NEWSLETTER

CMSA

Center of Mathematical Sciences and Applications

2024–2025

HARVARD UNIVERSITY
CENTER OF MATHEMATICAL
SCIENCES AND APPLICATIONS

Table of Contents

Message From the Director

Dan Freed

Shiing-Shen Chern Professor of Mathematics

Director of the CMSA

Welcome to the second annual CMSA newsletter. This is also the end of my second year as Director, and I am very pleased to share some of the programmatic and strategic successes of the Center. I will also give you a preview of what is to come.

My vision for the Center rests on my unwavering faith in the power and unity of Mathematics. Our core mission is the two-way interaction between Mathematics and Science, but we also engage in interactions between different subfields within Mathematics. One of my immediate goals was to broaden the range of Mathematics at the Center. Equally, I aimed to bring in a broader range of scientists, both in terms of field and career stage, including students. The breadth of mathematical and scientific ideas at the Center is a challenge and a stimulant to our local researchers and visitors, and we encourage everyone to broaden their perspective during their time here. We are also increasing the impact of the Center, both locally and globally. Finally, CMSA builds bridges among the many entities that comprise Mathematics at Harvard. Of course, this includes the Department of Mathematics, but also the Applied Mathematics and Computer Science areas in SEAS, as well as the Harvard departments of Statistics, Physics, Economics, the various Life Sciences departments, and of course CMSA itself. We continue to strengthen these bridges and are planning moves to achieve much more.

Our months-long programs continue to be a highlight at the Center. The excitement and high level of the Fall 2024 Mathematics and Machine Learning program is vividly captured in Mike Douglas' article. Indeed, the program was so successful and the topic so fertile that we are running a series of reunion workshops over the next several years. The beautiful interaction between combinatorics and quantum field theory was the subject of another CMSA program and future graduate summer school. As I write, the program on Classical, Quantum, and Probabilistic Integrable Systems is underway. Next spring Lakshminarayanan Mahadevan is leading the organization of a program on Shape in Biology, and more is in the works beyond that.

These pages also give a sense of shorter-term activities at the Center. Our many weeklong workshops cover a broad range of carefully chosen hot topics. The past and future events are listed at the back of this newsletter. There are also many special public lectures. Some are in connection with weeklong workshops or months-long programs, such as the lecture by Geordie Williamson on AI and Mathematics. Others are their own event, such as this year's Ding Shum lecture on expander graphs by Irit Dinur and Scott Aaronson's upcoming Yip lecture "How Much Math Is Knowable?" Not represented in these pages are the many weekly CMSA seminars and the weekly CMSA colloquium. They are organized by our energetic postdoctoral fellows, who run them at a very high level. These weekly activities are the backbone of our long-term research activities.

CMSA hosts the summer Harvard Math Summer Research Experience for Undergraduates, which is run by my math department colleagues Phil Wood and Wes Cain. This is a fantastic research opportunity in Mathematics for undergraduates, who benefit from the active research environment at CMSA. We hope to expand the program to benefit more undergraduates.

It is the quality of researchers at the Center that makes CMSA what it is. Here you will read about the multifaceted career of Mike Freedman, one of our senior research scientists. Two of our senior postdoctoral fellows are also profiled here. They are moving on from CMSA to prestigious positions elsewhere.

I am delighted to announce a series of seven monthly public lectures to celebrate the 25th anniversary of the Millennium Prize Problems. This set of genuinely hard mathematics problems was identified at the turn of the millennium by the Clay Mathematics Institute. The first lecture will be given by Mike Freedman on the only one of the seven problems to be solved so far: the three-dimensional Poincaré conjecture. I hope to see many of you there on September 17, in person or on Zoom. These lectures are a joint venture of CMSA, the Harvard Department of Mathematics, and the Clay Mathematics Institute. You can find out more on the CMSA website.

You may also enjoy a short film we made this year about the CMSA. In it you will hear from some of the researchers and from Harvard affiliates who make the work here possible. You will find it on our website at cmsa.fas.harvard.edu/film.

Finally, with this newsletter we are initiating the Harvard CMSA Leadership Circle. This is a group of outside supporters of CMSA and of the work we do here. We plan to have a few special events each year for members of this group. The first is in conjunction with the September 17 Millennium Prize Problem Lecture: there will be a dinner following the lecture that includes this group as well as many mathematicians and other CMSA affiliates. I encourage you to join, which you can do by clicking cmsa.fas.harvard.edu/lc.

With Best Wishes,

Dan Freed

Mathematical Aspects of Scattering Amplitudes at CMSA

Bringing together and fostering interaction between theoretical physicists and mathematicians

Program on Mathematical Aspects of Scattering Amplitudes participants in front of the CMSA building at 20 Garden Street.

In April and May of 2024, the CMSA hosted a six-week program on Mathematical Aspects of Scattering Amplitudes, organized by Nima Arkani-Hamed, Marcus Spradlin, Andrew Strominger, Anastasia Volovich, and Lauren Williams. The aim of the program was to bring together and facilitate interaction between theoretical physicists and mathematicians working on various topics connected to recent developments in our understanding of scattering amplitudes in quantum field theory. This field has advanced considerably since 2019 when the CMSA hosted the program "Spacetime and Quantum Mechanics, Total Positivity and Motives" organized by Lauren and Nima together with Thomas Lam and Alex Postnikov, and the time was ripe to bring together experts for discussions and collaboration that could trigger the next wave of advances.

The program featured around 3-4 talks per week and welcomed a total of about 35 participants, including a mix of senior researchers, postdocs, and graduate students. Immediately following the conclusion of the program the CMSA hosted an associated three-day conference on Amplituhedra, Cluster Algebras, and Positive Geometry organized by CMSA postdoctoral fellow Matteo Parisi and Lauren Williams.

Program participant Lance Dixon, who gave a CMSA colloquium in connection with his visit, has described scattering amplitudes as "the most perfect microscopic structures in the universe." What is a scattering amplitude? When elementary particles interact with each other, as in a collider experiment for example, amplitudes encode the probability distribution of possible outcomes as functions on "kinematic space" — the energies and momenta of the various particles. To hear them being described as "perfect" would come as a surprise to anyone who has taken a course in quantum field theory, which is the mathematical language in terms of which our understanding of elementary particle physics is expressed. It is a very rich and beautiful language, but it can also be very complex. In particular, it has a notorious reputation for the tedious and lengthy calculations required to calculate even the simplest amplitudes by summing over a very large number of "Feynman diagrams." However, the past couple decades have seen a revolution in our understanding of the mathematical structure of scattering amplitudes, and the discovery of deep connections to modern algebra, combinatorics, and geometry has allowed for the development of new, vastly simpler computational methods that allow these amazing objects to fully exhibit their "perfection."

The first two weeks of the program focused on celestial holography, which is an approach to amplitudes based on

Anastasia Volovich from Brown University.

a proposed duality between scattering in asymptotically flat spacetimes and a conformal field theory living on the celestial sphere at infinity. This framework manifests infinite dimensional symmetries that in traditional approaches are hidden in soft theorems, which describe the behavior of amplitudes when the energies of some of the interacting particles are zero.

Nima Arkani-Hamed gave a series of three lectures on "surfaceology", which is a new understanding of scattering amplitudes based on fundamentally combinatorial objects formulated in kinematic space. In its simplest incarnation, for a matrix-valued scalar field, this approach expresses any scattering amplitude as a single "curve integral" that can be written down using simple combinatorial rules instead of as a sum of many Feynman diagrams. This approach extends in principle to arbitrary local colored interactions, with particularly simple constructions providing the "real-world" amplitudes of pions and non-supersymmetric Yang-Mills theory. Related developments include the discovery of a remarkable class of polytopes called surfacehedra whose facet structure simultaneously contains the intricate boundary structure of Teichmüller space and the intricate combinatorics of singularities of amplitudes.

Several talks addressed recent progress and open problems on amplituhedra. The tree-level amplituhedron $A_{n,k,m}(Z)$ is the image of the positive Grassmannian $Gr_{k,n}$ under the linear map induced by (left-) multiplication by a fixed $n \times (k+m)$ matrix Z. It has recently been proven that this space can be covered by sets of tiles generated by the BCFW recursion relation, known from physics to also generate the tree-level scattering amplitudes of Yang-Mills theory, and that the facets of these tiles can be characterized by cluster variables for $Gr_{4,n}$. Progress was also reported on the structure of loop-level amplituhedra, which involve more complicated configuration spaces of lines and planes, including a new type of amplituhedron geometry formulated in dual momentum space, another constructed for application to correlation functions in super- symmetric Yang-Mills theory, and an approach that allows certain combinatorially simple parts of loop-level amplitudes in this theory to be computed to all orders in perturbation theory and resummed explicitly.

Other topics featured in program talks include a new geometric "double-copy" relation between one-loop open and closed string amplitudes related to the twisted (co) homology groups associated with the Riemann-Wirtinger integral, new results for expectation values of multiple light-like Wilson loops that can be thought of as generalizations of amplitudes in supersymmetric Yang-Mills theory, and progress on computing the top-weight cohomology of the moduli space of curves that draws some inspiration from path integrals in quantum field theory. Finally, several talks addressed the rich motivic structure of the multi-valued functions that arise in the computation of loop-level scattering amplitudes, including connections between cluster algebras and multiple polylogarithm functions, a new construction of generalized cuts that may shed light on the diagrammatic coaction for Feynman integrals, and general features of the algebraic and transcendental structure of perturbative quantum field theory.

Our understanding of scattering amplitudes has evolved considerably since the previous CMSA program in 2019, with new insights shedding light on previously hidden mathematical structure while also enabling new technology for carrying out computations of practical interest to physicists in adjacent fields. Many of these developments were reviewed at our program, while the many questions and puzzles raised during the talks and the many hours of informal blackboard discussions have set the stage for work to be presented at some point in the future, perhaps at the CMSA in 2029?

Article courtesy of Nima Arkani-Hamed (Institute for Advanced Study), Marcus Spradlin (Brown University), Andrew Strominger (Harvard University), Anastasia Volovich (Brown University), and Lauren Williams (Harvard University).

Mathematics and Machine Learning Program

Featuring Seminars, Workshops, and a Conference

Last fall, the CMSA hosted a two month program on mathematics and machine learning (ML), co-organized by François Charton of Meta AI, Fabian Ruehle of Northeastern, Geordie Williamson of the University of Sydney, and our own Mike Douglas and Mike Freedman.

Everyone knows that mathematics plays an essential role in machine learning. It is used in defining its models, in analyzing its results and in more deeply understanding its powers and limitations. Rather less well known, what we now call machine learning was done on very early computers to make important mathematical discoveries, such as the Birch and Swinnerton-Dyer conjecture of number theory. And what has emerged in recent years and deserves to be better known, is that modern machine learning and AI is a very general and powerful tool for mathematical discovery. Our program was devoted to exploring the latest advances in machine learning and their uses in mathematical research in depth.

Our ambition was to cover many of the diverse fields of mathematics in which ML is being used, and we did this by arranging focus weeks within the program: on number theory, graph theory, knot theory, theorem proving, and rigorous numerical methods. Over 80 experts in these many fields participated, some just for their focus weeks, and many for longer. This included 30 early career researchers with machine learning experience who responded to an open invitation to come and collaborate with mathematicians on cutting edge research problems. ML is a hands-on activity, in which one writes code and engages with datasets, and their collaboration was essential for the program's success.

The program kicked off with an introductory workshop "AI for mathematicians," featuring lectures by Boris Hanin, David McAllester, Adam Wagner, Mike Douglas, Leon Bottou, and François Charton. The lectures painted a broad picture of current research directions, including AI for guiding mathematical proof and searching for structure, and challenges in AI research that become evident when attempting to solve mathematical problems. Eli Grigsby continued to develop the foundations with a lecture course on the geometry of deep learning, given at the CMSA twice weekly throughout the program.

The first week also saw two of the program's three panel discussions around the future of mathematics and AI. The third panel discussed the use of AI in mathematics education, with Greg Kesten and Logan McCarty reporting on their undergraduate physics course using large language model (LLM) tutors, and Alexis Ross and Ilia Sucholutsky presenting the latest research in AI and education.

The second week addressed the practical question: how does a mathematician interested in these ideas actually start working with ML researchers? We began with talks by François Charton and Geordie Williamson about their experiences working with mathematicians and ML researchers respectively. A theme which emerged from both talks is that "engineering" questions play a major role and can't be ignored. There was also a valuable discussion around cultural differences between the fields, particularly around publication practices, author participation, and goals of the respective fields. Mathematicians did ML experiments, many for the first time, and it was delightful to see them engage. We also held a public lecture by Geordie Williamson entitled "Can AI help with hard mathematics?"

Two weeks focused on number theory, following an AIM-style approach in which the participants propose projects and split into working groups. Number theorists have a great resource in the L-functions and Modular Forms Database (LMFDB), and many discussions were led by Drew Sutherland, one of its creators. It was used in the first week to do "mathematical data science," the search for mathematically significant patterns in datasets. Several projects took inspiration from the "murmuration" phenomena recently discovered by participants Kyu-Hwan Lee and Alexey Pozdnyakov, an unexpected fluctuation in the distributions for Frobenius traces of families of elliptic curves. Projects included unsupervised learning of rational L-functions, investigations of murmurations and related phenomena in different families of L-functions, and attempts to learn class groups of number fields in particular families.

A second number theory week focused on the use of LLMs and other transformer models in research. This included two tools developed specifically for the program, the transformer-based int2int package developed by Charton which works with integer sequences, and a more general and user-friendly implementation of the funsearch algorithm by Kit Fraser-Taliente, extending the original package developed by Google DeepMind. These tools were applied to several problems: searches for narrow admissible tuples and rational points on genus 2 curves, attempts to learn the Möbius function and its square, missing Dirichlet coefficients of L-functions, and better models of modular curves.

The graph theory week produced many successful projects. The discussions were led by Adam Wagner, who with Gergely Berczi investigated slow percolation processes in hypercube graphs, and with Jordan Ellenberg, Charton and Williamson resolved an open question from Erdös and Graham concerning spanning subgraphs of the hypercube using a new method called PatternBoost. Two groups, one led by Alexander Chervov and another by Kit Fraser-Taliente, developed novel methods for navigation problems on Cayley graphs, inspired by the Rubik's cube problem.

The week on rigorous numerical methods introduced many of us to a research program, in which participants Tristan Buckmaster and Javier Gomez-Serrano are leaders, which uses verified numerical computation to prove rigorous existence theorems in PDE. We discussed advances in mathematical physics, such as the recent resolution of Hilbert's sixth problem by Yu Deng and Zaher Hani, who rigorously derived fluid equations from n-body particle dynamics, identifying combinatorial structures within random particle interactions. We investigated whether ML could detect these structures, and found that transformers accurately predict a "rank" associated with certain interactions. We also tried out transformers for predicting fundamental properties of PDE such as testing stability and eigenvalue computation, with success for certain one dimensional models.

The focus week on knot theory and representation theory was led by Sergei Gukov, who with his collaborators pioneered the study of knots using reinforcement learning. Other topics included ML computation of knot invariants and an application of interpretable ML techniques from classical knot invariants to quantum invariants in low-dimensional topology. Questions in knot theory were related to questions in representation theory, such as the Andrews-Curtis conjecture and solving word problems in braid groups. Using Kolmogorov-Arnold Networks as interpretable machine learning techniques, we also discovered an interesting relation in the Kronecker coefficients of the symmetric group.

Interactive theorem proving and many topics in theory of machine learning were covered in additional focus weeks and in a closing workshop organized by Stephane Mallat, Fabian Ruehle, Adam Wagner, and Melanie Weber.

All the participants agreed that beyond our specific projects and discoveries, we had seen the future of mathematics, a future in which researchers combine the power of traditional mathematical methods with new computational and statistical tools to see farther and dig deeper than before. This will even change the way we think: in Mike Freedman's words, "Some of the younger participants had literally been coding as toddlers and seemed to have already merged psychologically with their machines."

More than 20 papers came out of projects started and work done at the program. Many of these will be published in a special issue of Advances in Theoretical and Mathematical Physics, to appear in the summer of 2025.

Article courtesy of Michael R. Douglas (CMSA, Harvard University)

Expanders from local to global

2025 Ding Shum Lecture: Irit Dinur, IAS

On February 13, 2025, the CMSA hosted the sixth annual Ding Shum Lecture. This year, it was delivered by Irit Dinur, a professor at the Weizmann Institute of Science and the Institute for Advanced Study (AIS), who spoke about expander graphs and an exciting new kind of expanders called high dimensional expanders (HDXs).

In her lecture, Dinur defined expander graphs as the mathematical realization of networks where every part is robustly connected to the rest. In these structures, any small group of points (nodes) has multiple connections to the rest of the graph, ensuring that no part is isolated and information (or influence) spreads efficiently throughout. Throughout the course of the lecture, Dinur surveyed expander graphs, their discovery and construction, and went over some fascinating applications such as error-correcting codes, pseudorandomness, and probabilistically checkable proofs (PCPs). She also emphasized their role as a foundation for a number of breakthroughs in theoretical computer science. Toward the end, she shifted her focus to HDXs, the potential of which we are only starting to uncover.

According to Dinur, HDXs can teach us how to study the larger whole by studying a small puzzle piece of it. "These are very big objects that are made of a lot of small pieces connected in a special way. Even something you learn from a small piece gives you a lot of insight into the bigger picture," she clarified. "As scientists, we often try to come up with observations about the universe by peering at it through a very small lens. It's a very recurring theme in science and computation. A lot of the applications of HDXs take that feature and use it." An example are classical and quantum error correcting codes, where information needs to be encoded in a way that makes it resilient to noise. A particular feature of these codes allows scientists to only look at a small part of the code to determine if it's noisy or not.

HDXs can also be used to construct quantum codes, Dinur said. "We're trying to use them as an infrastructure for constructing computers," she explained. "If we succeed, then we'll have computers that are very resilient to errors because even a small piece of computation can check that the big computation is solid."

Dinur concluded the lecture with a Q&A session. Interspersed with the more technical questions was pure appreciation for her work. "There was one person who asked if I was going to give the lecture in Los Angeles because his son was there and he really wanted him to hear it," she recalled. "I thought that was sweet."

Dinur has loved math and found pleasure in it since she was a child. By the time she got to college, it felt like the natural choice. "But computer science was hip and so much more competitive," Dinur said. And she had always had a competitive streak. By graduation, there were two topics that she really loved: topology and computational complexity. Dinur explored the latter while getting her PhD at Tel Aviv University.

She loved the connections that computational complexity had to deep philosophical topics—the nature of computation, what randomness is, how to model interaction—that could nevertheless be approached in a systematic and rigorous mathematical way. "I just love this combination," Dinur said. "And I love the kind of mathematics that you need to learn for it." For her, that covered computation, theory of computing, probability, and a lot of combinatorics and algebra.

Over the course of her career, Dinur has made a number of transformative contributions to the study of computational complexity, publishing groundbreaking work on optimization, expansion of graphs and hypergraphs, coding theory, and differential privacy. She is especially renowned for a 2006 publication of a new proof of the PCP theorem that was significantly simpler than previous proofs of the same result. This achievement had a major impact in the field and earned her the 2019 Gödel Prize.

Dinur has also contributed significantly to the development of differential privacy theory, which was used in the 2020 U.S. Census and adapted by large companies as a method for conducting data analysis while protecting individual privacy. She received the 2021 ACM Paris Kanellakis Theory and Practice Award for this work.

CMSA Supports Undergraduate Math Research at Harvard

CMSA Postdocs Take on Mentorship Roles for Undergraduate Student Researchers

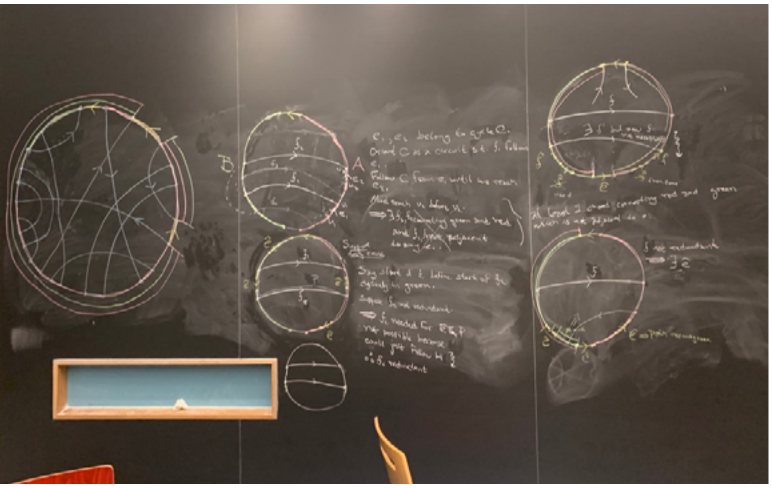


Photo courtesy of REU participant Quinn Brussel: "The writing on the blackboard is part of the proof of the theorem that the Frank number of every cubic, 3-edge-connected, Hamiltonian graph is 2. I wrote this as scratch work the night I proved the theorem, and took a picture so I could remember for later."

The summer of 2023 saw the launch of the Harvard Math Summer Research Experience for Undergraduates (REU), a partnership between the CMSA, the Harvard Department of Mathematics, and the Harvard College Research Program (HCRP). Harvard math senior lecturers Wes Cain and Philip Matchett Wood served as program supervisors and mentors. The REU sought to make a summer mathematics research experience accessible to students who had not previously taken part in one, especially math concentrators who are more advanced in their career.

The program is in its third year now and going strong. According to Cain and Wood, awareness and interest from students has been steady; they accepted 8 applicants for the summer of 2025. There will be a total of four research labs: a "Nonlinear Dynamics" Lab with Cain, a "Graph Theory and Combinatorics Lab" with Wood, a "Machine Learning and Mathematics Lab" with Harvard math preceptor Roderic Guigo Corominas, and a "Topology Lab" with CMSA postdoctoral fellow Sunghyuk Park.

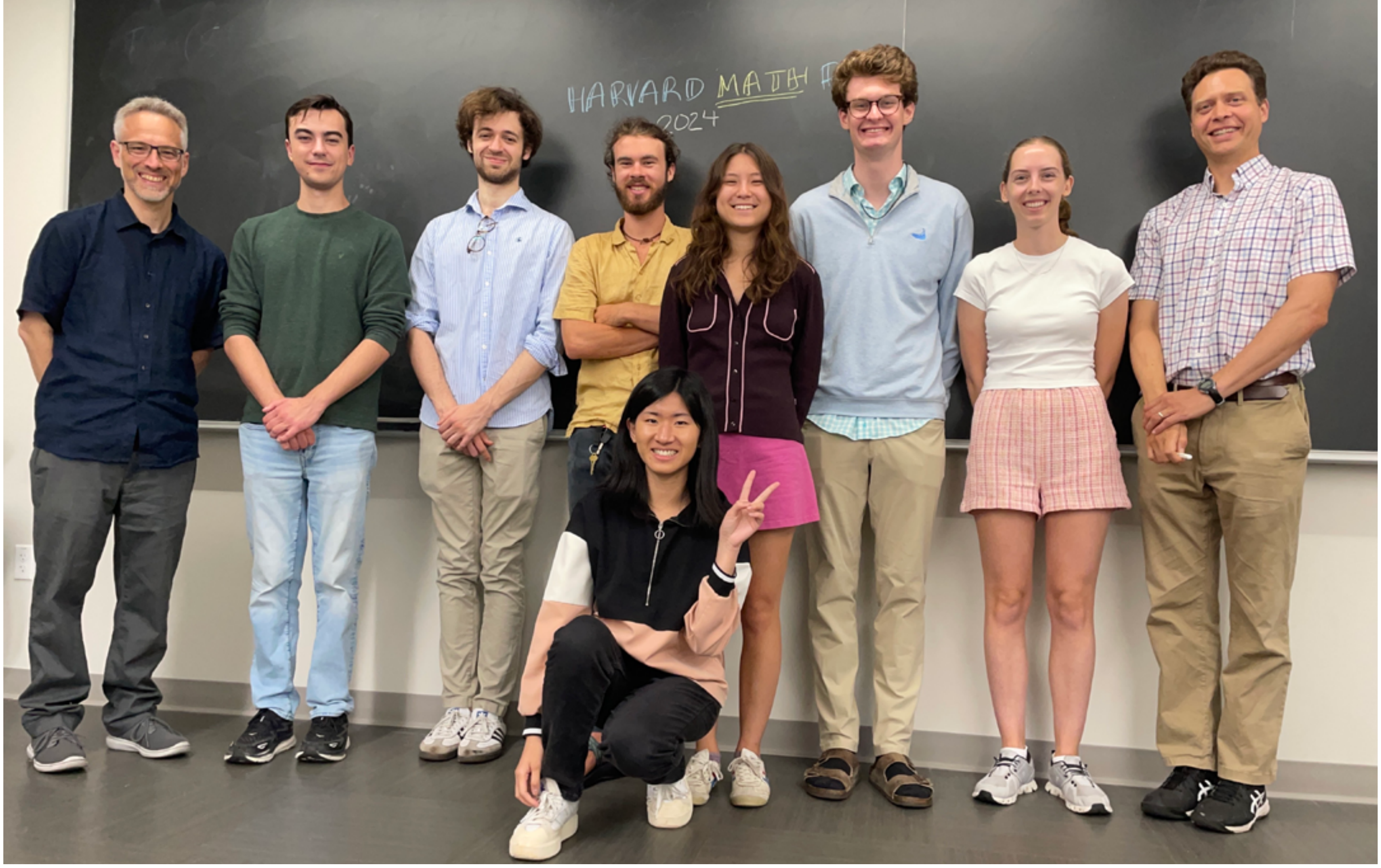
The CMSA has supported the REU financially since its first year, but the relationship between the program and the center grew as of last summer. Heavy construction at the Harvard Science Center building meant that most in-person elements of the program happened in the CMSA building at 20 Garden Street. This expanded the REU's community-building aspect and gave students the opportunity to practice presenting their work to a more varied audience. CMSA postdocs and visitors ended up joining students for lunch and occasionally staying for the 15-minute talks program participants are expected to give on their progress. Everyone in residence at the center was welcome. In fact, Wood hopes such guests only become a more frequent occurrence in the program's future. This, however, is the first year that will see a CMSA postdoc officially take up a mentorship position, enriching both the REU and the postdoc's experience.

Wood and Cain have identified the recruitment of additional mentors as the most surefire way to grow the program. While they both expect they will be able to serve as co-directors for the foreseeable future, they believe it's important to bring in people at different career stages with diverse mathematical training. "The types of things Phil and I would pitch would get stale and it would look like the same program over and over again if we didn't have more diversity of ideas from other mentors," Cain said. For CMSA postdocs, in particular, taking up a mentorship position as part of the REU could supplement the need for teaching opportunities. "It would fill a gap in the postdocs' professional development and serve as something they would talk about in their teaching letter when they are applying for jobs later," Wood said.

Sunghyuk Park first heard about the REU from Wood, who was advertising it at a CMSA lunch seminar. Park immediately thought it would be a great mentorship opportunity for postdocs such as himself and signed up as an official mentor for the summer of 2025. His students will work on a project in the fields of topology, representation theory, and hyperbolic geometry as it aligns with their own interests. "I'm excited to supervise well-motivated students on some fun projects," Park said.

Over the course of ten weeks—matching HCRP housing availability—students will attend team and individual meetings, give weekly presentations, and work independently on their projects. The end goal is either the beginnings of a paper or a technical report detailing the completed work.

"I always tell students that trying to put a timeline on whether or not a paper is going to get written is too ambitious for a several-week-long program," Cain said. "The research game is a long one. In the case of



Participants of the 2024 Harvard Math Summer REU at the CMSA. Pictured left to right, students and their mentors: Michael Nathanson, lecturer and mentor. Tyler Chamberlain presented on generic spectral simplicity of quantum trees. Ignasi Segura Vicente presented on perfect state transfer with a potential in graphs. Quinn Brussel presented on a property of graph orientations called the Frank Number. Dingding Dong, graduate student and mentor. Lauren Teichholz presented on dispersed labeling of trees. Joshua Rooney presented on sets of many balanced, non-transitive dice. Milligan Grinstead presented on graphs that are tough but not prism-hamiltonian. Phil Wood, senior lecturer, research scientist, and mentor.

two students I worked with in 2023, the act of reading the technical report gave some clarity on what was and what wasn't working, and what direction we should go in next. They were good sports about it and were happy to continue working even outside the scope of the program."

For some students, the Harvard Math Summer REU offered an invaluable opportunity. "Spots in external REUs are very hard to come by, especially for students new to research," Quinn Brussel '25 said. "The program confirmed for me that I enjoy the process of math research and made me more sure in my choice to become a career mathematician." Brussel gave a novel proof that the Rank number of a cubic, 3-edge-connected, Hamiltonian graph is always 2. He is applying for math graduate programs to study complex analysis, geometry, and dynamical systems. Milligan Gristead '26 was actually able to submit her work for publication at the end of the summer when she participated in the program. Her paper, which is currently under review, is titled "On prism-Hamiltonian bipartite graphs and roughness."

For other students, the REU actually changed the course of their academic career. Nora Caroline Källersjö '25 was originally considering a double concentration in economics and mathematics. However, after two years of taking courses in both subjects, she felt more drawn to math. "I started considering going into academia to do pure math after graduation," Källersjö said. "The summer program was a perfect opportunity to explore what a research career might look like." Her project covered combinatorial two-player positional games and focused on solving the 7^3 3D Tic-Tac-Toe game by showing that either player can force a draw. Källersjö is writing her thesis under Cain and applying for master's programs in pure math to supplement her mathematical foundations and eventually pursue a PhD degree.

Tomer Ezra

Postdoctoral Fellow

Tomer Ezra joined the CMSA as a postdoctoral fellow in 2024. Prior to that, he was a postdoctoral fellow at the Simons Laufer Mathematical Science Institute (SLMath) and a postdoctoral researcher at Sapienza University in Rome. Ezra's research interests lie on the border of computer science and economics, with a focus on the analysis and design of simple mechanisms and algorithms in limited information settings. After departing the CMSA, Ezra will join the Department of Statistics and Operations Research at the School of Mathematical Sciences at Tel Aviv University as an assistant professor.

Discovering Mathematics

Ezra always enjoyed solving mathematical riddles and participated in local math tournaments through high school. "Almost every other month there was a different math competition," he recalled. But it wasn't until he took a course about algorithmic game theory as a graduate student that things really clicked for him.

The problems discussed in the course were easy to grasp as they came from real life, but at the same time they maintained a nice combinatorial or algorithmic structure. "Usually when you study algorithm design, after a certain point you're left with very niche problems," Ezra said. "But when you're talking about mechanism design and algorithmic game theory in general, you have a very easy explanation about why you're doing what you're doing. The problems feel more natural without sacrificing the complexity that makes the field interesting."

About the CMSA

"Harvard and Boston in general are an amazing hub for the community of algorithmic game theory," Ezra said. The area is home to a number of universities, groups, seminars, and researchers in his specific field of interest. "I would say we have at least five seminars that are relevant for my specific field of study in the city," he said. "I can't even attend all of them!" Ezra was drawn to the CMSA in particular for its modern mathematical aspects.

During his time here, he was exposed to research areas he never would have thought to seek out on his own. "If I was a postdoc at another university, I'd probably only go to the algorithm and game theory seminars," Ezra said. "But there are so many seminars that happen just in the CMSA building, that I get to absorb different ideas from broader aspects of research not directly relevant to my own." For example, he frequently collaborates with Yannai Gonczarowski, a Harvard assistant professor of economics and computer science. "He also studies game theory, but he works with very different types of problems than what I usually work with," Ezra said. "The goal is to find an intersection where both of us can benefit and learn from each other." The two meet weekly to discuss various research directions.

Ezra's last project—"The Competition Complexity of Prophet Inequalities"—studies the classic single-choice prophet inequality problem through a resource augmentation lens. The results pave the way for exploring resource-augmented prophet inequalities in combinatorial settings, and have a natural competition complexity interpretation in mechanism design and pricing applications.

Outside the CMSA

In his limited free time, Ezra enjoys playing the trombone. In fact, the option to join an ensemble or a band was important to him when made the decision to move to Cambridge easier. "I joined the Harvard Wind Ensemble," Ezra said. "It's really fun! We have two rehearsals every week, which means we get to play a lot regularly. It's a part of my Harvard experience."

Matteo Parisi

Postdoctoral Fellow

Matteo Parisi is a postdoctoral fellow at the CMSA and a lecturer at the Harvard Department of Mathematics. He joined the center in 2021, and held a joint position until 2024 as a member of the Institute for Advanced Study (IAS) and a lecturer in physics at Princeton University. Parisi is onsidering a five-year senior postdoctoral position at the Max Planck Institute for Physics in Munich, Germany or a tenure-track offer at the Okinawa Institute of Science and Technology (OIST) in Okinawa, Japan.

Discovering Mathematics

For Parisi, the passion for science and math were always intertwined. As a child, he loved gazing at the stars and wondering at the truth of the universe. He discovered math at school and by spending time around his sister, who was studying engineering at university. "I would stare at the beautiful formulas on her pages and while I couldn't understand them, I got the impression that math was the most powerful and beautiful thing that humans had ever invented," Parisi recalled.

He studied physics as an undergraduate student, but craved a deeper understanding of the math his classes used. He chose to pursue a masters degree in theoretical and mathematical physics in Munich because it allowed him to take courses from both the math and physics departments.

Still, bridging the gap between pure math and physics only happened once he started his thesis on a novel object called the amplituhedron, the geometry and combinatorics of which underpin the probability of interactions of elementary particles in a certain quantum field theory. "I was so happy to see that beautiful, new math could be so important for new ways of thinking about fundamental interactions in physics," Parisi said. His research is still centered around the amplituhedron, at the intersection of algebraic combinatorics and high energy physics. Specifically, it focuses on scattering amplitudes in quantum field theories in relation to the positive Grassmannian amplituhedra, tropical geometry and cluster algebras.

About the CMSA

He first came to the CMSA in 2019 for a two-week workshop—"Spacetime and Quantum Mechanics, Total Positivity and Motives"—where he connected with CMSA affiliate and Harvard math department professor Lauren Williams. "I showed her a sequence of numbers that counted the ways to subdivide the amplituhedron into smaller pieces," Parisi said. "I was struggling to make sense of it, but she immediately recognized when I showed it to her. It was linked to an object she had defined during her PhD—the positive tropical Grassmannian." Neither initially understood why these two mathematical structures were related, making the discovery all the more surprising. They stayed in touch in the weeks that followed, gradually uncovering deeper connections between their work. This led to a breakthrough in the study of the amplituhedron and resulted in a series of published papers.

The 2021 offer of a joint appointment at the CMSA and IAS was Parisi's dream. He could continue his work with Williams in math, and explore high energy physics at Princeton. The CMSA afforded him the flexibility to do so. "There aren't a lot of places where I could have done this," he said. "I think I see things in a different way because I had the chance to be in both worlds. It was a very eye-opening and enriching experience."

Outside the CMSA

Teaching, outreach, and advocacy for inclusivity and diversity within and beyond academia are a key part of Parisi's identity. He taught classes in physics and combinatorics at the first ever Cameroon Maths Camp in Yaoundé, Cameroon, and held lectureships at two Oxford colleges, Princeton, and Harvard. He is part of the Cambridge Boston Volleyball Association (CBVA), an LGBTQ+ and allies league, and serves on the social committee of the Harvard Postdoctoral Association (FAS-PDA), where he organizes LGBTIQ+ Happy Hours. He also interacts with charities and activists on LGBTQ+ issues. "I really value the way I can connect to society intellectually through teaching, and as an LGBT individual through outreach," he said.

Parisi is an avid supporter of the arts. He's a patron of the Boston Ballet and joined a beginner's ballet class at Harvard. He enjoys the Museum of Fine Arts and the Harvard Art Museums, but believes the highlight of Boston is its music scene. "I have a group of friends, postdocs from different disciplines, that share my passion for classical music," he said. "We go to performances together."

Current Postdocs

Enric Boix
Mentor: Michael Douglas

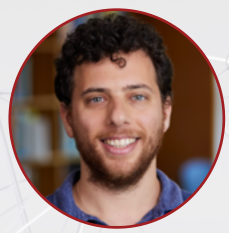
Research Interests
Mathematical science of deep learning.
Future Plans
Joining the Wharton Statistics and Data Science department at UPenn as an assistant professor.

Iacopo Brivio
Mentor: Mihnea Popa

Research Interests
My research interests are in higher dimensional algebraic geometry, especially in positive and mixed characteristic. More precisely, I like to think about the Minimal Model Program and its applications to the moduli theory of varieties of general type. More recently I have become interested in the study of fibrations and sub/super additivity properties of the Kodaira dimension.

Hugo Cui
Mentor: Michael Douglas

Research Interests
My research lies at the crossroads of machine learning theory, statistical physics and probability. My focus is on reaching a tight theoretical understanding of the workings of machine learning algorithms learning from high-dimensional data.



Tomer Ezra
Mentor: Yannai Gonczarowski and Scott Kominers

Research Interests
My research interests lie at the intersection of computer science and economics, with a focus on the development of simple mechanisms and algorithms in settings where information is limited.
Future Plans
Assistant Professor at the Department of Statistics and Operations Research at Tel Aviv University.

Samy Jelassi
Mentor: Boaz Barak and Mike Douglas

Research Interests
My field of research is deep learning. I am interested in designing large language models that are able to solve multi-step reasoning problems. This framework covers applications ranging from applying a cascade of simple modifications to a string to solving an olympiad-level coding problem.
Future Plans
Pursue my postdoc for a year with host, Proffessor Sham Kakade at Harvard SEAS.

Ahsan Khan
Mentor: Dan Freed

Research Interests
I am interested in questions related to quantum field theory and its underlying mathematical structure. My work covers algebraic structures emerging from the BPS sector of supersymmetric field theory, quantum field theories with mixed holomorphic-topological properties, and the connection of these topics to quantum groups, vertex algebras and higher category theory. By studying these topics my research aims to uncover ideas that lead to progress in both pure mathematics and theoretical physics.

Uri Kol
Mentor: Shing-Tung Yau

Research Interests
Various topics in theoretical high-energy physics, including black hole dynamics, scattering amplitudes, and the gauge/gravity holographic correspondence. Training dynamics of artificial neural networks, analyzed using physics-based tools.

Vasily Krylov
Mentor: Dan Freed

Research Interests
I am interested in the intersection of representation theory, geometry, and physics. My focus is particularly on symplectic resolutions of singularities, integrable systems, 3D-mirror symmetry, and Coulomb branches.

Daniel Mitropolsky
Mentor: Michael Douglas

Research Interests
Theoretical computer science, natural language processing, machine learning, theoretical neuroscience.

Puskar Mondal
Mentor: Shing-Tung Yau

Research Interests
General relativity and geometric analysis.
Future Plans
Tenure track Assistant Professor at Yau Mathematical Sciences Center, Tsinghua University, and the Beijing Institute of Mathematical Sciences and Applications.

Robert Moscrop
Mentor: Michael Hopkins

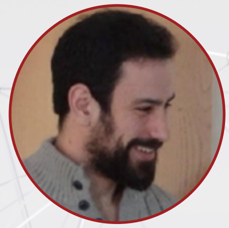
Research Interests
Superconformal field theories, mathematical physics, generalized global symmetries.

Matteo Parisi
Mentor: Lauren Williams

Research Interests
My research lies at the intersection of algebraic combinatorics and high-energy physics. My work focuses on a novel combinatorial understanding of scattering amplitudes in quantum field theories - which encode the probability of interaction of fundamental particles - from the (positive) Grassmannian, tropical geometry, cluster algebras and amplituhedra.
Future Plans
Considering a five-year senior postdoctoral position at the Max Planck Institute for Physics in Munich, Germany or a tenure-track offer at the Okinawa Institute of Science and Technology (OIST) in Okinawa, Japan.

Sunghyuk Park
Mentor: Dan Freed

Research Interests
Quantum topology and physical mathematics.



Alejandro Poveda
Mentor: Hugh Woodin

Research Interests
My research interests lie in set theory and its applications to other areas of pure mathematics, such as Topology, Functional Analysis and Module Theory.

Han Shao
Mentor: Cynthia Dwork and Ariel Procaccia

Research Interests
My primary research centers on machine learning theory, with a specific focus on modeling human strategic and adversarial behaviors within the learning process. I aim to understand how these behaviors affect machine learning systems and develop methods to enhance accuracy/robustness. Additionally, I am interested in gaining a theoretical understanding of empirical observations concerning adversarial robustness.
Future Plans
Assistant Professo at the University of Maryland Department of Computer Science.

Farzan Vafa
Mentor: David Nelson

Research Interests
I am interested in the non-perturbative features of superconformal field theories, the classification of such theories, generalized global symmetries, and the physical modeling of morphogenesis.

Bowen Yang
Mentor: Dan Freed

Research Interests
My research area is mathematical physics with a focus on lattice models. My work combines algebra, topology and coding theory to understand phases of matter. I am also curious about field theory, symmetries as well as category theory.

Keyou Zeng
Mentor: Dan Freed

Research Interests
I'm interested in quantum field theory and string theory. I'm currently studying twisted supersymmetric field theory and its duality.

Upcoming Postdocs

Houcine Ben Dali
Mentor: Lauren Williams

Research Interests
I am interested in algebraic combinatorics. I am currently working on connections between symmetric functions and enumeration of combinatorial maps.

Blake Bordelon
Mentor: TBD

Research Interests
My research focus is on the theory of neural computation. Some recent topics of interest include learning dynamics, sample complexity, scaling limits and scaling laws of large randomly initialized neural networks. My work utilizes ideas from statistical physics, random matrix theory, and dynamical systems to characterize the types of solutions and representations learned in deep networks.

Elliott Gesteau
Mentor: Dan Freed

Research Interests
My research revolves around mathematical aspects of quantum gravity. Current focuses include the application of the theory of von Neumann algebras and quantum chaos to the emergence of spacetime in holography, as well as the algebraic structures underlying topology change in the gravitational path integral.

Saman Habibi Esfahani
Mentor: Cliff Taubes

Research Interests
My research focuses on gauge theory and calibrated geometry on low-dimensional manifolds and manifolds with special holonomy groups, particularly Calabi-Yau 3-folds and special Lagrangians. I investigate compactness phenomena and singularity formation in moduli space problems using methods from PDE and geometric measure theory, as well as through connections to symplectic topology and algebraic geometry.

Francesco Mori
Mentor: TBD

Research Interests
I am interested in nonequilibrium physics, active matter, and learning. In particular, I am currently combining ideas from statistical physics and control theory to investigate optimal learning in artificial and biological systems.

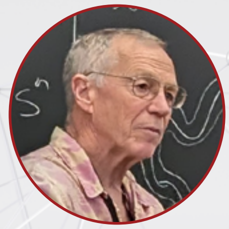
Lorenzo Riva
Mentor: Dan Freed

Research Interests
Broadly interested in algebraic topology and homotopy theory, and a side interest in logic. Currently thinking about higher homotopical algebra and its interactions with topological field theories

Current Senior Research Scientists

Michael Douglas

Research Interests
During his time at the CMSA, Douglas has been focused on the intersection of AI and science. One project has involved applying machine learning tools to geometry by calculating Calabi-Yau metrics on a computer. Another field of research has been interactive theorem proving.



Michael Freedman

Research Interests
Lately, he has been fascinated by the work of two Russian mathematical physicists from the 1950s, Vladimir Arnold and Andrey Kolmogorov. While they were not interested in computer science at the time, they laid foundational work that later became the basis for the kinds of neural networks that Geoffrey Hinton and others developed.

Special Feature: Michael Freedman

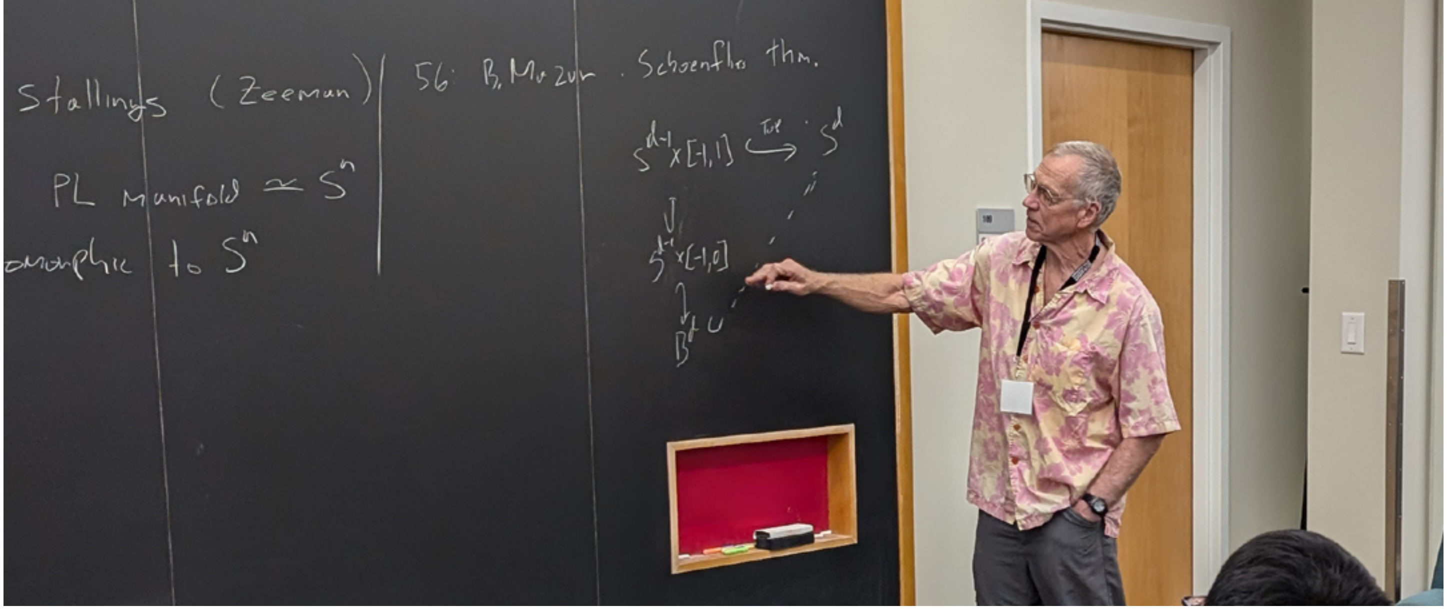
Senior Research Scientist

Michael Freedman's research interests have historically centered around topology and quantum physics. The nexus of the two is known as topological quantum field theory, which is important to understanding how quantum computers would one day work, as well as to black hole physics and high energy physics in general. Over the years, Freedman has received numerous awards and honors, including Sloan, Guggenheim, and MacArthur fellowships, the Veblen Prize, the National Medal of Science, and the Humboldt Research Award. He is an elected member of the National Academy of Sciences, as well as a fellow of the American Academy of Arts and Sciences and of the American Mathematical Society. In 1986, he was awarded a Fields Medal at the International Congress of Mathematicians (ICM) in Berkeley for proving the four-dimensional version of the Poincaré conjecture, one of the famous problems of 20th-century mathematics. Freedman's version stated that any compact four-manifold that can be gradually bent, contracted, and expanded into a four-dimensional sphere is, in fact, topologically the same as the four-dimensional sphere. Freedman was the Charles Lee Powell Professors of Mathematics at the University of California in San Diego until 1998, when he left the academic world to take up an appointment with Station Q, a Microsoft research group working on topological quantum computing. This made him the first Fields Medalist to leave the world of academics to work for a company. He returned to academia when he joined the CMSA in 2023.

Freedman grew up in a household that was the definition of arts and sciences. His mother was an actor and an artist, and his father was a musician and a mathematician with a degree in aeronautical engineering. Freedman enjoyed painting with his mother's encouragement and caught his father's love of mathematics research by the time he finished high school. He started college at the University of California, Berkeley with the intention of majoring in art, but quickly got sidetracked. While many freshmen had no idea what a mathematician spent their time doing, Freedman did because of his father. He skipped the first-year calculus course and enrolled directly in upper-level courses in abstract algebra, topology, and measure theory, all of which influenced the direction of his research for years to come. Barely a year later, Freedman entered the graduate program at Princeton University where he completed a dissertation in topology under Bill Browder.

After graduating, he took on visiting positions at Berkeley and the Institute of Advanced Study (IAS) at Princeton, before accepting a tenure-track job at the University of California, San Diego. In a stroke of fate, that's where he first met Shing-Tung Yau, future fellow Fields Medal winner and founding director of the CMSA. "I was an assistant professor and Yau had just been hired," Freedman recalled. "He had this fantastic energy and ambition to make wherever he was the greatest. It was very inspiring for me to see this because a lot of people feel that their career won't be exciting unless they land at Harvard, Princeton, or Berkeley. Yau had none of that in his thinking. He said, here I am, so this is going to be the best place. Those were great formative years and we've stayed close ever since."

In 1988, Freedman was visiting the Harvard Department of Mathematics when he went through what he calls a life-changing experience. Edward Witten had just come out with the mathematical paper that would eventually get him a Fields Medal, linking the topological theory of knots and links to the area of physics now known as topological quantum field theory. The draft of his work was circulating among the scientific community in the form of purple mimeograph notes when Harvard's professors Cliff Taubes and Raoul Bott asked Freedman for help



organizing a seminar to review Witten's work.

Freedman admits that, at first reading, the draft looked like complete gibberish to him. He wrote Witten, raising what he thought were very decisive points against his findings. "But then, pretty much as fast as the mail can go in both directions a week later, I get this beautiful letter back from Witten explaining the points I'd raised in remarkable detail," Freedman recalled. He was blown away by the response. He realized that Witten was wielding an incredibly powerful—and unfamiliar to Freedman—tool in the form of quantum field theory. "At that moment, I resolved that I was going to learn that subject," he said. Freedman was humbled by the knowledge that a well-trained physicist with just a smattering of knowledge in topology could act more powerfully in the field than he could, all because he had quantum field theory on his side.

This experience drove Freedman to teach himself physics, a subject with which he has a very different relationship than he does with mathematics. "I learned mathematics as a child," he said. "I have almost no books about mathematics around the house. If anyone asks me about the best place to read about something, I usually can't help them very much. But if someone asks me about physics, my bookshelves are full of books on the subject. I can tell them exactly which ones were useful to me and where they need to look for answers." According to Freedman, his friends in the field often remark that he speaks physics with an accent because he tends to use the mathematical term for the equivalent physical concept.

Freedman joined Microsoft's Station Q in 1997, where his team was involved in the development of the topological quantum computer. He was director from 2005 to 2018 and remained involved with Micorosft in a research capacity until he eventually joined the CMSA. To Freedman, the center his old friend Yau had founded represented a confluence of pure and applied mathematics that fit with his life history and interests. "I regard myself as interested in almost everything and an expert in nothing but I adapt, and I like to move between fields and collaborate with people in applications," he said. "The times we live in are particularly exciting for mathematical and physical applications such as renewable energy, machine learning, and quantum computing. There are so many areas with the potential to change the way we live and where mathematics is going to be crucial."

The first major effort Freedman was involved in as part of the CMSA was organizing and participating in the two-month-long "Mathematics and Machine Learning Program." The program covered the many diverse fields of mathematics in which machine learning is being used by arranging focus weeks on number theory, graph theory, knot theory, theorem proving, and rigorous numerical methods. "The question is, what's the role of humans going forward in mathematics?" Freedman said. "These language models seem rather clever when you chat with them, but can we adjust them in some way to help us do mathematics? It's a question on the minds of all mathematicians, particularly young mathematicians wondering what their career will be like 30 years ahead."

Freedman finds he is in an unusual situation when it comes to machine learning and math interface. He's not hands-on with respect to AI, but that means that while everyone else is writing code between 8 p.m. and 5 a.m., he is free to read literature and think. Lately, he has been fascinated by the work of two Russian mathematical physicists from the 1950s, Vladimir Arnold and Andrey Kolmogorov. While they were not interested in computer science at the time, they laid foundational work that later became the basis for the kinds of neural networks that Geoffrey Hinton and others developed.

"I think part of the CMSA's mission is to react to what's important and what it sees as becoming important," Freedman said. The "Mathematics and Machine Learning Program" he helped organize is one example of the center's ability to react rapidly and with a fairly short planning ramp-up. "Historically what we've seen is that mathematics has been hugely enriched by ideas that came from physics, and it has been very helpful in biology and economics. The question now is, will mathematics itself grow from interaction with these other scientific disciplines?"

Past CMSA Events

[Program on Mathematical Aspects of Scattering Amplitudes](#)
Program
April 15–May 24, 2024
Organizers: Nima Arkani-Hamed (Institute for Advanced Study), Marcus Spradlin (Brown University), Andrew Strominger (Harvard), Anastasia Volovich (Brown University), Lauren Williams (Harvard)

[Workshop on Global Categorical Symmetries](#)
Workshop
April 29–May 3, 2024
Organizers: Dan Freed (CMSA & Harvard), Constantin Teleman (UC Berkeley)

[Particle-Soliton Degeneracies from Spontaneously Broken Non-Invertible Symmetry](#)
Public Lectures: Workshop on Global Categorical Symmetries
May 2, 2024
Speaker: Clay Còrdova (University of Chicago)

[Symmetries, Invertible Field Theories, and Gauge Theory Phases](#)
Public Lectures: Workshop on Global Categorical Symmetries
May 2, 2024
Speaker: Thomas Dumitrescu (UCLA)

[The Universal Target Category](#)
Public Lectures: Workshop on Global Categorical Symmetries
May 2, 2024
Speaker: Theo Johnson-Freyd (Dalhousie University and Perimeter Institute)

[Amplituhedra, Cluster Algebras, and Positive Geometry](#)
Conference
May 29–31, 2024
Organizers: Matteo Parisi (CMSA), Lauren Williams (Harvard)

[Fibration and Degeneration in Calabi-Yau Geometry](#)
Workshop
June 24–26, 2024
Organizer: Chuck Doran (CMSA)

[Mathematics and Machine Learning Program](#)
Program
September 3–November 1, 2024
Organizers: Francois Charton (Meta AI), Michael Douglas (CMSA), Michael Freedman (CMSA), Fabian Ruehle (Northeastern), Geordie Williamson (Univ. of Sydney)

[Big Data Conference 2024](#)
Conference
September 6–7, 2024
Organizers: Rediet Abebe (Harvard Society of Fellows, Morgane Austern (Harvard Statistics), Michael Douglas (CMSA), Yannai Gonczarowski (Harvard Economics and Computer Science), Sam Kou (Harvard Statistics)

[Can AI help with hard mathematics?](#)
Public Talk: Mathematics and Machine Learning Program
September 12, 2024
Speaker: Geordie Williamson (University of Sydney)

[The complexity of knots](#)
CMSA/Tsinghua Math-Science Literature Lecture Series
September 18, 2024
Speaker: Marc Lackenby (University of Oxford)

[Machine Learning in Science Education Panel Discussion](#)
Panel Discussion: Mathematics and Machine Learning Program
September 30, 2024
Panelists: Gregory Kestin (Harvard), Logan McCarty (Harvard), Alexis Ross (MIT), Ilia Sucholutsky (New York University)

[Abelianization in analysis of ODEs and Abelianization in quantum topology](#)
Math Science Lectures in Honor of Raoul Bott
October 16 & 17, 2024
Speaker: Andrew Neitzke (Yale University)

[Ranks of elliptic curves](#)
CMSA/Tsinghua Math-Science Literature Lecture Series
November 21, 2024
Speaker: Bjorn Poonen (MIT)

[Workshop on Symmetries and Gravity](#)
Workshop
January 21–24, 2025
Organizers: Ibrahima Bah (Johns Hopkins University), Patrick Jefferson (Johns Hopkins University), Yiming Chen (Stanford)

[Expanders from local to global](#)
Ding Shum Lecture Series
February 13, 2025
Speaker: Irit Dinur (Institute for Advanced Study)

[Classical, quantum, and probabilistic integrable systems – novel interactions and applications](#)
Program

March 24–May 24, 2025
Organizers: Amol Aggarwal (Columbia University & Clay Mathematics Institute), Guillaume Barraquand (École normale supérieure, Paris), Alexei Borodin (MIT), Ivan Corwin (Columbia University), Pierre Le Doussal (École normale supérieure, Paris), Michael Wheeler (University of Melbourne)

Yang-Mills theory and random surfaces
CMSA/Tsinghua Math-Science Literature Lecture Series
April 8, 2025
Speaker: Scott Sheffield (MIT)

How Much Math Is Knowable?
Fifth Annual Yip Lecture
April 17, 2025
Speaker: Scott Aaronson (University of Texas, Austin)

Upcoming CMSA Events

Summer School in Total Positivity and Quantum Field Theory
Program
June 2–4, 2025
Organizers: Jonathan Boretsky (McGill University), Matteo Parisi (CMSA and IAS Princeton), Lauren Williams (Harvard Math)

Quantum Field Theory and Topological Phases via Homotopy Theory and Operator Algebras
Workshop
June 30–July 11, 2025
Organizers: Dan Freed (Harvard & CMSA), Dennis Gaitsgory (MPIM Bonn), Owen Gwilliam (UMass Amherst), Anton Kapustin (Caltech), Catherine Meusburger (University of Erlangen-Nürnberg)

Millennium Prize Problems Lectures
Public Lectures
September 17, October 15, November 12, December 3, 2025, February 4, March 11, April 15, 2026
Organizers: Martin Bridson (Oxford University), Dan Freed (CMSA), Mike Hopkins (Harvard Math)

Math and Machine Learning Reunion
Workshop
September 8–11, 2025
Organizer: Michael Douglas (CMSA)

Big Data Conference 2025
Conference
September 12–13, 2025
Organizer: Michael Douglas (CMSA)

Mathematical foundations of AI
Workshop
October 6–10, 2025
Organizer: Morgane Austern (Harvard Statistics)

Mathematics in Science: Perspectives and Prospects
Conference
October 23–25, 2025
Organizer: Dan Freed (CMSA)

Geometry meets Physics: Finiteness, Tameness, and Complexity
Conference
November 12–14, 2025
Organizers: Thomas Grimm (Utrecht University), Gal Binyamini (Weizmann Institute), Bruno Klingler (Humboldt University, Berlin)

Conference on Geometry and Statistics
Conference
November 18–20, 2025
Organizer: Zhigang Yao (National University of Singapore)

Shape in Biology
Program
February 23–March 13, 2026
Geometry, Statistics, and Morphogenesis
March 23–April 10, 2026
Geometry, Physics, and Morphogenesis
April 20–May 8, 2026
Geometry, Statistics, and Cognition
Organizers: Vanessa Barone (Stanford), Anjali Goswami (University College London), Olivier Pourquie (Harvard), Anuj Srivastava (Florida State University), Lakshminarayanan Mahadevan (Harvard), Salem al-Mosleh (University of Maryland Eastern Shore), Akankshi Munjal (Duke)

Swampland and our Universe
Workshop
April 9–10, 2026
Organizer: Cumrun Vafa (Harvard Physics)

Credits

PRODUCTION MANAGER

Anastasia Yefremova | Communications Specialist, Harvard Department of Mathematics

CONTRIBUTORS

Maureen Armstrong | Publications Coordinator, CMSA

Nima Arkani-Hamed | Gopal Prasad Professor, Institute for Advanced Study

Michael R. Douglas | CMSA Senior Research Scientist

Dan Freed | CMSA Director and Shiing-Shen Chern Professor of Mathematics, Harvard University

Marcus Spradlin | Professor of Physics, Brown University

Andrew Strominger | Gwill E. York Professor of Physics, Harvard University

Alison Sundet | Programs and Events Administrator, CMSA

Anastasia Volovich | Professor of Physics, Brown University

Lauren Williams | Dwight Parker Robinson Professor of Mathematics, Harvard University

HARVARD UNIVERSITY
CENTER OF MATHEMATICAL SCIENCES AND APPLICATIONS

20 Garden Street
Cambridge, MA 02138, USA

(617) 495-2171

cmsa_admin@cmsa.fas.harvard.edu

cmsa.fas.harvard.edu

@HarvardCMSA

SUPPORT THE CMSA