed by peer mentors. More than 300 new MPS students were matched with current students in their intended majors, offering them valuable resources and guidance to ensure a smooth transition into their first semester. This program was organized by MPS Scholars, an initiative that launched in fall 2022 to help students thrive in their math, physics, astronomy, and earth and planetary science majors and, ultimately, in their careers.

Mathematics student Marius Castro (center) at MPS Scholars retreat. Photo: Brittany Hosea-Smalll

Many students, especially those from underrepresented backgrounds or under-resourced high schools, lack access to influential networks that can help drive their success. MPS Scholars addresses this gap. It offers students structured mentoring from faculty, alumni, graduate students, and peers, along with funded research experiences, career development, orientation activities, and social networks that increase students' sense of belonging.

While new students were meeting with their mentors over the summer, 29 advanced students were completing their projects as MPS Scholars-funded undergraduate researchers under the guidance of faculty and graduate student mentors.

Lauren Aycott, a fourth-year student majoring in mathematics, reflected on her summer research experience saying, "The fact that I was able to narrow the topic according to my personal interests provided a special opportunity for my research partner and I to make a statement that reaches beyond mathematical applications. I'm unsure if I would have been afforded a similar opportunity to conduct research as a transfer student and student parent attempting to adjust to the larger-than-life academic landscape of UC Berkeley."

Building on the success of our first retreat at Asilomar State Beach, MPS Scholars is excited to plan a second annual retreat for the spring semester. Attendees at the first MPS Scholars retreat benefited from keynote speeches, panel discussions, and public speaking practice, while also networking with faculty, alumni, and learning from department chairs' advice on academic and career pathways.

Mathematics and physics student Michelle Dong presenting her undergraduate research. Photo: Brittany Hosea-Small

Marius Castro, a fourth-year student double majoring in applied mathematics and computer science, had never thought a Ph.D. would be in his future. "I'm a first-generation student of color from a low-income background, so no one has ever sat down with me and let me know how real of an option that was. I walked away from that retreat with a very real contemplation of continuing my education past Cal for the first time in my life."

Marius's and Lauren's experiences exemplify the impact that MPS Scholars seeks to achieve, including giving students resources, networks, and inspiration to envision and pursue their academic and career aspirations with confidence.

A Conversation with Nick Ryder

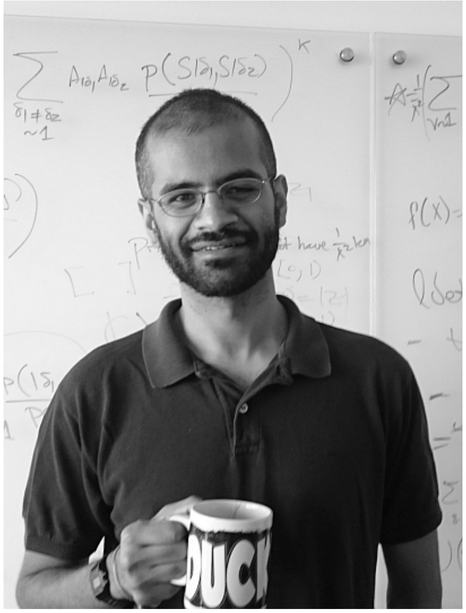
Prof. Nikhil Srivastava (pictured left) visited Grad Alum Nick Ryder, PhD'2019 (right) at OpenAI in October, 2024. The interview below has been edited for length and clarity.

Nikhil: You studied math at Rice and Berkeley. Can you say a bit about your interests during that time and how they led you to AI?

Nick: It was a bit of a wandering path to be perfectly honest. I started off being interested in math from a very pure place of just finding it very interesting. As an undergrad, once I started to pull that thread, I realized, oh, I really like this thread. And so at Rice my goal was to take every graduate class. It was very beautiful. I also loved hacking on computers and always found that to be a really interesting hobby. I knew going into grad school that I wanted to be able to do both, and that was the main thing that dictated my decision to go to Berkeley.

At Berkeley, I met you and I was like, this is exactly what I want — to do something in the intersection of math and theoretical computer science. I didn't have a specific research area in mind, so I was very happy to inherit yours, which I thought was very captivating. I kind of lived in that intersection and attended the Simons Institute all the time. In my first semester at Berkeley, I went to the algebraic geometry and matrix multiplication program. I met Bernd [Sturmfels] there, and did a collaboration with J. M. Landsberg and we wrote a bunch of papers. I also took some great math courses at Berkeley like the Lie Algebras course, which was one of my all-time favorites.

I had a wonderful time in grad school. And I think, as I got near the end of grad school, I was very split on what to do next. The things I loved about academia were: I loved learning and I loved teaching. But I don't know if I was totally compelled by publishing. Part of it was that I felt some itch about building things that academia didn't really scratch for me. Part of that was that in academia



negative results are very hard to advertise or make progress off of. Whereas in engineering things don't need to be airtight to be valuable. There's an 80/20 principle in engineering which says that 80% of the results come from 20% of the work. There's no 80/20 in math: you either prove it or you don't.

Around that time I remember hearing about AlphaGo and I was like, what the hell? I don't play go but I appreciated that this was something way outside what people expected. I thought, not only is this incredible, but I have no idea how it works. How can you get a computer to beat people at this really complicated game? I was very captivated by that and around the same time, OpenAI was working on DotA, and I had played and watched a lot of DotA. These things were happening in confluence. I was like wow this is like a very alien thing to me and I want to know more about it.

That was around 2017-2018. I did an internship at Amazon Web Services (AWS) that summer and learned a lot. What does it mean to do research in Industry? What does it mean to have a manager? I remember going to AWS and being incredibly pleasantly surprised. Being like wow, the lunch room conversations are just as interesting as what I'd seen in math. I walked away from it basically convinced that I wanted to try industry.

OpenAI was intriguing because at the time it was very small, something like 70-80 people. There was no product, or even a premise of a product, it was just a research lab. In hindsight I'm grateful because I've gotten to grow up and learn about products and industry and bigger companies with the company itself. It's been a very gradual process.

I started at OpenAI in something that was then called the fellowship program, now called the Residency program. It's designed to bring in people from academia. Machine learning is a young field, it's a crazy young field compared to math, or even to computer science I would argue. Most of the results that have captivated the field are very modern, within the last 10-15 years. Because of that it's possible to catch up on a lot of the reading really quickly, whereas in grad school some of my colleagues would take five years to speak intelligibly about the thing they wanted to solve.

Nikhil: I remember the summer after you graduated, you sent me an arXiv preprint which I later realized was the GPT3 paper. Can you say a bit about that discovery and how it came about?

Nick: I came to OpenAI in 2019 and as I said, my main motivations were (a) I wanted to learn what the secret is, what magic is possibly behind things like AlphaGo, and (b) I wanted to learn how to be a good engineer.

When I walked in the door, I wanted to

Mathematics Graduate Student Association Halloween Tea, October 2024

find an engineering project that was about scaling and learn how to do that. And at the time that was language models. GPT2 had just come out and they'd done this great work called scaling laws, which showed that there should be great promise by predictably scaling it: you should be able to have confidence that as you pour in resources you reliably get better outcomes. And so I spent the first nine months or a year working on the distributed systems for language models and learning how to do software engineering. You have some fixed algorithm but it won't all fit on one chip, how do you run it on lots of chips? I kind of learned the whole stack. It was probably one of the years of my life when I learned the most. Even though I'd taken all these courses in CS, I don't think I'd really internalized it until I actually needed to make something run fast.

During that time I was around all these instrumental thinkers in the field. I asked as many questions as I could, and they answered almost all of them. The second important thing I learned, which the whole GPT paradigm is built on, is that language is an encapsulation of intelligence. Fundamentally machine learning is about modeling data and there's a lot of different data in the world. You're constantly getting a visual stream of data. There's audio data, you can be collecting heat maps, all that stuff. But there's one source of data in the world that is purely a human artifact: the text that we write, is truly the bits that we have created as humans and it is therefore the most compressed encapsulation of intelligence. Like if you watch a video you can see intelligent behavior there, but the amount of bits in a video is massive compared to the sentence that describes the action in the video which is like very very few bits, that exactly gets cross this intelligent behavior. Again, these are things that were taught to me, and I don't mean these to make these as claims of my own.

2024 Graduating PhDs

(with their advisors)

Frances Dean (Michael Lindsey, Bernd Sturmfels)
Michael Heinz (Per-Olof Persson)
Mostafa Adnane (Nicolai Reshetikhin)
Yulia Alexandr (Bernd Sturmfels and Serkan Hoşten)
Esme Bajo (Matthias Beck and Sylvie Corteel)
Luke Corcos (James Sethian)
James Dix (Ian Agol)
Ethan Dlugie (Ian Agol)
Yulong Dong (Lin Lin, Birgitta Whaley)
Oliver Edtmair (Michael Hutchings)
Raehyun Kim (Lin Lin)
Larsen Linov (Ian Agol)
Shivaram Rao Lingamneni (Lara Buchak, Wesley Holliday)
Yelena Mandelshtam (Bernd Sturmfels)
Guillaume Massas (Wes Holliday and Paolo Mancosu)
Xianglong Ni (David Eisenbud)
Izak Oltman (Maciej Zworski)
Benjamin Pineau (Daniel Tataru)
Yanshuai Qin (Xinyi Yuan)
Sridhar Ramesh (Dana Scott and Thomas Scanlon)
Tahsin Saffat (David Nadler)
Jiasu Wang (Lin Lin)
Jiahao Yao (Lin Lin)
Haixiang Zhang (Javad Lavaei, Jon Wilkening)
Ziwen Zhao (Michael Hutchings)
Zirui Zhou (Michael Christ)
Tong Zhou (David Nadler)
Qinyi Zhu (Lin Lin)
Maksym Zubkov (David Nadler)

So yeah, I learned all these principles in this time and we trained this model and we wrote this paper and I think that was the point where I realized how captivating this research program was. Not only are we modeling the thing that encapsulates intelligence, not only is it giving us away through few shot learning to solve many tasks, but most importantly, it's giving us a scalable algorithm that we can continue to scale using more resources to get more and more intelligent systems. And that captivated me personally to pursue this until, as I would say, until we "understand the whole thing", ...which I suspect will take a long time [laughter]. *(continues on page 10)*

Nikhil: Do you think a math PhD prepared you for the work you are doing now?

Yeah, I think in two ways. One is that a big part of machine learning is linear algebra. The core thing that's happening is a lot of matrix multiplication. Neural networks are not linear, but having this linear algebraic intuition truly does come in handy, time and time again. I definitely think teaching Math 54 nine times [laughter] instilled in me a deep intuition around linear algebra because you have probably 300-400 students in that course, and you answer all these random questions that are really out of left field. And so I do think I walked away from grad school with a pretty deep intuition around linear algebra. There is also a ton of probability in machine learning, which I also studied and which is also useful.

The other half of it is just: how do you conduct a research program? I think that is actually the primary skill a lot of people learn in grad school. When you come out of undergrad you've been taking all these courses and you've learned a lot but you've always been given problems that you know have an answer. And now you need to learn, okay, here's a problem: (a) what is the scientific narrative of your field? What is the through line in what people find interesting, why they find it interesting, what one should explore, what one should not explore? (b) given that scientific narrative. How do you form problems you want to solve and make those into hypotheses? (c) How do you do experiment design to iterate on those hypotheses and (d) How do you know when to call quits and say, oh this looks like a dead end. This is someone of an oversimplified loop, but a loop nonetheless that academia teaches you and is incredibly important in any scientific pursuit, empirical or theoretical.

I have now hired many people with all kinds of backgrounds. One thing you see from grad students in particular is a maturity on how to do experiment design and a confidence in knowing when they say this is a negative result, it's negative result, or this is a positive result, it's a positive result. And definitely a clarity of mind on scientific narrative, which is a super important. It's super important to be able to always have a consistent world model of all the evidence you see and know how it strings together. And that's very different from just solving problems.

Prof. Hannah Larson chats with the audience at Math on Tap, October, 2024. Photo: Lauren Miller

Nikhil: You're the VP of research for foundations at OpenAI. What have you learned about maintaining coherence in a large research team and making sure everybody feels nurtured?

There are a few notes. One is OpenAI has a very compelling mission. And having a compelling mission is incredible. You get people who are really captivated by their work. And they're very excited about tomorrow, they're very excited about what's coming and that produces a natural motivator and drive that's very powerful.

Another is focusing on good mentorship up and down the stack and investing into people and understanding how they want to grow where they want to grow.

Finally, one tenet I really hold dear is: have more interesting problems than people. So, always be people, constrained, not problem, constrained. I think when you have more people than problems --- and it's easy to accidentally end up in that state --- that's where politics comes from. That's where people need to fight over interesting projects and who owns what and why they own it, and where the lines. If you're in a world where there are more interesting problems than people then collaboration exists.

Do you think AI will be able to do research level math?

I do. I guess my personal take is: AI being able to do research level math seems quite close to me to achieving "AGI", artificial general intelligence, because it seems like if you can really truly do open-ended research, then you can innovate and push the scientific boundary. I have no reason at this point to believe that that will not eventually happen. To me it's all a question of when. And I don't have very tight error bars on when, even being in the nexus of it all.

But I definitely think in the short term, it will be very, very useful to accelerating research, even if it cannot execute open-ended research by itself. I think the connection to formalization is particularly interesting. I would love to just autoformalize all my papers from grad school and see where the bugs are.

Nikhil: Which paper are you least sure about? Is it the one that we wrote in like, one night?

Nick: Yeah yeah, it might be that one. [laughs]

Staff News

Above: Staff members Hanh Tran, Thomas Brown, Marsha Snow, and Vicky Lee welcome new students

Right: New staff members Stephen Hernandez and Anusha Joga.

As we conclude another productive and exciting year in our department, we have several important staff updates to share, showcasing our growing team and their contributions to our program.

In November 2023, we welcomed Stephen Hernandez as our new Department Scheduler and Enrollment Coordinator. Stephen, a Cal alum who graduated in 2020 with a BA in History, first joined the university as a transfer student in 2018. Before joining our department, Stephen spent over two years in the College of Environmental Design in the Department of Architecture as a Department Assistant and Scheduler. His experience at Cal has given him a deep understanding of the student experience, along with valuable insights into the challenges our students face. We are thrilled to have Stephen on board, as he will undoubtedly enhance our program and support for students.

In April 2024, Alev Hatay, our Non-Senate Academic Personnel Analyst, transitioned to the Department of Neuroscience here at UC Berkeley.

In October 2024, Anusha Joga joined us as our new Non-Senate Academic Personnel Analyst. Anusha earned her BA in Computer Science from Jawaharlal Nehru Technological University and began her career at Cal in 2015. Over the past six years here at Berkeley, Anusha has continued to grow professionally as her interest in academic human resources found her taking on increasing responsibility, positioning her to pursue opportunities with ERSO as a Human Resources Generalist, with CDSS as an HR Analyst and, most recently, as an HR Business Partner with the SHARE region, where she has worked for the past 2+ years. Anusha is known for her commitment to excellent customer service and a solution-oriented approach, making her a fantastic addition to our team.

We are proud to highlight our exceptional and dedicated staff, many of whom were recognized this past year with a "SPOT Award" through the campus Staff Appreciation and Recognition Program. This year's recipients included Arryanna Mendoza, Cecilia Coca, Christian Natividad, Clay Calder, Jasan Fujii, Kathryn Mills, Marsha Snow, Siti Keo, Vicky Lee, and Zhanara Gallegos. Additionally, we are excited to share that Vicky Lee, our Director of Student Services, received one of the inaugural "Golden Bear Staff Achievement Awards" from the College of Letters and Science, for exceptional commitment to the College's shared mission, and Thomas Brown, our Lead Undergraduate Major Advisor, received Berkeley's Excellence in Advising and Student Services Award in the category of "Outstanding Advisor or Student Services Staff".

—Brian Underwood,
Department Manager

Graduate Student Honors

The 2023-24 Herb Alexander Prize for outstanding dissertations in pure mathematics was awarded to Oliver Edtmair, Benjamin Pineau, and Junsheng Zhang

The 2023-24 Bernard Friedman Memorial Prize in Applied Mathematics was awarded to Luke Corcos and Haixiang Zhang

Xianglong Ni and Tong Zhou received the Kenneth Ribet & Lisa Goldberg Award in Algebra

The Nikki Kose memorial teaching prize was awarded to Esme Bajo and Ziwen Zhao

Juwayria Ahmed, Drisana Bhatia, Cassi Chen, Alice Drozd, Pranav Enugandla, Daniel Etaat, Kishan Jani, Seewoo Lee, Fangyuan Lin, Francois Logak, Ryan Martinez, Xiaoke Song, Carl Sun, Brian Sun, Spencer Taylor, Troy Tsubota, Leo Villani, and Jeannie Wang received 2023-24 Outstanding Graduate Student Instructor Awards.

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MATHEMATICS + BERKELEY

Fall 2024 newsletter

Graduating PhD students in Mathematics and Logic, May 2024 (Photo: Vicky Lee)

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. Martin Olsson, e-mail: chair@math.berkeley.edu.

Newsletter Contributors: *Editors:* Martin Olsson and Nikhil Srivastava. Thanks to Melanie VandenBerghe, Vicky Lee, and Brian Underwood. *Photography:* George Bergman, Vicky Lee. Cover: Elliot Kienzle.

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