NEWSLETTER

CMSA

Center of Mathematical Sciences and Applications

2025–2026

HARVARD UNIVERSITY
CENTER OF MATHEMATICAL
SCIENCES AND APPLICATIONS

Table of Contents

Message from the Director..............2

Special Features
Millennium Prize Problems Lecture Series..............3
Two Talks on Function-Theoretic Implications of Geometric Langlands..............8
Program on Classical, Quantum, and Probabilistic Integrable Systems..............9
Eran Nevo: Visiting Scholar..............17

Postdoctoral Fellow Profiles
Sunghyuk Park..............11
Francesco Mori..............12

CMSA People
Current CMSA Postdocs..............13
Upcoming CMSA Postdocs..............15
CMSA Research Associates and Senior Research Scientists..............16

CMSA Events
Past Events..............19
Upcoming Events..............20

Credits..............23

Stay Connected..............24

Message From the Director

Dan Freed

Shiing-Shen Chern Professor of Mathematics

Director of the CMSA

I am excited to bring you the annual CMSA newsletter. It was an active year at CMSA, especially with our popular lecture series on the Millennium Prize Problems. As always, my vision for the Center rests on my unwavering faith in the power, unity, and beauty of Mathematics. The breadth of mathematical and scientific ideas at the Center is a joy and a challenge. It is a stimulant to our local researchers and visitors, and we encourage everyone to broaden their perspective during their time at CMSA. In these pages you'll see a bit of the research at CMSA and you'll meet some of the people who carry it out. For a more firsthand experience, I highly recommend that you check out the videos on our YouTube Channel. You can also learn more about CMSA from our short film.

Special lectures featured prominently this year, and none more so than the series on the Millennium Prize Problems. Twenty-five years ago, seven open Mathematics problems were singled out by the Clay Mathematics Institute as worthy of attention...and of a $1M prize. On the occasion of this quarter century anniversary, together with the Harvard Department of Mathematics and the Clay Mathematics Institute, the CMSA organized a series of public lectures to once more shine a spotlight on these problems and on the vitality of Mathematics. Each problem has its own personality and history, as does each of the seven lecturers, and that variety came through in the presentations: sample them on our YouTube Channel to see for yourself.

Other special lectures this year were also memorable. Dennis Gaitsgory delivered two lectures in honor of Raoul Bott. His current work, which uses a form of the fixed point formula, was particularly appropriate for the Bott lectures. In his Ding Shum Lecture, Sanjeev Arora took up the intriguing question "How could a Superhuman AI mathematician come about?". Martin Bridson gave a beautiful lecture in our joint CMSA/Tsinghua Math-Science Literature Lecture series. He explored how much the action of infinite groups on finite objects can tell us about the infinite group. I am writing this message at the beginning of a busy week in which we will have two more special lectures: the Yip Lecture by Regina Barzilay and a Math-Science Literature Lecture by Nicolai Reshetikhin. And we expect to inaugurate some new special lectures in the coming years: stay tuned!

As with Sanjeev Arora's lecture, CMSA continues to engage with the exploding field of AI and its relationship to Mathematics. It is a time of rapid change in how we do Mathematics research, and CMSA is very much in the mix of these developments. Our academic year began with a reunion workshop from last year's Math and Machine Learning program, as well as a workshop on The Geometry of Machine Learning. Our annual Big Data conference featured several talks on AI. We also ran a workshop on Mathematical Foundations of AI. Mike Douglas continues to run his weekly New Technologies in Mathematics seminar. This fall we plan to inaugurate a new "AI for the Working Mathematician" weekly seminar as well. Other plans are in the works.

A sample recent long program is "Classical, Quantum, and Probabilistic Integrable Systems". The organizers' article illustrates beautifully features of CMSA that run through all of our activities. We bring together subjects and communities for novel interactions, as articulated by one of the organizers: "Perhaps one of the most important aspects of the program was that it collected mathematicians and physicists in the same area for an extended period of time. This compelled the two communities to interact in ways that would be unlikely at a conference, where time would have been too limited to enable deep conversations." At CMSA we engineer serendipitous interactions. This program had many fruitful unforeseen encounters that led to new projects, as you'll read at the end of the article. We have two exciting programs planned for the coming academic year, which we will report about in the next newsletter.

We encourage mathematicians and scientists to spend their sabbaticals here at CMSA. This year we have two year-long sabbatical visitors: Thomas Grimm and Eran Nevo. Each has greatly enriched the mathematical environment. For example, Thomas organized a workshop Geometry meets Physics: Finiteness, Tameness, and Complexity. Eran is profiled in this newsletter. The article conveys how he has been stimulated by CMSA people and activities, and how he has contributed to the vibrancy of Harvard Mathematics. We have lined up more long-term visitors for the coming few years. Please reach out if you'd like to join them.

Our postdoctoral fellows continue to be the lifeblood of CMSA. They organize weekly seminars and colloquia, and they push the interactions of Mathematics and Science in new directions. They will carry the open view of Mathematics they experience here to the rest of their careers. We have eight new postdocs joining us in the fall. They are an amazingly strong bunch and we look forward to welcoming them and helping shape their future.

In an exciting development, CMSA will soon move to the Science Center. There we will be adjacent to the Department of Mathematics and we will be much closer to Physics, Economics, Statistics, Applied Math, and Biology. This will facilitate the interactions we foster. We are excited to relocate.

Our plans for special lectures and workshops for the coming year are rapidly evolving. The nimbleness of CMSA—the short timescale on which we can organize activities—continues to be one of our greatest strengths. I look forward to telling you about them next year!

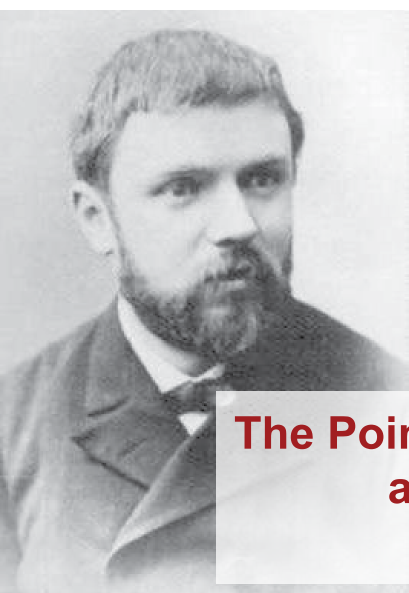
With Best Wishes,

Dan Freed

Millennium Prize Problems Lecture Series

Seven Public Lectures Honor the Spirit of the Millennium Prize Problems

To celebrate mathematics in the new millennium, the Clay Mathematics Institute (CMI) established seven Prize Problems and offered a $1 million bounty for each. The list of problems was finalized and presented at Collège de France in 2000. It was assembled to highlight major unsolved mathematical questions, to emphasize the importance of tackling genuinely hard problems, and to acknowledge significant achievements in mathematics. A final stated goal was to "elevate in the consciousness of the general public the fact that, in mathematics, the frontier is still open and abounds in important unsolved problems." It was in this spirit that the Center of Mathematical Sciences and Applications (CMSA), the Harvard University Department of Mathematics, and the CMI offered seven public lectures—one dedicated to each of the seven Prize Problems—held at Harvard between September, 2025 and April, 2026.



The Poincaré Conjecture and Mathematical Discovery

September, 2025

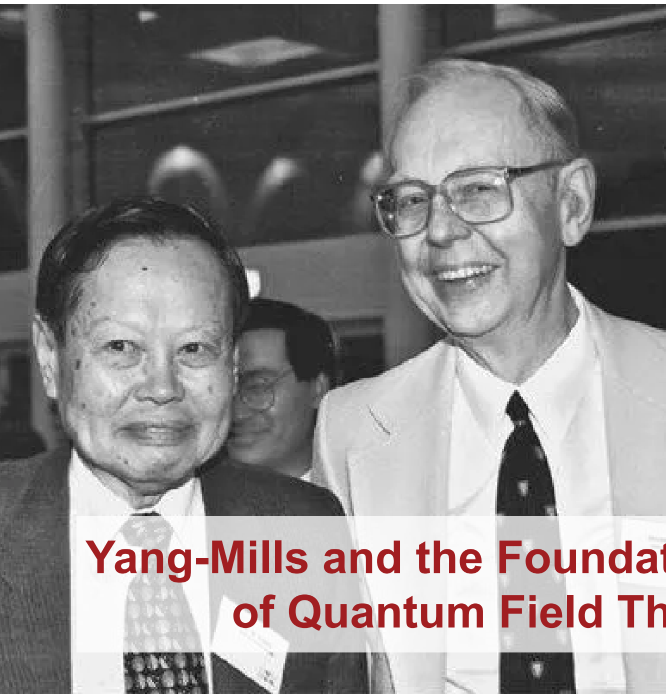
Michael Freedman
Harvard CMSA and Logical Intelligence

In 1904, French mathematician Henri Poincaré asked if the three-dimensional sphere is characterized as the unique simply connected three manifold. This question, the Poincaré conjecture, represents a core mathematical subject, manifold topology. Freedman described it as "a bit of a wild—but inspired—guess…that became a cultural icon, motivating many developments in 3D topology (Heegaard decompositions), group theory (Andrews-Curtis problem), and high dimensional topology(handle body theory)." The Poincaré conjecture is also the only Prize Problem that has been solved.

Grigoriy Perelman announced the solution in preprints posted on ArXiv.org in 2002 and 2003. It followed Richard Hamilton's theory of Ricci flow, ultimately through the study of parabolic equations. It profoundly transformed that field of geometric analysis through the introduction of new conserved quantities, and has been an important driver in bringing math and physics closer. "Until it was solved, no one would even say what field of mathematics was applicable," Freedman said. "William Thurston built an amazingly productive program starting from the opposite end of geometry (hyperbolic), which fell just short of arriving at PC3. But the program changed 3D topology forever."

In his lecture, Freedman explained the Poincaré conjecture, its broader context, and why people cared so much about finding a solution. He ended his talk with a rope metaphor for mathematics: "strands of ideas twisted together, sometimes individually flawed, but together creating a structure of enormous strength and resilience. PC3 is itself such a rope."

Michael Freedman, Harvard CMSA and Logical Intelligence.



Yang-Mills and the Foundations of Quantum Field Theory

October, 2025

Sourav Chatterjee
Stanford University

In the early 1950s, Chen-Ning Yang and Robert Mills introduced a remarkable new framework to describe elementary particles using structures that also occur in geometry. Yang-Mills theories are now the building blocks of the Standard Model of quantum mechanics, which is the best available model for our universe at the quantum scale. However, while these theories have been tested at many experimental laboratories, they still do not have a rigorous mathematical foundation. The successful use of Yang-Mills theory to describe the strong interaction of elementary particles depends on a subtle quantum mechanical property called the "mass gap": the quantum particles have positive masses, even though the classical waves travel at the speed of light and are massless.

"What makes the problem so challenging is that the most interesting phenomena are genuinely nonperturbative," Chatterjee said. "We have strong physical intuition and many deep partial results, but turning that understanding into a complete mathematical theory is extraordinarily difficult." That is not to say that even attempts to understand the problem better haven't opened new directions of research. It has inspired important developments in gauge theory, in geometric analysis, in mathematical physics, and in Chatterjee's own area of probability theory.

His lecture gave a general introduction to the main question and an overview of exciting recent progress that has rejuvenated the quest for a solution. "This problem is not only famous because it is unsolved, but because it points to a profound and productive gap between physical insight and mathematical rigor," he said. "I hope I conveyed how rich and beautiful the surrounding ideas are, even apart from a final solution.

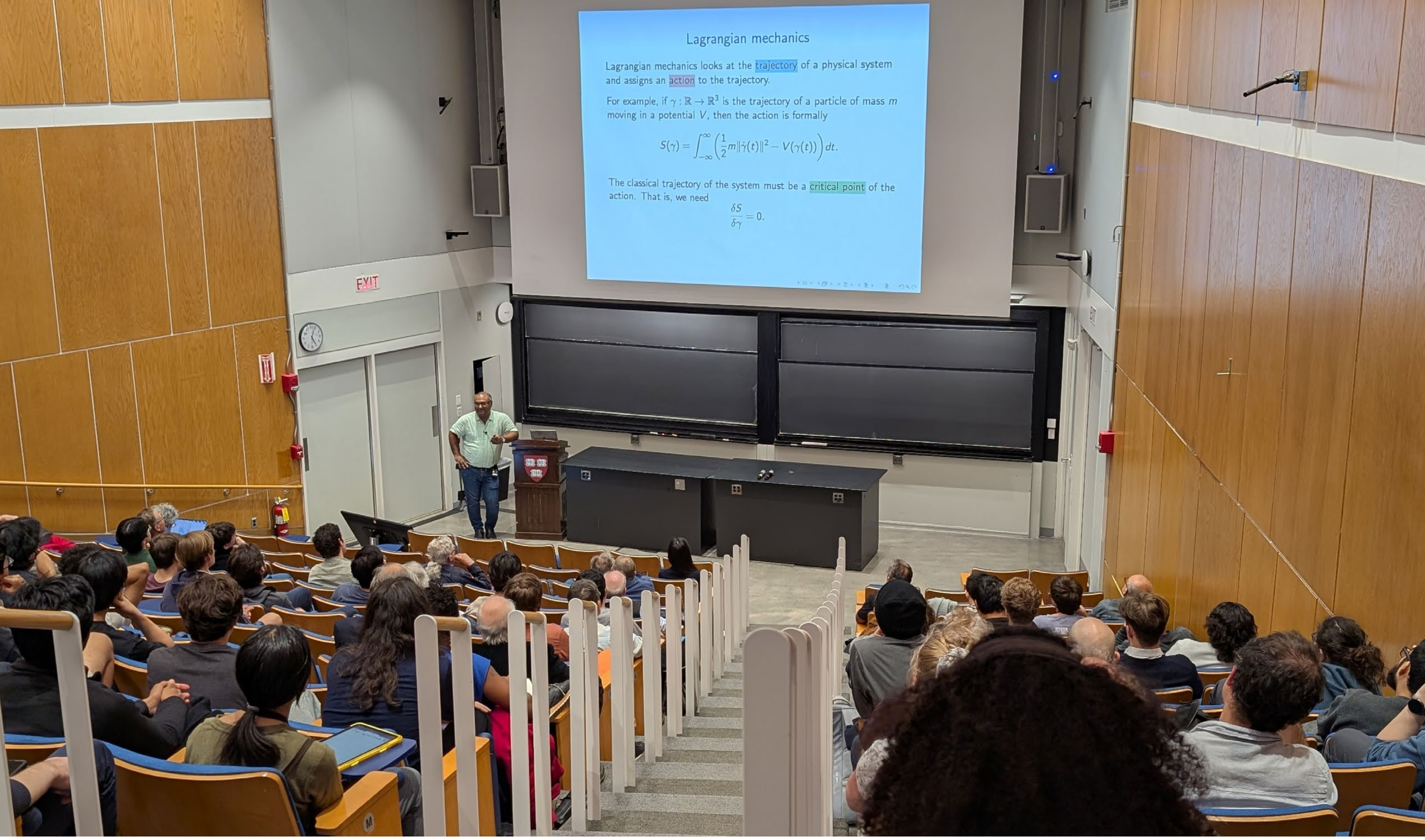
What is the Hodge Conjecture?

November, 2025

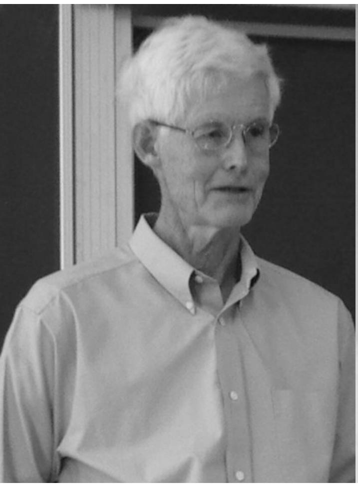
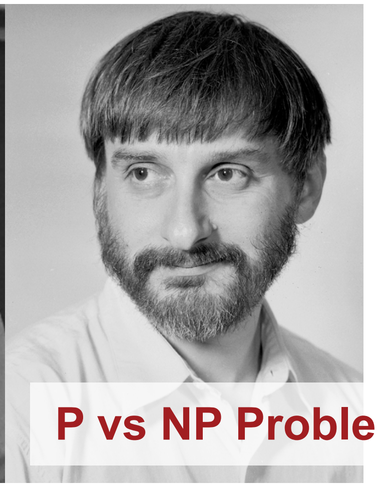
Pierre Deligne
Institute for Advanced Study

In the 20th century, mathematicians discovered powerful ways to investigate the shapes of complicated objects. The basic idea is to ask to what extent we can approximate the shape of a given object by gluing together simple geometric building blocks of increasing dimension. This technique turned out to be so useful that it got generalized in a number of ways, eventually leading to powerful tools that enabled mathematicians to make great progress in cataloging the variety of objects they encountered in their investigation. Formulated by the Scottish mathematician William Vallance Douglas Hodge, the Hodge conjecture asserts that for particularly nice types of spaces called projective algebraic varieties, the pieces called Hodge cycles are actually (rational linear) combinations of geometric objects called algebraic cycles.

The majority of Deligne's lecture was aimed at explaining concepts needed to state the Hodge conjecture, such as algebraic variety, cohomology, algebraic cycles, and Hodge structure. He also spoke about why the conjecture is so hard to attack, and why mathematicians care. "The Hodge conjecture is about projective non-singular complex algebraic varieties," Deligne said, "It characterizes the cohomology classes coming from algebraic cycles. There are, in fact, two challenges. Some classes are easily shown to be Hodge, but we lack methods to construct corresponding cycles. In the other case, we have no way to ascertain which classes should be Hodge."



Sourav Chatterjee, Stanford University.

P vs NP Problem

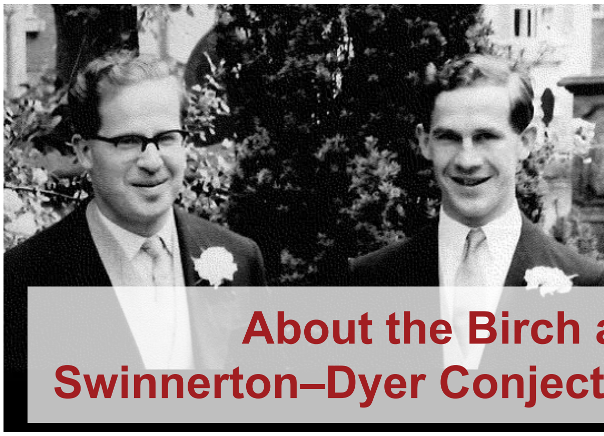
December, 2025

Madhu Sudan
Harvard University

At its core, P vs NP is a basic, fundamental human quest. When we design anything, when we wish for something, we know the specs of what we want. The question is, how do we get it? Is there an object that fulfills our desires? P vs NP asks exactly that question in an information world: are the two classes—P and NP—equal? The only thing that was late to the game was the mathematical formulation. Stephen Cook and Leonid Levin formulated the P (easy to find) vs NP (easy to check) problem independently in 1971. "Since then, almost every development we can think of has been accelerated or held back by considerations about whether P is equal to NP or not," Madhu said. Cryptography entirely depends on the fact that we can not find solutions just because we can specify our desires. Optimization—the field that asks given some mathematical function: can I find its minimum under various constraints?—has been revolutionized by our understanding of P vs NP. It lies at the heart of questions in computer science, biology, and economics.

According to Madhu, we have already discovered the algorithm that would work if the answer was that P was equal to NP. The challenge lies in proving that P is not equal to NP. "As algorithmicists, we only have to succeed once and prove that P is equal to NP," he said. "As complexity theorists we have to succeed infinitely many times to say that no algorithm will work. It's not impossible, but it does force us to think very hard."

The burning question right now, Madhu believes, is how effectively can LLMs like ChatGPT (P) substitute mathematicians (NP). The one thing he wanted people attending his lecture to take away is that LLMs may be able to solve the questions we're asking, but it is not going to ask the right questions by itself. "A lot of mathematics is not proving one theorem, just as a lot of human knowledge is not about satisfying one conclusion but building a system that works reliably," Madhu said. "There is going to be lots of utility for strong mathematicians, but more and more we will be asking them to set directions instead of multiplying numbers quickly."



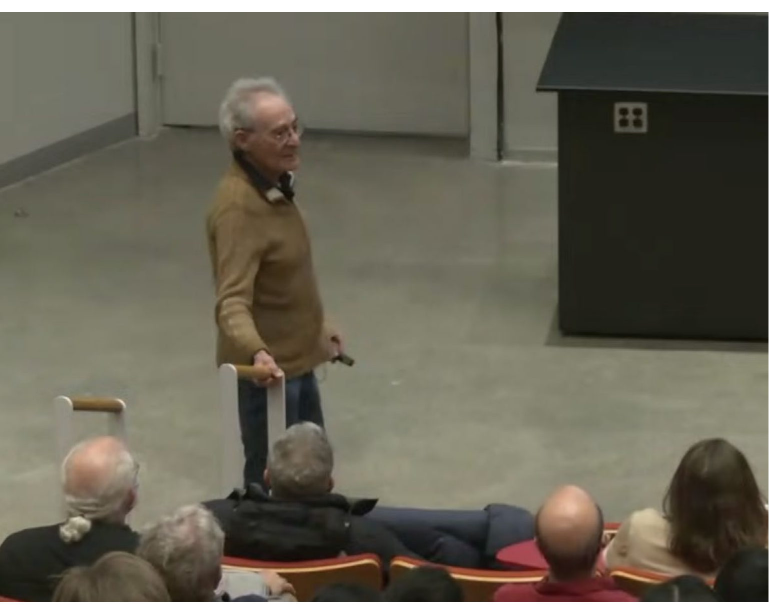
About the Birch and Swinnerton–Dyer Conjecture

February, 2025

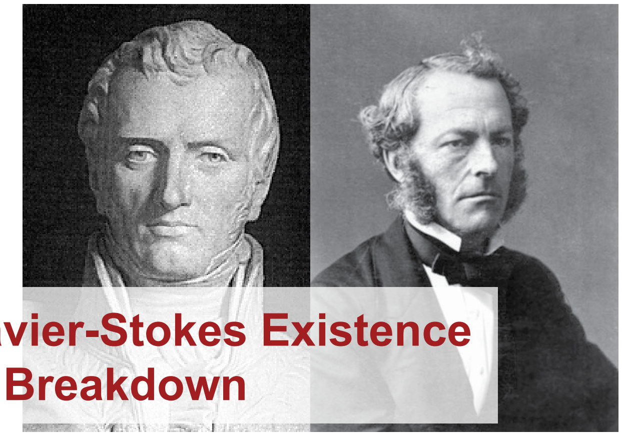
Barry Mazur
Harvard University

In the 1950s, Bryan John Birch and Peter Swinnerton-Dyer made computations that suggested a striking connection between a basic global invariant of an elliptic curve E over the field of rational numbers (namely, the rank of its group of rational points) and certain asymptotics of its local arithmetic invariants (i.e., the number of its rational points over finite fields). By the early 1960s, these initial observations had evolved into a conjecture: if a given elliptic curve has an infinite number of solutions, then the associated L-series has value 0 at a certain fixed point.

Mazur's lecture was an introduction to the general ideas begging the ever-expanding development of the Birch and Swinnerton-Dyer conjecture. "It is a unifier," he said. "Initially, it brought together local and global arithmetic invariants, but it is constantly evolving, even as certain consequences of the conjecture are being proved. It itself is emerging as—if not an area of mathematics—as a beacon for possible further progress in number theory." According to Mazur, in order to make serious progress working with the conjecture utterly new ideas are required.



Barry Mazur, Harvard University.



Navier-Stokes Existence or Breakdown

March, 2026

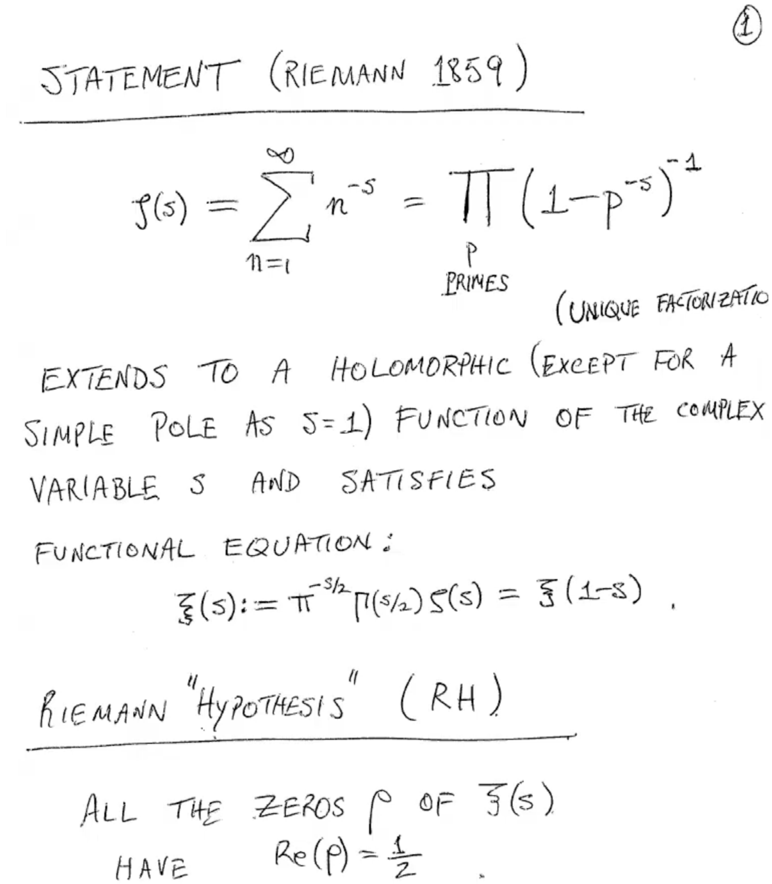
Javier Gómez-Serrano
Brown University

Although Claude-Louis Navier and George Gabriel Stokes wrote down the Navier-Stokes equations—which describe the flow of viscous fluids such as water and air—in the 19th century, our understanding of them is minimal. Despite their fundamental importance to mathematics and physics, a basic question remains unanswered: do solutions to these equations exist for all time, or can they break down and develop singularities, points where the equations lose their validity?

According to Gómez-Serrano, the problem has been more influential as an open question than it probably would have been as a solved one. The fact that we still don't know whether solutions blow up in finite time has forced people to build new, sophisticated tools useful far beyond Navier Stokes itself. It's also one of the few problems that keeps pure mathematicians and physicists talking to each other. Gómez-Serrano's lecture covered the historical context surrounding the Navier-Stokes and related equations, the ongoing search for global regularity versus finite-time blowup, and the latest analytical and computational breakthroughs pushing the boundaries of what we know about fluid behavior. "More recently, AI and machine learning are entering the picture," Gómez-Serrano said. "Not to "solve" Navier-Stokes in one shot, but to help discover candidate structures, optimize functionals, and search for blowup profiles. The problem is hard enough that it's pushing people to invent new ways of doing mathematics, and I think that's one of its most lasting contributions."

The past few years have seen a surge of activity, with new blowup construction for related equations, new computational approaches, and new ways of combining the two. Because theory and computation are so tightly linked in this area, modern methods have become very useful. Researchers were already going back and forth between analysis and numerics, so modern methods fit into the existing workflow. "The field has real momentum, and these newer tools are accelerating it," Gómez-Serrano said. "This is a very exciting time to be working in this area!"

Riemann Hypothesis



Slide from Peter Sarnak's lecture.

April, 2026

Peter Sarnak
Institute for Advanced Study

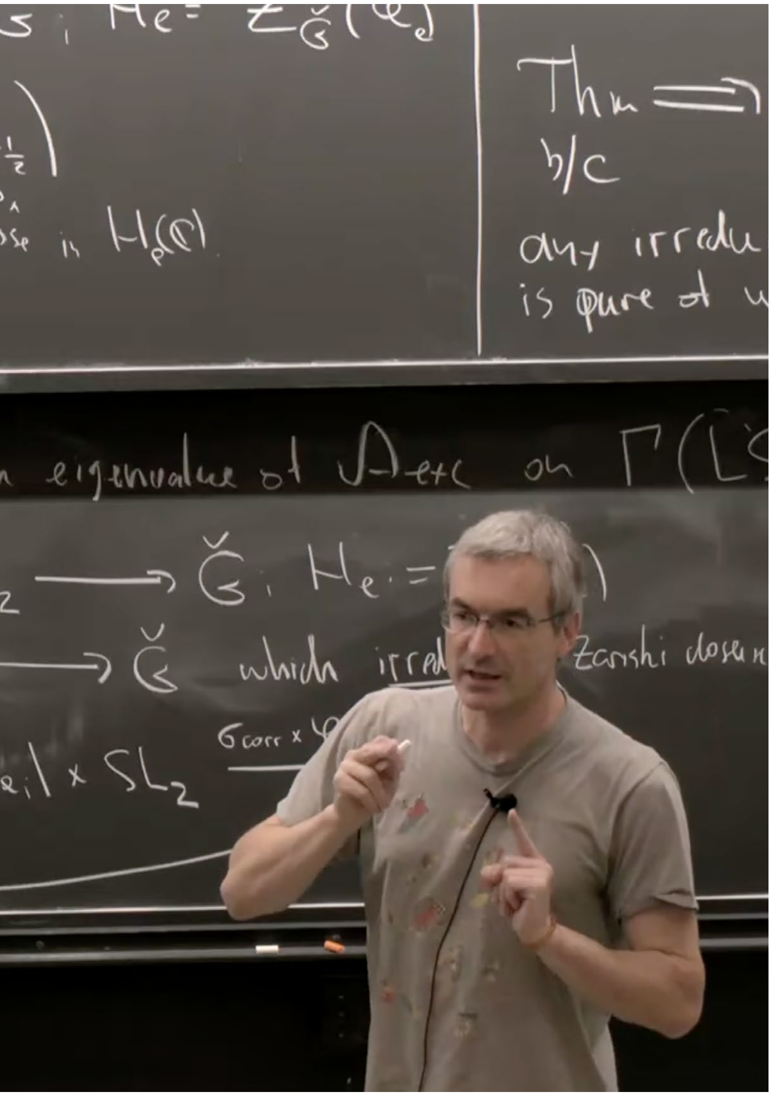
Georg Friedrich Bernhard Riemann formulated what we call the "Riemann hypothesis" in an 1859 paper. It was an elegant and elementary falsifiable statement, which he probed briefly and "hypothesized" rather than conjectured to be true, as it allowed him to conclude the main aim of his work, namely to prove the prime number theorem which determines the average distribution of the primes. In fact, the first proof of the prime number theorem followed the ideas that Riemann introduced. The statement it proved was weaker than Riemann's hypothesis but strong enough to establish the prime number theorem. "In this way, generalizations of the Riemann hypothesis have served as working hypotheses which have multitudes of striking consequences," Sarnak said. "These "generalized Riemann hypotheses" are thus elegant falsifiable statements which, if true, express apparently deep facts about whole numbers and have many striking applications."

In his lecture, Sarnak reviewed the hypothesis as put forth by Riemann and discussed its generalizations and analogues. Many of its analogues in the arithmetic geometric setting where the rational numbers are replaced by rational functions over a finite field (a function field) have been formulated and proven, and constitute a striking chapter of 20th century mathematics with implications in engineering. "Many of us read a lot into the proof of the analogue of the Riemann hypothesis in the function field case," he said. Here, cohomology and group theory (via Galois groups) allow researchers to linearize and study the problem. "For the original problem, a linearization and symmetry group that has proved to be fruitful has not been found, and direct attacks have proven to be hopeless," Sarnak said. "So while I believe that these generalized Riemann hypotheses are true and "provable," we appear to be quite far from doing so with present methods. New ideas and insights are needed."

Scan the QR code below to view recordings of the Millennium Prize Problem Lecture Series or visit our YouTube channel:

Two Talks on Function-Theoretic Implications of Geometric Langlands

2025 Math Science Lectures in Honor of Raoul Bott: Dennis Gaitsgory, Max Planck Institute for Mathematics



In October 2025, the Harvard Center of Mathematical Sciences and Applications (CMSA) hosted the annual Math Science Lectures in Honor of Raoul Bott with speaker Dennis Gaitsgory from the Max Planck Institute for Mathematics. Gaitsgory gave two talks: “From Geometric to Classical Langlands,” and “Analytic Properties of Automorphic Functions as Seen from Algebraic Geometry.”

The Langlands program, also described as the “grand unified theory of mathematics,” was founded by Robert Langlands in the 1960s. It provides a beautifully intricate set of connections between three separate areas of mathematics: number theory, geometry, and representation theory. The 2025 Bott lectures were about work that had built upon itself over a number of years, starting with French mathematician Vincent Lafforgue’s contributions to the Langlands program in the function field case, or classical Langlands. Lafforgue received the 2019 Breakthrough Prize in Mathematics for his contributions in this area. In 2022, a series of three papers by six authors—Dima Arinkin, Gaitsgory, David Kazhdan, Sam Raskin, Nick Rozenblyum, and Yakov Varshavsky—combined Lafforgue’s ideas with geometric Langlands ideas to produce the first link between the classical and the geometric. “It’s called “take the trace,”” Gaitsgory said. “You just take the trace on the geometric and you obtain the classical.” Gaitsgory himself received the 2025 Breakthrough Prize for his central role in the proof of the geometric Langlands conjecture.

The first Bott lecture he gave was “a summary of this 2022 work of six authors, and what the recently obtained proof of the geometric buys you, in principle, from the classical.” The second lecture was about the application of this newly acquired knowledge to deduce some expected properties of automorphic functions, e.g., Ramanujan and Arthur multiplicity conjectures. The one takeaway Gaitsgory hopes he left his audience with is that “by taking the trace of Froebenius, singularities in algebraic geometry produce non-temperedness phenomena in analysis.” Both talks were based on his most recent joint work with Lafforgue and Raskin.

Gaitsgory’s fascination with the geometric Langlands conjecture goes back to his days as a graduate student at Tel Aviv University in Israel. He remembers clearly the day in 1994 when Alexander Beilinson, one of the main progenitors of the geometric version of the Langlands program, gave a series of talks. “It just struck me how beautiful it was,” Gaitsgory said. “It combined all the elements that I really liked in math.” The blend of geometry, representation theory, and category theory was exactly the flavor of math that he loved. He decided to pursue it at the urging of his advisor and—coincidentally—former Harvard math professor, Joseph Bernstein.

Harvard Mathematics Professor Raoul Bott (1923–2005) was a Hungarian-American mathematician known for numerous foundational contributions to geometry in its broad sense. He is best known for his Bott periodicity theorem, the Morse-Bott functions which he used in this context, and the Borel-Bott-Weil theorem.

Program on Classical, Quantum, and Probabilistic Integrable Systems

Novel Interactions and Applications

Andrea De Luca, CNRS Cergy Paris University: Monitored quantum systems, product of random matrices and permutations.

The program explored and developed a recent wave of the influence of exactly solvable models in stochastic models together with accompanying combinatorial, classical, and quantum integrable systems. It ran from March 24 through May 24, 2025 and was organized by Amol Aggarwal, Guillaume Barraquand, Alexei Borodin, Ivan Corwin, Pierre Le Doussal, and Michael Wheeler. Topics included: colored and uncolored interacting particle systems with associated vertex models and line ensembles; Yang-Baxter integrability and its applications in algebraic combinatorics, quantum systems, and conformal field theory; quantum stochastic models, quantum exclusion processes, and free probability; emerging new aspects of classical and quantum integrable systems such as hydrodynamics, large deviations of stochastic models, and random surface models.

“Perhaps one of the most important aspects of the program was that it collected mathematicians and physicists in the same area for an extended period of time,” Aggarwal said. “This compelled the two communities to interact in ways that would be unlikely at a conference, where time would have been too limited to enable deep conversations.”

The first few weeks featured a series of lectures given by Denis Bernard, Atsuo Kuniba, Benjamin Doyon, and Kurt Johansson. Bernard gave an introduction to quantum exclusion processes, which are toy models used to study the effect of noise on quantum diffusive systems of particles. His lectures focused on the quantum simple exclusion process whose steady state can be characterized through the notion of free cumulants in free probability theory. This suggests the development of mathematical tools for structured random matrices and provides a new perspective on old results about the large deviations behaviour of the classical simple exclusion processes.

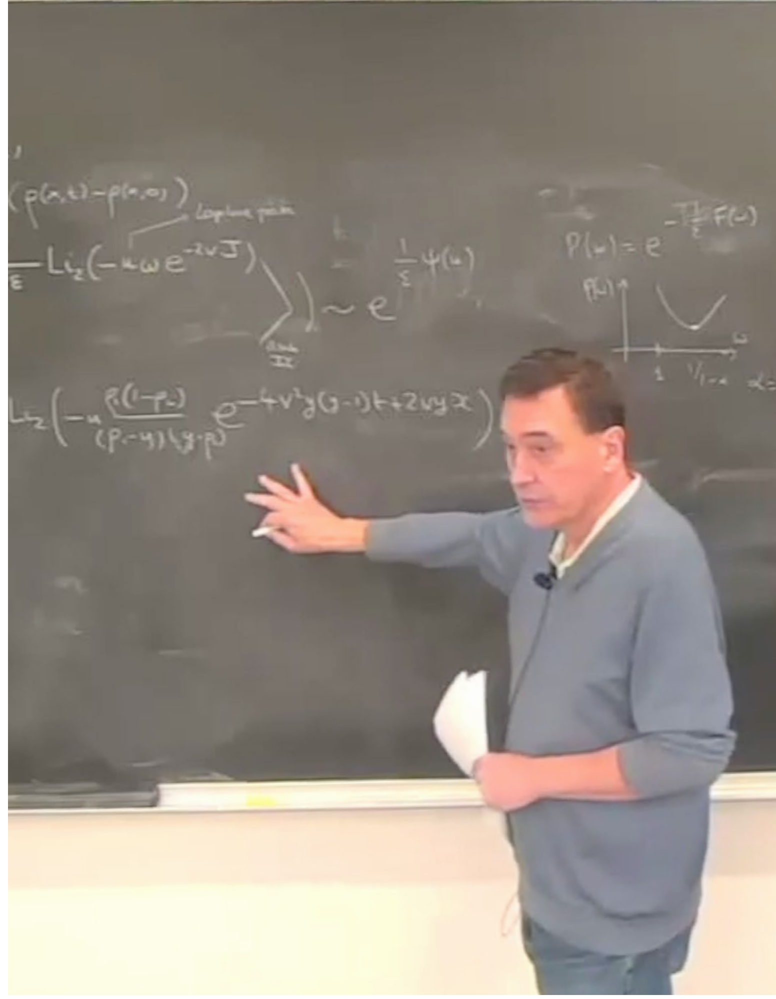
Kuniba illustrated several facets of the interplay between solvable stochastic processes, integrability, and symmetric function theory. His first lecture focused on classical exclusion processes with multiple species. He then moved on to 3D integrability, explaining links between the tetrahedron equation and quantum cluster algebras. He concluded with a survey talk on a special class of discrete classical integrable systems called box-ball systems, their combinatorial properties, and their hydrodynamics. The hydrodynamics of integrable systems is a very active area referred to as “generalized hydrodynamics.” This was the topic of Doyon’s lectures, who gave an introduction to the subject, recalling old results in the Euler scale, and presenting new results in the diffusive scale.

These first few weeks were rounded out by Aggarwal’s colloquium talk on the mathematical foundations of generalized hydrodynamics, Patrik Ferrari and Sylvie Corteel’s seminar talks on distinct topics. There was also a series of lectures by Kurt Johansson on uniform Gelfand-Tsetlin patterns, a structure that naturally emerges in random matrix theory, tiling models, and solvable particle systems.

The middle of the program was calmer and offered a perfect occasion for collaboration. It featured talks given by some of the organizers, as well as a talk by Tamara Grava on the fluctuations of many solutions of integrable dispersive PDEs. Pasquale Calabrese spoke on the Mpemba effect (did you know that hot liquids can freeze faster than warm ones under the same conditions?) and on the quasi particle picture of quantum integrable systems, which allows in particular to compute the time evolution of the entanglement entropy.

The last two weeks saw a number of visitors give seminars on random graphs (Jiaoyang Huang), dimer models (Rick Kenyon), monitored quantum systems (Andrea de Luca), random partitions (Cesar Cuenca and Jimmy He), p-adic random matrix theory (Roger Van Peski), and symmetric functions (Matteo Mucciconi). Jan de Gier presented, in a series of lectures, recent results on the combinatorics

Guillaume Barraquand, École normale supérieure de Paris: Large time cumulants of the open KPZ equation.



Pierre Le Doussal, École normale supérieure de Paris: Exact results for the macroscopic fluctuation theory of the 1D weakly asymmetric exclusion process.

and the asymptotics of the asymmetric simple exclusion process on a half-line, which is a particle system on a one dimensional lattice where particles come from a reservoir and hop onto lattice sites indexed by 1,2,3,... In contrast with the case where particles hop on the infinite integer lattice ...-2,-1,0,1,..., the half-line case has more involved combinatorics (Pfaffians vs determinants) and richer asymptotics, obeying a phase transition as the density of particles near the origin varies.

The months following the conclusion of the program saw a number of discussions and collaborations bear fruit.

"The pace was nice and relaxed, and left a lot of time for conversation with other participants," said Jimmy He. "I was able to discuss an ongoing project with Amol and Milind [Hegde], and we were able to make some progress on it. I had some very interesting discussions with Matteo [Mucciconi] and we started a project about a conjectural matching between non-symmetric q-Whittaker measures and periodic Schur measures. We've already made progress."

Another participant, Jan De Gier, described his experience of the program as "very inspiring." He was particularly moved by Calabrese's ideas related to multi-sheet partition functions as well as a discussion with Kenyon about rigorous approaches to Bethe ansatz solutions and non-free fermionic tilings. Calabrese himself recalled an interesting conversation with De Gier about a possible calculation of entanglement entropy by Bethe ansatz via the replica method, and Kenyon said he and De Gier "found some nice determinantal formulas for the 5-vertex model generalizing in a surprising way the Gessel-Viennot method." Kenyon and De Gier are currently working on a paper about this alongside De Gier's students.

Herbert Spohn remarked on Aggarwal's talk about discovering the connection between the time-dependent eigenvectors of the Lax matrix and quasi-particles. "Related is the surprising use of the Thouless relation in the context of GHD," Spohn said.

Le Doussal started projects with Li-Cheng Tsai on KPZ in 2d, with Sylvain Prolhac and Barraquand on large time cumulants of the KPZ equation in an interval, as well as with Aggarwal and Alexandre Krajenbrink on weak noise theory and Yang-Baxter integrability. "Two papers were finished there" Le Doussal said. In the acknowledgements section of one of those papers—"Integrability and exact large deviations of the weakly-asymmetric exclusion process"—Le Doussal and co-author Krajenbrink thank the CMSA for hospitality and partial support.

Article contributors: Amol Aggarwal (Columbia University & Clay Mathematics Institute), Guillaume Barraquand (École normale supérieure, Paris), Alexei Borodin (MIT), and Pierre Le Doussal (École normale supérieure, Paris)

Sunghyuk Park

Postdoctoral Fellow

Sunghyuk Park is a Simons Collaboration Postdoctoral Fellow at the CMSA and a Benjamin Peirce Fellow at the Harvard Department of Mathematics. He joined the center in 2023, after completing a postdoctoral position at the University of Texas at Austin.

Discovering Mathematics

There is a story Park loves telling people: "When I was in middle school, I actually wanted to be a magician." His passion for the world of illusions and sleight-of-hand never fully left; during his time as an undergraduate student at the Korea Advanced Institute of Science and Technology (KAIST) he was part of the magic club "MindFreak." But after taking a number of advanced math and physics classes in high school, Park knew exactly where his future lay. "I remember taking a linear algebra class and thinking, this is really cool," he recalled. "That class was one of the first times I experienced the concept of mathematical beauty." Park has been working in the interface between math and physics since those high school classes.

During his undergraduate studies, he read a few papers by renowned theoretical physicist Edward Witten that left an impression. While pursuing his Ph.D. degree at the California Institute of Technology, he studied quantum topology and physical mathematics under the supervision of Sergei Gukov, who himself was a former student of Witten. Over the years, Park's research has naturally evolved to focus on problems in geometry and topology, with an emphasis on quantum and symplectic topology.

Quantum topology is a vibrant field at the crossroads of topology, algebra, and representation theory that studies low-dimensional spaces such as three- and four-dimensional manifolds and knots through the lens of rich algebraic structures like quantum groups, tensor categories, and higher categories. Symplectic topology is a central field in modern differential topology that studies spaces equipped with a symplectic structure—a geometric structure originally studied in classical mechanics to describe the evolution of physical systems. Park's work addresses foundational questions in quantum topology, while simultaneously exploring new connections with symplectic topology.

"Over the past few years, I've been especially fascinated by these objects called skein modules, which are vector space-valued invariants of 3-manifolds," Park said. "Even though the definition is so simple, it turns out they have a lot of fascinating properties and connections to various areas of math." Skein theory, the study of skein modules, reveals deep links among quantum invariants, hyperbolic geometry, symplectic topology, and representation theory.

About the CMSA

Park first heard about the CMSA as a graduate student at the California Institute of Technology. "My academic brother, Du Pei, was a postdoc at the CMSA back then," he said. Park even gave an online talk at the CMSA Geometry and Physics Seminar in 2020.

"I like how there are always so many seminars and workshops at the CMSA, both in my own area of mathematical physics and in various other fields," Park said. "People here study all sorts of math and its applications. While talking to them hasn't directly impacted my research, it's fun and I always learn something new."

And while Park loves doing research, he enjoys the balance teaching offers. Research on its own at times can be isolating, and a lack of progress—even temporary—can be discouraging. Sharing knowledge with the next generation of mathematicians in his capacity as a Harvard Benjamin Peirce Fellow is a fulfilling counterbalance. This spring, he taught differential topology; incidentally, one of his favorite subjects.

Outside the CMSA

In his free time, Park plays piano and the ukulele. He enjoys hiking, board games, painting, and baking. He also codes for fun. "There's this fun project that I did with my friend a few years ago," Park said. "We coded an online game together based on Conway's Game of Life." These days, he's also really into jazz. He's been teaching himself how to improvise on the piano and attending jazz concerts. "There are a lot of them here in Boston," he said. "It's one of the perks of living here."

Francesco Mori

Research Associate

Francesco Mori joined the CMSA as a research associate in 2025 after a postdoctoral fellowship at the Rudolf Peierls Centre for Theoretical Physics at the University of Oxford. He received the 2025 Early Career Prize for Statistical and Nonlinear Physics by the European Physical Society "for his outstanding contributions on the statistical properties of run and tumble particles, thermodynamic cost of stochastic resetting and optimal control protocols." In Spring 2027, he will join the Department of Mathematics of Imperial College London as an assistant professor.

Discovering Mathematics

When Mori began his undergraduate studies at Italy's Politecnico di Torino, he did so with plans of eventually working in industry. Originally on the mechanical engineering track, he quickly realized that what he was really drawn to were fundamental problems in mathematics and physics rather than their applications. By the time he was working on his masters degree, he had drifted towards the physics of complex systems. "That's really what I've kept doing in my research," Mori said. "This new perspective in physics that uses mathematical techniques to understand complex systems, which are broadly defined as systems of many interacting units."

His research spans nonequilibrium statistical physics, active matter, and machine learning. These topics may seem disparate at first glance, but when Mori gets excited about a project, he doesn't consider whether it's thematically aligned with what he's done previously; he just starts working. Nonetheless, there are two common themes in his research.

One is the study of nonequilibrium phenomena, or systems constantly exchanging energy or matter with their environment, preventing them from reaching a stable, equilibrium state. "Living systems are an example of nonequilibrium systems and new theoretical techniques have been developed in the past decades to study their physical properties," Mori said. "And some of the same ideas and techniques can be applied to how we train machine learning (ML) models."

The second theme is that of control theory. While there has been a lot of progress in recent years to understand nonequilibrium systems, it's harder to control their behavior. In the case of active systems—systems composed of many individual units such as flocks of birds or bacterial colonies—each unit is able to absorb energy from the environment and convert it into persistent motion. This makes them chaotic, as they behave in ways that are hard to predict and exploit in a technological application. Mori is interested in using control theory—a set of mathematical techniques developed mainly for engineering—on nonequilibrium systems. In the case of ML, while there has been plenty of progress, it has largely been driven by heuristic methods, and trial and error. "We know that some ML training strategies work better with respect to others but we don't really know why," Mori said. "It would be very insightful if we could frame this learning process as one we can control in order to train ML models efficiently."

About the CMSA

The CMSA felt like a natural place for Mori to continue his academic journey. Not only does Harvard as a whole have a long tradition of studying neural networks with ideas from physics and complex systems, but the center itself is a hub that allows him to experience the broad spectrum of mathematics. This fosters the perfect environment to share scientific knowledge and collaborate. "On one of my first days at the CMSA, I started a new project with Blake Bordelon, another CMSA postdoc" Mori said. "He came to me with the idea to apply my ideas about control theory to his ideas about neural scaling laws, a very important phenomenon in machine learning." The result of this collaboration is a paper, currently preprint, titled "Theory of Optimal Learning Rate Schedules and Scaling Laws for a Random Feature Model."

Outside the CMSA

In his free time, Mori likes running, bouldering, and food. After three years at Oxford, where his college affiliation afforded him lunch and dinner every day, he found he had forgotten how to cook. He has been slowly re-discovering the joy of cooking for himself. "It may be a bit stereotypical of me, but I like making fresh pasta," Mori said. "My grandmother taught me a few years ago and I just follow her recipe."

Current Postdocs

Houcine Ben Dali
Mentor: Lauren Williams

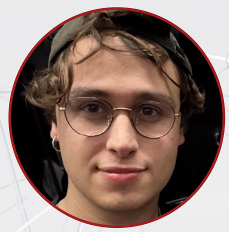
Research Interests
My research focuses on algebraic and enumerative combinatorics. I work on problems connecting symmetric functions with combinatorial structures such as maps on non-orientable surfaces, lattice paths, and multiline queues. I am also interested in their connections with mathematical physics.

Blake Bordelon
Mentor: Michael Douglas

Research Interests
Research interests are in deep learning theory and computational neuroscience.
Future Plans
An assistant professor at UT Austin as of August, 2026.

Iacopo Brivio
Mentor: Mihnea Popa

Research Interests
Higher dimensional algebraic geometry, especially positive and mixed characteristic. The Minimal Model Program and its applications to the moduli theory of varieties of general type. Recently interested in the study of fibrations and sub/super additivity properties of the Kodaira dimension.
Future Plans
Assistant Professor at YMSC in Tsinghua University in Beijing.



Elliott Gesteau
Mentor: Dan Freed and Jordan Cotler

Research Interests
I am interested in mathematical aspects of quantum gravity, such as operator algebraic aspects of holographic correspondences and connections to quantum information theory and chaos theory. A current focus is the description of closed universes in holographic theories.

Saman Habibi Esfahani
Mentor: Cliff Taubes

Research Interests
Differential geometry (G2-manifolds and Calabi-Yau 3-folds), gauge theory (non-compactness problems), symplectic topology (Floer theories, curve counting, and skein modules), and connections to algebraic geometry.

Ahsan Khan
Mentor: Dan Freed

Research Interests
Quantum field theory and its underlying mathematical structure. 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. Aim to make progress in both pure math and theoretical physics.

Vasily Krylov
Mentor: Dan Freed

Research Interests
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.

Francesco Mori
Mentor: L. Mahadevan

Research Interests
Nonequilibrium statistical physics, machine learning, and optimal control.
Future Plans
Assistant Professor at Imperial College London.

Sunghyuk Park
Mentor: Dan Freed

Research Interests
Quantum topology and physical mathematics.

Lorenzo Riva
Mentor: Dan Freed

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

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

Elena Kim
Mentor: Curtis McMullen

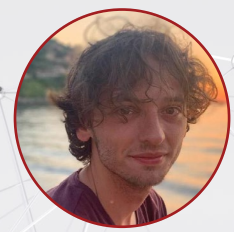
Research Interests
I am interested in quantum chaos and microlocal analysis. In particular, I am interested in the spectrum of hyperbolic manifolds and related discrete models.

Aaron Landesman
Mentor: Joe Harris

Research Interests
Aaron has worked on problems in algebraic geometry and arithmetic topology, especially related to arithmetic statistics and representations of fundamental groups of varieties. More recently, he has been using techniques in homotopy theory to study questions about the cohomology of varieties.

Yiqi Liu
Mentor: Elie Tamer

Research Interests
I study econometric problems with a focus on how identification assumptions shape empirical conclusions and on developing statistical inference methods that can help inform better policy design.



Luca Pesce
Mentors: Michael Douglas, Cengiz Pehlevan

Research Interests
My research investigates the theoretical foundations of modern deep learning systems to understand why they are so effective in practice. I explore how general-purpose training methods (e.g., SGD) exploit low-dimensional latent structures in high-dimensional data, leveraging analytical tools from statistical physics and high-dimensional statistics.

David Ritzwoller
Mentor: Elie Tamer

Research Interests
I study theoretical econometrics and causal inference. My research centers on the development of statistical methods for understanding data that exhibit complex dependence, nonlinearity, and unobserved heterogeneity.

Tobias Schmidt
Mentor: Mark Selke

Research Interests
My research interests lie at the intersection of probability, mathematical physics, and computer science. In general, I am interested in models where a large number of particles interact with each other. Most of my research uses probabilistic as well as analytic techniques.

Michal Shavit
Mentor: Xi Yin

Research Interests
Turbulence and geometry.

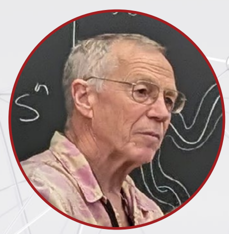
Nikita Sopenko
Mentor: Dan Freed

Research Interests
I'm interested in mathematical physics of quantum many-body systems and quantum field theory. In particular, I'm trying to understand how to classify phases of matter using methods of operator algebra.

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.

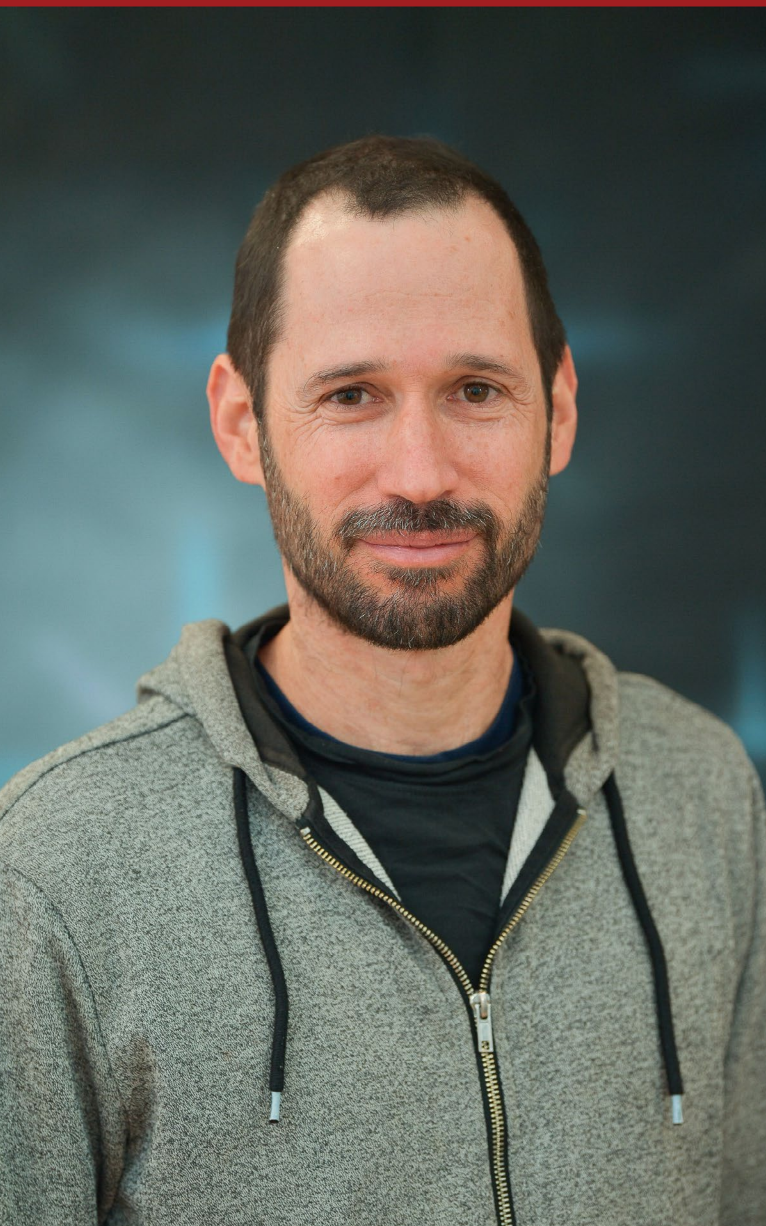


Michael Freedman

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: Eran Nevo

Visiting Scholar



The epiphany came 12 years into Eran Nevo's foray into academia: "I was going to my office at Cornell University, where I was a postdoc, when I saw my name on the door, again" he recalled. "I thought, ok, maybe math is my actual profession." Up to that point, Nevo had simply followed his heart, doing what he loved. And that happened to be mathematical research. So the realization that he'd actually made a career for himself in the field he loved most and that his future lay there didn't change much. Instead, it crystallized into a certainty what had always been on the periphery of Nevo's awareness: "I feel very fortunate to have a profession that aligns with what I love and what I'm passionate about," he said.

Eran Nevo came to the Technion Institute of Technology in Israel with two "hobbies"—math and photography—and was initially uncertain as to which he wanted to pursue. He enjoyed photography; it allowed him to look at things more closely, and pay attention to details and composition. He remembers a guide in the youth movement he was involved with teaching him and a few of his friends who were interested. "We converted a shelter into a dark room," Nevo remembered. "I liked to process the black-and-white photos there and watch the picture as it appeared on the silver paper." As digital cameras gained popularity, however, Nevo gradually lost interest.

His fascination with math, on the other hand, only grew with time. Because he wasn't really thinking about a career in the subject at that point, he started out on a combined track of math and computer science. It didn't take him long to realize that he wasn't a fan of programming and that what he did like about computer science was, in truth, mathematical in nature. "Computational complexity and coding theory were simply mathematics offered by the computer science department," he reflected. So after only one semester, Nevo continued with pure math.

Every course he took—topology, complex analysis, group theory, and more—seemed to open up a whole new world to him. He liked all of it but found that combinatorics in particular resonated with his childhood love of math riddles. Nevo completed a small research project to test whether he enjoyed the process and found that he did. He decided to continue with a masters and, eventually, a Ph.D. degree at the Hebrew University of Jerusalem in Israel.

Nevo had intended to pursue combinatorics until a senior mathematician, an algebraist he'd known since his days as an undergraduate student, advised him to pivot to algebra. "He said that in combinatorics every kid can understand the question so there's too much competition trying to solve the same problems," Nevo said. "But algebra is safer because you have to take so many courses before you can speak the language." With this advice fresh in his mind, Nevo combined combinatorics with algebra. Under the guidance of Gil Kalai—an Israeli mathematician and computer scientist, as well as Nevo's masters and Ph.D. advisor—Nevo wrote during his masters a paper on Kalai's algebraic shifting operator, and later a Ph.D. thesis titled "Algebraic shifting and f-vector theory." "I like solving problems in combinatorics using tools from other areas of mathematics like algebra, topology, and geometry," he said. That's still at the core of what he does in his research.

Today, Nevo is a professor at the Einstein Institute of

Jerusalem and holds an appointment at the Universidad de Valladolid in Spain. A sabbatical gave him the opportunity to travel abroad and his first stop combined Harvard and the CMSA. "It's a hub of mathematics," Nevo said. He found that between the CMSA, the Harvard math department, MIT, and all the other institutions and universities in the area, there is no shortage of seminars, workshops, lectures, and talks covering a wide breadth of mathematics.

2015 Geometric and Algebraic Combinatorics at the Mathematisches Forschungsinstitut Oberwolfach. Photo courtesy of: Michael Joswig and the Archives of the Mathematisches Forschungsinstitut Oberwolfach.

"Eran is a terrific presence this year at the CMSA," said CMSA Director Dan Freed. "His active participation in all CMSA activities enriches the environment here for everyone."

According to Nevo, while the CMSA's current slant doesn't align perfectly with his own area of research, the experience has still been highly enriching. He remembers a series of workshops about the interaction between mathematics and AI that took place around the time he first joined the center. The subject was new to Nevo, who considered himself an observer to the workshops more than an active participant, but he was excited to attend. He was surprised at some of what he learned.

"Some students that went to those talks were saying that they might not continue to graduate school even though they love mathematics, because by the time they graduate AI would perform better than a young math Ph.D.," Nevo said. That left him thinking. "In math, we have this sense of community," he reflected. "People generously share ideas with each other and communicate thoughts and results. There's this joy of discovering things as a community." His hope is that even if the process of doing mathematics becomes more mechanized, the joy of discovery and sense of community will prevail.

Nevo has also taught in all the various positions he's held over the years. He regularly volunteers by teaching math, mentoring gifted high schoolers, and guiding undergraduate international students through research projects. "I may enjoy research more, but when I teach I want to make sure I do it well and that the students enjoy and benefit from it," Nevo said. As a lecturer in the Harvard math department, he most recently taught a graduate course titled "Face numbers of polytopes, spheres and beyond", reviewing f-vector theory, from classical results to recent developments.

Past CMSA Events

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

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

Math and Machine Learning Reunion Workshop
Workshop
September 8–10, 2025
Organizer: Michael Douglas (Harvard CMSA)

Big Data Conference 2025
Conference
September 11–12, 2025
Organizers: Michael M. Desai (Harvard OEB), Michael R. Douglas (Harvard CMSA), Yannai A. Gonczarowski (Harvard Economics), Efthimios Kaxiras (Harvard Physics), Melanie Weber (Harvard SEAS)

The Geometry of Machine Learning
Conference
September 15–18, 2025
Organizers: Michael R. Douglas (Harvard CMSA), Mike Freedman (Harvard CMSA)

The Poincaré Conjecture and Mathematical Discovery
Millennium Prize Problems Lecture
September 17, 2025
Speaker: Michael Freedman (Harvard CMSA, Logical Intelligence)

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

Yang-Mills and the Foundations of Quantum Field Theory
Millennium Prize Problems Lecture
October 15, 2025
Speaker: Sourav Chatterjee (Stanford University)

Function-Theoretic Implications of Geometric Langlands
Math Science Lectures in Honor of Raoul Bott
October 20–21, 2025
Speaker: Dennis Gaitsgory (Max Planck Institute for Mathematics)

What is the Hodge Conjecture?
Millennium Prize Problems Lecture
November 12, 2025
Speaker: Pierre Deligne (Institute for Advanced Study)

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

Conference on Geometry and Statistics
Conference
November 17–19, 2025
Organizer: Zhigang Yao (National University of Singapore)

P vs NP Problem
Millennium Prize Problems Lecture
December 3, 2025
Speaker: Madhu Sudan (Harvard)

About the Birch and Swinnerton–Dyer Conjecture
Millennium Prize Problems Lecture
February 4, 2026
Speaker: Barry Mazur (Harvard)

How Could a Superhuman AI Mathematician Come About?
Ding Shum Lecture Series
March 4, 2026
Speaker: Sanjeev Arora (Princeton)

Profinite Rigidity: Chasing Finite Shadows of Infinite Groups
CMSA/Tsinghua Math-Science Literature Lecture
March 10, 2026
Speaker: Martin Bridson (Oxford and Clay Mathematics Institute)

Navier-Stokes Existence or Breakdown
Millennium Prize Problems Lecture
March 11, 2026
Speaker: Javier Gómez-Serrano (Brown University)

[Swampland and Our Universe](#)
Workshop
April 15–16, 2026
Organizers: Luis Anchordoqui (CUNY Lehman College), Sonia Paban (Harvard Physics), Cumrun Vafa (Harvard Physics)

[The Riemann Hypothesis](#)
Millennium Prize Problems Lecture
April 15, 2026
Speaker: Peter Sarnak (Institute for Advanced Study)

[Asymptotic Representation Theory](#)
CMSA/Tsinghua Math-Science Literature Lecture
April 22, 2026
Speaker: Nicolai Reshetikhin (Yau Mathematical Sciences Center, Tsinghua University)

[Can Machine Learning Methods Design Drugs?](#)
Sixth Annual Yip Lecture
Speaker: Regina Barzilay (MIT)

[Mathematics and Biology II: Mathematics and Science of Behavior](#)
Program
April 27–May 1, 2026
Organizers: L. Mahadevan (Harvard), Francesco Mori (Harvard CMSA), Venkatesh Murthy (Harvard)

Upcoming CMSA Events

[Workshop on Calabi-Yau Metrics and Optimal Transport](#)
Workshop
May 18–22, 2026
Organizers: Tristan Collins (University of Toronto), Mattias Jonsson (University of Michigan), Connor Mooney (University of California, Irvine) Freid Tong (University of Toronto)

[Big Data Conference 2026](#)
Conference
September 3–4, 2026
Organizer: Michael R. Douglas (Harvard CMSA)

[The Geometry of Machine Learning 2026](#)
Conference
September 8–11, 2026
Organizers: Michael R. Douglas (Harvard CMSA), Mike Freedman (Harvard CMSA)

[TBA](#)
CMSA/Tsinghua Math-Science Literature Lecture
September 16, 2026
Speaker: Robert E. Gompf (University of Texas, Austin)

[Lagrangian Floer Theory and Applications Program](#)
Program
September 15–November 21, 2026
Organizers: Denis Auroux (Harvard), Jonny Evans (Lancaster), Chris Woodward (Rutgers)

[Workshop on Lagrangian Floer Theory and Applications](#)
Workshop
September 28–October 2, 2026
Organizers: Denis Auroux (Harvard), Jonny Evans (Lancaster), Chris Woodward (Rutgers)

[Northeast Conference on Categorical Methods](#)
Conference
November 6–7, 2026
Organizers: Dan Freed (Harvard Math, CMSA), Owen Gwilliam (UMass Amherst), Lorenzo Riva (Harvard CMSA)

[Stable Homotopy Theory and Arithmetic Geometry](#)
Program
February 15–May 15, 2027
Organizers: Jeremy Hahn (MIT), Mark Kisin (Harvard), Lucas Mann (Münster), Tomer Schlank (Harvard), Jared Weinstein (Boston University)

Credits

PRODUCTION MANAGER

Anastasia Yefremova | Communications Specialist, Harvard Department of Mathematics

CONTRIBUTORS

Amol Aggarwal | Columbia University and Clay Mathematics Institute

Maureen Armstrong | Publications Coordinator, CMSA

Guillaume Barraquand | École Normale Supérieure, Paris

Alexei Borodin | MIT

Pierre Le Doussal | École Normale Supérieure, Paris

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

Alison Sundet | Programs and Events Administrator, CMSA

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