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17 Gauss Way

FALL 2025

SLMATH.ORG

IN THIS ISSUE

SLMATH | # 17 Gauss Way

On the Cover: Random motion of a string on a manifold, governed by a geometric heat equation with singular random forcing, studied by Bruned–Gabriel–Hairer–Zambotti. Take a (less than random) stroll through this semester's *Recent Trends in Stochastic Partial Differential Equations* program on page 16.

FALL 2025

Questions and comments regarding *17 Gauss Way* should be directed to **newsletter@slmath.org**

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SLMath, formerly MSRI, has been supported from its origins by the U.S. National Science Foundation, joined by other government agencies, over 110 Academic Sponsor Institutions, private foundations and corporations, and generous and farsighted individuals.

DIRECTOR'S Update

Tatiana Toro, Director

A gathering of this semester's members with their families at Berkeley's Cedar Rose Park for a potluck in the autumn sunshine.

NSF Grant Updates

When I wrote to our community in May of this year, the U.S. math institutes were awaiting news of our core National Science Foundation (NSF) grant proposals for 2025–2030 funding as the whole of U.S. higher education and research braced for the impact of drastic cuts to government agencies and major policy shifts affecting every aspect of our organizations. Through the long months of wait, our Academic Sponsor institutions were there with us, keeping in touch and planning for the upcoming Summer 2026 graduate schools, despite their own financial challenges this year.

The good news: on August 4, the NSF announced that six math institutes were awarded grants. In early December, the seventh institute, IPAM, received their award as well. We congratulate our fellow institutes and welcome the brand new Institute for Computer-Aided Reasoning in Mathematics (ICARM) at Carnegie Mellon University. SLMath was awarded a grant of $17 million over the five-year grant period. In a time of upheaval, we are grateful to be able to continue to open doors to our community in partnership with the NSF.

However, the $17 million NSF award — the maximum amount granted for any math institute — represents a **43% cut** from our submitted proposal. While SLMath received $5 million for 2025–26 programs, this will drop to $3 million for each subsequent academic year through 2029–30. The last six months have been dedicated to working closely with our trustees and governance committees to determine the best path to sustaining the Institute as a home for world-class collaboration and innovation. **The support of our private funders and donor community is vital to our future.** If you are able to include SLMath in your giving priorities this year, we are particularly focused on initiatives aimed at early and mid-career mathematicians, many of whom have been deeply affected by reductions in individual federal grant funding and fellowships.

Looking Ahead: Change and Opportunity

As federally-supported institutions nationwide prepare for the future, SLMath's scientific offerings are also changing. Beginning in Summer 2026, SLMath's scientific activities structure, as funded by the NSF, will be moving to a new model. The new programming is better adapted to a scientific landscape that is being transformed by the presence of new technologies and governmental policies.

Summer Schedule (Beginning Summer 2026)
- Summer Graduate Schools
- MSRI Undergraduate Program (MSRI-UP)
- NEW: Summer research in teams

Fall Schedule (Beginning Fall 2026)
- Two semester-long research programs
- Four workshops

Spring Schedule (Beginning Spring 2027)
- NEW: AxIOM month-long research programs
- One workshop

Introducing Three New Research Initiatives

AxIOM (Accelerating Innovation in Mathematics) are month-long scientific programs at SLMath consisting of four consecutive weeks of concentrated activity centered on a timely theme, from foundational mathematical challenges to fast-moving intersections with fields like artificial intelligence, data science, biology, physics, and medicine. Some programs will amplify the momentum of recent "hot topic" workshops or build on the outcomes of semester-long programs, while others will chart new territory — engaging with emerging technologies or revisiting classical problems through a modern lens.

PROOF (Promoting Research Opportunities and Open Forums) is a summer research program for teams, facilitating two-week visits to SLMath.

LATTICE (Lasting Alliance Through Team Immersion and Collaborative Exploration) is a yearlong program which starts with an intensive two-week summer session at SLMath for U.S. mathematical scientists working as independent teams or joining new projects.

See page 11 for more details about all three programs, including how to apply or propose.

(Update continues⟶)

AxIOM has a great deal of potential and has generated lots of interest already: five proposals were received for initial review, and our Scientific Advisory Committee requests that SLMath academic sponsor institutions and departments of mathematics encourage submitting AxIOM proposals for consideration by the upcoming review deadlines in March and October of 2026.

To ensure that we have full programming during the Spring terms for years to come, we are exploring possibilities for self-sustaining programs, for example, ones that will explore how new technologies affect the mathematical sciences: research, teaching, thought process, and the role of mathematics in the development of these new technologies.

Fall 2025 in Berkeley

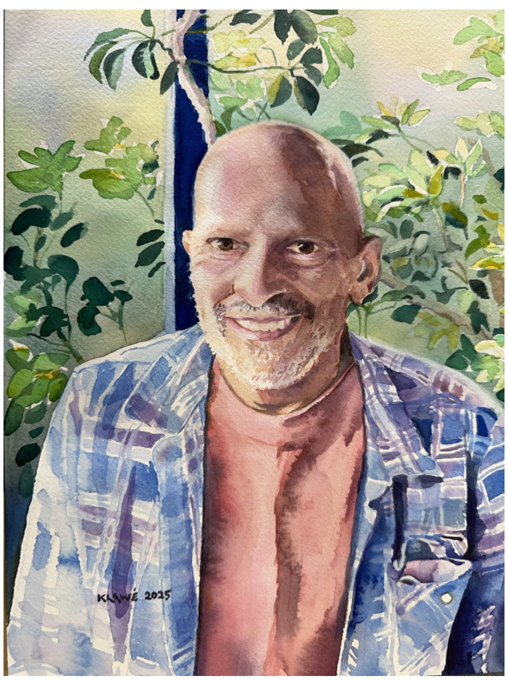
This semester, SLMath is hosting two programs: *Kinetic Theory: Novel Statistical, Stochastic and Analytical Methods* and *Recent Trends in Stochastic Partial Differential Equations*. While these programs have been severely affected by the extended federal funding uncertainty, we are pleased to have 90% of our normal visitor capacity this fall. I have had many positive reports from researchers of how their collaborations are progressing. We remain grateful to all organizers and participants for their flexibility and their efforts to make the programs a success.

The inaugural Revisiting Fundamental Problems workshop took place in December, reviewing decades of progress on infinite-dimensional division algebras and novel techniques and theories with potential for facilitating breakthroughs on open problems.

Formalization, also an area of interest for AxIOM, continues to generate lively discussions among our visitors, following a widely-attended talk on Machine Assisted Proofs by **Terry Tao** (UCLA) at our 40th Anniversary Symposium and a 2023 SLMath summer school featured in the *New York Times*. In October, SLMath partnered with the newest NSF math institute, ICARM, on a special hands-on workshop on LEAN for PDEs featuring **Rémy Degenne** (University of Lille) and **Michael Rothgang** (Universität Bonn). **Tudor Achim**, CEO of Harmonic, whose formal reasoning model, Aristotle, achieved gold-medal-equivalent performance on the 2025 International Mathematical Olympiad problems, invited researchers to test the limits of his company's model at a seminar in December. We look with curiosity to where this might lead us, but one thing is certainly becoming clear: change is already here and more is coming, faster than ever.

ICM 2026

The International Congress of Mathematicians (ICM) takes place July 23–30, 2026, in Philadelphia, PA, the first to take place in the U.S. in 40 years. To learn more about the meeting, view speaker details, and to register, visit icm2026.org.



In memoriam: Arthur Bossé

It is with a heavy heart that we share the sad news that Mr. Arthur Bossé, SLMath Operations Manager, passed away on July 23, 2025. As part of the Institute staff for the last 12 years, Arthur joined MSRI after his previous role as executive director of a Bay Area nonprofit organization. In addition to his dedicated support of our employees and visitors over the years, many who came to know him enjoyed his love of music and classic films and the colorful tales of working as a nightclub disc jockey in his youth. Teatime visitors to the Institute were treated each year to snacks served with honey he enjoyed sharing from his apiary in San Francisco, where he lived for nearly three decades with his family and beloved pet birds and backyard beehives. Arthur's spirit was warm and generous. He deeply cared for our community in Berkeley and beyond, and he will be greatly missed.

Portrait by Maria Klawe.

Graduate Fellows / FALL 2025

*Graduate fellowships support current graduate students to take part in our research programs, thanks to the support of **SLMath individual donors** and **private foundations**. These fellowships allow graduate students to receive financial support so that they can remain in residence at SLMath for the entire semester with their advisor, fully integrated into the semester's research program.*

Rodrigo Jose Gonzalez Hernandez is the Stephen Della Pietra graduate fellow in the *Kinetic Theory: Novel Statistical, Stochastic, and Analytical Methods* program. He is a fourth-year Ph.D. candidate at the Oden Institute of The University of Texas at Austin, researching computational plasma physics under the supervision of Irene Gamba. He recently started a collaboration with scientists at Los Alamos National Laboratory to study the efficient simulation of the Vlasov–Poisson system.

Sophie Mildenberger is the Kristin E. Lauter graduate fellow in the *Recent Trends in Stochastic Partial Differential Equations* program. She is currently a Ph.D. candidate at the University of Münster under the supervision of Hendrik Weber. Her research focuses on singular stochastic partial differential equations, in particular pathwise approaches to stochastic equations, and thus lies at the intersection of analysis and probability.

Call for ***Proposals***

All proposals can be submitted to the Directorate or any member of the Scientific Advisory Committee with a copy to proposals@slmath.org. For detailed information, please see the website slmath.org.

[New] AxIOM
Each Spring, SLMath runs month-long scientific programs consisting of four consecutive weeks of concentrated activity centered on a timely theme, from foundational mathematical challenges to fast-moving intersections with fields like artificial intelligence, data science, biology, physics, and medicine. Proposals should be received by Mar 1, Oct 1, and Dec 1 for review at the upcoming SAC meeting. See slmath.org/proposals-axiom.

Hot Topics Workshops
Each year SLMath runs a week-long workshop on some area of intense mathematical activity chosen the previous fall. Proposals should be received by Mar 1, Oct 1, and Dec 1 for review at the upcoming SAC meeting. See slmath.org/proposals-hot-topics-workshops.

Revisiting Fundamental Problems Workshop
The annual Revisiting Fundamental Problems Workshop addresses fundamental questions in mathematics that have, for one reason or another, been abandoned or forgotten. Proposals should be received by Mar 1, Oct 1, and Dec 1 for review at the upcoming SAC meeting. See slmath.org/proposals-revisiting-fundamental-problems-workshops.

Workshop on Critical Issues in Math Education
The Critical Issues in Mathematics Education (CIME) workshop series addresses critical issues in mathematics education today. Workshops are designed to engage mathematicians from research-focused and teaching-focused institutions, mathematics education researchers, K-12 teachers, and other interested stakeholders. Proposals may be submitted throughout the year, but the standard target date is Jan 31. See slmath.org/proposals-critical-issues-in-mathematics-education.

Summer Graduate Schools
Every summer SLMath organizes several two-week long summer graduate workshops, both at SLMath and at other locations. Proposals must be submitted by Sep 1 of each year for review at the upcoming SAC meeting. See slmath.org/proposals-summer-graduate-schools.

Program Article

Kinetic Theory: Novel Statistical, Stochastic, and Analytical Methods

José A. Cañizo

Consider this famous quote by physicist Richard Feynman (taken from the introductory physics books by Feynman, Leighton and Sands):

> “If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis that *all things are made of atoms — little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another*.”

A suggestive implication of this idea is that *we should be able to understand the behavior of things at a human scale from the way that particles behave*. If we have a precise mathematical model that tells us how each particle interacts with others, then one should be able to deduce from it the behavior of a piece of rock, a galaxy, a cloud, a glass of water, or more ambitiously *anything* as long as we know which particles it is formed by, and in which positions. This is the core of Hilbert's sixth problem on the mathematical treatment of the axioms of physics. The fields of physics and mathematics that are most concerned with this deduction are statistical mechanics and kinetic theory; and it is hard to overstate the difficulties that they face when undertaking this task.

The first difficulty is that the number of particles involved is necessarily huge, of the order of Avogadro's number: any human-sized portion of anything contains at least 10^{24} particles, too many for keeping track of, or even for simulating by computer. But the surprising fact which lies at the heart of these fields is that if we have many particles with similar laws, then *the behavior of a large number of them may be described by a simpler model*, often a partial differential equation (PDE) of some kind. Kinetic theory is generally understood to comprise the part of the theory that deals with out-of-equilibrium systems, whose behavior changes with time. It deals with many types of partial differential equations, stochastic differential equations, and the techniques to obtain them as a limit of the behavior of a large number of particles.

The Boltzmann Equation

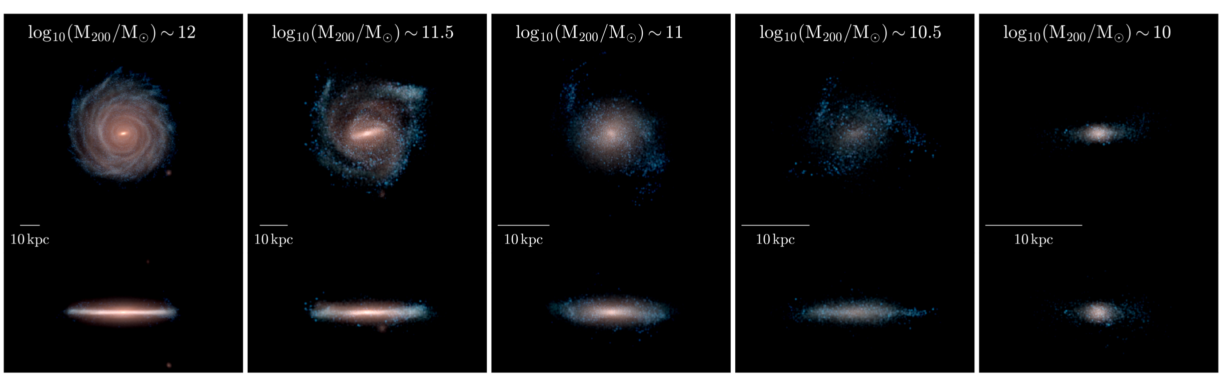
One can agree that the beginning of kinetic theory lies with Maxwell and Boltzmann, who derived the well-known *Boltzmann equation*, an integro-differential PDE which reads as follows:

$$\partial_t f + v\nabla_x f = Q(f), \qquad (\dagger)$$

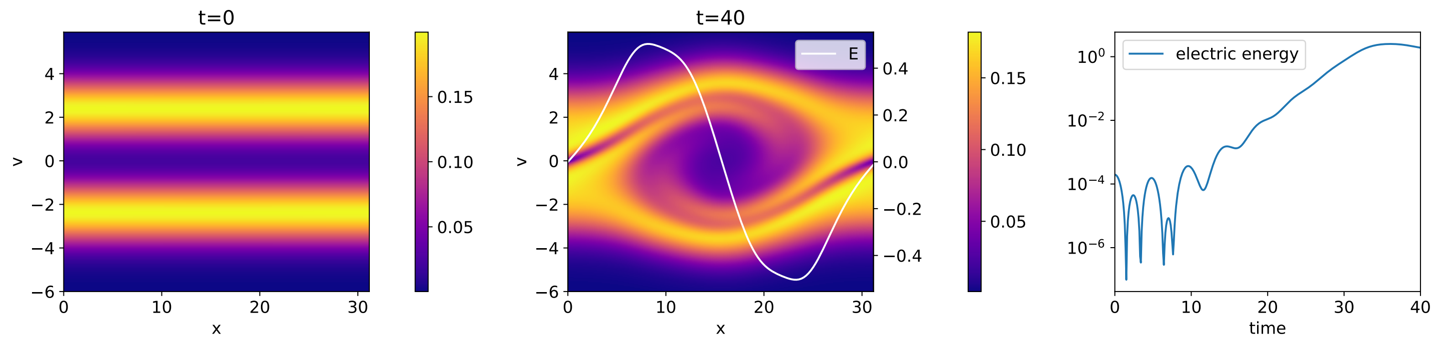
where $Q(f)$ denotes the *Boltzmann collision operator*, and the quantity to solve for is $f = f(t,x,v)$, a particle density depending on time t, position $x \in \mathbb{R}^3$, and velocity $v \in \mathbb{R}^3$. If there is one PDE in a short article about kinetic theory it must be Boltzmann's, so we will write the operator itself:

$$Q(f)(t,x,v) = \int_{\mathbb{R}^3}\int_{\mathbb{S}^2} B(|v-v_*|,\sigma)\big(f(t,x,v')f(t,x,v'_*) - f(t,x,v)f(t,x,v_*)\big)\,d\sigma\,dv_*,$$

where $B(|v-v_*|,\sigma)$ is the *collision kernel* (just take it constantly equal to 1 for a simple example), and v', v'_* are the post-collisional velocities that give all possible velocities after a momentum- and energy-conserving collision of two particles with velocities v and v_*



Simulations of galaxy formation must include the effect of dark matter, modeled by the Vlasov–Poisson equation. The image shows face-on and edge-on stellar light projections of a selection of simulated galaxies at redshift $z=0$ obtained from the Auriga Project public data release. From Grand et al., Overview and public data release of the augmented Auriga Project: cosmological simulations of dwarf and Milky Way-mass galaxies, *Monthly Notices of the Royal Astronomical Society, Vol. 532, Is. 2, 1814-1831, Fig. 5 (2024).*



Time evolution of the two-stream instability for the Vlasov–Poisson equation. This is a well known effect in plasma dynamics: two streams of charged particles which cross each other in opposite directions are unstable. Simulation and control of this instability are current research problems. From Einkemmer, Li, Wang and Yunan, *Journal of Computational Physics:* 498, 2024.

parametrized by $\sigma \in \mathbb{S}^2$:

$$v' = \frac{v+v_*}{2} + \sigma\frac{|v-v_*|}{2}, \quad v_*' = \frac{v+v_*}{2} - \sigma\frac{|v-v_*|}{2}.$$

The Boltzmann equation (†) contains a lot of information about the thermodynamics of a (monoatomic) gas: it tells you exactly how physical entropy must increase, how temperature evolves at every point in space, and how the gas moves around. One can derive it by considering N identical classical Newtonian particles that behave like billiard balls: they move around with constant speed until a collision happens, and then they bounce off each other in an elastic way which preserves momentum and kinetic energy. Given the time-dependent positions $x_j = x_j(t)$ and velocities $v_j = v_j(t)$ of these N particles you can consider the *empirical measure* $\mu^N = \mu^N(t)$ given by

$$\mu^N(t) := \frac{1}{N}\sum_{j=1}^{N} \delta_{(x_j(t), v_j(t))},$$

which at every time t is a probability measure on $\mathbb{R}^3 \times \mathbb{R}^3$. Now, a basic question in kinetic theory is the following: *Assume that at time* $t = 0$ *the measure* $\mu^N(0)$ *is "close" to the initial condition* f^0 *of the Boltzmann equation* (†). *Is it true that for very large* N *the measure* $\mu^N(t)$ *is "close" to the solution* $f(t,\cdot,\cdot)$ *of* (†)*?* (We can measure this closeness in terms of the weak convergence of measures, for example.) That is: is it true that, in a suitable weak sense,

$$\mu^N(t) \to f(t,\cdot,\cdot) \quad \text{as} \quad N \to +\infty\,? \qquad (‡)$$

When this is true for some PDE, we say that the PDE is the *mean-field limit* of the N-particle equations. The answer in this case is a clear *not always*, for the following deep reason: the laws governing the billiard balls are reversible in time, while the Boltzmann equation (†) is *not*; if the convergence $\mu^N(t) \to f(t,\cdot,\cdot)$ is true for some sequence of initial conditions, then you can equally well reverse the velocities of all your particles at time 1 (for example), take that as an initial condition, and find that now $\mu^N(t) \to g(t,\cdot,\cdot)$ where g is a solution to the *time-reversed* Boltzmann equation with initial condition $f(1, x, -v)$. This reflects the fundamental problem that gases, fluids, and things in general behave in a non-reversible way which is obvious in everyday experience; but the laws governing particles seem to be reversible in time. So there must be something dodgy going on if we want to obtain one from the other.

When first described by Boltzmann towards the end of the 1800s, the atomic hypothesis was not generally accepted, and the previous argument was seen as a serious criticism to it: how can everyday experience have irreversible processes if the basic particle laws are reversible? I would love to have been a silent observer at a table discussing arguments for and against this in Boltzmann's time. But like many philosophical problems, this has increasingly become something you can answer rigorously once you formulate it in a clear way. Here is something you can rigorously prove:

> *(Informal) theorem.* If you draw the initial positions and velocities of particles *at random, independently according to a given probability distribution* f^0, then (‡) holds for all times $t \geqslant 0$ with the hard-sphere kernel $B(|v-v_*|,\sigma) := |v-v_*|$, with probability 1.

This was previously known, by a result of Lanford in the 1970s, for very short times. It has been recently proved for all times in a breakthrough that was the subject of a course at the beginning of this semester's program at SLMath.

The Vlasov–Poisson Equation

For gravitational or electric interactions (instead of billiard-like collisions, which are an idealization of nuclear forces), the relevant PDE is known as the *Vlasov–Poisson equation.* A complete proof that one can obtain it as the mean-field limit of N gravitationally (or electrically) interacting particles is an unsolved problem that has been the subject of many works, and is still a central question in kinetic theory. The problem here is *not* reversibility, since both Newton's laws and the Vlasov–Poisson PDE are reversible, but the singularity of the Coulomb interaction which makes many methods fail. The numerical simulation and qualitative behavior of this system is also a prominent field of study. Significant challenges are presented by more complex systems, for example the

Vlasov–Maxwell system including magnetic interactions, relevant in plasma physics.

Hydrodynamic Equations, Existence, and Regularity

The PDEs that describe the motion of fluids were derived in the 18th and 19th centuries by (Daniel) Bernoulli, Navier, and Stokes, using considerations based on the conservation of mass, energy, and momentum. If these equations really describe the behavior of a fluid, we should be able to deduce them directly from the laws that particles follow. This is an endeavor with a long history that has also seen many recent developments. One possible rigorous path to do this is the following:

1. Show that the Boltzmann equation can be rigorously deduced from Newtonian dynamics, as we discussed earlier.

2. Show that if we rescale solutions to the Boltzmann equation appropriately, they will converge to solutions of the Navier–Stokes equations.

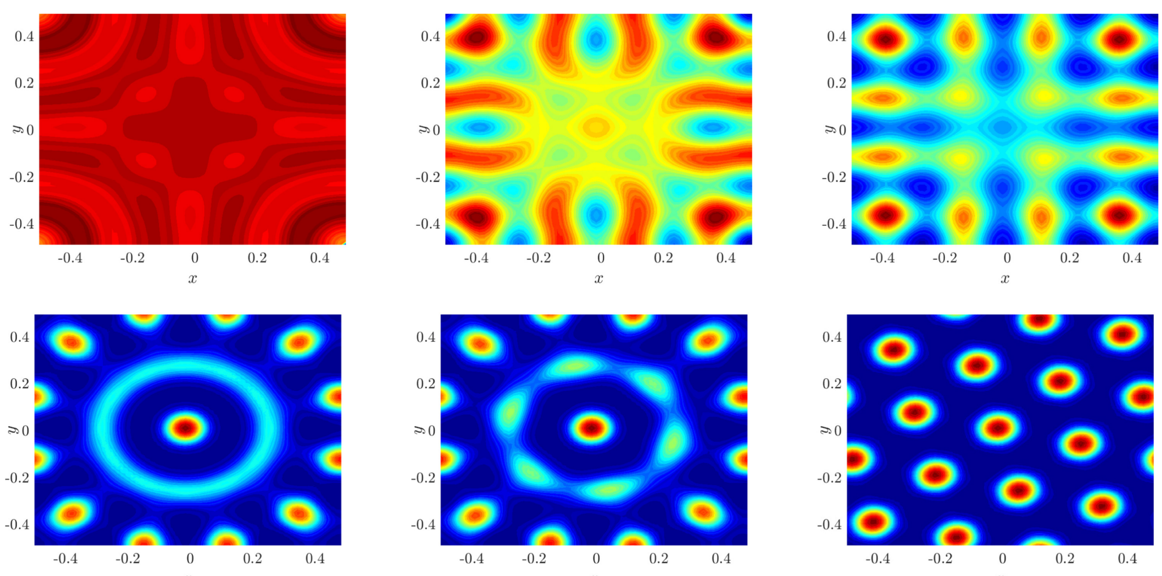
The second point is usually stated by saying that the hydrodynamic limit of the Boltzmann equation gives the incompressible Navier–Stokes equations. This path is now paved in a reasonably satisfactory way, but many questions still remain open. An obvious obstacle is that we do not know whether the Boltzmann equation or the Navier–Stokes equations have smooth solutions for general compactly supported, smooth initial data.

For the Navier–Stokes equations, this is the subject of one of the Millennium Prize Problems, and the corresponding question for the Boltzmann equation is probably at least as hard to answer. This is one of the problems where it is not just that we don't have a proof; it is that people don't agree on what the solution should be. Whether there can be non-smooth solutions to the Boltzmann equation with "nice" initial data is really a widely open problem. Recent developments, also discussed in this semester's SLMath program, have given regularity results for linear kinetic equations with "rough" coefficients, in an extension of the elliptic and parabolic regularity results of De Giorgi, Nash, and Moser. How far these methods can reach for the nonlinear theory is the subject of current research.

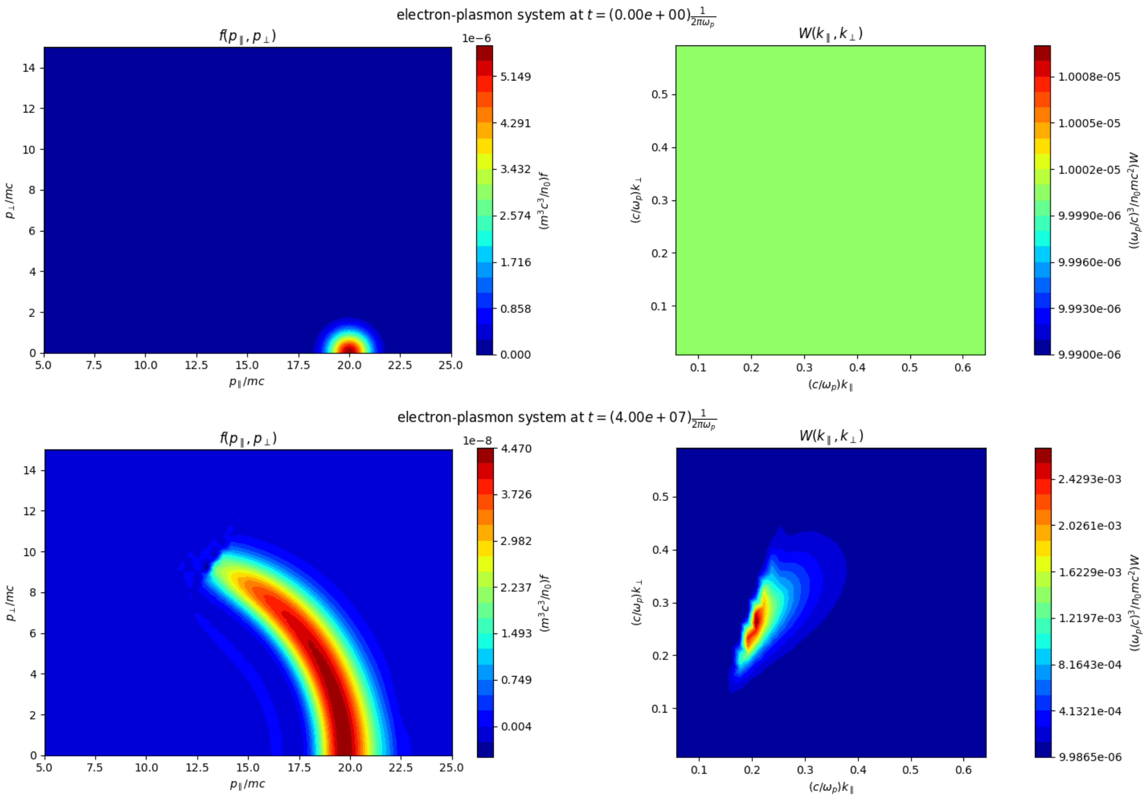
Analogous questions can be asked of the Landau equation, which is a limit of the Boltzmann equation with a similar form. In a very recent result, regularity of solutions to the *homogeneous* Landau equation (the equation *without* the x variable) has been proved (and discussed in a course at SLMath!), which gives an idea of the magnitude of the problem: even the question of regularity of solutions *without any space-dependent effects* has been open until recently for this equation, and is of course still open when space is taken into account.

Other PDE Questions

Even forgetting about their derivation from particle physics, the PDE models in kinetic theory pose a wide range of questions by themselves. Their long-time behavior is especially interesting, since it should reflect the equilibrium of the physical systems they model.



Grid cells, a structure in the brain of mammals discovered in 2005 and the subject of the 2014 Nobel prize in Physiology or Medicine, are a basic mechanism for spatial orientation. The figure shows the numerical simulation of a simplified model for grid cells starting from a small perturbation of a constant function, at times $t = 40, 220, 1500, 1810, 2190,$ and 2400 ms. It shows the formation of the typical hexagonal patterns. This model has been derived from the individual behavior of cells following ideas such as those described above. From Carrillo, Roux, and Solem in *Physica D*, 449, 133736 (2023). Used under CC BY 4.0.



Numerical simulation results of a reduced model for magnetized plasmas. On the left the particle density is shown, while the right hand side shows the wave spectral energy density. Simulating these interactions is important for understanding plasmas in magnetic confinement fusion reactors. From Huang, Abdelmalik, Breizman, and Gamba, A conservative Galerkin solver for the quasilinear diffusion model in magnetized plasmas, *Journal of Computational Physics* 488 (2023).

This question has motivated the development of entropy methods, hypocoercivity ideas, and functional inequalities, and uncovered links with probability theory that continue to have a two-way impact on these fields. The fact that conservative, deterministic processes can still tend to an equilibrium and exhibit the same type of irreversible behavior as random systems has also been rigorously proved for the Vlasov–Poisson equation, and is known as *Landau damping* in this context. Different models are proposed for more involved systems: inelastic collisions, multiatomic gases, gas mixtures, interactions with walls or recipients, quantum effects — giving a whole taxonomy of living things which guard their own secrets.

Beyond Physics

Following the same family of ideas in fields away from physics has also led to a huge amount of recent activity in biology, complex systems, and even social sciences. Given the behavior of a certain type of cell, can we give a mean-field PDE model for a large population of such cells? If we know how an average car driver behaves, can we give a model for the density of road traffic that is more manageable than simulating thousands of cars? If we model the interactions among a group of individuals as a graph, can we have a corresponding "mean-field graph" that models interactions at a PDE level? If we give rules for the individual behavior of an insect, can we deduce the behavior of a swarm? All of these questions involve some type of mean-field limit like the one in physics, and suggest new models which introduce many new ideas into the theory.

The field of optimization is fond of using physical or biological analogies to motivate its methods: simulated annealing, genetic algorithms, particle swarm optimization, and collective-based optimization are some names that come to mind. The latter two suggest that the problem of finding the minimum of a function can be approached by having a set of moving agents "explore" a landscape, trying to agree among them on which direction to follow next in order to increase the chances of finding a minimum and minimizing their effort. When the number of such agents is large, one can give a PDE to model their behavior which shares many similarities with kinetic theory PDE. This PDE can then give insights into the behavior of our N agents and help decide whether they will reach their goal or not, and also give clues on how to better design them.

Since the recently booming field of artificial intelligence involves expensive numerical calculations to minimize extremely complex functions on high-dimensional spaces, these kinetic theory techniques are also being actively explored here. There are also recent ideas which consider an artificial neural network and try to find a simplified model for its behavior when its width (the number of neurons in a layer) tends to infinity. These quite distant relatives of the basic physics ideas still make use of tools which were developed to understand thermodynamics, but keep the field changing and fresh by introducing new applications, new questions, and perhaps also new ways of answering the old ones.

FOCUS *on the Scientist* Irene Martínez Gamba

Irene Martínez Gamba is one of the organizers of this semester's *Kinetic Theory: Novel Statistical, Stochastic and Analytical Methods* program. Born in Argentina, she received her Ph.D. from the University of Chicago (1989). Her doctoral advisor, Jim Douglas Jr., a distinguished numericalist in the developing of Garlerkin scheme methods for porous media models and beyond, gave her a research subject on semiconductor models. After that, Irene worked with Cathleen Morawetz at the Courant Institute as a postdoc and as Assistant and Associate Professor. In 1997 she moved with her family to the University of Texas at Austin as a Full Professor. She currently holds the W.A. Moncrief, Jr. Chair in Computational Engineering and Sciences and is the head of the Applied Mathematics Group in the Oden Institute.

At variance with the theory of flows in continuous media (involving densities in space of various physical quantities), kinetic equations are more detailed, phase space statistical models. Since the work of H. Grad in the late 1940s, the kinetic theory of gases and plasmas has been a prominent subject in the U.S. Remarkable contributions on this subject were made from the 1970s to the early 1990s, and the long-awaited global existence of "large" (renormalized) solutions of the Boltzmann equation due to R.J. DiPerna and P.-L. Lions appeared in 1990.

Building upon the experience gained from her Ph.D., Irene started collaborating with A. Arnold, N. Ben Abdallah, J.A. Carrillo, C. Cercignani, P. Degond, M. Gualdani, A. Jüngel, A. Klar, C.D. Levermore, A. Majorana, C-W Shu, R.Sharp, C. Sparber, A. Vasseur, and P. Zhang on analytical and numerical methods for mean field kinetic models for submicron semiconductors devices, a relatively new topic in the U.S. in 1990. In 1999, she started collaborations with A.V. Bobylev, C. Villani, V. Panferov, R.J. Alonso, C. Mouhot, J.A. Canizo, and S.H. Tharkabhushaman on different aspects of Boltzmann equations for elastic and granular gases, while expanding on Vlasov–Poisson–Boltzmann systems for plasmas in various physical contexts.

> *Irene is a driving force in fostering research on kinetic models in the U.S.*

In the last 15 years, she expanded her contributions to analytical work on Boltzmann equations, not only improving results for broader data in classical elastic theory, but also solving the well posedness for kinetic mixtures and polyatomic gases on the quantum Boltzmann–Gross–Pitaevskii system, and weak turbulence theory on stratified ocean flows with S. Akopian, R.J. Alonso, N. Pavlovic, M. Pavic-Colic, L. Smith, M. Taskovic, and M.B. Tran. Irene's work on numerical simulations of Boltzmann and Landau systems spans 28 years, with collaborations with Y. Cheng, P. Morrison, J. Haack, C. Zhang, C. Pennie, and K. Huang. Her latest work discusses weak turbulence modeling for electrostatic or highly magnetized Vlasov–Maxwell/Poisson systems. I myself had the good fortune to work on the scattering problem for the Boltzmann equation with C. Bardos, C.D. Levermore, and Irene in 2016.

Irene is a driving force in fostering research on kinetic models in the U.S. Along with E. Tadmor and S. Jin, they run the eight-year long NSF–RNMS "KI-Net" program. She served on the SLMath Scientific Advisory Committee from 2020–24. She has given several distinguished lectures: the 2014 Sonia Kovalevsky Lecture, as well as the 2022 Kirk Distinguished Lecture (Cambridge), the Mathematics Congress of the Americas (Buenos Aires, 2021), not to mention invited lectures at the AMS-SIAM annual joint meeting (Atlanta, 2017), and plenary lectures at the SIAM Conference on PDEs (La Quinta, CA, 2019) and SIAM Conference on Material Science (Pittsburgh, 2024). She is a fellow of SIAM (2012) and of AMS (2013).

— François Golse

Clay Senior Scholars

The Clay Mathematics Institute (claymath.org) has announced the 2025–26 recipients of its Senior Scholar awards. The awards provide support for established mathematicians to play a leading role in a topical program at an institute or university away from their home institution. Here are the Clay Senior Scholars who will work at SLMath in 2025–2026.

Fall 2025

Kinetic Theory: Novel Statistical, Stochastic, and Analytical Methods
Eric Carlen (Rutgers University)

Recent Trends in Stochastic Partial Differential Equations
Hendrik Weber (Westfälische Wilhelms-Universität Münster)

Spring 2026

Topological and Geometric Structures in Low Dimensions
David Gabai (Princeton University)

Geometry and Dynamics for Discrete Subgroups of Higher Rank Lie Groups
François Labourie (Université Côte d'Azur)

SLMath Launches Three Exciting New Initiatives

SLMath is pleased to announce three new research initiatives for mathematicians: AxIOM, PROOF, and LATTICE.

AxIOM

AxIOM (Accelerating Innovation in Mathematics) is a new, month-long research program at SLMath designed to accelerate innovation and introduce transformative ideas into the mathematical sciences. These focused programs are meant to create a dynamic environment for intensive collaboration, where researchers converge to push boundaries, explore bold ideas, and catalyze breakthroughs. AxIOM is supported by the U.S. National Science Foundation (NSF) and additional sponsors — see website for details.

Each AxIOM program centers on a timely theme, from foundational mathematical challenges to fast-moving intersections with fields like artificial intelligence, data science, biology, physics, and medicine. Some programs will amplify the momentum of recent "hot topic" workshops or build on the outcomes of semester-long programs, while others will chart new territory — engaging with emerging technologies or revisiting classical problems through a modern lens.

PROOF

PROOF (Promoting Research Opportunities and Open Forums) is a two-week summer program designed to provide research opportunities for U.S.-based mathematicians, statisticians, and their collaborators in the U.S. and abroad, whose ongoing research may have been impacted by factors such as heavy teaching loads, professional isolation, limited access to funding, heavy administrative duties, personal obligations, or other constraints. PROOF is supported by the NSF and the American Mathematical Society.

The program welcomes in-person participation from faculty and advanced graduate students at all U.S. colleges and universities. It aligns with SLMath's broader goal to open doors to mathematics by creating environments where researchers from a wide range of institutional settings can thrive, pursue projects, and reach their full academic/scientific potential. Groups of two to five mathematicians with partial results on an established project may submit an application to the program, and at least 50% of the team members must be U.S.-based.

LATTICE

LATTICE (Lasting Alliance Through Team Immersion and Collaborative Exploration) is a yearlong program which provides opportunities for U.S. mathematicians to conduct collaborative research on topics at the forefront of the mathematical and statistical sciences. The goal of the program is to advance mathematical research by offering a structured environment where participants can concentrate on their work, make substantial progress, build professional connections, and contribute to the growth of the mathematical sciences. This program is designed for faculty whose research momentum may be affected by demanding teaching loads, limited access to research infrastructure, professional isolation, administrative responsibilities, or personal obligations.

All LATTICE participants must be U.S. citizens or permanent residents, possess a Ph.D. in the mathematical or statistical sciences, and be employed at a U.S. institution. Participants will spend two weeks during the summer taking part in intensive collaborative research at SLMath as part of an existing or new small research group. Participants must be in residence at SLMath for these two weeks and willing to pursue their project during the following academic year. LATTICE is supported by the Alfred P. Sloan Foundation and the American Mathematical Society.

How to Apply/Propose

SLMath invites the submission of proposals for future **AxIOM** programs for review by the Institute's Scientific Advisory Committee. Programs will be held in the Spring of each year, beginning in Spring 2027, and the planning for such programs generally begins approximately 18 months in advance.

Applications for **PROOF** and **LATTICE** open Sep 1 of each year via the website MathPrograms.org. While PROOF team applications are now closed for 2026, LATTICE 2026 applications end on February 1, 2026.

Tau Day 2025

Congratulations to **Michael Popov** and **John Owens**, winners of the 2025 SLMath Tau Day Puzzle Contest on Jun 28, 2025. While Pi Day on Mar 14 is familiar to many as the International Day of Mathematics, Tau Day on Jun 28 playfully celebrates $\tau = 6.28...$, or 2π.

In the spirit of "twice as much pi," SLMath offered a double puzzle contest this year, along with with 2025 Puzzlemaster **Peter Winkler** (Dartmouth College). Peter recently made his third visit to 17 Gauss Way in Spring 2025 as a member of the *Probability and Statistics of Discrete Structures* program. The 2025 puzzles are featured at the Tau Day webpage.

SLMath extends our thanks to Sejongmall, makers of Hagoromo Chalk, for their generous support of the contest prizes.

Distinguished Postdoctoral Fellowships / FALL 2025

UHLENBECK

HALEY ARMENTROUT

Hindy Drillick is the Uhlenbeck postdoctoral fellow in the *Recent Trends in Stochastic Partial Differential Equations* program. Hindy received her bachelor's degree from Stony Brook University in 2019 and her Ph.D. in mathematics in 2025 from Columbia University, where she was advised by Ivan Corwin. Starting in Spring 2026, she will join New York University's Courant Institute of Mathematical Sciences as a Courant Instructor. Hindy's research is in probability theory, exploring universal fluctuation phenomena in random growth models and interacting particle systems. In particular, her work focuses on proving scaling limits of such systems to solutions of stochastic partial differential equations, such as the stochastic heat equation and the Kardar–Parisi–Zhang equation.

The Uhlenbeck fellowship was established by an anonymous donor in honor of Karen Uhlenbeck, a distinguished mathematician and former MSRI trustee. She is a member of the National Academy of Sciences and a recipient of the 2019 Abel Prize, the AMS Leroy P. Steele Prize, and a MacArthur "Genius" Fellowship.

VITERBI

HALEY ARMENTROUT

Simon Gabriel is the Viterbi postdoctoral fellow in the *Recent Trends in Stochastic Partial Differential Equations* program. Simon obtained his Ph.D. in 2023 from the University of Warwick, under the supervision of Nikos Zygouras and Paul Chleboun. Before his postdoctoral fellowship at SLMath, he held a postdoctoral position in the Mathematics Cluster of Excellence at the University of Münster. Simon's research focuses on singular stochastic partial differential equations in the critical dimension, which arise naturally in contexts such as quantum field theory in four-dimensional spacetime. Among his results are the analysis of fluctuations in the weakly coupled 4D Anderson Hamiltonian and the study of the Allen–Cahn equation with white noise initial datum.

The Viterbi postdoctoral fellowship is funded by a generous endowment from Dr. Andrew Viterbi, well known as the co-inventor of Code Division Multiple Access based digital cellular technology and the Viterbi decoding algorithm, used in many digital communication systems.

DONOHO

Kihoon Seong is the Donoho postdoctoral fellow in the *Recent Trends in Stochastic Partial Differential Equations* program. He received his Ph.D. in 2022 from KAIST and was previously a postdoctoral fellow at Cornell University and the Max Planck Institute. Following his time at SLMath, he will join the École Polytechnique Fédérale de Lausanne as a postdoctoral fellow. Kihoon's research lies at the intersection of probability and stochastic analysis. His recent works have focused on Gibbs measures associated with statistical mechanics and quantum field theory, including their construction, concentration phenomena, phase transitions, and fluctuation behavior.

The Donoho fellowship was established in 2022 by David Donoho and Miriam (Miki) Gasko Donoho. David Donoho has made fundamental contributions to theoretical and computational statistics throughout his career, as well as to signal processing and harmonic analysis. He has served as a Trustee of MSRI/SLMath since 2016.

Distinguished Postdoctoral Fellowships / FALL 2025

VITERBI

HALEY ARMENTROUT

Esteban Cárdenas is the Viterbi postdoctoral fellow the *Kinetic Theory: Novel Statistical, Stochastic, and Analytical Methods* program. Esteban was born in Chile, where he completed his studies in physics and mathematics. He then pursued his Ph.D. at the University of Texas at Austin, working under the supervision of Thomas Chen. He received the Frank Gerth III Dissertation Award for his thesis on the derivation of the quantum Boltzmann equation for a Fermi gas (2025). His research widely revolves around the mathematical analysis of complex physical systems and their rigorous understanding from first principles. He has special interest in the emergence of effective PDEs from many-particle systems in quantum mechanics and its connection to kinetic theory.

The Viterbi postdoctoral fellowship is funded by a generous endowment from Dr. Andrew Viterbi, well known as the co-inventor of Code Division Multiple Access based digital cellular technology and the Viterbi decoding algorithm, used in many digital communication systems.

HUNEKE

Patrick Flynn is the Huneke postdoctoral fellow in the *Kinetic Theory: Novel Statistical, Stochastic, and Analytical Methods* program. He received his Ph.D. from Brown University under the supervision of Benoit Pausader in 2023. Since then, he joined UCLA as a Hedrick Assistant Adjunct Professor, from which he is currently on leave. Patrick is interested in problems in kinetic theory and fluid mechanics that involve asymptotic behavior, including singular limits and long time stability.

The Huneke postdoctoral fellowship is funded by a generous endowment from Professor Craig Huneke, who is internationally recognized for his work in commutative algebra and algebraic geometry.

S. DELLA PIETRA

HALEY ARMENTROUT

Amélie Justine Loher is the Stephen Della Pietra postdoctoral fellow in the *Kinetic Theory: Novel Statistical, Stochastic and Analytical Methods* program. She recently finished her Ph.D. at the University of Cambridge under the supervision of Clément Mouhot. Before her postdoctoral fellowship at SLMath, she was an Early Career Fellow of the London Mathematical Society. Her work focuses on regularity theory of equations in kinetic theory that are derived from first principles. Her contributions range from establishing a quantitative De Giorgi method and deriving a strong Harnack inequality for solutions to the Boltzmann equation, to investigating the well-posedness of the spatially homogeneous Landau equation for rough initial data.

The Stephen Della Pietra fellowship was established in 2017 by the Della Pietra Family Foundation. Stephen received his Ph.D. in mathematical physics from Harvard University. He is a partner at Renaissance Technologies, a board member of the Simons Center for Geometry and Physics, and treasurer of the National Museum of Mathematics in New York. He is also currently a trustee of SLMath.

Art at 17 Gauss Way: Stephen Beal

From December 2025, SLMath architect William R. Glass presents a new art exhibit featuring the works of painter **Stephen Beal**, in partnership with Sarah Shepard Gallery. A Bay Area resident, Beal's work has been widely exhibited at George Lawson Gallery, Mark Wolfe Contemporary Art, Bucheon Gallery, Chicago Cultural Center, Galereya A3, Oliver Art Center, and School of the Art Institute of Chicago. Beal served as President of California College of the Arts (CCA) from 2008–2023, before which he was the provost.

In Beal's work, the grid—ubiquitous, logical, resolute, infinite—acts as inspiration, structure, and image. In the exhibit's paintings, the penciled matrices function as vehicles to explore the subtleties of color and brush stroke. Beal's interest in the surface quality of paint, and its physical interaction with and manipulation of the grid, is what transforms his canvases into methodical, material studies with an undeniable presence. With grid as structure and paint as subject, this collection of work offers a musical reflection on an illustrious visual form.

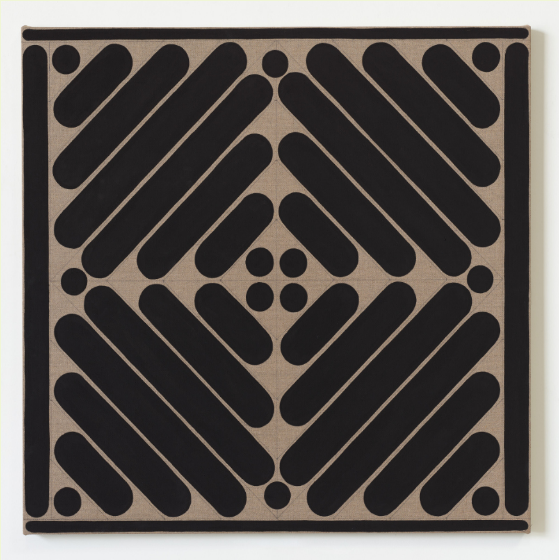


PHOTO ©JOSEF JACQUES

Stephen Beal, Untitled, 2024.

Forthcoming **Workshops**

Jan 21–23, 2026: *Pathways Workshop:* Topological and Geometric Structures in Low Dimensions & Geometry and Dynamics for Discrete Subgroups of Higher Rank Lie Groups

Jan 26–Jan 30, 2026: *Introductory Workshop:* Topological and Geometric Structures in Low Dimensions & Geometry and Dynamics for Discrete Subgroups of Higher Rank Lie Groups

Mar 23–27, 2026: Recent Progress in Topological and Geometric Structures in Low Dimensions

Apr 6–10, 2026: *Hot Topics:* Geometric Langlands Conjecture

Apr 20–24, 2026: Homogeneous Dynamics and Anosov Representations

Apr 29–May 1, 2026: *Critical Issues in Mathematics Education 2026:* Math Literacy for 21st Century Citizenship—Part II

2026 Summer Graduate Schools

May 4–15, 2026: Séminaire de Mathématiques Supérieures 2026: Universal Statistics in Number Theory (Montréal, Canada)

Jun 8–18, 2026: Geometric Measure Theory (SLMath)

Jun 8–19, 2026: Percolation and Lattice Models of Statistical Physics (Columbia University, NY)

Jun 15–26, 2026: Random Growth Models, Phase Separation, and Hamilton-Jacobi PDE (UC Berkeley, CA)

Jun 15–26, 2026: *ICTP–IndAM–SLMath School:* Mathematics For Machine Learning (Trieste, Italy)

Jun 22–Jul 3, 2026: Mathematics of Generative Models (SLMath)

Jun 22–Jul 3, 2026: *SLMath–Oxford–OIST School:* Analysis of Partial Differential Equations (Okinawa, Japan)

Jul 6–17, 2026: Dynamical Systems for Machine Learning and AI (IBM Yorktown, NY)

Jul 6–17, 2026: Singularities in Commutative Algebra Through Cohomological Methods (SLMath)

Jul 20–31, 2026: Moduli of Varieties (SLMath)

2026 Summer Activities

Jun 8–Jul 31, 2026: PROOF (Promoting Research Opportunities and Open Forums) 2026 (see page 11)

Jun 22–Jul 3, 2026: LATTICE (Lasting Alliance Through Team Immersion and Collaborative Exploration) 2026 (see page 11)

For more information about any of SLMath's scientific activities, please see slmath.org/scientific-activities.

Community News: Awards and Staff Announcements

- **Semyon Dyatlov** (MIT), former postdoc, research member, and research professor, and **Maciej Zworski** (UC Berkeley), many-time organizer and research professor, will receive the 2026 AMS Joseph L. Doob Prize.
- **Wilfrid Gangbo** (UCLA), many-time research professor and SAC member, will receive the 2026 AMS Award for Distinguished Public Service.
- Trustee **Sylvester James Gates, Jr.** was awarded the 2025 Barry Prize by the American Academy of Science and Letters.
- **Edray Goins** (Pomona College), co-director of LATTICE, has been elected to lead the Mathematical Association of America.
- **Lauren K. Williams** (Harvard University), the first Viterbi Postdoctoral Fellow and organizer and member of several programs since, has been named to the 2025 class of MacArthur Foundation Fellows.
- Director **George Csicsery** (Zala Films) was named a 2025 Buzzies Award winner at the World Congress of Science & Factual Producers in Rio de Janeiro, Brazil, receiving the Diversity Leadership Award for his work on the *Journeys of Black Mathematicians* film series.


DAVID EISENBUD

- *In staff news,* we congratulate SLMath staff member **Christine Marshall** (above left) on her well-deserved promotion: Chris is now Associate Director of Scientific Activities.
- And finally, we welcome SLMath's new Director of Advancement and External Relations, **Brian Yocum** (above right). Brian joins us from his previous role as Senior Director of Development, Physics, Mathematics & Astronomy at Caltech.

View all recent Institute news on our website, and share updates with us: communications@slmath.org.

Named Positions / FALL 2025

SLMath is grateful for the generous support that comes from endowments and annual gifts that support members of its programs each semester.

Chern, V. Della Pietra, Eisenbud, and Simons Professors

Sandra Cerrai, University of Maryland
Yingda Cheng, Virginia Tech
Franco Flandoli, Scuola Normale Superiore
Irene Gamba, University of Texas, Austin
Wilfrid Gangbo, University of California, Los Angeles
Clément Mouhot, CMS, University of Cambridge
Andrea Nahmod, University of Massachusetts, Amherst
Natasa Pavlovic, University of Texas at Austin
Hao Shen, University of Wisconsin-Madison
Lorenzo Zambotti, Sorbonne Université

Named Postdoctoral Fellows

Donoho: Kihoon Seong, Cornell University
Huneke: Patrick Flynn, University of California, Los Angeles
Stephen Della Pietra: Amélie Loher, University of Cambridge
Uhlenbeck: Hindy Drillick, Columbia University
Viterbi: Esteban Cárdenas, University of Texas at Austin
Viterbi: Simon Gabriel, University of Münster

Named Program Associates

Lauter: Sophie Mildenberger, Universität Münster
Stephen Della Pietra: Rodrigo Gonzalez-Hernandez, University of Texas at Austin

Program Article

Recent Trends in Stochastic Partial Differential Equations

Sandra Cerrai, Yu Gu, Massimiliano Gubinelli, Davar Khoshnevisan, Andrea Nahmod, Hao Shen, and Lorenzo Zambotti

Stochastic partial differential equations (SPDEs) study the interplay between PDEs and randomness. They arise in numerous contexts, including turbulent fluids, population genetics, reaction-diffusion systems with noise, random growth, and quantum physics, to name just a few. The subject lies at the crossroads of stochastic analysis, nonlinear PDEs, mathematical physics, and geometry, and it now stands at the center of a rapidly expanding field. A major challenge, though simple to state, is that many naturally occurring SPDEs involve nonlinearities and random forcing so singular that standard solution concepts fail. This difficulty motivated the development of new theories beginning in the 1980s and 1990s.

Over the past decade, the field has experienced remarkable advances. The introduction of powerful analytic frameworks — most notably the theory of regularity structures and the paracontrolled distributions approach — has opened the door to treating equations where nonlinearity and randomness interact in highly irregular ways. Building on these breakthroughs, central problems in universality, scaling limits, asymptotic behavior, and the connections to quantum field theory and statistical mechanics have come into sharp focus. New landscapes have emerged: the study of critical dimensions, global solution theories, renormalization techniques, derivations from microscopic models, universality questions, and geometric and algebraic structures underlying these equations.

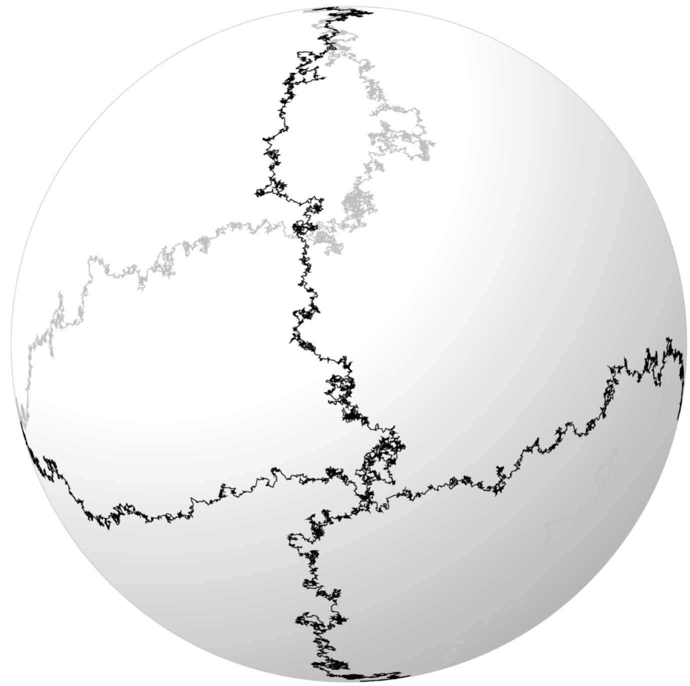
This semester's program is designed to bring together researchers across disciplines to consolidate the advances, train the next generation, and chart the directions for the decade ahead.

From Ill-Posed Equations to Robust Theories

For classical SPDEs, such as the stochastic heat equation, the solution theories can often be understood with tools from Itô calculus or semigroup theory. But in singular SPDEs, the driving noise and the nonlinear terms interact in ways that render even basic quantities undefined. A paradigm example is the KPZ (Kardar–Parisi–Zhang) equation, central in statistical physics. Written formally as

$$\partial_t h = \Delta h + (\nabla h)^2 + \xi$$

(with ξ representing space-time white noise), the equation makes no classical sense: the gradient is too irregular to square, due to the noise being too singular.

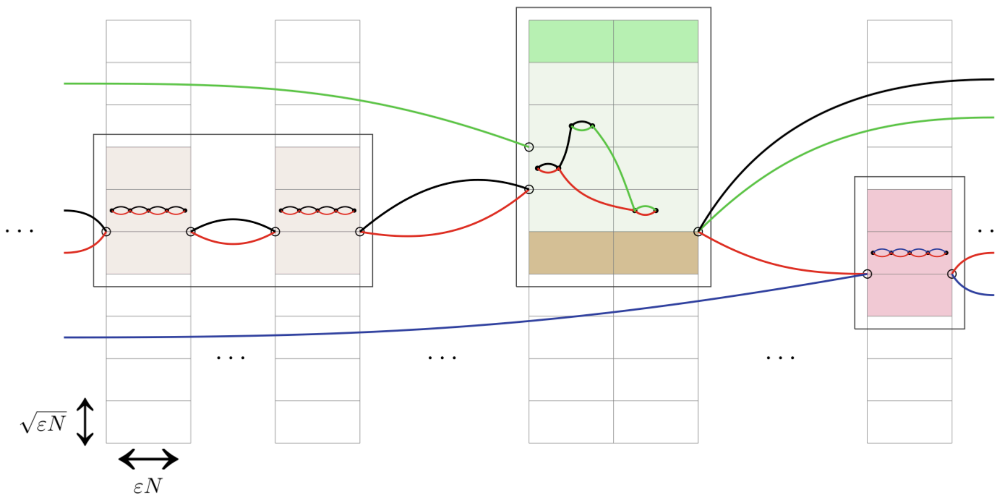


Random motion of a string on a manifold, governed by a geometric heat equation with singular random forcing, studied by Bruned–Gabriel–Hairer–Zambotti.

The breakthrough came with renormalization techniques inspired by quantum field theory, combined with entirely new functional frameworks. Hairer's theory of regularity structures recast the problem in terms of a tailored algebra of abstract symbols and models, enabling precise definitions of products of distributions. The paracontrolled calculus method, developed by Imkeller–Gubinelli–Perkowski, among other collaborators, introduced systematic expansions and commutator estimates that restore analytic control. The effectiveness of these methods on important equations such as KPZ and the Φ^4_3 quantum field model signaled the beginning of a new era. The resulting frameworks quickly proved to be both robust and flexible, extending to a wide variety of problems. In particular, "black box" theorems within the theory of regularity structures have established that a broad class of "subcritical" singular SPDEs admit a well-defined local solution theory, with a systematic renormalization procedure.

Universality and Scaling Limits

Just as Brownian motion arises universally as the scaling limit of many random walks, singular SPDEs capture universal limits of discrete models in statistical mechanics. A central example is the KPZ equation which is believed to describe the universal behavior



"Feynman diagrams" arising from coarse-graining analysis of moments of the critical 2D stochastic heat flow by Caravenna–Sun–Zygouras.

of growing random interfaces. Establishing such rigorous scaling limits has been a major challenge, requiring delicate analytic and probabilistic techniques, and recent progress has demonstrated convergence of a variety of lattice models — such as interacting particle systems, random polymers, random walk in random environments, and dynamics of ferromagnetic models — toward continuum SPDEs in appropriate scalings.

Renormalization and Quantum Field Theory

An intriguing aspect of singular SPDEs is their deep connection with quantum field theory (QFT). The regularity structures approach, for example, requires systematic subtraction of divergent terms, reminiscent of BPHZ renormalization in QFT. Recent work also shows structural correspondences between SPDE renormalizations and combinatorial Hopf algebras of Feynman diagrams. Many singular SPDEs are intimately linked to specific QFT models, and this parallel has enriched both fields. One example is the connection between the Φ^4 model in QFT defined through the functional integral over the formal measure

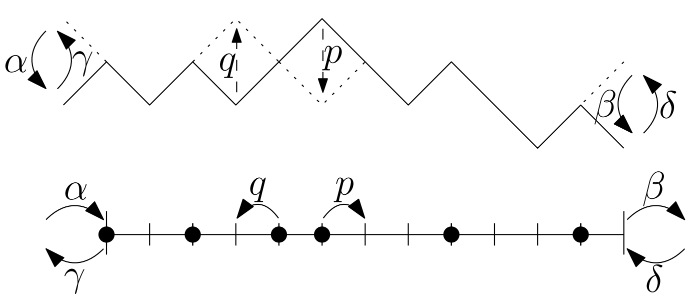
$$\exp(-\mathcal{S}(\Phi))D\Phi,$$

where

$$\mathcal{S}(\Phi) = \int_{\mathbb{R}^d} (\nabla\Phi(x))^2 + \frac{1}{2}\Phi(x)^4 \, dx,$$

and its SPDE counterpart given by $\partial_t \Phi = \Delta\Phi - \Phi^3 + \xi$, with ξ being a space-time white noise.

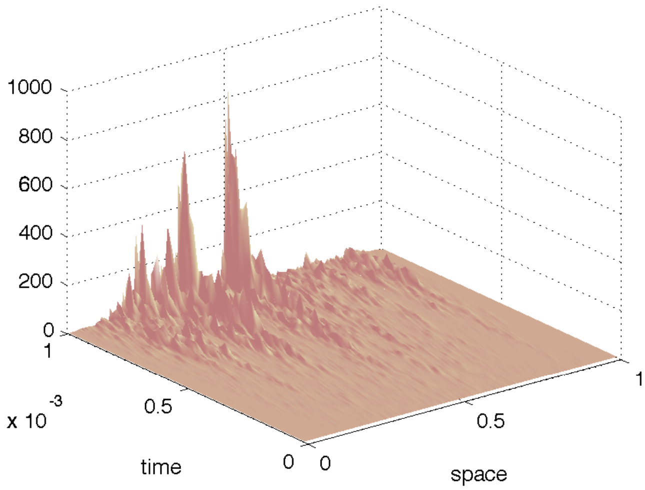
The analytic and probabilistic tools developed for SPDEs in turn feed back into the mathematical foundations of QFT, yielding rigorous understanding of QFT models including Φ^4, Høegh-Krohn, sine-Gordon, and certain types of gauge theories. Significant progress has been made in proving that these QFT models arise as invariant measures of wave or dispersive equations, a program initiated by Bourgain. This rich interplay between SPDEs and QFT is one of the most vibrant frontiers of the subject, yet it continues to pose a wealth of deep open questions.

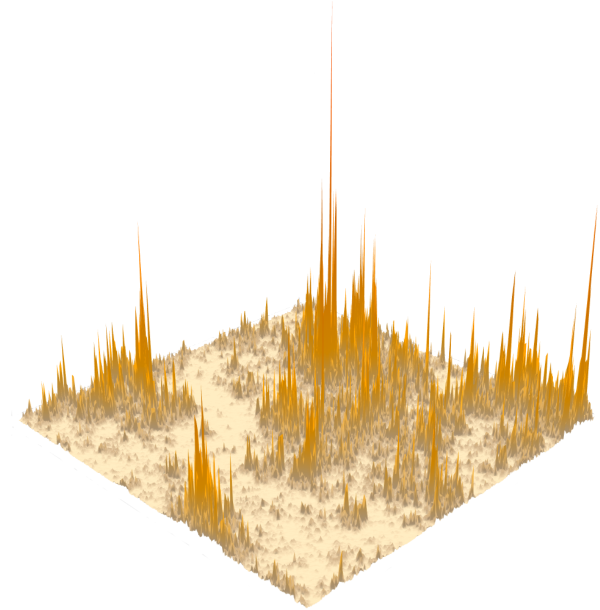


A non-equilibrium statistical physics model called the asymmetric simple exclusion process. Particles jump to the right or left to an empty site with probabilities p, q and are added or removed from boundaries with certain rates. A particle-counting curve on the top is a random interface, locally flipping up or down. Under proper scaling, the interface growth converges to the KPZ equation with suitable boundary conditions.

Subcritical and Critical Regimes

In the past decade parabolic SPDEs in subcritical regimes have developed into a relatively robust and general local solution theory. Subcriticality means that the small-scale singularities of the nonlinearity are dominated by the linear terms. For example, KPZ is subcritical in one space dimension: linear theory shows that h has Hölder regularity close to $\frac{1}{2}$, so $(\nabla h)^2$ scales like -1, more regular than Δh. In two space dimensions, however, it becomes critical since h would have scaling dimension 0. Hyperbolic and dispersive problems are more subtle. They exhibit their own probabilistic scaling, which typically imposes stricter thresholds than in the





At left: Simulation of the stochastic heat equation in one space dimension (from D. Khoshnevisan).
At right: Zoomed-in snapshot of the critical 2D stochastic heat flow (from Caravenna–Sun–Zygouras).

parabolic case, and often requires different analytical tools to establish well-posedness. Relative to such a probabilistic scaling, the theory of random tensors, developed by Deng–Nahmod–Yue, allows one to deal with the dispersive (Schrödinger) case for the entire subcritical range; and yields the dispersive counterpart "black box" theorems to those obtained in the parabolic setting.

In criticality regimes, only a few cases are currently understood, but recent results reveal striking new structures. The techniques behind the results are drastically different, and a diverging number of terms needs to be included in the expansion of solutions, causing the analysis and combinatorics substantially more intricate. One notable example is the stochastic heat equation (SHE) formally written as $\partial_t u = \Delta u + \beta u \xi$ with $\beta \geqslant 0$ and ξ a space-time white noise. In the critical two dimension, upon suitable renormalization, a phase transition emerges depending on β. Within a critical window of β, a unique scaling limit has been identified, now known as the critical 2D stochastic heat flow. Another example is the work of Deng and Hani on wave turbulence in the Schrödinger setting, who developed a sophisticated combinatorial molecular analysis to capture the dynamics.

Geometry, Asymptotics, Random Fields, and New Structures

The long term effects caused by small perturbations, both deterministic and stochastic, are of great interest in both theory and applications. The study of various limit results for SPDEs, in the framework of the theory of large deviations and metastability, of various realizations of the averaging principle, of stochastic homogenization problems, and of singular perturbations, as for example the small-mass limit problems, is receiving a large attention in the community. Interesting intermittency, and associated multifractal or dissipatory behavior, emerge in diverse contexts that range from various versions of Anderson localization models to chaotic dynamical systems and fluid. Multiscale analysis often plays a role, exposing how randomness manifests differently across scales.

The interplay becomes even more interesting when randomness interacts with geometric equations, such as wave maps, Maxwell–Klein–Gordon, Yang–Mills, and Liouville theory, in both parabolic and hyperbolic settings. These again have deep connections with quantum field theories, including σ-models, gauge theories, and conformal field theories.

Outlook

Despite the rapid progress, many fundamental questions remain. For instance: *Can solutions constructed locally in space and time be extended to the full Euclidean space and to global time horizons, for the most singular equations? What is the general behavior at or above the critical dimensions? Can we develop systematic methods to rigorously derive SPDEs as universal limits of microscopic physical models? Can we strengthen the tie between the mathematical frameworks and quantum field theories and thereby achieve a rigorous understanding of general QFT models such as σ-models or supersymmetric theories? How can renormalization be translated into reliable numerical simulations, thereby bridging abstract theory with practical modeling?*

These questions will shape much of the research in the coming decade. This semester's program aims not only to address them directly but also to build the intellectual bridges necessary for sustained progress across disciplines.

FOCUS *on the Scientist* **Franco Flandoli**

Franco Flandoli is a Research Professor in this semester's program on *Recent Trends in Stochastic Partial Differential Equations* (SPDEs). Franco is an internationally recognized expert in the theory of SPDEs and especially applications to stochastically perturbed fluids.

> *Franco is an internationally recognized expert in the theory of SPDEs and applications to stochastically perturbed fluids.*

Franco completed both his undergraduate and graduate studies at the Scuola Normale Superiore in Pisa, Italy, where he was a student of Giuseppe Da Prato. Today, he is a Professor at the Scuola Normale Superiore. Franco has supervised more than twenty Ph.D. and masters students. He has authored four books and over 200 academic papers and his research has been supported by several European Research Council grants.

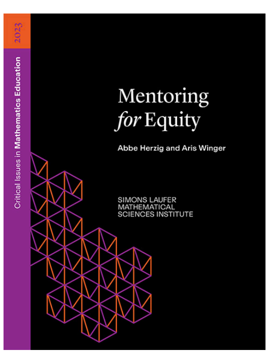
SPDEs describe the evolution in space and time of systems that are exposed to random perturbations. For example, the Navier–Stokes partial differential equations describe the evolution of a fluid, like air or water, under various forces. If these fluids are exposed to unpredictable random perturbations, their behaviors can be described by the stochastic Navier–Stokes equations. Franco has developed many mathematical tools to model the behaviors of stochastic fluids and to explain complicated physical phenomena like turbulence.

The addition of random forces to these physical systems leads to solutions with paths that are much rougher than the original unperturbed systems. Roughness, here, means that the solutions to the stochastic systems move up and down quickly and the solution curves are much bumpier than than the original non-random systems, which tend to have smooth curves. Franco has demonstrated that, despite the roughness of the paths, stochastic systems can exhibit many behaviors that are mathematically more desirable and more physically relevant than their non-random counterparts. Some non-random partial differential equations either have no solution, or too many solutions, or solutions that explode or feature other non-physical behaviors. Franco advanced the study of regularization by noise, demonstrating that adding random perturbations to some of these non-random systems can lead to a stochastic system with exactly one solution that is well behaved.

He also helped develop the theories of random attractors and synchronization by noise. In non-random systems, solutions that start from distant initial states generally exhibit different long-time behaviors. Franco showed that, under appropriate assumptions, stochastic systems that start from very distant initial states, when exposed to the same random perturbations, will eventually have the same behaviors after a long period of time.

Franco enjoys cooking, looking for mushrooms in the mountains, and painting, especially with his grandchildren. He is afraid of sharks and spiders, but he will never hesitate to approach a barking dog.

— *Mickey Salins*



Critical Issues in Mathematics Education Vol. 16

This compendium features the proceedings of the 2023 Critical Issues in Mathematics Education (CIME) workshop held in Berkeley, CA, on March 22–24, 2023. The volume is authored by **Abbe Herzig** (Sarah Lawrence College) and **Aris Winger** (Georgia Gwinnett College). The workshop included presentation and discussion of research evidence on the science of mentoring, review and adaptation of practical tools, and training in effective mentoring, with emphasis on bringing training and tools to participants' home institutions to meaningfully impact the mathematics community at the postsecondary level and beyond.

Mathical News

Readathon Returns

The Mathical Readathon has returned this fall, inviting U.S. educators from Pre-K through 8th grade to explore the Mathical Book List, with 179 titles to date for Pre-K through high school readers. As of early October, 39 educators from 18 states who teach 7,652 students have joined this year's reading program. The Readathon offers additional classroom resources to participating schools, including special video interviews with winning authors, activities for students, and deeper dives into the mathematical ideas featured in the fiction and nonfiction titles.

DON TATE

Posters for the Mathical Readathon by author and illustrator Don Tate (*Jerry Changed the Game!*).

In the 2024–25 school year, the inaugural Readathon was celebrated by 17,250 Pre-K through eighth grade students, led by 106 educators in 16 U.S. states, who read 13,284 Mathical books from Sep 2024 through May 2025.

Alameda County Book Distribution

SLMath has partnered with the Alameda County Office of Education (ACOE) in the East Bay for distributing approximately 1,025 Mathical Books for grades K-12 to 98 Title I schools serving low-income communities in Fall 2025.

Participating school districts in the county include Alameda, Berkeley, Castro Valley, Dublin, Emery, Fremont, Hayward, Livermore Valley, Mountain House, New Haven, Pleasanton, San Leandro, San Lorenzo, and Sunol Glen.

ALAMEDA COUNTY OFFICE OF EDUCATION

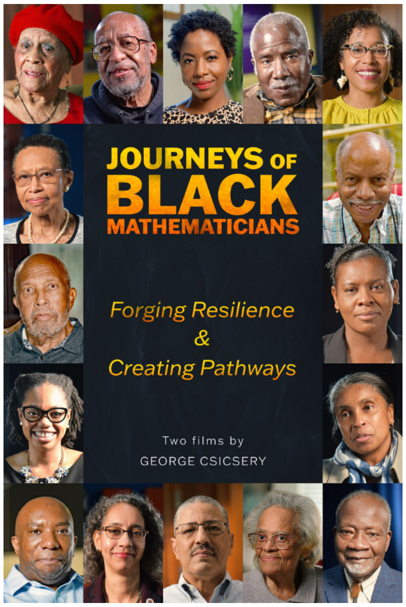
All donated books are part of the Mathical List, and include editions in both English and Spanish translation for school library collections. This donation of new books is made possible through the generosity of the Firedoll Foundation.

Celebrating *Journeys of Black Mathematicians* Films' Public Television Debut

Journeys of Black Mathematicians, SLMath's latest documentary film series with director George Csicsery of Zala Films, has been broadcast on U.S. public television stations since February this year. During its first six months of release, the two-part series was aired nearly 2,000 times on 361 television stations in 48 states, accessible to over 88% of the American viewing public, as well as via the PBS Passport online streaming service. The film continues to add broadcast dates over the next five years, in addition to screenings at universities, conferences, and special events worldwide.

Having collected hundreds of hours of interview footage with dozens of participating mathematicians, SLMath and Zala Films are partnering with the National Association of Mathematicians (NAM) on a forthcoming project to preserve these important histories for future generations of mathematicians and scholars. More details to come in Spring 2026.

The two-film series is available for online streaming video rental or purchase, or on DVD via Zala Films.



The **Puzzles** *Column*

Joe Buhler, Tanya Khovanova, and Pavlo Pylyavskyy

1 You are given ten numbers: one 1 and nine 0's. You are allowed to replace any two numbers with their average (arithmetic mean). What is the smallest number that can appear in place of the 1 after a series of such operations?

Comment: Leningrad Mathematical Olympiad, 1984. The author of the problem was Grigori Perelman when he was about 18 years old!

2 Find an expression for each of the integers from 1 to 12 that uses three 2's, *no* other digits, and *any* other standard mathematical symbols of your choosing! For example: $1 = 2 - 2/2$.

3 The trace of a matrix A equals 0. Prove that A can be decomposed into a finite sum of matrices, such that the square of each of them equals the zero matrix.

Comment: National University of Kyiv, 1996

4 Consider an 8×8 chessboard where walls may be placed between some pairs of adjacent squares. Such a board will be called a maze. A maze is said to be good if a rook can move to reach every square without ever crossing a wall; otherwise, it is called bad. Which type of mazes are more numerous: good or bad?

Comment: Tournament of Towns, 1997

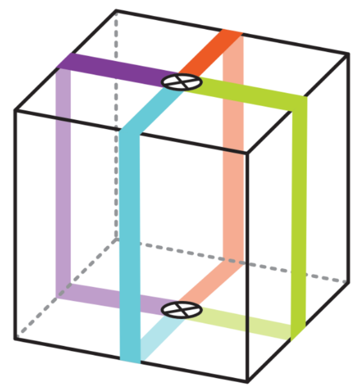
5 Is it possible to dissect an equilateral triangle into five pairwise non-congruent isosceles triangles?

Comment: Lomonosov Tournament, 1997

6 Do there exist two functions $f, g\colon \mathbb{R} \to \mathbb{R}$ such that for all $x \neq y$ the following inequality holds:

$$|f(x) - f(y)| + |g(x) - g(y)| > 1\,?$$

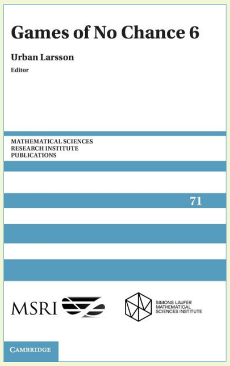
Comment: Iranian Math Olympiad, 2009



7 The centers of two opposite faces of a cube are connected by four distinct shortest paths, as shown in the picture above. Can you find two points on the surface of a cube, such that there are exactly three shortest paths connecting them?

Comment: This problem will appear early in 2026 in the forthcoming *Mathematical Puzzles and Curiosities*, by Ivo Fagundes David de Oliveira, Tanya Khovanova, and Yogev Shpilman (published by World Scientific).

Send your thoughts to the authors at puzzles@slmath.org. Solutions will usually be posted online before the next issue is published.



MSRI Publications Vol. 71: *Games of No Chance 6*

MSRI Publications is a series based on work undertaken at SLMath (and formerly at MSRI), that publishes surveys and workshop proceedings of long-lasting value, as well as lecture notes and monographs by visitors to the Institute. The newest volume is edited by **Urban Larsson** (Indian Institute of Technology, Bombay), and features 22 research papers and state-of-the-art surveys extending the subseries "Games of No Chance" pioneered in 1996. Survey topics include Richman bidding combinatorial games, classical subtraction games and absolute additive theory. The series editor is Silvio Levy (Mathematical Sciences Publishers). Earlier volumes in the series may be available from the former publisher, Springer-Verlag.

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Marriott Marquis Washington, DC

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See a full list of sessions on our website

Walter E. Washington Convention Center, Room 144C

Friends of SLMath (MSRI) Teatime Reception*

Featuring a celebration of the 20th anniversary of MSRI-UP

Tuesday, January 6, 2026
3:00–4:30pm

Marquis Ballroom Salon 15
(Meeting Level 2)
Marriott Marquis Washington, DC

**The Teatime Reception does not appear in the JMM conference agenda, but all are welcome to attend. Questions about either event? Contact development@slmath.org*