SIMONS LAUFER
MATHEMATICAL
SCIENCES INSTITUTE

17 Gauss Way

SPRING 2024

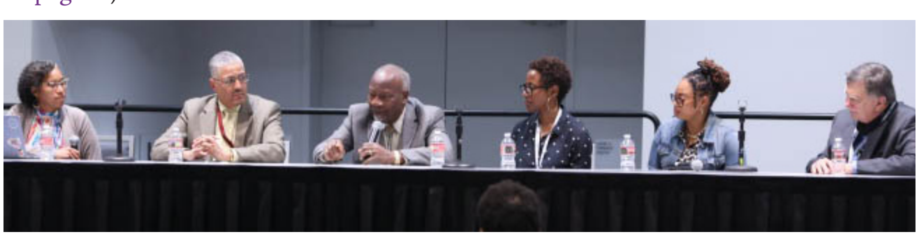
SLMATH.ORG

IN THIS ISSUE

SLMATH | # 17 Gauss Way

On the Cover: A quadratic cone intersecting a smooth quadratic surface in the union of a vertical line and a twisted cubic. Picture courtesy of Herwig Hauser, University of Vienna. See the *Commutative Algebra* program article on page 14.

Below: SLMath–NAM panelists discuss the new *Journeys of Black Mathematicians* film at the 2024 Joint Mathematics Meetings in San Francisco (see Update, page 4, and article on page 18).



SPRING 2024

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 National Science Foundation, joined by the National Security Agency, over 100 Academic Sponsor Institutions, a range of private foundations, and generous and farsighted individuals.

DIRECTOR'S

Update

Tatiana Toro, Director

At CIME 2024, stakeholders in undergraduate math education met to explore "Bringing Innovation to Scale: Teaching-Focused Faculty as Change Agents."

Spring Activities

This spring has been a busy time at SLMath for visitors and staff. Chern Hall is filled with the activity of the many mathematicians who have joined us as researchers and workshop participants in the *Commutative Algebra* and *Noncommutative Algebraic Geometry* programs. Additionally, the Institute's National Science Foundation (NSF) recompetition proposal was submitted in March and engaged most of SLMath's staff.

Since we welcomed our first research programs 40 years ago, the NSF's support has been the bedrock of our scientific activities, bringing together the most creative domestic and international mathematical scientists across generations towards the expansion of research at the frontiers of knowledge. NSF support also helps us attract additional public and private funding that has broadened our mission to develop mathematical talent, cultivate a sense of belonging and engagement, and support initiatives to increase the public's understanding of math both across the U.S. and worldwide.

In the NSF proposal, we have emphasized that SLMath is a collaborative endeavor with the mathematical community, who are represented by 117 Academic Sponsor Institutions, our Board of Trustees and advisory committees, and our many program and workshop organizers, all of whom volunteer their time and expertise to make SLMath the incredible, multi-generational center of activity it has become. Hélène and I extend our deepest thanks to everyone who has helped with the grant proposal, and we will share further news in the coming months.

First Endowed Summer Graduate School

SLMath's Summer Graduate Schools (SGS) serve the wider mathematical community. Graduate student nominations are welcomed from all U.S. mathematics-Ph.D.-granting institutions and from SLMath's international academic sponsors. For many years, the Institute hosted 4–6 SGS annually. SLMath now hosts 12 summer schools serving nearly 400 students annually, with over half taking place at partner institutions around the world. Hélène gives further details of this growth on page 9.

As part of our expanded offerings, a new SGS honoring **John Wilder Tukey** (1915–2000) has been fully endowed in his memory by **Robert and Luisa Fernholz** through the Fernholz Foundation. A mathematician at Princeton University and a technologist who served as vice president of Bell Labs, Tukey was particularly interested in using computers to transform intellectual activity and research; in his 1961 article "The Future of Data Analysis," Tukey predicted the advent of something akin to today's data science movement.

Beginning in 2026, the biennial Tukey SGS will explore how science and technology are revolutionizing the intellectual activity of human beings. Artificial intelligence and machine learning are redrawing the scientific landscape, and this school furthers SLMath's commitment to highlighting the power and value of the mathematical sciences to society.

Journalist in Residence Program

This year will also bring a different type of visitor: **Siobhan Roberts**, SLMath's inaugural Journalist in Residence. The Journalist in Residence program will expand the public's awareness of the role the mathematical sciences play in everyday life. Roberts (pictured) will be in residence at SLMath for up to four months. She will interact with mathematicians, write at least three articles about mathematics (none about the Institute, to avoid potential conflicts of interest), give a public talk, and lead a professional development workshop about how to effectively communicate scientific information to the public.

Roberts is a Canadian author, *New York Times* contributor, and independent science journalist. She has also written for *Quanta*, *The New Yorker* "Elements" blog, and *The Mathematical Intelligencer*, among other publications. Roberts' first book, *King of Infinite Space: Donald Coxeter, The Man Who Saved Geometry*, was the winner of the Mathematical Association of America's 2009 Euler Prize for expanding the public's view of mathematics. Her latest book is *Genius at Play, The Curious Mind of John Horton Conway*, and she is currently writing a book about the group theorist and mathematical logician Verena Huber-Dyson.

(Update continues→)

New Film Release: *Journeys of Black Mathematicians*

In January, SLMath partnered with the National Association of Mathematicians (**NAM**) and director **George Csicsery** of Zala Films for the world premiere of *Journeys of Black Mathematicians: Forging Resilience* at the Joint Math Meetings in San Francisco, with a panel of mathematicians featured in the film joining us to share their experiences. Panel chair **Omayra Ortega**, panelists **Duane Cooper**, **Johnny L. Houston**, **Emille D. Lawrence**, **Anisah Nu'Man**, and director George Csicsery are pictured on page 2. You can read more on page 18, including how to view the film or screen it at your institution or event. Thank you to everyone who has shared their stories with us for this project. We look forward to the anticipated release of the second film in the series in 2025.

Remembering Georgia M. Benkart

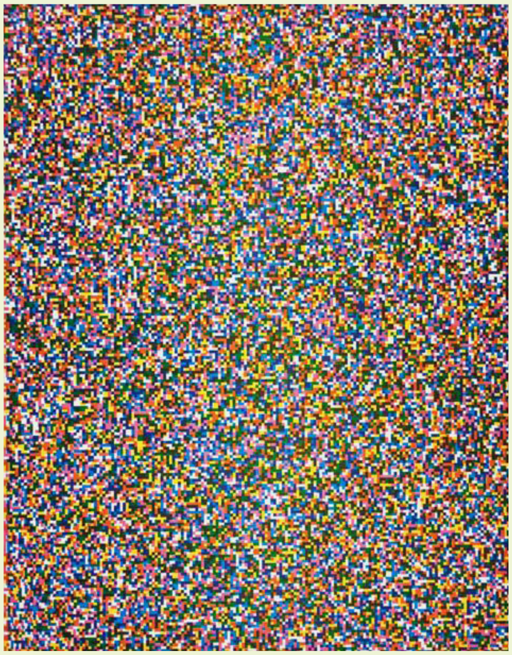
This May, we are honored to host a special workshop, *Advances in Lie Theory, Representation Theory, and Combinatorics*, inspired by the work of **Georgia Benkart** (1947–2022). In addition to her extraordinary legacy in the mathematical community, Georgia was a longtime member of the Institute's Board of Trustees, served as Chair and member of the Committee on Women in Mathematics, and supported a number of initiatives at MSRI, including the Summer Research in Mathematics program. In partnership with the American Mathematical Society and the Association for Women in Mathematics, this workshop will bring together scholars working in these fields to celebrate her legacy, remembering her inspiring and welcoming spirit in both collaborative research and life.

AARON FAGERSTROM

Participants anticipate the February 2024 introductory workshop in the *Noncommutative Algebraic Geometry* program.

Strength in Collaboration

The spring semester at SLMath demonstrates how productive collaborations lead to successful initiatives, from our scientific and outreach activities to our NSF proposal submission. We thank our many collaborators and partners for ensuring SLMath's current and continued success.



Art at 17 Gauss Way: Tauba Auerbach

Curated by SLMath architect William Glass, the Institute is hosting an exhibit of 13 color aquatint etchings by artist Tauba Auerbach in cooperation with Paulson Fontaine Press of Berkeley. Auerbach creates art about language and logic through painting, drawing, photography, sculpture, and instrument building. Her one-person exhibition *Tetrachromat* has been hosted in Norway, Sweden, and Brussels.

In 2011 Auerbach was awarded the Smithsonian's Artist Research Fellowship. Auerbach's work has been included in exhibits at MoMA PS1 and the New Museum in New York, and is in the permanent collections of The Whitney Museum of American Art and the Museum of Modern Art (New York), among others. In 2021–22 her work was featured in a solo exhibit at the San Francisco Museum of Modern Art. She is represented by Paula Cooper Gallery, New York, and STANDARD, Oslo, Norway.

The exhibit is on view through June 2024 on the second floor of SLMath.

"A Half Times a Half Times a Half," Tauba Auerbach (2008).

Program Article

Noncommutative Algebraic Geometry

Mikhail Kapranov

Why do we need different types of geometry? While geometry is one of the oldest branches of mathematics, its underlying reality — the space around us — is a physical object, and its understanding changes as our knowledge develops. For example, the structure of our space (or spacetime) at very short distances in not known. Indeed, to "observe" it (visually or otherwise) we need something like light (or, in practice, other media) of extremely short wavelength, which requires increasing amounts of energy and eventually becomes impossible to produce.

So we cannot assume that at extremely small ranges our space has the same general structure as we are used to from everyday life: that it consists of points which are arranged continuously next to each other, with well defined distances between them, and so forth. The premises on which we base our development of geometry must be reexamined.

There have traditionally been several branches of geometry: differential geometry, algebraic geometry, topology, combinatorial geometry, and so on. But all these types agreed on certain assumptions (like those above) on what we should understand by a "space" in the first place, and differed only in the approaches they took in studying it: differential calculus, algebraic equations, and so on.

However, in recent decades, several new directions of geometry appeared that require a change in the very way we think about geometric shapes. Noncommutative geometry is one of them. It is the subject of one of the two thematic programs currently held at SLMath; the other is dedicated to commutative algebra which, together with algebraic geometry, is one of the parent disciplines of our subject.

Commutative Algebra and Algebraic Geometry

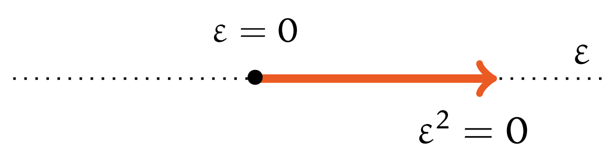
Classical algebraic geometry studies geometric images, called *varieties*, given by algebraic (polynomial) equations such as

$$x_1^5 + x_2^5 + \ldots + x_5^5 = 0. \qquad (\dagger)$$

The newer organizing principle, introduced by A. Grothendieck in the 1960s, is that a variety (in fact a "space" in a much more general sense) X is determined by the collection R of functions on X. Such functions can be added, subtracted, and multiplied pointwise — that is, they form a mathematical structure called a *ring*. The rings of functions have one obvious but important property, that the multiplication is commutative: $f \cdot g = g \cdot f$. This is crucial for the formalism of algebraic geometry to work.

For example, if X is the n-dimensional coordinate space, then the corresponding R consists of all polynomials $f(x_1, \cdots, x_n)$ in n variables. If X is given by a polynomial equation, like (†), then the corresponding R is obtained from the polynomial ring by a natural identification: We consider as one any two polynomials f, g whose difference is a multiple of the equation. One refers to X as the *spectrum* of R and writes $X = \mathrm{Spec}(R)$. The word "spectrum" comes from spectral theory of linear operators (the theory of eigenvalues): commuting operators have joint spectrum.

The important (and initially controversial) step in Grothendieck's theory is that one can associate the geometric image (called a *scheme*) $\mathrm{Spec}(R)$ to any commutative ring R whatsoever. An important nonclassical example is given by the *ring of dual numbers* D. An element of this ring is an expression $a + b\varepsilon$; such expressions are multiplied formally using the rule $\varepsilon^2 = 0$, which is the equation in this case. Naively, D cannot be realized as the set of functions on anything, because there is no number other than 0 that squares to 0. Nevertheless, the scheme $\mathrm{Spec}(D)$ has a meaningful geometric interpretation: it is viewed as having one point (where $\varepsilon = 0$) and also having the tangent direction at this point, but no further data. In a way, this is a revival of the old idea of "infinitesimally small quantities": ε itself is not yet zero, but is "so small" that ε^2 is already negligible.



The scheme given by the equation $\varepsilon^2 = 0$.

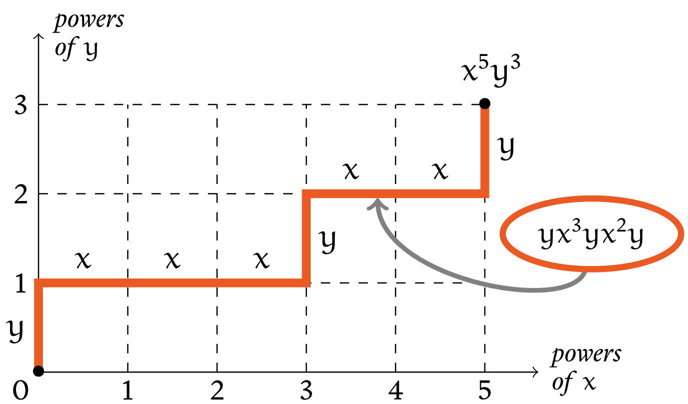
In this way, commutative algebra — the study of commutative rings — becomes identical with algebraic geometry "in the medium range," describing elementary charts that can be glued together to form more complicated schemes. This interrelation has been mutually enriching for both fields.

Noncommutative Geometry

The spectacular success of "visualization of commutative rings" given by the scheme theory led to repeated attempts to extend it to *noncommutative rings*, algebraic structures in which the multiplication can lead to $f \cdot g \neq g \cdot f$.

In fact, it was the advent of quantum mechanics which brought noncommutative rings into the forefront of physics. Usual physical quantities are promoted there to noncommuting "operators." A typical commutation relation is $p \cdot q - q \cdot p = i\hbar$ between the operators corresponding to the coordinate and momentum of a particle. There are many other examples in pure mathematics, such as multiplication of matrices, or composing transformations (that is, operations of some kind). In fact, if we do any actions in a sequence, the result usually depends on the order. To put on a shirt and then a jacket is not the same as to first put on a jacket and then a shirt!

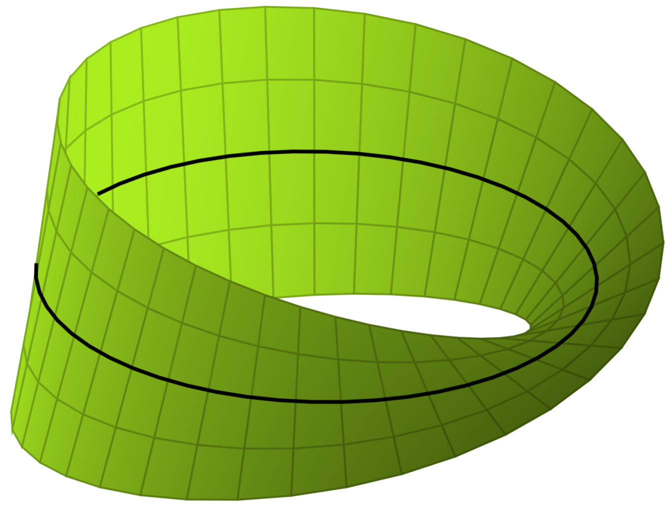
A good illustration of the challenges presented by noncommutativity is provided by the concept of "noncommutative polynomials." For instance, consider two variables x, y that do not commute. Then we have four quadratic monomials: x^2, xy, yx, y^2, all different. If we think of x, y as commuting, then xy and yx are the same, but as noncommutative monomials they are different. In this way, a single commutative monomial can be represented by several noncommutative ones. For example, x^5y^3 can be lifted to yx^3yx^2y, or to xyx^2yxyx, or to several others. It is convenient to make a picture (known as *Newton's diagram*) depicting a usual monomial, say x^5y^3, by a point on the plane with coordinates $(5, 3)$. Then a noncommutative lifting of this monomial corresponds to a "taxicab path" (like in a city with a grid of street blocks) starting from $(0, 0)$ and ending at $(5, 3)$. That is, one move to the east corresponds to x and one move to the north corresponds to y. See the figure below.



A noncommutative monomial represented by a path.

Thus a noncommutative polynomial is really a sum over such paths. Making x and y commute means that we perform *summation over paths* with fixed beginning and end. This means that "commutativization" (forcing noncommutative rings to be commutative) can be seen as an algebraic analog of path integration, which is a fundamental conceptual tool of modern physics.

One way of attaching geometric intuition to noncommutative rings is to use the concept of a *vector bundle* in geometry, a continuous family of vector spaces parametrized by a space X. For example, the Möbius strip (see top of next column) is a vector bundle over its central (black) circle: a family of "vertical" lines parametrized by it. If X corresponds to a ring R, then a vector bundle on X gives rise to an algebraic object M called a *module* over R, where we can multiply elements r of R and m of M to get an element $m' = r \cdot m$ of M.



$$r \cdot m = m'$$

The Möbius strip and the multiplication in a module.

This concept makes sense for noncommutative rings R as well. The collection (or in more precise terminology, the *category*) of all R-modules is an important invariant of R of decidedly noncommutative flavor, even if R is commutative. This is because homomorphisms (structure-preserving maps) of modules are essentially matrix-type data and matrices do not commute in general.

It is often useful to work not with single modules but with *complexes*: sequences

$$\cdots \xrightarrow{d_{-2}} M_{-1} \xrightarrow{d_{-1}} M_0 \xrightarrow{d_0} M_1 \xrightarrow{d_1} \cdots$$

of modules M_i and homomorphisms d_i such that $d_i d_{i-1} = 0$. The so-called *derived category* $D(R)$ formed by these is a fundamental object of study. This approach can also be applied to ordinary (commutative) schemes X, using coherent sheaves on X instead of modules. It gives the *coherent derived category* $D(X)$.

Directions of Current Research

(1) Poisson algebras and their quantization. Studying noncommutative rings as deformation of commutative ones leads to the concept of Poisson algebras: commutative rings with infinitesimal noncommutativity data — *Poisson brackets* — added. While the concept is as old as classical mechanics (Hamilton's equations of motion can be written using such brackets), recent research has uncovered a whole world of highly nontrivial examples, coming from both pure mathematics (symplectic resolutions) and physics (Coulomb branches of quantum field theories). Quantizing these examples, that is, actually performing the deformation, leads to a very important class of noncommutative algebras which are the subject of intensive study.

(2) Quiver representations. A fruitful generalization of the ring of noncommutative polynomials is obtained when the variables x_i are assigned to edges of an oriented graph (quiver) Q so that only consecutive edges are multiplied in nonzero way. A monomial

FOCUS *on the Scientist* Michel Van den Bergh

AARON FAGERSTROM

Michel Van den Bergh is a Chern Professor in this semester's *Noncommutative Algebraic Geometry* program. He is director of research at the Research Foundation Flanders, based at Universiteit Hasselt, and part-time professor at the Vrije Universiteit Brussel.

Michel obtained his Ph.D. in 1985 from the University of Antwerp with supervisors Fred Van Oystaeyen and Jan Van Geel. Already in 1987, he was a Laureate of the Belgian Academy of Sciences. In 2003 he was awarded the prestigious interdisciplinary Franqui Prize from the Belgian Franqui Foundation and and in 2021 he held the Franqui Chair at the Université Libre de Bruxelles. In 2020 he received an ERC Advanced Grant for the project "Schobers, mutations and stability (SCHEMES)."

Having his mathematical roots in ring theory, Michel laid the foundations for the subject currently known as noncommutative algebraic geometry (NCAG) in the famous 1990 paper with Artin and Tate on "Some Algebras Associated to Automorphisms of Elliptic Curves." His categorical perspective on the resulting noncommutative projective planes and more general schemes took the vision of Grothendieck to the next level.

Apart from developing key geometric constructions like blowing up (and down) in the noncommutative realm, Michel introduced fundamental concepts ranging from double Poisson algebras to, joint with Bondal, strong generation of triangulated categories. His work on duality in noncommutative contexts has also proven very influential, with the duality for Hochschild (co)homology of Gorenstein rings, which was named after him, being just one example. Using deformation theoretic methods, Michel realized breakthroughs like the proof, with Calaque and Rossi, of Căldăraru's conjecture and more recently his work with Rizzardo on nonexistence of various enhancements. A particularly striking

Not only has Michel's work shaped the noncommutative landscape, his vistas from the mountaintop continue to inspire.

contribution of Michel's is the concept of a noncommutative crepant resolution and subsequent work, which perfectly illustrates the power of NCAG methods in subjects like birational geometry and geometric invariant theory.

Michel was an invited speaker at the International Congress of Mathematicians for the first time in 1994 in the algebra section, where he spoke on his work on Cohen–Macaulay modules of invariants and Stanley's conjecture, and then again in 2022 as plenary speaker with a natural sequel on "Noncommutative resolutions of quotient singularities and the stringy Kähler moduli space," highlighting the recent spectacular results with Špenko.

Not only has Michel's work shaped the noncommutative landscape, his vistas from the mountaintop continue to inspire highly esteemed colleagues and new generations of researchers alike to further explore his profound and beautiful ideas.

Finally, Michel's interests extend well beyond mathematics, including topics of technological, scientific, and philosophical flavor, such as AI (to give just one example). His extraordinary insight and esprit make him a wonderful discussion partner on basically any intellectually challenging subject.

— Wendy Lowen

is now a path in Q and the ring is known as the *path algebra*. Modules over such algebras (and over their natural quotients). are known as representations of quivers (with relations). Especially interesting are parameter spaces parametrizing different such representations. Studying the topology of these spaces leads to new noncommutative objects known as *cohomological Hall algebras* which are powerful tools in the theory of Donaldson–Thomas invariants of algebraic varieties.

(3) Noncommutative desingularizations. The noncommutative point of view brings new insights already for ordinary (commutative) varieties. Thus, singular (non-smooth) varieties can often be "smoothed" very naturally using noncommutative objects. Such smoothings can be easier and more useful than more traditional commutative smoothings.

(4) Derived categories. Studying varieties (commutative or noncommutative) by means of their coherent derived categories uncovers new symmetries which are not visible at the ordinary level. For example, the famous homological mirror symmetry conjecture of Kontsevich, which conceptualized physicists' predictions for the numbers of algebraic curves on the projective variety defined by (†), cannot even be formulated without using derived categories. For a large class of varieties X, it identifies D(X) with a category of a totally different nature (known as the Fukaya category) and predicts an action on D(X) of a large discrete group of transformations related to the "dual" variety. Various ramifications of this conjecture remain important sources of inspiration and problems in the forefront of active research.

Graduate Fellows / SPRING 2024




PHOTOS AARON FAGERSTROM

Sandra Sandoval Gómez is the Marie A. Vitulli graduate fellow in the *Commutative Algebra* program. She is a fourth-year graduate student at the University of Notre Dame under the supervision of Claudia Polini and Bernd Ulrich. She received a bachelor's degree in mathematics at the University of Guanajuato in México advised by Luis Núñez-Betancourt and Jack Jeffries with a thesis on symbolic powers. Her graduate work focuses on DG-algebra structures of resolutions of determinantal rings and their uses to compute and compare Kähler and Dedekind differents.

Ravali Nookala is the Salgo-Noren Foundation graduate fellow in the *Noncommutative Algebraic Geometry* program. Ravali is currently pursuing her Ph.D. in Mathematics at Carleton University under the supervision of Colin Ingalls. Prior to embarking on her doctoral journey, she earned her master's degree in mathematics from the National Institute of Technology, Rourkela. Her research endeavors are primarily focused on exploring components of the moduli space of Koszul Artin–Schelter regular algebras of dimension four.

Eliana Tolosa Villarreal is the Salgo-Noren Foundation graduate fellow in this spring's program on *Commutative Algebra*. She completed her undergraduate studies at the Universidad Nacional de Colombia at Bogotá, where she is from. In 2019 she obtained her master's degree from San Francisco State University as a student of Federico Ardila. She is currently a Ph.D. student at the Università degli Studi di Genova, advised by Aldo Conca. Eliana's research lies in the intersection of commutative algebra and combinatorics. In particular, she studies algebraic properties of Lovász–Saks–Schrijver ideals, which are ideals of the polynomial ring that are associated with orthogonal representation of graphs.

Antonios-Alexandros "Alekos" Robotis is the Stephen Della Pietra graduate fellow in the *Noncommutative Algebraic Geometry* program. He is currently a fifth year Ph.D. student at Cornell university working under the supervision of Daniel Halpern-Leistner. He earned his undergraduate degree in mathematics from U.C. Berkeley before obtaining a master's degree from NYU's Courant Institute of Mathematical Sciences. His research is in the field of complex algebraic geometry, with particular interests in derived categories, Bridgeland stability conditions, moduli of curves, and relations between these objects.

*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.*

Call for Membership

SLMath invites membership applications for the 2025–2026 academic year in these positions:

Research Professors by Oct 1, 2024
Research Members by Nov 15, 2024
Postdoctoral Fellows by Nov 15, 2024

In the academic year 2025–2026, the research programs are:

Kinetic Theory: Novel Statistical, Stochastic, and Analytical Methods, Aug 18–Dec 19, 2025
Organized by Laurent Desvillettes, Irene M. Gamba, François Golze, Pierre Emmanuel Jabin, Qin Li, Chiara Saffirio, Lexing Ying

Recent Trends in Stochastic Partial Differential Equations, Aug 18–Dec 19, 2025
Organized by Sandra Cerrai, Yu Gu, Massimiliano Gubinelli, Davar Khoshnevisan, Andrea Nahmod, Hao Shen, Lorenzo Zambotti

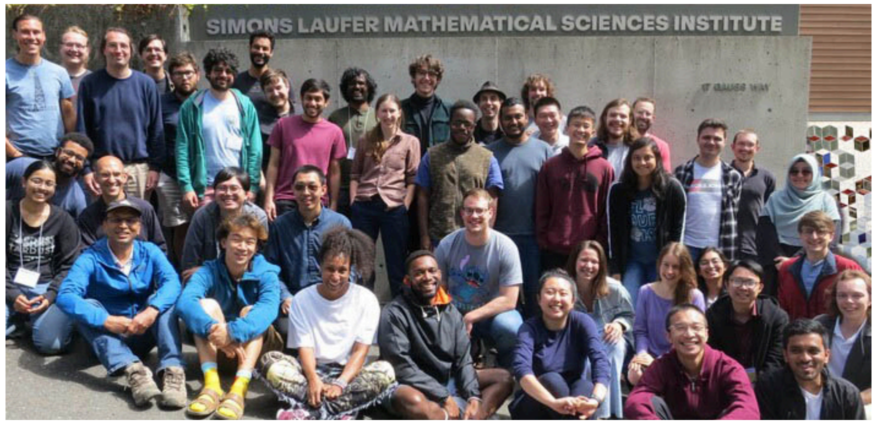
Geometry and Dynamics for Discrete Subgroups of Higher Rank Lie Groups, Jan 20–May 22, 2026
Organized by Martin Bridgeman, Richard Canary, Amir Mohammadi, Hee Oh, Maria Beatrice Pozzetti, Jean-François Quint

Topological and Geometric Structures in Low Dimensions, Jan 20–May 22, 2026
Organized by Ian Agol, Kenneth Bromberg, Sebastian Hensel, Christopher Leininger, Kathryn Mann, Yair Minsky, Rachel Roberts

SLMath uses MathJobs to process applications for its positions. Interested candidates must apply online at www.mathjobs.org after Aug 1, 2024. For more information about any of the programs, please see www.slmath.org/programs.

A Chance to Reflect on Five Years of Progress

Hélène Barcelo, Deputy Director



Participants in the Formalization of Mathematics SGS, June 2023

Preparing SLMath's 2025–30 NSF core grant has given us the opportunity to reflect on the remarkable strides made since 2018.

Over the past five years, SLMath has been a bustling hub of mathematical research. From August 2018 through July 2023, we hosted an impressive array of scientific activities, bringing together more than 12,000 researchers, educators, and students from across the globe. Among these were 20 semester-long programs and reunions, 40 summer graduate schools, 68 workshops, and five iterations of ADJOINT, MSRI-UP, and Summer Research in Mathematics!

A National Resource

According to NCSES data, of the 199 U.S. institutions granting a Ph.D. in mathematics since 2008, 95% have sent participant(s) to SLMath activit(ies). We were proud to observe that, since 2009, only ten U.S. math-Ph.D.-granting institutions have not sent participants to SLMath. We hope to expand our reach to 100% of the U.S. mathematical community in the coming years. We were also happy to see that 35 "super users" have sent participants to five (26) or six (9) of SLMath's activities, including six minority-serving institutions.

Summer Graduate Schools

In recent years, SLMath's Summer Graduate Schools have seen a surge in demand. From 345 nominations in 2017 to a staggering 680 in 2022, SLMath's impact on future mathematicians is clear. In the past three years alone, we have served 127 U.S. Ph.D.-granting departments, 29 non-U.S. institutions, and 11 non-Ph.D.-granting U.S. institutions.

We have developed a robust suite of local, national, and international Summer Graduate School partnerships to enhance the research experience and networks of early-career mathematicians. Two new international partnerships are in the works for Summer 2025.

Postdoctoral Fellowships

SLMath's commitment to fostering early-career talent is also evident in the success of its postdoctoral fellowship program. An external evaluation of our 2017–23 postdoctoral program has just been completed. With approximately 60% U.S.-based fellows, nearly a third being women, and 14% being underrepresented minorities (as defined by the NSF), we proudly surpass national averages. Fellows report high levels of satisfaction with the mentoring program and credit SLMath as a key stepping stone as they advance in their careers.

Celebratio Mathematica

As reported in detail on page 24, in 2023 SLMath published volumes honoring The Miracle Group (Alice Chang, Jang-Mei Wu, Chuu-Lian Terng, Fan Chung, Winnie Li, Mei-Chi Shaw), Georgia Benkart, and Yvonne Choquet-Bruhat. An edition dedicated to Maryam Mirzakhani is slated for completion in 2024.

As we anticipate forthcoming opportunities with an optimistic outlook on the success of our 2025–30 NSF grant proposal, we extend our heartfelt gratitude for your diverse and invaluable contributions to the SLMath community.

AMS/NSF Math Institutes Congressional Briefings

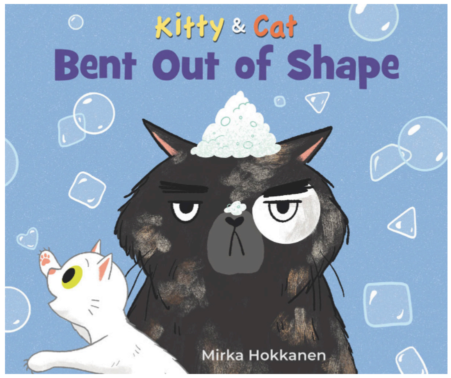
The American Mathematical Society holds annual congressional briefings in partnership with the six NSF-funded Mathematical Sciences Institutes as a means to share stories about how federal investment in basic research in math and science pays off for American taxpayers and helps the nation remain a world leader in innovation.

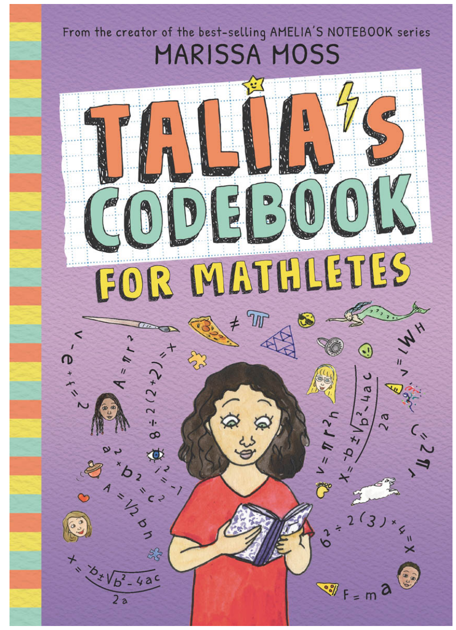
The April 2024 briefing was organized by SLMath and features **Dana Randall** (Georgia Institute of Technology) on "Collective Intelligence: How Local Interactions Determine Global Coordination." Randall's research in randomized algorithms and stochastic processes bridges computer science, discrete mathematics, and statistical physics. She is a fellow of the American Mathematical Society and a National Associate of the National Academies, as well as a former Sloan fellow and NSF Career award recipient.

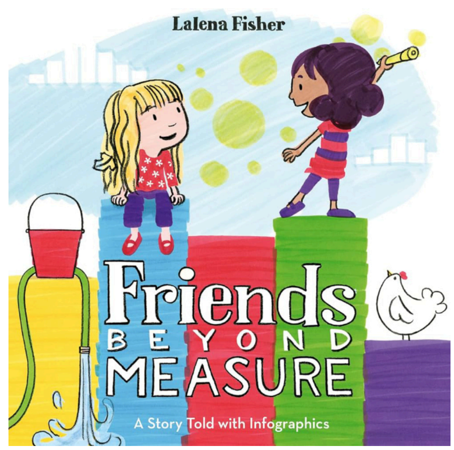
Randall was a research professor in SLMath's Fall 2023 *Algorithms, Fairness, and Equity* program and is an organizer of the upcoming Spring 2025 program on *Probability and Statistics of Discrete Structures*.

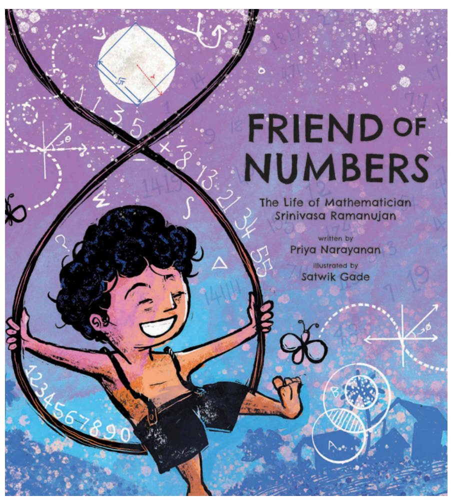
2024 Mathical Book Prize Winners…

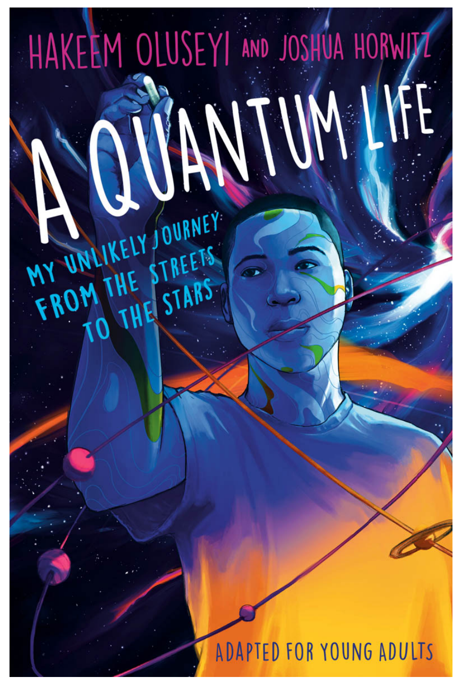
SLMath has announced the 2024 winners of the Mathical Book Prize, which recognizes outstanding fiction and literary nonfiction for youth ages 2–18. Here are the 2024 Prize winners; additional Honor Books winners follow on page 11.











Pre-K

Kitty & Cat: Bent Out of Shape, written and illustrated by Mirka Hokkanen (Candlewick Press)

Grades K–2

Friends Beyond Measure: A Story Told with Infographics, written and illustrated by Lalena Fisher (HarperCollins)

Grades 3–5

Friend of Numbers: The Life of Mathematician Srinivasa Ramanujan by Priya Narayanan, with illustrations by Satwik Gade (Eerdmans Publishing/ Eerdmans Books for Young Readers)

Grades 6–8

Talia's Codebook for Mathletes, written and illustrated by Marissa Moss (Candlewick Press)

Grades 9–12

A Quantum Life (Adapted for Young Adults): My Unlikely Journey from the Streets to the Stars by Hakeem Oluseyi and Joshua Horwitz (Random House Children's Books)

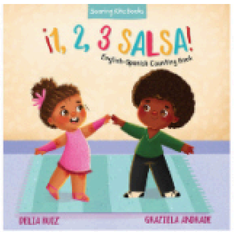
The Mathical Prize, now in its tenth year, is selected annually by a committee of Pre-K–12 math and language arts teachers, librarians, mathematicians, early childhood experts, and others. This year's selection committee was co-chaired by **Katie Hendrickson** of Code.org, **Chris Nho** of Desmos, and **John Urschel** of the MIT Mathematics Department.

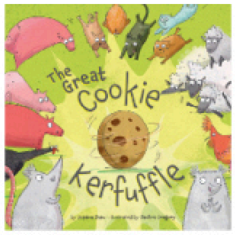
*The 2024 Mathical Book Prize is awarded by SLMath in partnership with the **National Council of Teachers of English** (NCTE) and the **National Council of Teachers of Mathematics** (NCTM), and in coordination with the **Children's Book Council** (CBC). Mathical is made possible through the generous support of the **Firedoll Foundation**, the **Guru Krupa Foundation**, and the foresight of individual donors, including **Sean Fahey** and **Robin Luce Fahey**.*

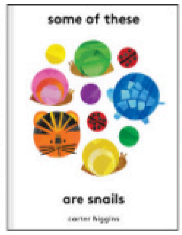
*SLMath partners with organizations to distribute Mathical titles and resources nationally to children in need. Partners include the **Children's Book Council**, the **DREME Network** at Stanford University, the **Early Math Project**, the **Guru Krupa Foundation**, **NCTE**, **NCTM**, the **Oakland Unified School District** (CA), **ParentChild+**, **School Library Journal**, **TeachingBooks.net**, and selected organizations serving unhoused women and children in the San Francisco Bay Area, West Coast, and Pacific Northwest.*

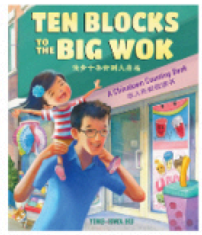
Additional resources to support educators, librarians, and families, including grade-level flyers, printable bookmarks, and more, can be accessed at mathicalbooks.org.

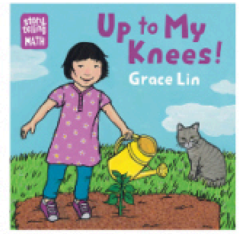
…and 2024 Mathical Honor Books

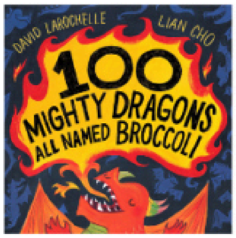


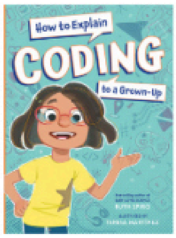


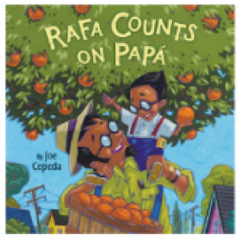


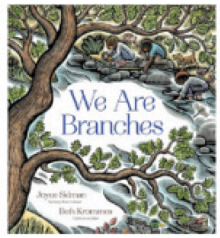


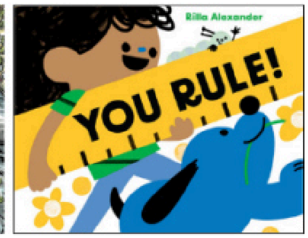


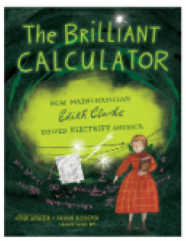


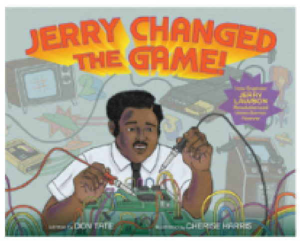


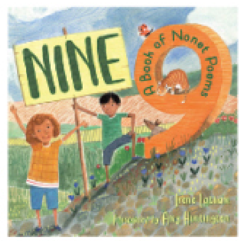


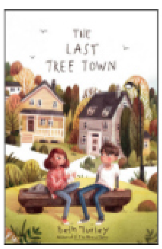


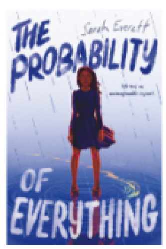


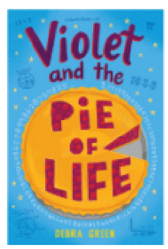


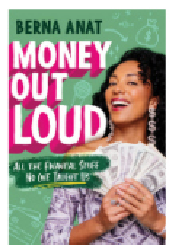


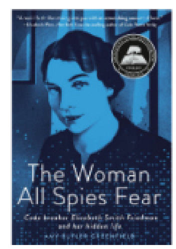












See this year's winners and learn more about the Mathical Prize on *page 10*.

Pre-K

¡1, 2, 3 Salsa! by Delia Cruz, illustrated by Graziela Andrade (Soaring Kite Books)

The Great Cookie Kerfuffle by Jessica Shaw, illustrated by Pauline Gregory (Amicus Publishing)

Some of These Are Snails, written and illustrated by Carter Higgins (Chronicle Books)

Ten Blocks to the Big Wok: A Chinatown Counting Book, written and illustrated by Ying-Hwa Hu (Lee and Low Books)

Up to My Knees!, written and illustrated by Grace Lin (Charlesbridge Publishing)

Grades K–2

100 Mighty Dragons All Named Broccoli by David LaRochelle, illustrated by Lian Cho (Penguin Young Readers)

How to Explain Coding to a Grown-Up by Ruth Spiro, illustrated by Teresa Martínez (Charlesbridge Publishing)

Rafa Counts on Papá, written and illustrated by Joe Cepeda (Little, Brown, and Company)

We Are Branches by Joyce Sidman, illustrated by Beth Krommes (HarperCollins)

You Rule!, written and illustrated by Rilla Alexander (Chronicle Books)

Grades 3–5

The Brilliant Calculator: How Mathematician Edith Clarke Helped Electrify America by Jan Lower, illustrated by Susan Reagan (Astra Books for Young Readers)

Jerry Changed the Game!: How Engineer Jerry Lawson Revolutionized Video Games Forever by Don Tate, illustrated by Cherise Harris (Simon and Schuster)

Nine: A Book of Nonet Poems by Irene Latham, illustrated by Amy Huntington (Charlesbridge Publishing)

Grades 6–8

The Last Tree Town by Beth Hurley (Simon and Schuster Books for Young Readers)

The Probability of Everything by Sarah Everett (HarperCollins)

Violet and the Pie of Life by Debra L. Green (Holiday House)

Grades 9–12

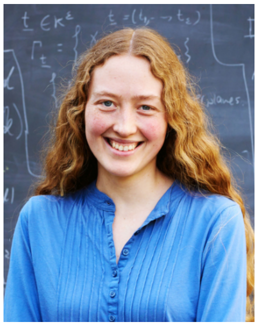
Money Out Loud: All the Financial Stuff No One Taught Us by Berna Anat, with illustrations by Monique Sterling (HarperCollins)

My Mechanical Romance by Alexene Farol Follmuth (Holiday House)

The Woman All Spies Fear: Code Breaker Elizebeth Smith Friedman and Her Hidden Life by Amy Butler Greenfield (Random House)

Distinguished Postdoctoral Fellowships / SPRING 2024

HUNEKE


AARON FAGERSTROM

Lauren Cranton Heller is the Huneke postdoctoral fellow in the *Commutative Algebra* program. She attended Wellesley College as an undergraduate and then received her Ph.D. in 2023 from the University of California, Berkeley under the guidance of David Eisenbud. Before returning to SLMath she spent her first semester as a Postdoctoral Research Associate at the University of Nebraska, Lincoln. Lauren's interests lie at the intersection of commutative algebra and algebraic geometry, particularly in the homological algebra of toric varieties.

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.

UHLENBECK


AARON FAGERSTROM

Lucien Hennecart is the Uhlenbeck postdoctoral fellow in the *Noncommutative Algebraic Geometry* program. Having earned his Ph.D. in 2021 from Paris-Saclay University under the guidance of Olivier Schiffmann, Lucien subsequently held a postdoctoral position at the University of Edinburgh under the mentorship of Ben Davison. His research focus lies in geometric representation theory. He studies the symmetries of geometric spaces arising from diverse moduli problems involving algebraic curves and surfaces, quivers, and smooth algebras. Lucien's work has tight connections with the Langlands program via the Hitchin fibration, the representation theory of Kac–Moody algebras, and nonabelian Hodge theory. He employs cohomological Hall algebras as a unifying tool in exploring these topics.

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 Le roy P. Steele Prize, and a MacArthur "Genius" Fellowship.

V. DELLA PIETRA

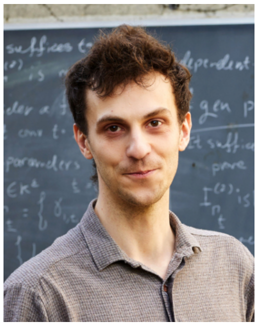

AARON FAGERSTROM

James Hotchkiss is the Vincent Della Pietra postdoctoral fellow in the program on *Noncommutative Algebraic Geometry*. James received his Ph.D. from the University of Michigan, where he was advised by Alex Perry. Before joining SLMath, he was a Ritt Assistant Professor at Columbia University. James applies techniques from derived categories and moduli theory to the study of classical problems about Brauer groups of fields and algebraic cycles on complex algebraic varieties. With Perry, he proved the period-index conjecture for Brauer groups of abelian threefolds.

The Vincent Della Pietra fellowship was established in 2017 by the Della Pietra Foundation. Vincent received his Ph.D. in mathematical physics from Harvard University. He is a partner at Renaissance Technologies, co-founder of the Della Pietra Lecture Series at Stony Brook University, and a board member of PIVOT. He is also currently a trustee of SLMath.

Distinguished Postdoctoral Fellowships / SPRING 2024

S. DELLA PIETRA



AARON FAGERSTROM

Ben Briggs is the Steven Della Pietra postdoctoral fellow in the *Commutative Algebra* program. He obtained his Ph.D. in Toronto with Ragnar-Olaf Buchweitz, doing a mixture of commutative and noncommutative algebra, in particular working on the homotopy Lie algebra, which connects commutative algebra with topology. He then spent three years in Utah working with Srikanth Iyengar on the cotangent complex, which oversees the deformation theory of certain geometric objects. Together they proved results saying that the cotangent complex is about as complicated as people were worried it would be. Ben then spent a year at MSRI doing commutative and noncommutative algebra, then went to Copenhagen to work on Hochschild cohomology, and then came right back to MSRI, now SLMath, to participate in this semester's program.

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.

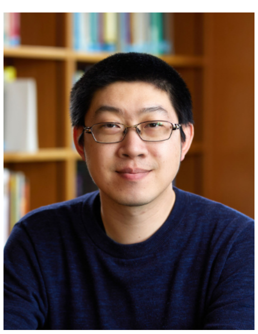
VITERBI

AARON FAGERSTROM

Hang (Amy) Huang is the Viterbi postdoctoral fellow in the *Commutative Algebra* program. She received her Ph.D. in 2019 from the University of Wisconsin Madison under the direction of Steven Sam and Daniel Erman. She then spent five years as a postdoctoral researcher at Texas A&M University and Auburn University. After the SLMath program, she will be joining Texas A&M University as a tenure-track assistant professor in this fall. Amy studies problems in the interactions between representation theory, algebraic geometry, and commutative algebra.

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.

MCDUFF



AARON FAGERSTROM

Cheng Meng is the McDuff postdoctoral fellow in the *Commutative Algebra* Program. He obtained his bachelor's degree in 2016 from Tsinghua University and his Ph.D. in 2023 from Purdue University under the supervision of Giulio Caviglia and Linquan Ma. Cheng's research focuses on different topics in commutative algebra, including methods of characteristic p, multiplicity theory, graded rings, and homological invariants in commutative algebra. In his dissertation, he proved a new case of Lech's conjecture, which describes how multiplicities change under flat ring maps. Recently, he has worked with Mukhopadhyay on a generalization of Hilbert–Kunz multiplicity named h-function, which is also related to other invariants in characteristic p, including the F-signature and the F-threshold. He received the Abhyankar Award for outstanding thesis work in the area of commutative algebra in 2023 .

The McDuff fellowship was established by an anonymous donor in honor of Dusa McDuff. She is an internationally renowned mathematician, a member of the National Academy of Sciences, and a recipient of the AMS Leroy P. Steele Prize (2017). She is also currently a trustee of SLMath.

Program Article

Commutative Algebra at 17 Gauss Way

David Eisenbud

The current program on *Commutative Algebra* at SLMath follows three others: a three-week microprogram in 1987 and two year-long programs in 2002–03 and 2012–13. Many of the senior participants in the current program were graduate students or postdocs in the earlier ones, and the cumulative effect on the field has been very great.

My first experience at MSRI was during a sabbatical in 1986–87. The 1987 microprogram was a highlight! Led by Mel Hochster, Craig Huneke (who is a current member), and Judith Sally (whose death last month at 86 saddened us all), the program gave the commutative algebraists a taste of how nice it was to be at MSRI. My own experience that year led to my application for the job of director twenty years later!

There are perhaps a dozen intertwined themes being pursued in the current semester, from singularities and representation theory in positive characteristic, to free resolutions, finite and infinite — a wonderful stew of commutative algebra. It's far too various to describe succinctly, so instead I'll focus on one topic with a long history: *residual intersections*, the study of "what's left over" when you subtract one algebraic variety from another. The question arose in at least three independent areas over the course of the late 19th and early 20th centuries, and I'll describe these origins, which all involve projective varieties over the complex numbers.

The Five Conics Problem: Residual Intersections

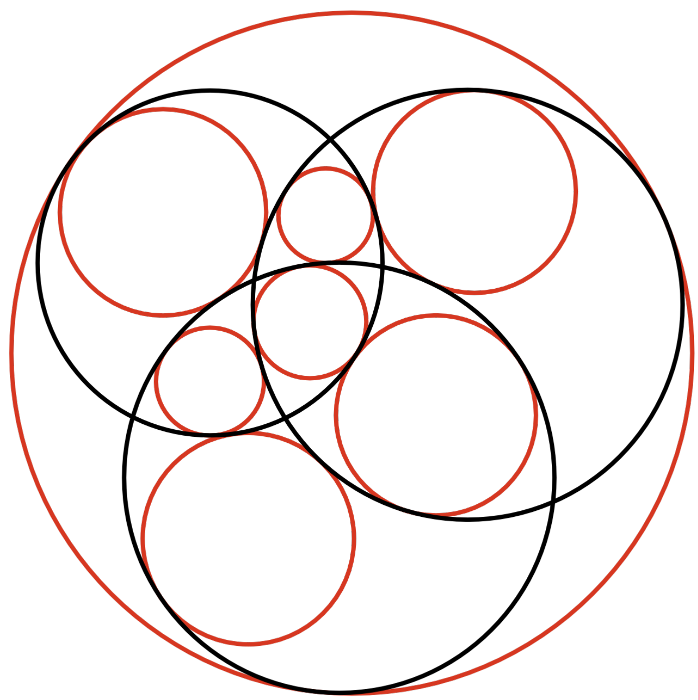
The first appearance of residual intersections remains, to me, the least intuitively reasonable:

In the middle of the 19th century, many mathematicians studied the enumerative geometry of plane curves. To get an idea of what this means, consider first an easy problem: *How many circles are simultaneously tangent to three general circles in the plane?* The answer is illustrated in the image to the right: each of the $8 = 2^3$ red circles can pass either inside or outside of one of the three black circles.

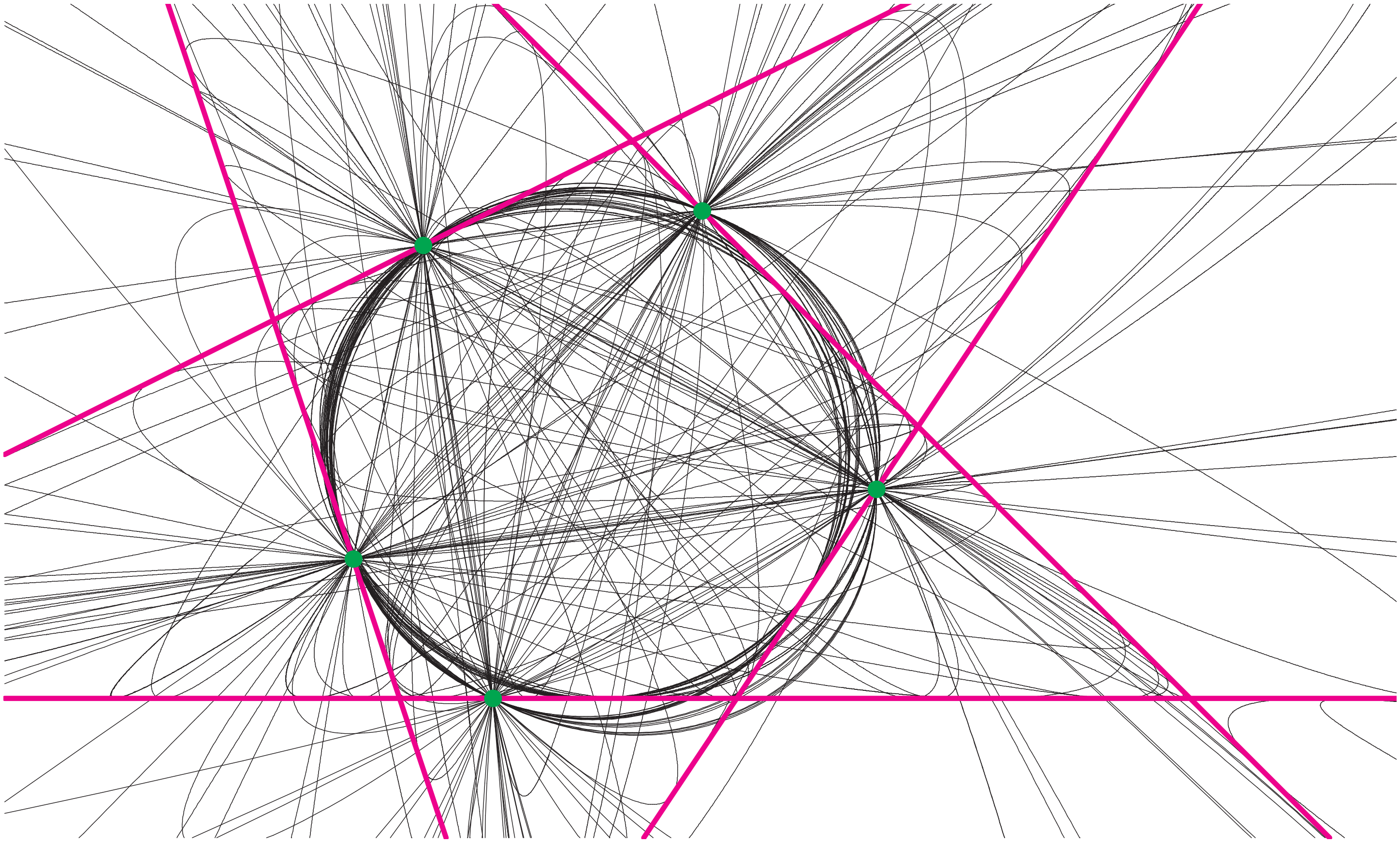
From a more algebraic point of view, the family of circles is 3-dimensional (two dimensions for the center and one for the radius), and the condition on the coefficients of the equation of a circle C for it to be tangent to a given circle D is a quadratic condition. (Proof: Fix the center of C and vary just the radius r; in general there will be two values of r for which C is tangent to D.) Bézout's theorem states that three quadratic surfaces in 3-space generally meet in eight points.

In 1848 Jakob Steiner proposed the harder problem: *How many plane conics are simultaneously tangent to five given general conics?* He proposed to answer it by generalizing the argument above: The space of conics is 5-dimensional (a quadratic equation has six coefficients, but a multiple of the equation defines the same conic). The condition that a conic be tangent to a given conic is an equation of degree six on the coefficients, and since there are five tangencies required, Steiner reasoned that, by Bézout's theorem, the answer should be $6^5 = 7776$ conics.

This is not correct: the algebraic condition is satisfied by any "conic" whose equation is the square of a linear equation, so the equations satisfying the algebraic conditions include an infinite set of "irrelevant" solutions. These must be removed to get the correct answer. How can one count the little parts — points — left over when one has to subtract such a big component, one of the "wrong" dimension? The method, and the correct answer, was discovered by Michel Chasles in 1864, though it would be nearly another 100 years before this was given a rigorous general foundation: there



There are eight circles (shown in red) simultaneously tangent to three general circles (black) in a plane. Courtesy of D. Eisenbud and J. Harris from their book, *3264 and All That: A Second Course in Algebraic Geometry* (Cambridge University Press, 2016).



102 of the 3264 conics simultaneously tangent to five given conics in a configuration in which all 3264 are defined over the real numbers, courtesy of Frank Sottile. For the construction and the story, see franksottile.github.io//research/stories/3264/.

are 3264 "honest" conics (in general, smooth) tangent to five given general conics. Two different approaches to the proof are explained in the book that provided the figure on the previous page.

In fact for a suitable choice of the five conics, Ronga, Tognoli, and Vust showed that all the solutions can be represented over the real numbers; some of these are illustrated in the figure above, created by Frank Sottile.

The natural extension of this idea is to determine the invariants of an algebraic set "residual" to another inside a larger algebraic set. Fulton and MacPherson put the geometric theory on a firm foundation in 1978, given certain assumptions about the singularities of the spaces involved. A 1972 paper of Artin and Nagata initiated the study of the singularities of the residual set. Their paper contained a fundamental error, which was soon corrected by Craig Huneke. The field has spawned many problems and theories, one of which is described in the last section of this article.

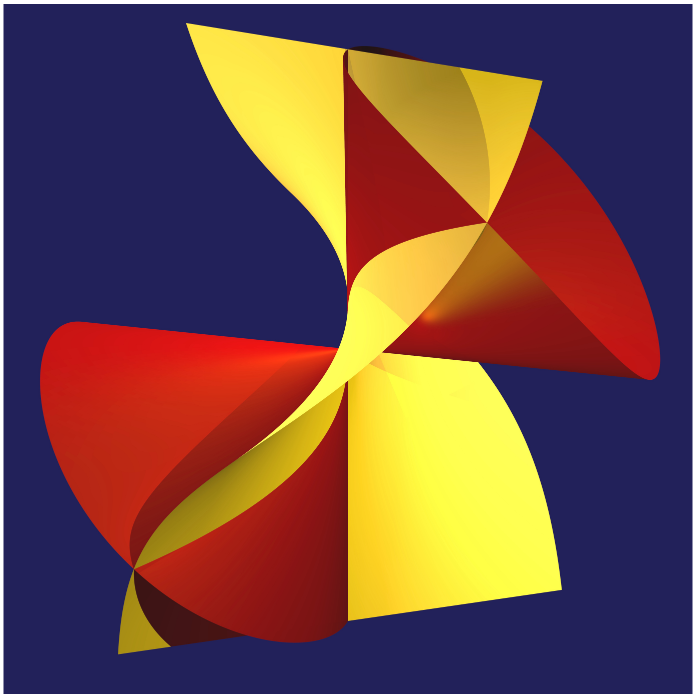
The Riemann–Roch Theorem

A different manifestation of residual intersections is necessary for the algebraic treatment of the Riemann–Roch theorem. The results of Riemann's famous dissertation in 1851, on what we now call Riemann surfaces, were initially considered dubious because of his unjustified use of the "Dirichlet principle" (and perhaps also because it was simply so far ahead of contemporary thought). First Clebsch and then Brill, (Max) Noether, and others undertook to put it on the firm foundation of the algebraic theory of plane curves. One of the terms in the Riemann–Roch theorem involves a difference of divisors, a classic use of residuation. It was Macaulay who discovered why this works (and a limit of the method); that theory later blossomed into his theory of "inverse systems."

Curves in 3-Space: Linkage

The easiest of the three source problems to understand is historically the most recent: *How can one classify curves in 3-space?* A smooth curve in our sense is the same thing as a Riemann surface, and there are just two topological invariants that characterize such a curve in projective space: its genus g (the number of handles in the Riemann surface) and its degree d (the number of points in which it meets a general plane). So the first question is: *What are the possible pairs* (g, d) *for a smooth curve in (complex projective) 3-space?*

A smooth curve in 2-space is defined by a single equation, and if the degree of the equation is d, then the curve is a Riemann surface of genus $\binom{d-1}{2}$. But already for curves of degree four in 3-space, there are two possible genera (0 and 1), so the tight connection between degree and genus is lost.



A quadratic cone (red) intersecting a smooth quadratic curve (yellow) in the union of a vertical line and a twisted cubic. Picture courtesy of Herwig Hauser, University of Vienna, www.hh.hauser.cc.

Suppose first that the ideal of homogeneous polynomials vanishing on C is generated by just two of them — the smallest possible number — and that their degrees are e and f. In this case, like that of the plane curves, the genus and degree are determined by e, f. For example, if $e=2$ then $d=2f$ and $g=(f-1)^2$. But there are also curves of any degree d having genus 0, such as those parameterized by $t \mapsto (t, t^{d-1}, t^d)$.

The landscape of curves in 3-space was explored by Max Noether (Emmy's father, whom van de Waerden called the "father of algebraic geometry") and Georges-Henri Halphen. They jointly received in the Steiner prize of the Prussian Academy of Sciences in 1880 for their work. A primary technique is what is now called *linkage* of curves (also known by its French term *liaison*): Given a curve C, find two equations from its defining ideal, and look at the "curve" D that is defined by these two; in general it will turn out that $D = C \cup C'$, where C' is another smooth curve, said to be *linked* to C. A formula from F.S. Macaulay's great paper of 1913 computes the degree and genus of C' from that of C and the degrees of the two equations; this gives a way of looking for new possibilities for (g, d).

The simplest nontrivial case is illustrated by the figure shown at left (and on the cover). In the figure, the red surface is a cone over a circle, and the yellow surface is also defined by a quadratic equation. Since both have degree two, Bézout's theorem tells us that the degree of the intersection "curve" will be $2 \times 2 = 4$. In the picture it's clear that the vertical line is part of the intersection; the rest must therefore have degree three, and in fact it is the *twisted cubic*, parameterized by $t \mapsto (t, t^2, t^3)$.

The theory of linkage has a long tail! Curves linked (in many steps) to one another are said to be in the same "linkage equivalence class," and the curves in 3-space in the linkage class of a line were classified in the 1940s by Federico Gaeta. A remarkably simple complete algebraic invariant for linkage of curves in 3-space was discovered by Robin Hartshorne and Prabhakar Rao in 1976. Meanwhile, Peskine and Szpiro had rediscovered Macaulay's results and generalized them to the modern setting of Gorenstein local rings. A working group in this semester's program is trying to decide whether the closure in projective 3-space of the curve $t \mapsto (t, t^3, t^4)$ is a set-theoretic complete intersection; in other words, is there a scheme structure on this curve that is linked to the curve itself?

There have been many papers refining and generalizing the story since the 1940s. An important emphasis of this semester's program is centered on a dramatic new understanding of linkage of curves in 4-space and beyond by Jerzy Weyman and his collaborators Lorenzo Guerrieri and Xianglong Ni. (The latter is a Berkeley graduate student participating in this semester's program.) In contrast to the story for curves in 3-space, now tidily absorbed in the canon of commutative algebra as indicated above, the necessary tools seem to come from the theory of Kac–Moody Lie algebras. It's a shining example of how progress can be made when one field touches a seemingly distant field, as if through a wormhole in the mathematical cosmos!

Clay Senior Scholars

The Clay Mathematics Institute (www.claymath.org) has announced the 2024–25 recipients of its Senior Scholar awards. The awards provide support for established mathematicians to play a leading role in topical program at an institute or university away from their home institution. Here are the Clay Senior Scholars who will work at SLMath in 2024–2025.

New Frontiers in Curvature: Flows, General Relativity, Minimal Submanifolds, and Symmetry (Fall 2024)
André Neves (University of Chicago)

Special Geometric Structures and Analysis (Fall 2024)
Vincent Guedj (Université Paul Sabatier)

Probability and Statistics of Discrete Structures (Spring 2025)
Omer Angel (University of British Columbia)

Extremal Combinatorics (Spring 2025)
Gábor Tardos (Alfréd Rényi Institute of Mathematics)

FOCUS *on the Scientist* Srikanth Iyengar

AARON FAGERSTROM

Srikanth Iyengar is a mathematician of remarkable depth and breath. He is well-acquainted with SLMath, having been at SLMath/MSRI for four long-term visits. He was a postdoc in the *Commutative Algebra* program in the Spring of 2003, was one of the organizers for the *Commutative Algebra* program in 2012–13, was a Research Member in the 2018 *Group Representation Theory and Applications* program, and is now the Eisenbud Research Professor in this semester's *Commutative Algebra* program.

Srikanth grew up in Hyderabad, in India. After a detour studying computer science during his undergraduate days, he went to Purdue, obtaining his Ph.D. in mathematics under the direction of Luchezar Avramov. He is currently a professor at the University of Utah. Srikanth is well known as a great collaborator and mentor, already having almost 70 collaborators and guided 20 past or current Ph.D. students. Many of his collaborations have their roots in SLMath programs, including his postdoc at MSRI where he began a long-term collaboration with Dave Benson and Henning Krause, and more recently (arising from the 2012–13 program) with Julia Pevtsova on various aspects of the modular representation theory of finite groups. That collaboration is still going strong, and a significant portion of his research in the past twenty years is on this topic.

Srikanth has made many important contributions to our understanding of central themes in commutative algebra, especially smoothness, duality, and free resolutions. Many of his most important contributions lie in understanding various manifestations of duality. He has used his deep insight into Gorenstein rings (these are rings which have strong duality properties) to build a framework which places many dualities under the same umbrella, including Poincaré duality for manifolds, duality in group cohomology, and duality in homotopy theory. Iyengar's paper with Avramov, Ragnar Buchweitz, and Claudia Miller opened new worlds for the study of perfect complexes.

Many of his collaborations have their roots in SLMath programs.

Among many results, they show that the sum of the Loewy lengths of the homology always is at least a number depending only on the free rank of the conormal module of the ring (over all possible presentations). The Loewy length of a module is the least power of the maximal ideal which annihilates it. Such estimates play a crucial role in a great many problems.

Results on detecting smoothness encompass many of his papers. In recent beautiful work with Ben Briggs (who is also in the current program as a postdoc), Srikanth proves that the André–Quillen homology functors are rigid — that is, if one vanishes for some integer $n \geqslant 2$, then all higher ones vanish, which then forces the algebra to be locally a complete intersection. This work extends Avramov's theorem that draws the same conclusion but assumes vanishing for all high values, confirming a conjecture of Quillen.

Although his main work is in commutative algebra, opportunities to work in other fields are clearly important to him, and his research touches modular representation theory of finite groups and group schemes, and more recently, algebraic number theory. In his words,

> “*I am not entirely sure why I am interested in these topics, but especially in the work outside commutative algebra, it is partly the thrill of discovering the familiar in (to me) unfamiliar contexts. It is still amazing to me that intuition and techniques from my training in commutative algebra prove to be useful in these different contexts.*”

— Craig Huneke

Pacific Journal of Mathematics

Founded in 1951, the *Pacific Journal of Mathematics* has published mathematics research for more than 70 years. PJM is run by mathematicians from the Pacific Rim and aims to publish high-quality articles in all branches of mathematics, at low cost to libraries and individuals. PJM publishes 12 issues per year. Please consider submitting articles to PJM — the process is easy and responses are timely. See msp.org/publications/journals/.

Journeys of Black Mathematicians: Forging Resilience

In January 2024, SLMath's newest documentary film with director George Csicsery premiered to enthusiastic audiences at a special JMM screening and panel session held in partnership with the National Association of Mathematicians (NAM), followed by the sold-out public premiere at Berkeley's David Brower Center.

Journeys of Black Mathematicians: Forging Resilience traces the evolution of a culture of Black scholars, scientists and educators in the United States. The film follows the stories of prominent pioneers, showing how the challenges they faced and their triumphs are reflected in the experiences of today's mid-career Black mathematicians. Their mathematical descendants in turn are contemporary college students and K–12 children across the U.S. who are learning that they belong in mathematics and STEM. With over 50 individuals featured, *Forging Resilience* is the first of two documentary films produced by Zala Films, with part two expected in 2025.

View or Host a Screening

- Video access is available at jbmfilm.com. For home viewing, you can rent the film on Vimeo.
- For classroom use and screenings of under 200 people, a Digital Film+ License for Institutional Screenings is available. (It is also available with English open captions.)
- For large screenings of 200+ viewers, or for questions not addressed above, contact info@zalafilms.com.

Named Positions / SPRING 2024

Distinguished Professorships

Commutative Algebra
Srikanth Iyengar, University of Utah
Claudia Polini, University of Notre Dame
Frank-Olaf Schreyer, Universität des Saarlandes
Anurag Singh, University of Utah
Bernd Ulrich, Purdue University

Noncommutative Algebraic Geometry
Andrei Caldararu, University of Wisconsin-Madison
Dmitry Kaledin, Steklov Mathematics Institute
Mikhail Kapranov, Kavli Institute for the Physics and Mathematics of the Universe
Ludmil Katzarkov, University of Miami
Alexander Polishchuk, University of Oregon
Michel Van den Bergh, University of Hasselt

Distinguished Postdoctoral Fellows

Commutative Algebra
S. Della Pietra: Benjamin Briggs, University of Copenhagen
Huneke: Lauren Heller, University of California, Berkeley
Viterbi: Amy Huang, Auburn University
McDuff: Cheng Meng, Purdue University

Noncommutative Algebraic Geometry
Uhlenbeck: Lucien Hennecart, University of Edinburgh
V. Della Pietra: James Hotchkiss, University of Michigan

Graduate Fellows

Commutative Algebra
Vituli: Sandra Sandoval Gomez, University of Notre Dame
Salgo-Noren: Eliana Tolosa Villarreal, Università di Genova

Noncommutative Algebraic Geometry
Salgo-Noren: Ravali Nookala, Carleton University
S. Della Pietra: Antonios-Alexandros Robotis, Cornell University

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

MSRI-UP 2023 Alum Welcomes Classmates to JMM 2024

Inspired by her experience at SLMath and the supportive mentoring she received in MSRI-UP, **Elise Alvarez-Salazar** (far right in photo) is already making an impact at her home institution, the University of California, Santa Barbara (UCSB).

A 2023 participant in the *Topological Data Analysis* summer program, Elise wanted to create an opportunity for her fellow math undergraduates to experience the wider world of mathematical research beyond campus by inviting others to the January 2024 Joint Mathematics Meetings (JMM) in San Francisco.

While her own travel to the JMM was funded as part of her MSRI-UP experience, Elise realized many students did not have the financial ability to pay out of pocket for the conference and travel. Following a consultation with one of her MSRI-UP mentors, program organizer **Maria Mercedes Franco** (CUNY Queensborough Community College), Elise petitioned the UCSB administration and successfully negotiated funding to bring 13 additional students with her to meet her fellow MSRI-UP cohort and program leaders and participate in the JMM for the first time.

Call for ***Proposals***

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

Thematic Programs
The Scientific Advisory Committee (SAC) of the Institute meets in January, May, and November each year to consider letters of intent, pre-proposals, and proposals for programs. The deadlines to submit proposals of any kind for review by the SAC are Mar 1, Oct 1, and Dec 1. Successful proposals are usually developed from the pre-proposal in a collaborative process between the proposers, the Directorate, and the SAC, and may be considered at more than one meeting of the SAC before selection. For complete details, see slmath.org/proposals-scientific-programs.

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 Workshops
This new workshop addresses fundamental questions in mathematics that have, for one reason or another, been abandoned or forgotten. This workshop series is anticipated to begin in Academic Year 2025–26. In some cases, a problem was deemed intractable; in others, there was a partial breakthrough only for the field to focus on other applications of the new methods. The purpose of this workshop is to bring together mathematicians at all career stages to revisit these fundamental open problems, with fresh eyes and modern technology. Specific goals of a workshop will be to answer such questions as: What is the exact current status of the problem(s)? Is there a connection to any recent advances? Another goal is the formulation of a conjectural picture where one does not yet exist. See slmath.org/proposals-revisiting-fundamental-problems-workshops.

Summer Graduate Schools
Every summer, SLMath organizes several two-week long summer graduate schools, both at SLMath and at partnering locations around the globe. Proposals must be submitted by Sep 1 for review by the Committee of Academic Sponsors and the Scientific Advisory Committee. See slmath.org/proposals-summer-graduate-schools.

The **Puzzles** *Column*

Joe Buhler and Tanya Khovanova

1 Let G be a graph on the surface of a sphere whose faces are all quadrilaterals (that is, they have four edges and four vertices). Assume that all vertices on G are colored, and say that a face is *balanced* if it has two opposite (that is, non-adjacent) vertices with the same color. Show that if all faces except possibly for one are balanced, then the last face is also balanced.

Comment: This problem is due to Sergey Fomin and Pasha Pylyavskyy.

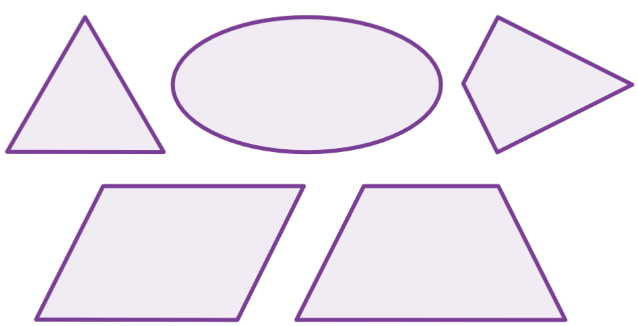
2 Let $f(x)$ be a quadratic polynomial. Show that the graph of f is tangent to the graph of its derivative f' if and only if the imaginary parts of the roots of $f(x)$ are $\pm i$.

Comment: This problem is due to Alexander Karabegov.

3 Amelia's mother says:

> "Choose two of the figures below. I will then draw them on a sheet of paper, in whatever position and orientation I want, except that the figures won't overlap. Then your task is to draw a straight line that cuts your each of your chosen shapes into two congruent pieces."

The pieces are an equilateral triangle, an ellipse, a kite, a parallelogram, and an isosceles trapezoid, which are drawn to scale below.



Which figures should Amelia choose so that she will always be able to succeed? Explain.

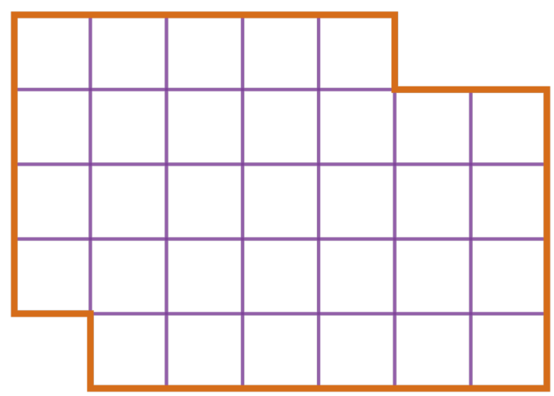
Comment: This problem, and the next two, were on this year's BAMO (Bay Area Math Olympiad) exam for middle and high school students. BAMO was held on March 6 and was taken by 650 students in schools from the Bay Area and a handful of other west coast cities. This exam has been held annually since 1999 and receives support from SLMath.

4 Let S_n denote the sum of the first n primes. (For example, $S_4 = 17$.) Is there a perfect square between S_{2023} and S_{2024}?

5 An underground rabbit hotel has rooms labeled by the integers $\dots, -2, -1, 0, 1, 2, \dots$. Rabbits like privacy, and they use the following process to disperse: At the top of each hour, in each room with $m > 1$ rabbits, $\lfloor m/2 \rfloor$ rabbits move down a room and $\lfloor m/2 \rfloor$ move up a room. (These happen simultaneously; the "floor" $\lfloor x \rfloor$ is the largest integer n such that $n \leqslant x$.) For a starting configuration of k rabbits in each room k for $1 \leqslant k \leqslant 11$ (and all other rooms empty), show that the rabbits eventually stop moving. What is the final configuration?

Comment: Only two students on this year's BAMO got complete credit on this problem.

6 A 5×7 rectangle has a unit square cut out of one corner, and two unit squares cut out of the antipodal corner, as illustrated in the figure. Can the resulting shape be cut into two congruent polyominoes? (A polyomino is a connected union of unit squares.)



7 There are four suspects in a murder case, and one of them is guilty. There are also four witnesses who know which of the four is the killer. Three of the witnesses always tell the truth but, unfortunately, the fourth always lies. You are allowed to query the witnesses sequentially, but are only allowed to ask the i^{th} witness a single yes/no question of the form "Is the murderer in the set S_i?" What should you do? *Extra credit*: Can you do this if the questions have to be specified beforehand (that is, the S_i have to be specified in advance)?

Comment: This problem is due to Xiaoyu He.

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

2023 ANNUAL

Donor Report

We gratefully acknowledge the supporters of SLMath whose generosity allows us to fulfill SLMath's mission to advance and communicate the fundamental knowledge in mathematics and the mathematical sciences; to develop human capital for the growth and use of such knowledge; and to cultivate in the larger society awareness and appreciation of the beauty, power, and importance of mathematical ideas and ways of understanding the world.

This report acknowledges grants and gifts received from Jan 1 – Dec 31, 2023. In preparation of this report, we have tried to avoid errors and omissions. If any are found, please accept our apologies, and report them to development@slmath.org. If your name was not listed as you prefer, let us know so we can correct our records. If your gift was received after Dec 31, 2023, your name will appear in the 2024 Donor Report. For more information on our giving program, please visit www.slmath.org.

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Forthcoming **Workshops**

May 1–3, 2024: Advances in Lie Theory, Representation Theory, and Combinatorics: Inspired by the work of Georgia M. Benkart

Aug 21–23, 2024: Connections Workshop: New Frontiers in Curvature & Special Geometric Structures and Analysis

Aug 26–30,2024: Introductory Workshop: New Frontiers in Curvature

Sep 3–6, 2024: Introductory Workshop: Special Geometric Structures and Analysis

Oct 21–25, 2024: Recent Progress on Geometric Analysis and Riemannian Geometry

Oct 28–Nov 1, 2024: Geometry and Analysis of Special Structures on Manifolds

Dec 9–13, 2024: Hot Topics: Life after the Telescope Conjecture

2024 Summer Activities

Jun 15–Jul 27, 2024: MSRI–UP 2024: Mathematical Endocrinology

Jun 10–Jul 12, 2024: Summer Research in Mathematics

Jun 24–Jul 5, 2024: ADJOINT

2024 Summer Graduate Schools

Jun 3–Jun 14, 2024: Séminaire de Mathématiques Supérieures 2024: Flows and Variational Methods in Riemannian and Complex Geometry: Classical and Modern Methods (Montréal, Canada)

Jun 17–28, 2024: Particle Interactive Systems: Analysis and Computational Methods (SLMath)

Jun 17–28, 2024: Special Geometric Structures and Analysis (St. Mary's College, Moraga, CA)

Jun 24–Jul 5, 2024: Introduction to Quantum-Safe Cryptography (IBM, Zurich)

Jul 1–12, 2024: Stochastic Quantization (SLMath)

Jul 1–12, 2024: Koszul Duality in the Local Langlands Program (St. Mary's College, Moraga, CA)

Jul 1–12, 2024: H-principle (Sendai, Japan)

Jul 8–19, 2024: Introduction to the Theory of Algebraic Curves (UC Berkeley)

Jul 21–Aug 2, 2024: Mathematics of General Relativity and Fluids (Crete, Greece)

Jul 29–Aug 9, 2024: Structure and Representation Theory of Reductive p-adic Groups (St. Mary's College, Moraga, CA)

Jul 29–Aug 9, 2024: Analysis of Partial Differential Equations (Okinawa, Japan)

Aug 5–16, 2024: Mathematical Spin Glass Theory (Courant, NY)

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

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Celebratio Mathematica: New Volumes with SLMath

Celebratio Mathematica is an open-access web publication of Mathematical Sciences Publishers (msp.org) that celebrates mathematics and related fields, and their people. It is structured as a series of enhanced guides to the collected works of selected scientists. Since 2017, MSRI, now SLMath, has been supporting the publication of volumes dedicated to distinguished women in mathematics.

In 2023–24, we commemorate the careers of three women from widely different backgrounds: **Yvonne Choquet-Bruhat** (born Lille, France, 1923); **Georgia Benkart** (b. Youngstown, Ohio, 1947), and **Maryam Mirzakhani** (b. Tehran, 1977).

Choquet-Bruhat came from an intellectual family (her mother a philosopher and her father a physicist) and enjoyed early success in publishing her groundbreaking results in Einstein equations at the age of 30.

Benkart graduated summa cum laude from Ohio State University and took her Ph.D. at Yale University before beginning a long career at the University of Wisconsin, Madison. She is known for her contributions to the study of Lie algebras and for extraordinary service to the profession of mathematics, including her unstinting support and encouragement to other women in the field.

Mirzakhani graduated from Sharif University in Tehran and completed her Ph.D. at Harvard. A Fields medalist (2014), her luminous mathematical imagination and intellectual tenacity were matched by her warmth, humor and generosity.

In addition to the individual volumes, a new long-form essay by Allyn Jackson, ***The Miracle Group: Six Women from Taiwan and their Journey into Mathematics***, highlights the remarkable lives of six women mathematicians who graduated from the National Taiwan University (NTU) around 1970: **Sun-Yung Alice Chang**, **Fan-Rong King Chung**, **Wen-Ching Winnie Li**, **Mei-Chi Shaw**, **Chuu-Lian Terng**, and **Jang-Mei Wu**. Shiing-Shen Chern once called the emergence of their mathematical talent in post-World War II Taiwan "a miracle." Based on interviews with each of the six, Jackson's article invites us to consider the personal costs and daring of a woman pursuing a future in mathematics in mid-twentieth-century Taiwan.

Learn more at ***celebratio.org****.*