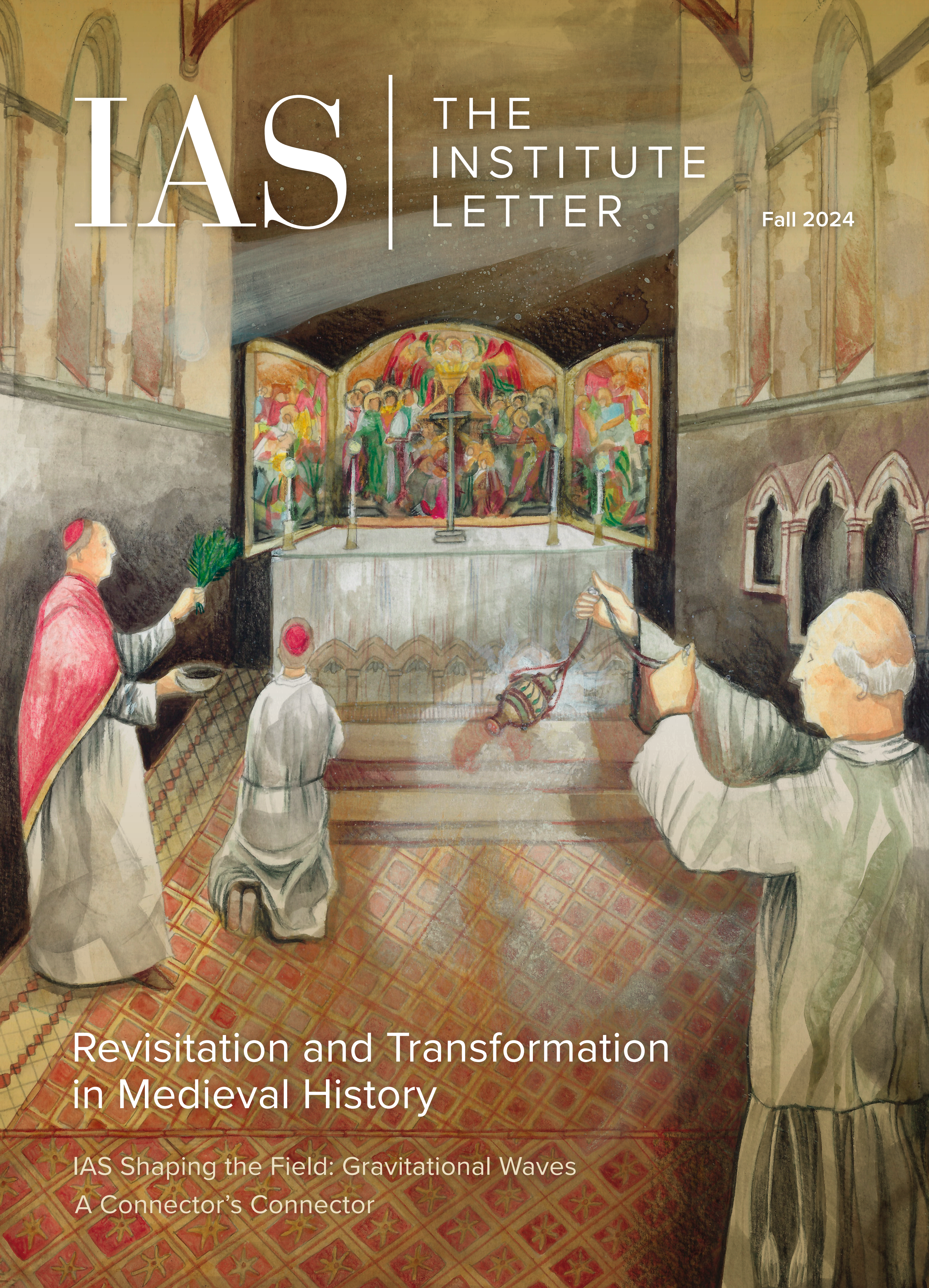
IAS | THE INSTITUTE LETTER

Fall 2024



Revisitation and Transformation in Medieval History

IAS Shaping the Field: Gravitational Waves

A Connector's Connector

A TIMELY PARTNERSHIP

Just over 2,500 books currently make their home in the Rosenwald Room, the Historical Studies - Social Science Library's site for rare books. And in the 2024 calendar year, new acquisitions across all the libraries numbered more than 1,370. See how these treasures together—new and old—shine a light on historical scholarship on romantic nationalism in this issue's From the Reading List on page 36.

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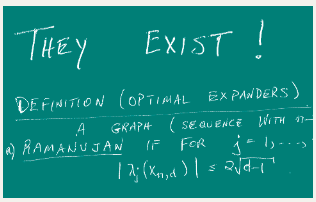

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Fall 2024

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A reconstruction of a 15th century retable displayed on a church altar. Laura Grace Haines is an artist and illustrator based in Kent, U.K., who has an MA with distinction in Archaeological Illustration, and enjoys interpreting sites and artifacts as well as painting local landscapes. Clients include *BBC History Magazine*, Butser Ancient Farm and University of Leicester Archaeological Services.

Inside Front Cover, Inside Back Cover, and Back Cover Images
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Questions and comments regarding ***The Institute Letter*** should be directed to publications@ias.edu.

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Culture of Conversation

The Institute for Advanced Study thrives on conversation, and recently there's been a lot to talk about. This summer brought exciting news from the School of Mathematics. Three new permanent Faculty commenced their IAS appointments: **Irit Dveer Dinur** (theoretical computer science), **Elon Lindenstrauss** (dynamical systems), and **Aaron Naber** (geometric analysis). These world-leading mathematicians bring unique expertise to the Institute's scholarly community, further elevating the pursuit of fundamental knowledge at IAS.

In addition to these three new Institute interlocutors, 267 visiting scholars have joined us for the 2024–25 academic year. They represent 35 nations and more than 130 institutions. Here, they are free to work on whatever project piques their curiosity, and explore any unique—or even unlikely—collaborations that might be fostered by a teatime chat or an evening in Rubenstein Commons.

Important conversations of a more scheduled nature are also taking place. This year, the School of Social Science is embarking on a theme seminar titled "The Politics of Migration and Displacement as a Form of Life," addressing questions about immigration and asylum, migrants and refugees. The seminar will be led by **Didier Fassin**, James D. Wolfensohn Professor in the School, and Visiting Professor **David Owen**, who serves as a professor in politics at the University of Southampton. Owen comes to IAS with extensive expertise in philosophy, political theory, and migration studies. A fellow of the British Academy, Owen's distinguished career includes significant contributions to the ethics of refugee protection, and global migration governance.

In the School of Mathematics, a special year on algebraic and geometric combinatorics is being held. Past IAS scholar and Princeton mathematics professor **June Huh** will serve as Distinguished Visiting Professor in the School, helping to organize a range of academic

Welcome to the Dialogue

Four incoming scholars for the 2024–25 academic year touched on various topics such as the hometown traditions they're bringing to the Institute, the adventures on their Princeton bucket lists, their favorite mantras and mottos, and the IAS scholars who have influenced their own research in this year's scholar Q&A sessions.

Scan the QR code to learn more about these new members of the Institute's community of discovery.

Maria O'Leary

Tendayi E. Achiume
Challenging Conceptions of "Borders" and "Race"

Andrea Kane

Ellen Eischen
Searching for Striking Mathematical Patterns

activities and workshops. The recipient of the 2022 Fields Medal, Huh brings to IAS his wealth of groundbreaking insights in bridging disparate areas of mathematics. His previous efforts to bring together combinatorics and algebraic geometry have led to key results in fields such as graph theory and matroid theory.

The School of Historical Studies has appointed the papyrologist Sofía Torallas Tovar as a long-term Distinguished Visiting Professor. A scholar of Greek and Coptic, her innovative work on the materiality of written texts and scribal practices in Egypt strengthens the School's enduring commitment to the study of the ancient world, and enriches its long history of conversations about the textual artifacts of antiquity.

The community's collective dialogue bolsters its legacy of discovery. This edition of *The Institute Letter* traces the history of such ideas—detailing how ideas spark further insight, how scholars build on their own and each other's work, and how interactions fuel new breakthroughs. Read how **Caroline Walker Bynum**, Professor Emerita in the School of Historical Studies, has revisited the same material objects throughout her career, broadening their interpretive frameworks with each analysis. Explore the influence of **Peter Sarnak**, Professor Emeritus in the School of Mathematics, on broad areas of mathematics with his work on Ramanujan graphs. Discover the innovative research being conducted in the School of Natural Sciences on gravitational waves, detailing how each individual Member or small group of scholars plays a role in driving forward scientific understanding in this field.

As **J. Robert Oppenheimer**, IAS Director (1947–66), envisioned, the Institute continues to foster a "common culture where we talk to each other." Having time in this special place, at this singular moment, with these distinctive people, is an open invitation to take part in the exchange.

Andrea Kane

Beatrix Muehlmann
Mapping the Fate of the Universe

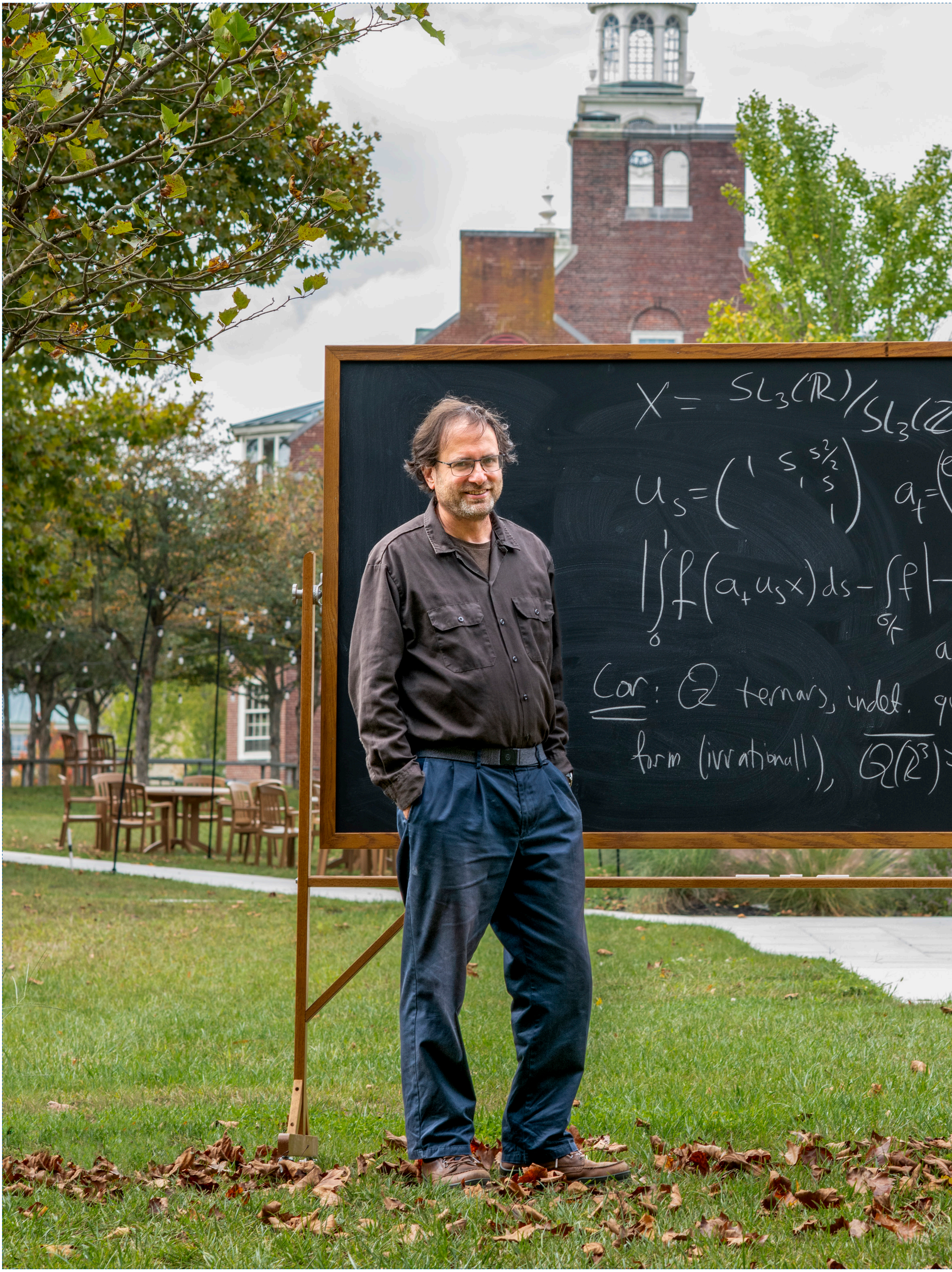
Andrea Kane

Celia Sánchez Natalías
Demystifying Ancient Magical Practices

Q Have any IAS scholars, past or present influenced your research?

A In the fields of ancient history, religions, and epigraphy, it would be hard not to have been deeply influenced and inspired by different scholars who have passed through the Institute. Two names that immediately come to my mind are Angelos Chaniotis, Professor in the School of Historical Studies, and Sofía Torallas Tovar, Distinguished Visiting Professor in the School, because of whose work I wanted to come to IAS.

— Celia Sánchez Natalías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THE INSTITUTE WELCOMES...

Elon Lindenstrauss

"It's a bit complicated to define my area of mathematics," explains Elon Lindenstrauss. "I work sort of between areas."

But working between areas often proves fruitful at the Institute, where Lindenstrauss has, in the past, found much inspiration. "Initially I was influenced by Peter Sarnak," he explains. "When I came to IAS for post-doc talks, he made a suggestion that turned out to be very useful towards proving some results about eigenfunctions of the Laplacian using dynamics." Eigenfunctions of the Laplacian are special functions that describe how quantities change in space, such as natural vibration patterns in physical systems. Lindenstrauss's insights on the subject turned out to be one of his most significant contributions.

Currently, he is focused on developing quantitative results for unipotent flows, a special type of mathematical system that describes how certain objects move or change over time in a smooth and predictable way. It builds upon the qualitative findings of Marina Ratner and Gregory Margulis, Member (1991, 2006) in the School. "They're really wonderful results and have had surprisingly diverse applications," he notes, continuing, "its actually their theorem I have on the board."

Lindenstrauss's research builds new bridges between the field of dynamics, which can trace its origins to the study of statistical aspects of long-term evolution of physical systems like the solar system, and number theory which deals with properties of static objects like integer solutions to equations.

Photography by Maria O'Leary

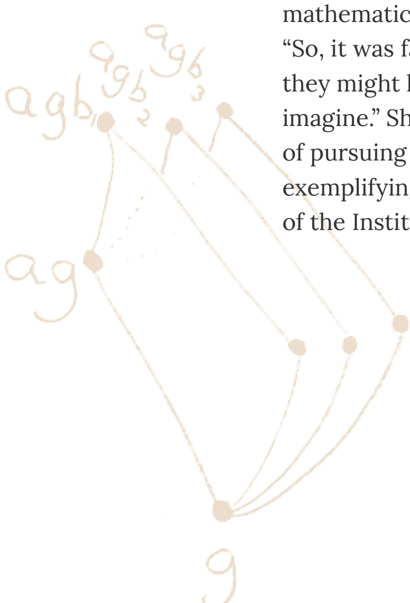
Irit Dveer Dinur

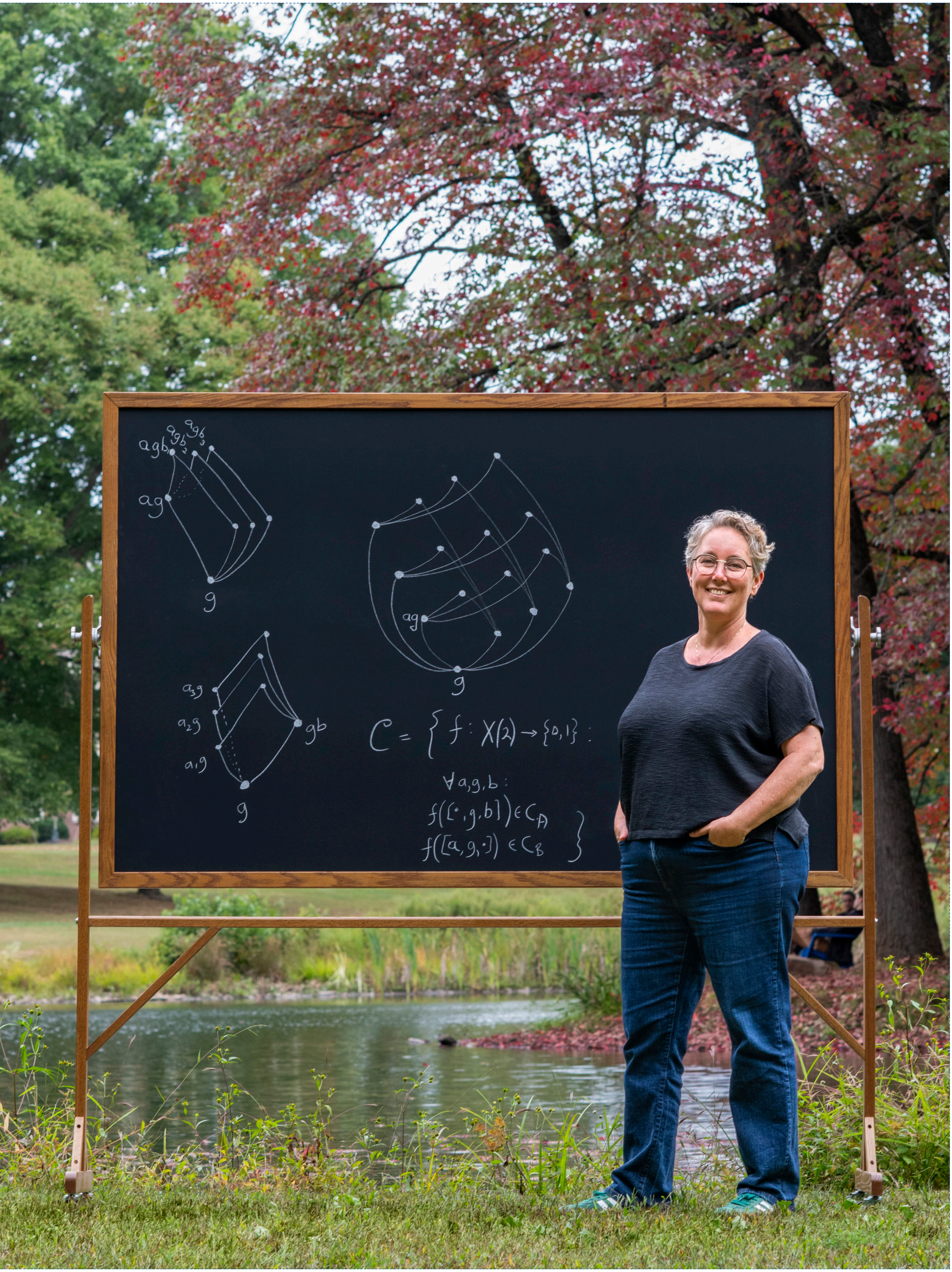
“**Sometimes people develop** something just for the beauty of it, without any inkling that one day you’ll find uses that you can’t expect,” states Irit Dveer Dinur, walking to the blackboard. As an example of this, she continues: “A few years back, I learned about Ramanujan complexes,” she continues, “but on the face of it, they have nothing to do with my area of study: computation. Nevertheless, we had this intuition that they could be useful or interesting to learn about and that maybe we could use them for something.”

Ramanujan complexes are a type of high-dimensional expander, a mathematical object that exhibits remarkable local-to-global properties. They enable the examination of small pieces of large computations to provide insights into the overall process.

Dinur’s investigations into these complexes, driven entirely by her curiosity, started a journey of several years that involved “learning a lot of really beautiful mathematics.” This ultimately led to a breakthrough: Dinur used high-dimensional expansion to construct error correcting codes. These codes, which are resilient to noise, allow for the detection of errors by examining small portions of the code.

“In the past, I had even tried to prove that such mathematical objects could not exist!” Dinur laughs. “So, it was fantastic to see that they do exist and that they might have future applications we can’t even imagine.” She describes her discovery as the result of pursuing knowledge “purely for its own sake,” exemplifying, in her words, “the founding axioms of the Institute.”

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FULD HALL
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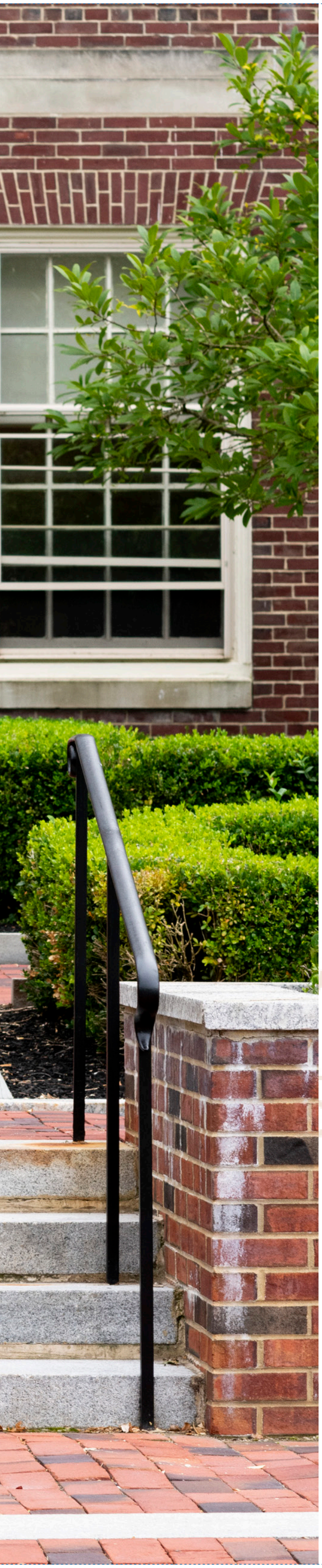


Aaron Naber

"Most of what I study is shapes," explains Aaron Naber, gesturing to the blackboard behind him. More specifically, Naber studies the mathematical connections between what a shape looks like—its topology—and how it can bend. "The usual 200-year-old version of the story starts with something like a basketball, and you deflate it a little bit. No matter how you move it around, everyone recognizes it's a basketball. That's called topology."

His work focuses on understanding how the equations through which these connections are expressed can, in Naber's words, "break" or develop singularities, namely points where the shape stops looking smooth. "Basically, they stop looking nice," he says.

He emphasizes the relationship between topology and optimal shapes, noting that "shapes have one natural form that's better than all the others," referring to the basketball's spherical form as its most efficient configuration. His work extends to complex, high-dimensional objects that are difficult to visualize but are vital for understanding geometric structures.

"Those connections, between a thing's topology and the way it bends, are usually in the form of equations that get solved. These equations pop up in all kinds of natural ways for people, but as a mathematician, I don't care. I usually just study them because they're interesting.".

A Stellar Framework for Galactic Disk Evolution

A trio of scholars from the School of Natural Sciences, John N. Bahcall Fellow **Chris Hamilton** (2021–26), visiting graduate student **Shaunak Modak** (2023–26), and Professor Emeritus **Scott Tremaine**, have developed a new theoretical framework for understanding galactic disks.

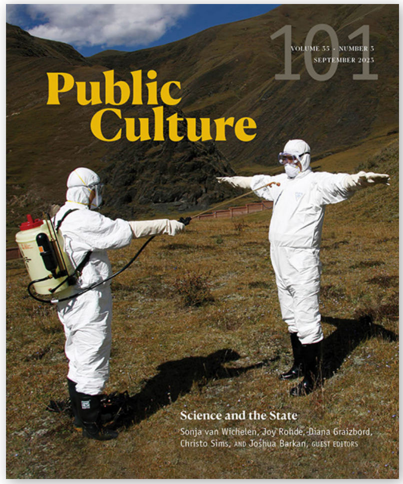
In recent years, scientists' capability to observe galactic disks has significantly improved, both within our own Milky Way galaxy through the Gaia space telescope, and in external galaxies using the James Webb Space Telescope. These amazingly precise observations demand an equally sophisticated theory if they are to be understood. "Such theories do exist, but they are so complicated that connecting them with the observations is difficult," explains Hamilton. To make these theories easier to use, he and his colleagues have developed an approximation scheme which drastically simplifies the mathematical formulae without compromising their accuracy. "Galactic disks evolve due to gravitational perturbations that occur on many different length scales," continues Hamilton. "Previous theories have tended to treat all of these perturbations using one very complicated formula. The key advance of our work is to split these perturbations up into different wavelength categories (long, intermediate, and short), and then to treat each category separately."

The insight for this paper came from an analog with plasma physics of the kind that Hamilton described in "Dynamics in Translation," an article published in the Fall 2023 issue of *The Institute Letter*. "In a magnetized plasma, electrons revolve around the magnetic field lines in tiny circles, like the orbits of stars within a galactic disk," says Hamilton. "The orbits of the electrons change over time because of electromagnetic perturbations of different length scales. We used exactly this idea to describe how stars' orbits evolve under gravitational perturbations in a galactic disk." In plasma physics, the mathematical framework used to understand the electrons' orbits is called "gyrokinetics." In honor of the connection that they have established, Hamilton, Modak, and Tremaine have titled their paper "Galactokinetics."

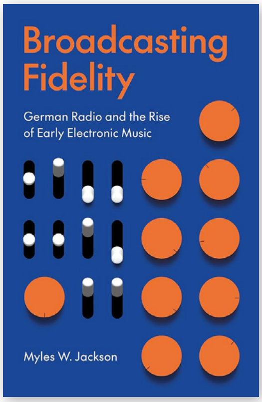
Spiral Galaxy NGC 1566. The portion of the image on the right, generated by the James Webb Space Telescope, is made up of short, clumpy wavelength features. The portion of the image on the left, generated by the Hubble Telescope, is made up of much smoother, longer wavelength features. All of these features produce gravitational forces, and "Galactokinetics" allows scholars to better describe them.

NASA, ESA, CSA, STScI, Janice Lee (STScI), Thomas Williams (Oxford), Rupali Chandar (UToledo), Daniela Calzetti (UMass), PHANGS Team.

Intersecting Science and Governance



In September 2023, all 17 scholars who participated in the 2020–21 School of Social Science theme seminar contributed to a special edition of *Public Culture*, titled “Science and the State.” Led by Harold F. Linder Professor **Alondra Nelson** and Visiting Professor **Charis Thompson**, the theme seminar (and the resulting publication) explored the intersection of technological advancement and governance, covering topics like AI, colonization, social inequality, and climate change.



From Nazi Germany to Hitchcock Horror

Anyone who has watched Alfred Hitchcock’s classic horror film *The Birds* has surely been haunted by the screech of the eponymous feathered foes. However, viewers should be relieved to know that this sound was not actually created by a living bird, but by a unique electronic instrument called the trautonium. In his upcoming book, “Broadcasting Fidelity: German Radio and the Rise of Early Electronic Music,” **Myles Jackson**, Albers-Schönberg Professor in the History of Science in the School of Historical Studies, delves into the origin, invention, and impact of the trautonium. Created in 1930, the instrument emerged from a multidisciplinary collaboration between German physicists and electrical engineers, and composers and musicians. The book traces how the instrument was embraced by the Nazis and was subsequently used to subvert Nazi aesthetics after the war, revealing how the interplay of science, technology, politics, and culture gave rise to new aesthetic concepts, innovative musical genres, and the modern discipline of electroacoustics.


Morn the Gorn, Wikimedia Commons

Andrea Kane

The Long and the Short of Locally Correctable Codes

In a groundbreaking study, **Pravesh Kothari**, Visiting Professor (2024) in the School of Mathematics, and **Peter Manohar**, Member (2024–26) in the School, have transformed theoretical computer scientists' knowledge of locally correctable codes (LCCs).

A locally correctable code is an error correcting code that contains a self-correction algorithm that can recover, with high probability, any symbol of the original codeword by querying a small number of randomly chosen symbols from a received corrupted codeword. LCCs enable highly efficient procedures for recovering small amounts of data, and have several applications in complexity theory. For instance, they are useful in proving the "hardness" (the difficulty of solving) of problems concerning the approximation of optimization.

Kothari and Manohar were interested in LCCs that have three queries, meaning codes that can correct errors in any single bit of an encoded message by randomly sampling only three positions in the codeword. More specifically, they investigated the "rate," or redundancy, of these three query LCCs. Redundancy refers to the additional information included in data that is not strictly necessary for conveying the core content, but is nevertheless important for the detection and correction of errors.

For LCCs with two queries, tight exponential lower and upper bounds on their rate have been known for a long time, but in the case of three queries, there was an exponential gap between the known upper and lower bounds. Kothari and Manohar proved an exponential lower bound. In short, they showed that for LCCs with three queries to work effectively, the code must be lengthy. More specifically, it must grow exponentially as the amount of original data increases.

The pair's findings have important implications for complexity theory and various cryptographic applications, including private information retrieval. Their research contributes to our understanding of the fundamental limits of error correction in information transmission and storage.

The pair's findings have important implications for complexity theory and various cryptographic applications, including private information retrieval.

Lifting the Curtain on On-Demand Work

With the press of a button, your favorite meal can be delivered to your door using GrubHub, and you can hail a ride across town with Uber. All of this is made possible through workers on these gig-based platforms. **Lindsey D. Cameron**, Member (2023–24) in the School of Social Science, investigates the human impact of this ever-growing gig-economy.

Cameron conducted extensive fieldwork, including 100 hours as a ride-hail driver, to uncover the complexities of gig work. Her research highlights how gig-based platforms create transactional relationships between customers and gig workers, where ratings and tips could mean the difference between a living wage or pocket change. She also emphasizes how the design of the platforms incorporates elements that turn work into a game-like experience, encouraging workers to strive for high customer ratings or maximizing earnings. These "workplace games" help gig workers find purpose and enjoyment in their tasks. By elucidating the dynamics at play in gig work, Cameron aims to enhance its benefits while reducing its drawbacks.


Grab, Unsplash

Pim de Boer, Unsplash

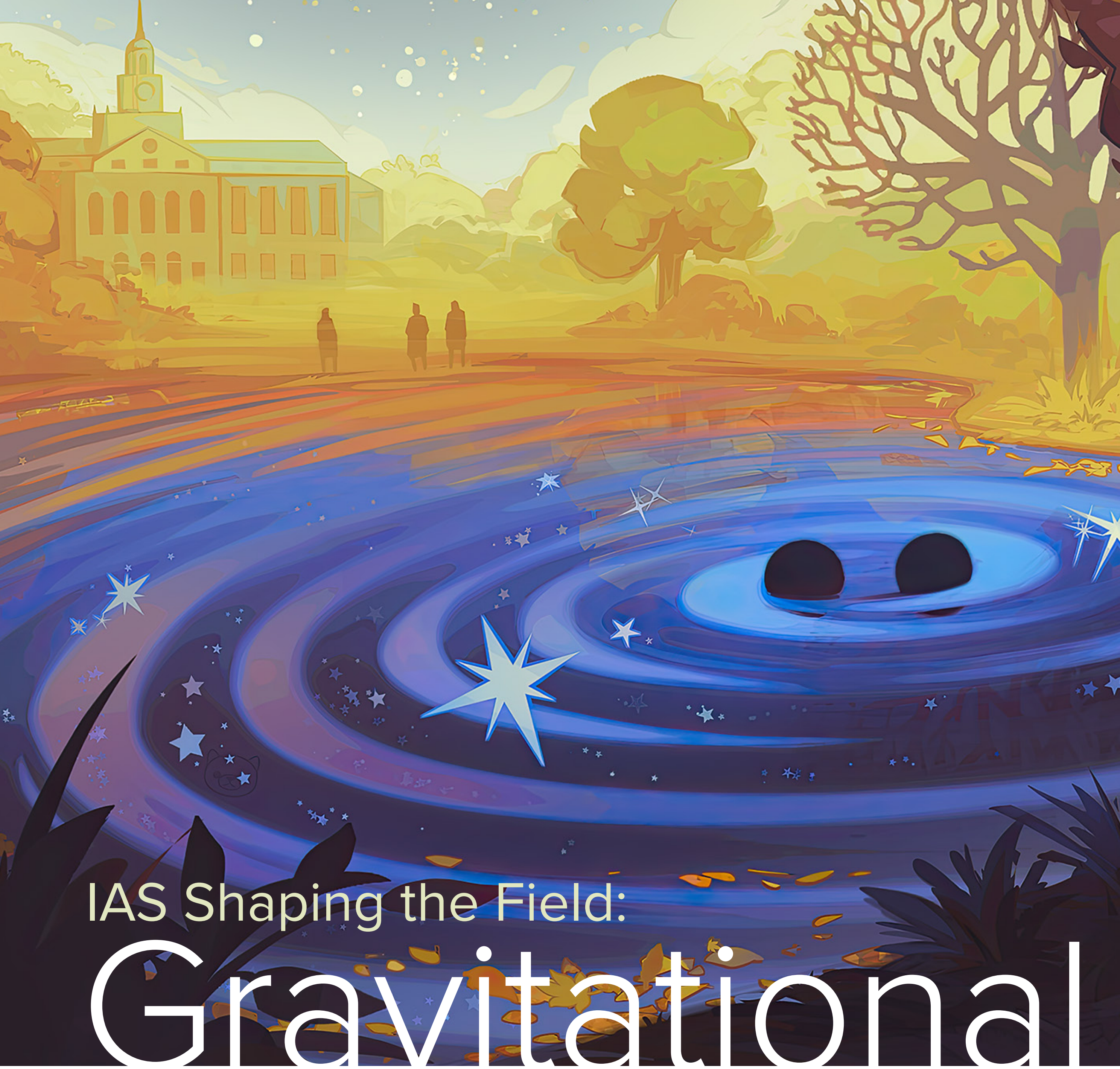

Abbey Ellis

IAS ON Instagram

WORKING OUT WORKING MEMORY

Working memory typically holds only four items, but a process called "chunking" helps process larger information streams. **Weishun Zhong**, Eric and Wendy Schmidt Member in Biology (2023–25), and his School of Natural Sciences colleagues **Mikhail Katkov**, a frequent Visitor, and C.V. Starr Professor **Misha Tsodyks** have proposed a new model for how this works. They suggest that specialized neurons suppress other stimuli, organizing information into chunks. The model found verification in observations of neural activity in epilepsy patients watching movies.

Scan to watch from our series of blackboard reels on Instagram.



IAS Shaping the Field: Gravitational

BY ABBEY ELLIS

As with many things in the realm of physics, it all began with Albert Einstein. In 1916, the founding IAS Professor predicted the existence of gravitational waves. His theory of general relativity demonstrated that space and time are not fixed coordinates or absolutes, as they were assumed to be in Newtonian physics. And, just as accelerating charges produce electromagnetic waves according to Maxwell's equations, he concluded that spacetime gets bent and warped by energy, and by the presence of massive objects such as planets. Einstein proposed that these massive objects cause ripples, or waves, to propagate in the fabric of spacetime.

On September 14, 2015, these waves, known as

Waves

Illustrations by Olena Shmahalo

gravitational waves, were detected on Earth for the first time. Since then, scholars from the Institute's School of Natural Sciences have been at the forefront of discovery in this revolutionary field. Working either independently or in small groups, IAS scholars are leading investigations into crucial questions such as the sources of gravitational wave signals, the unexpectedly high frequency of detections, and—extending beyond these direct questions—establishing innovative and unexpected connections between gravitational wave research and particle collider physics. These contributions are pushing the boundaries of knowledge in this field, facilitating the interpretation and analysis of the data currently being gathered, and shaping the trajectory of future discoveries.

WHAT IS A GRAVITATIONAL WAVE?

The clichéd example that can be used to understand the phenomenon of gravitational waves is a bowling ball sitting in the center of a trampoline: the mass of the bowling ball causes the fabric of the trampoline mat to warp, just like spacetime around a planet. Now imagine that you (very foolishly) jump into the center of the trampoline, colliding with the bowling ball. As you crash into each other, both you and the ball would bounce up and down, causing ripples in the trampoline mat. Similarly, if the earth were to collide with an object which has a comparable mass, both the earth and its spacetime curvature would be shaken and ripples in spacetime would result. It is precisely these kinds of oscillations, caused by colliding astrophysical objects such as black holes and neutron stars,[1] that are picked up by gravitational wave detectors.

A second analogy is helpful for understanding precisely how gravitational waves are detected: imagine that (having recovered from your collision with the bowling ball) you take a walk around the Institute pond. You throw a pebble into the pond and watch the ripples that travel away from it. Gravitational waves can be understood as the spacetime version of the ripples in the water. Of course, if your colleague, standing on the other side of the pond, also throws in a tiny pebble, the ripples they create might be so tiny that you do not notice them by the time they reach you. But, if they launched an enormous boulder into the water, you would likely detect it at your location. Black hole and neutron star collisions act similarly: they create a huge warping of spacetime in their vicinity which then travels, like the ripples on the water, far enough that we can detect them on Earth.

The gravitational waves that are currently being detected predominantly result from the mergers of black holes—more specifically, black holes that have masses of ten or twenty times that of the sun. However, a few mergers involving neutron stars have also been detected. Each type of merger has a distinct gravitational wave signature. For example, when two neutron stars are merging (each of which is comparable in mass to the sun), the signal detected lasts much longer than that for two black holes. This is because our detectors only notice waves within a limited range of frequencies, and the less massive neutron stars spend more time orbiting each other in the correct frequency range.

The first detection of gravitational waves on Earth was made in 2015 by the twin Laser Interferometer Gravitational-Wave Observatory (LIGO). The first signal, named GW150914, was produced by the merger of two black holes about 1.3 billion years ago. This detection, and those that have followed, has been immensely significant for the study of astrophysics. Gravitational waves provide a new way to observe the universe and study astrophysical phenomena that are largely invisible via other observational methods. They have revealed previously unseen populations of black holes and provide a new understanding of stellar evolution and the building blocks of galaxies.

While black hole and neutron star collisions are confidently identified as the main source of gravitational wave detections, researchers are also seeking other sources of gravitational wave signals that have heretofore gone unrecognized. Member Mor Rozner investigates the effects that the gaseous environments surrounding tightly bound clusters of stars have on gravitational wave outputs. And this is not the only

[1] A neutron star is an extremely dense and compact stellar object formed from the collapsed core of a massive star after a supernova explosion.

other detection process that scholars have at their disposal; where Rozner's theories relate to gravitational waves detected by LIGO, Friends of the Institute for Advanced Study Member Gabriela Sato-Polito, Richard Black Professor Matias Zaldarriaga, and past Member and Visitor Eliot Quataert explore gravitational waves that are detected by analyzing the behavior of other stars in the galaxy. Their efforts are directed towards understanding why an unexpectedly high number of gravitational waves have been detected.

Surprisingly, astrophysicists are not the only scholars within the School of Natural Sciences who are taking a keen interest in gravitational wave research. Members Holmfridur Hannesdottir and Sebastian Mizera, whose primary interests are in particle physics, are also contributing to this field. They have identified fundamental mathematical commonalities between black hole collisions and the collisions of particles, providing a valuable tool for the process of analyzing gravitational wave detections. By pursuing these wide-ranging yet complementary lines of inquiry, the School of Natural Sciences is collectively contributing to a tangible transformation of knowledge in this field.

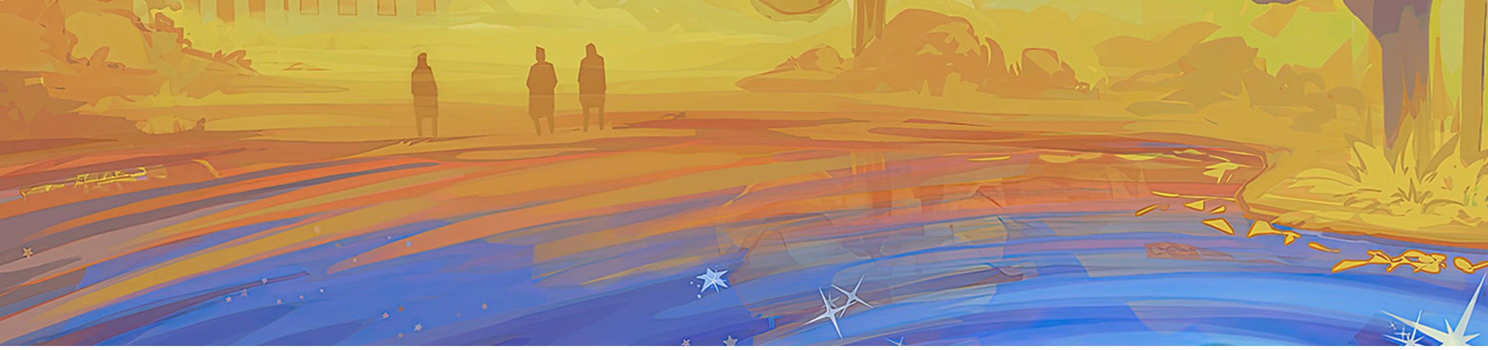
WHERE ARE GRAVITATIONAL WAVE SIGNALS COMING FROM?

Through her work, Member Mor Rozner has suggested a major additional source of gravitational wave signals that needs to be accounted for when analyzing data from LIGO: the gaseous environments within globular clusters.

Globular clusters are roughly spherical collections of hundreds of thousands, or even millions, of stars that orbit a common center. They appear with great regularity: there are about 200 globular clusters dotted around the Milky Way, while other galaxies sometimes contain many thousands. At 10–13 billion years old, they are among the oldest objects in the universe.

Rozner describes the traditional picture of these globular clusters as being "very simple." "For many years," she says, "people thought that, for globular clusters, there was one burst of star formation and that's it! The cluster is formed." However, today it is well established that such clusters were not formed in a simple, single event. Instead, clusters are known to consist of multiple star populations that came into being in several distinct episodes.[2] Rozner is interested in the "second population" of stars that formed early on in the cluster's life. The fact that these second-generation stars are so numerous means that a large amount of gaseous material must have been left over from the first

[2] Each star population is characterized by its unique chemical composition.

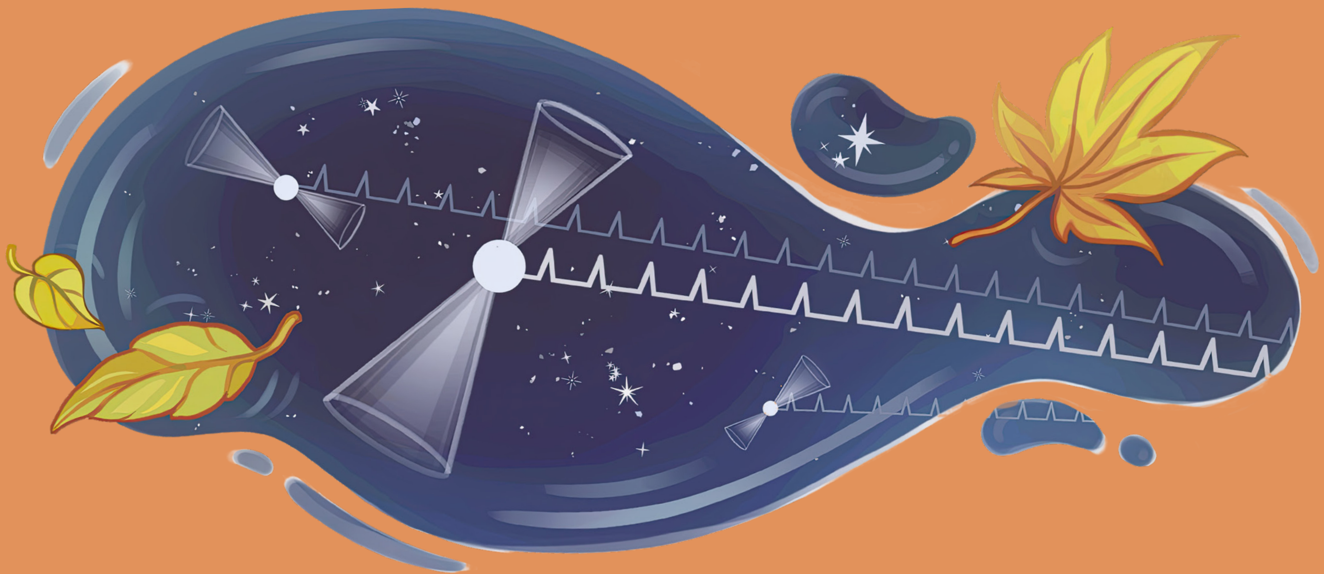


phase of the cluster's development, in order to provide sufficient raw material for their creation.

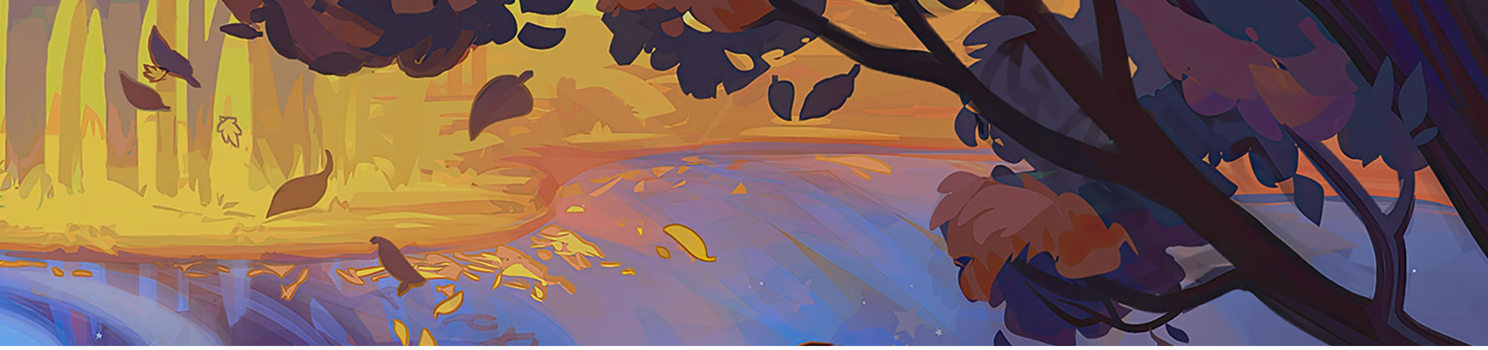
In her research, Rozner asks how the presence of this gas might have affected the evolution of a specific type of astrophysical object that exists within the cluster: binary black holes.[3] These are pairs of black holes that orbit each other due to their immense gravitational attraction. As Rozner states, "the vast majority of massive objects in the universe are found in binary pairs. So, it's really interesting and, I would say, very important to understand what is going on with these systems."

As the binary black holes orbit each other, moving closer and closer, they begin to emit gravitational waves. These gravitational waves play a role in the eventual collision and merging of the black holes: the emission of gravitational waves carries energy and angular momentum away from the binary system, causing its orbit to shrink. Eventually, when the black holes get close enough, the gravitational wave emission becomes so intense that the system is rapidly drained of its orbital energy, leading to an unstoppable inspiral that causes the collision.

Rozner's work adds detail to this picture, highlighting how the surrounding gaseous material within globular clusters also contributes to the evolution of binary black hole orbits. "The gas swirling around the black hole pairs also leeches energy from the system. "That's another factor helping to make their orbits gradually tighter and tighter over time," she explains.[4] Her theory explains that the gaseous environments present during the early stages of globular cluster evolution may have significantly impacted the dynamics of binary systems within them, potentially providing a major, previously unidentified source of gravitational wave signals. While it is unlikely that all



[3] Rozner, M., and Perets, H. B. 2022. "Binary Evolution, Gravitational-wave Mergers, and Explosive Transients in Multiplepopulation Gas-enriched Globular Clusters." https://doi.org/10.48550/arXiv.2203.01330



gravitational wave signals result from gas-rich globular clusters, the analysis of unique environments such as those considered by Rozner helps to establish a more holistic picture of, in her words, "what's going on in the universe to produce gravitational waves."

WHY ARE WE DETECTING MORE GRAVITATIONAL WAVE SIGNALS THAN EXPECTED?

Friends of the Institute for Advanced Study Member Gabriela Sato-Polito, Richard Black Professor Matias Zaldarriaga, and Member (1999–2001, 2023) and Visitor (2005) Eliot Quataert work with gravitational wave data captured by harnessing other stars within the universe as detectors. More specifically, they work with pulsar timing arrays (PTAs). As their name suggests, PTAs involve the observation of pulsars, which are rapidly rotating neutron stars scattered throughout our galaxy.

"Pulsars can be treated like clocks," says Sato-Polito. "They emit jets of radiation that sweep across space as the star rotates, and they have remarkably stable rotation periods. When these jets pass Earth, we detect, using radio astronomy facilities, a brief pulse of energy, hence the name pulsars. These pulses are seen at very specific, predictable intervals, meaning that they can serve as excellent timekeepers." When a gravitational wave passes between a pulsar and Earth, this alters the arrival time of the pulses. By carefully studying the accumulation of these timing "errors," astronomers can infer the presence of the invisible gravitational waves.

The gravitational waves detected with PTAs are fundamentally different from those measured with LIGO. In the case of LIGO, astronomers are detecting signals received in the space of seconds or minutes. Meanwhile with PTAs, astronomers are looking for fluctuations in the spin periods of pulsars that occur over decades. "We have been monitoring these pulsars for roughly 15–20 years," explains Sato-Polito. The main astrophysical source that produces gravitational waves of the frequencies detected by PTAs are supermassive black holes. Until 2023, when the first discovery of gravitational waves through PTAs was announced, the presence of supermassive black holes in our own galaxy and in nearby galaxies could be inferred by analyzing the gas or stars surrounding them, as well as through electromagnetic observations of the quasars, or jets, that the black holes eject, but with PTAs, the observations are more direct. Scholars can now measure the rates at which supermassive black holes are merging and can also learn more about the masses of the black holes involved.

In her work with Zaldarriaga and Quataert, Sato-Polito took the long-standing theoretical prediction for 1) what the population size of supermassive black holes ought to be, and 2) the expected number of different masses of those supermassive black holes, and compared it to the PTA data. "What we found is that the theory and the data were not incredibly consistent," she says. "There are quite significantly more gravitational waves being detected than the theory currently predicts. To produce the gravitational wave background that we are currently seeing through PTAs, we would need ten times more supermassive black holes than the theory currently accounts for."

Why is the theoretical picture so different from that gained through the data? In their initial paper, Sato-Polito, Zaldarriaga, and Quataert suggested that there might be a few particularly supermassive black holes out there that had not been previously measured,

[4] The gas drains energy from black hole binaries both through its outflows or winds, which carry away material from the system, and through various torques and drag forces that extract angular momentum and rotational energy.

explaining the unexpected amount of gravitational waves in the data.[5] But a subsequent analysis of the frequency patterns of gravitational waves detected by the PTAs has led to a different conclusion.[6] "If the observed signals were produced by a small number of powerful sources, we would anticipate seeing significant statistical variations between the data captured at different frequencies," explained Sato-Polito. "But such fluctuations were not present, so we now prefer a theory that there is a larger number of less massive black holes to explain the unexpected number of gravitational wave detections."

However, this answer is not definitive, and how precisely to resolve the discrepancies between the theory and the reality exposed by Sato-Polito, Zaldarriaga, and Quataert remains something of an open question. But this is precisely what excites Sato-Polito about this field of research. "One of the things that I find the most interesting about gravitational wave research is that it's a way of looking at the universe in a way that's never been done before," she says. "This result was something we were a bit surprised by, and the surprises are what intrigue me."

HOW ARE MERGING BLACK HOLES LIKE A PARTICLE COLLIDER?

With their interest in subatomic phenomena, scholars working within the particle physics group typically investigate some of the smallest building blocks of our universe—which makes their contributions to the study of gravitational waves, which emanate from some of the most massive objects known to man, quite unexpected. Despite this, Members Holmfridur Hannesdottir, Sebastian Mizera (2019–24), and Simon Caron-Huot (2009–14), and their colleague Mathieu Giroux of McGill University, have identified some striking mathematical similarities between these fields in the form of "scattering amplitudes."

As Hannesdottir explains, "at CERN's Large Hadron Collider (LHC), we can measure what happens when two particles collide with each other: materials scatter off in different directions. Using the mathematical technique of scattering amplitudes, we describe what happens when those particles collide or interact, predicting the likelihood of different outcomes." The new insight from Hannesdottir and her colleagues' work is that the mathematical expression for the scattering amplitude of particles and the gravitational waveform are, in her words, "one and the same." [7] In short, they have demonstrated that the physics of gravitational wave emissions in black hole collisions can be understood by computing scattering amplitudes of particles. They have drawn these links by using complex analysis, namely the mathematical study of functions of so-called "complex numbers."

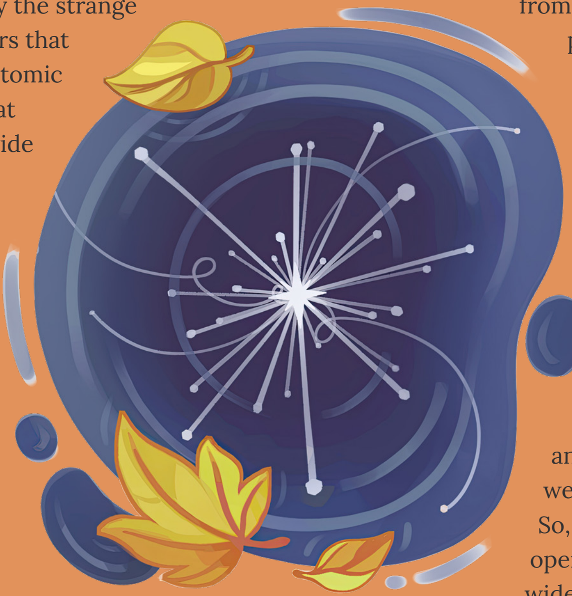
[5] Sato-Polito, G., Zaldarriaga, M., and Quataert, E. 2023. "Where are NANOGrav's big black holes?" https://doi.org/10.48550/arXiv.2312.06756

[6] Sato-Polito, G., and Zaldarriaga, M. 2024. "The distribution of the gravitational-wave background from supermassive black holes." https://doi.org/10.48550/arXiv.2406.17010

[7] Caron-Huot, S., Giroux, M., Hannesdottir, H. S., and Mizera, S. 2023. "What can be measured asymptotically?" https://doi.org/10.48550/arXiv.2308.02125 and Caron-Huot, S., Giroux, M., Hannesdottir, H. S., and Mizera, S. 2023. "Crossing beyond scattering amplitudes." https://doi.org/10.48550/arXiv.2310.12199

Complex numbers combine both "real" and "imaginary" parts. A "real" number is a standard number such as 1, 2, 3, 4...that can describe the everyday world, but imaginary numbers are different in that, when squared, they give a negative result. The most basic imaginary number is i, defined as the square root of -1. Imaginary numbers (like i) do not directly correspond to measurable physical quantities but are an immensely useful mathematical tool. They can accurately describe quantum phenomena, namely the strange and counterintuitive behaviors that occur at the atomic and subatomic scales.[8] Hannesdottir says that these complex numbers provide an "exact correspondence" between scattering amplitudes and gravitational wave signals.

Why is this significant? Mizera explains that these mathematical expressions make it possible to "quickly determine what kind of black holes or other heavy objects were present in the universe millions of years ago when these interactions took place, causing the gravitational waves that we see today," providing an immensely useful time-saving tool.



How particle physicists can continue to contribute to the astrophysics community's understanding of the universe in this way was highlighted in a panel at the Amplitudes 2024 conference, which brought more than 250 participants from across the globe to the Institute campus in June. "There used to be a language barrier between the two disciplines, but we're slowly learning to better communicate," says Mizera. "Around the time of the first gravitational wave detection, it was like one side was speaking Spanish and the other Klingon, but now it's like Spanish and French!" Despite the differences in jargon, there is much to be gained from this boundary-crossing approach.

Hannesdottir adds, "Understanding the universe from Earth is hard! It's not like in a particle collider where we can measure almost everything that comes out of a collision. Instead, it's like we're in a basement where there is a tiny window to the universe, and we're trying to figure out everything about the universe from just the grass and flowers that we see from this window. Gravitational waves are an amazing new tool and they can measure things that we can't measure in any other way. So, gravitational wave research opens the basement window a little wider, and that is fascinating for those working in both areas of physics."

The work of IAS scholars is opening windows, so to speak, in many areas, pushing the boundaries of our understanding of the cosmos. The Institute continues to be at the forefront of unraveling the mysteries of gravitational waves, a legacy extending from Einstein's initial prediction all the way to today's cutting-edge research.

[8] An example of such a quantum phenomenon for which complex numbers are useful is superposition, where quantum objects can exist in multiple states at once until they are measured. This is famously illustrated by the Schrödinger's cat thought experiment, where a cat is theoretically both alive and dead until observed.

When Maureen C. Miller, Elizabeth and J. Richardson Dilworth Member (2021) in the School of Historical Studies, was completing her dissertation in the late 1980s, she found herself rather lonely, knowing not a soul in the diocese of Verona, Italy, where she was based for her research. In need of an activity to satisfy her curiosity and fill her free time when the archives and libraries were closed, she started to explore the churches in Verona and its countryside—of which there were surprisingly many, considering that medieval churches are often built of an ephemeral material: wood.

What became clear to her, as she explored, was the ways in which the physical evidence of the churches themselves often yielded a different—much earlier—foundation date than those she had found in her textual sources. Curiosity piqued, she began to build a database of all the churches in the area, searching more concertedly for the material evidence needed to make it more accurate. And so, despite her initial intentions to only use textual sources for her doctoral research, Miller followed her interests into the world of physical objects.

Revisitation and Transformation in Medieval History

By Abbey Ellis and Genevieve Looby

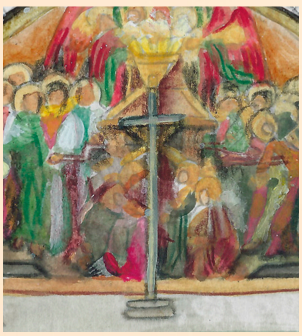
The humanities are replete with the study of objects—their history and significance have long been examined through varied disciplinary lenses. But, in the 1990s, right alongside Miller's venture in Verona, developments within anthropology, archaeology, history, and art history had streamed together to produce the vibrant interdisciplinary field of material culture studies.

Material culture studies takes as its task the investigation of the relationship between objects and people. Where art history is interested in (often high-end) objects themselves—for example, comparing their forms and styles across time—material culture studies seek to engage (both high-end and everyday) objects as sources for human actions and ideas—for example, using a shift in style to investigate the human ideas or practices that drove such a change.

A key innovator in this infant discipline, who played a noteworthy role in nurturing and developing it within the realm of Medieval studies, was Caroline Walker Bynum, Professor Emerita in the Institute's School of Historical Studies. Bynum's significant—even field-shaping—impact on historical scholarship was celebrated earlier this year with a symposium published in the journal *Common Knowledge*. Miller, whose continued work in the world of objects has been much influenced by Bynum, spent some of her time at the Institute revisiting Bynum's work to contribute to the symposium.

Illustration by Laura Haines

A key characteristic defining Bynum's scholarship, Miller says, is a meticulous process of revisiting her subjects, be they texts, objects, or artworks—something quite unique in an academic culture which encourages scholars to leap from one topic to another in an effort to demonstrate productivity.



By the 1990s, Bynum had already distinguished herself with groundbreaking work on textual sources for religious life in the twelfth to fifteenth centuries C.E. "How strange," but what a "wonder" it was that she turned her hand to this emerging discipline of material culture studies, noted Miller in her essay. "It was neither obvious nor inevitable that she would cap her extraordinary career by illuminating Christian devotional objects," she continued.

A key characteristic defining Bynum's scholarship, Miller says, is a meticulous process of revisiting her subjects, be they texts, objects, or artworks—something quite unique in an academic culture which encourages scholars to leap from one topic to another in an effort to demonstrate productivity. Miller focuses her essay on one particular object that Bynum revisited several times, a fifteenth-century "beguine" cradle that originally held an effigy of the baby Jesus, now housed in the Metropolitan Museum of Art, New York. Through detailing Bynum's investigations of this cradle over several revisitations, Miller shows how her initial approaches involve a skillful deployment of the object as an illustration of arguments originating primarily from textual sources. Miller then goes on to highlight how, in later studies of the cradle, Bynum's focus is the object itself, as she investigates how and why it works as it does. Miller describes the cradle as having agency of its own, or as possessing the key quality of "insistence," in that it demands certain actions from the people that interact with it.

This fall, Miller worked with *The Institute Letter* to chart Bynum's scholarship in material culture studies even more broadly, through the lens of a few Medieval objects that she regularly revisited throughout her career. In addition to the cradle, the *Letter* explores Bynum's work on a wooden "retable," a painted wooden panel which depicts the Virgin Mary emptying sacks of wheat into a funnel, from which both the baby Jesus and pieces of bread emerge, and a "pietà," meaning "pity" or "compassion" in Italian, a sculpture that depicts Mary holding the body of Jesus after his crucifixion. The impact of Bynum's return to all three objects is profound. The objects are transformed from background characters in a textual-focused narrative to central, influential players that perform a formative role in Medieval Christian piety.

The legacies of Bynum's work, described by Miller in her symposium contribution, function as a series of invitations. The way Bynum centers objects and investigates them in later works invites readers to embrace wonder, beyond a "passive form of bedazzlement." Asking questions of the objects engages an active form of wonder. It also inspires readers to have confidence in their own curiosity, as Bynum did: Miller asserts, "She teaches us again and again about the self-confidence that it takes to ask 'How?' and 'Why?'."

Finally, with her practice of revisiting sources, Bynum's work encourages readers to take pleasure in returning to past work, be it questions or sources, to see what new insights arise. "The consolation I find in my recent immersion in Bynum's rich oeuvre," Miller concludes, "is that there is so much to be gained from resisting the pressures to rush on to the next thing and, instead, choosing to spend a little more time with sources that we know and love. In her honor, return to an object or text that you have enjoyed and afford yourself the pleasure of meeting an old friend and finding out something new."

The Mystical Mill

The wooden retable, dated to around 1440, is referred to by Bynum as a "Mystical Mill" or a "Host Mill." [1] She first introduces the object in her book *Holy Feast and Holy Fast* (1987), which examines the importance of food for religious women in the Middle Ages. The section in which the Mystical Mill appears is focused on the Eucharist, a Christian ritual commemoration of Jesus's Last Supper with his disciples, where he instituted the practice of sharing bread and wine. Through a process known as transubstantiation, Catholics believe that the bread and the wine taken during the Eucharist literally transform into the body and blood of Christ. In Bynum's words: "Christ had said it *was* human life, was body and blood."

By 200 C.E., recreating this ritual had become a central practice in the church. But, by the late thirteenth century, there was a gradual restriction of the congregants who were allowed to receive the Eucharist. Eventually, only the priest received the bread (also known as the "host") and wine on behalf of his flock. The withdrawal of the ability to receive the Eucharist further elevated its status—so much so that textual sources attest to congregants entering what Bynum calls a "spiritually and psychologically heightened state," experiencing visions of Christ, after simply gazing upon the bread and wine. Simply put, at this time there was an enhanced sense that the bread and wine were God himself. Having highlighted this idea of God as food through surviving texts, Bynum goes on to make the point that this same notion began to pervade Christian iconography at this time. The Mystical Mill is cited as an example. The object evokes the amplified association between God and food seen in the texts, since, in Bynum's words, "both Christ child and the host" emerge from the milled grain.

> The object evokes the amplified association between God and food seen in the texts, since, … "both Christ child and the host" emerge from the milled grain.

Rufus46, Wikimedia Commons

In *Christian Materiality* (2011), Bynum's examination of how late Medieval Christians engaged with miraculous material objects, the Mystical Mill is itself the focus. Bynum first introduces it as part of a discussion of what she describes as "often quite expressionist and bizarre" Medieval iconography that was later "attacked," sometimes physically, by Protestant reformers. She describes the Mill as "bold," almost to the extent of being "religiously perverse." Illuminating the "strangeness of medieval Christianity" in this way is "a recurrent, and important, theme in Bynum's work," states Miller. Bynum then goes on to outline how such images function in both "materializing" (i.e., making God's presence physically manifest or tangible in the material world) and "somatizing" (i.e., embodying or expressing God's nature in a corporeal form) ways. In the Mystical Mill, and other examples that Bynum cites, "body and material thing…seem to fuse or become each other." Here, the Mill serves to emphasize what Bynum describes as the "extravagant" physicality of Medieval art. The sense that a reader gains from this discussion is that such images were not merely decorative but operated on multiple levels, including the theological, material, and symbolic.

[1] The object measures 137cm x 156cm. Today, it can be found at the Ulmer Museum, Germany (Inv.-Nr. AV 2150).

The Fritzlar Pietà

We see a similar pattern in Bynum's analysis of a second object to which she repeatedly returns: a linden wood "pietà" from Fritzlar, a small town in central Germany, which was probably made before 1350.[2]

Bynum analyzes the piece in *Wonderful Blood* (2007), a book which explores how Christ's blood came to be the center of devotional practices and theological discourses between 1300–1500 C.E. In her discussion, she calls attention to the fact that the pietà, in its Medieval form, "actually had blood drops of papier-mâché affixed to the body." For Bynum, "the discreteness of those elements," namely the fact that the blood was rendered in individual drops, was significant. She linked them to a late Medieval "obsession" with quantification that again emerges through texts. Her textual evidence includes a story used by late Medieval preachers where the number of drops of blood was important: "a dying monk, seeing in a vision devils and angels weighing his deeds, begs for one drop of *sanguis Christi* [the blood of Christ] to be added on the scales on the side of his virtues in order to effect his salvation." "Virtues, merits, and credits toward salvation," could be, in her words, "counted off" in the same way as blood drops on pieces like the pietà could be enumerated.

"The graphically rendered side wound," where today we see two holes, would have originally had a small shrine or container attached which housed a relic."

When Bynum returns to the Fritzlar pietà in *Christian Materiality*, the object itself emerges triumphant. She uses the pietà to indicate that the distinction between an object being something and representing it in image form "was far from clear" in the Medieval period; some devotional objects, such as sculptures of Christ, were thought to actually be Christ in what Bynum calls "a special sense." They functioned in a similar way to the manner in which the bread and wine of the Eucharist were thought to be Christ's body and blood. Some objects achieved this status because they contained relics—the Fritzlar pietà is one such item. In Bynum's words, "the graphically rendered side wound," where today we see two holes, would have originally had a small shrine or container attached which housed a relic, such as a piece of holy bone said to be from the body of Jesus.[3] When a relic physically touched or became embedded within another object, the significance of that object changed: materials that had been touched to holy relics were thought to become that with which they had made contact. As a result, when viewing the Fritzlar pietà, she argues that the Christian viewer would have responded both to the depiction of blood from Jesus's body and the holy relic, which elevated the sculpture to the status of actually being Jesus's body. The object and the thing they represented "were conflated, with no sense of incongruity." In this analysis, the pietà is by no means an illustration—the power it would have held in its own right for a Christian believer shines through in Bynum's writing.


Dierk Schaefer, Flickr

[2] The sculpture stands at just under 5 feet in height. Today, it remains on display within a baptismal chapel in Fritzlar's cathedral tower.

[3] However, she declared it "impossible to tell" what this relic might have been.

The Beguine Cradle

The final object, the "beguine" cradle, is so-called because it hails from the Grand Béguinage of Louvain, Belgium, a religious community established for lay women in the twelfth century C.E.[4] The object itself dates to the fifteenth century and is made from polychromed and gilded wood.

In *Fragmentation and Redemption* (1992), the object appears in Bynum's discussion of the deep connections between Medieval women's spirituality and their societal roles. She argues that the expectation that women would produce, nurture, and care for children influenced how women experienced visions of themselves bathing and nursing the infant Jesus, a trend that she identifies in the textual sources. In her *Common Knowledge* essay, Miller describes how, in this case, objects such as the beguine cradle "cluster in the chapter's sections detailing the institutional, social, and intellectual contexts that answer the question 'Why is this so?'"

The beguine cradle, with its striking emptiness, powerfully calls out for activity and engagement.

By contrast, in *Christian Materiality*, the cradle appears not as an answer to an external question but as something that provokes many different questions and responses in its own right. In this publication, the object's own agency, or "insistence," is the focus. Bynum evokes how the beguine cradle, with its striking emptiness, powerfully calls out for activity and engagement. The absence of the baby Jesus creates a void that invites the viewer to respond: perhaps by placing the figure back in the cradle. This is the most obvious response that the cradle might insist upon, but, as Miller points out, Bynum emphasizes that it is merely one possibility. The cradle's emptiness, Bynum goes on to argue, could be interpreted as a metaphor for the soul awaiting divine presence, inviting believers to contemplate what it means to welcome Christ into their hearts. In this instance, the beguine cradle appears in Bynum's scholarship as an object with the agency to open numerous avenues for piety. In her words, it encourages believers to not only "see" the physical object in front of them, but also to "see beyond," encouraging a spiritual experience and deepening their connection to God.

Metropolitan Museum of Art, New York

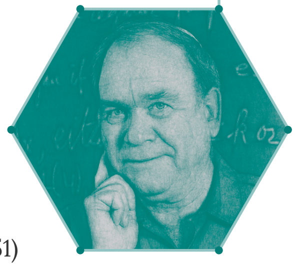
Maureen C. Miller is the Jane K. Sather Distinguished Professor of History at the University of California, Berkeley. She was the Elizabeth and J. Richardson Dilworth Member (2021) in the School of Historical Studies. The author of three award-winning monographs on medieval ecclesiastical history and culture, her work has focused primarily on Italy and on the material culture of the secular clergy. She is presently researching the role of the church and its institutions in processes of documentary innovation.

[4] The object measures 35.4cm x 28.9cm x 18.4cm. Today, it can be found within the collections of the Metropolitan Museum of Art (Inv.-Nr. 1974.121a–d).

A Connector's Connector

Peter Sarnak and Ramanujan Graphs: The Quintessence an of Idea as it Transmits, Translates, Transforms

By Siobhan Roberts



To innumerable degrees, **Peter Sarnak**, Professor Emeritus in the School of Mathematics, is connected. "He is extraordinarily broad and influential," Helmut Hofer, Hermann Weyl Professor in the School, said of his colleague. "He's a connector."

Jacob Tsimerman, a mathematician at the University of Toronto and a former Ph.D. student of Sarnak's, agreed: "Peter is definitely one of the most connected mathematicians in the world."

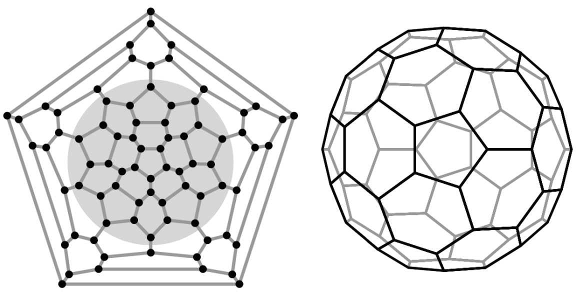
According to the Mathematics Genealogy Project, Sarnak has 57 students and 221 descendants. Another metric is his tally of 7,648 citations by 3,567 authors on MathSciNet, the American Mathematical Society's bibliographic database.

One of those authors is the Yale computer scientist **Daniel Spielman**. Spielman delivered the opening lecture at "Visions in Arithmetic and Beyond: Celebrating Peter Sarnak's Work and Impact," a conference held at the Institute and neighboring Princeton University in June. To meet the moment, Spielman zeroed in on Sarnak's most famous paper: "Ramanujan Graphs." Published in 1988, the paper was co-authored with two past IAS scholars, frequent Visiting Professor in the School of Mathematics, **Alexander Lubotzky**, and Ralph S. Phillips, Member (1939–40, 1950–51) in the School. The "Ramanujan Graphs" paper inaugurated and introduced the namesake concept. It is Sarnak's most cited paper, 531 hits and counting.

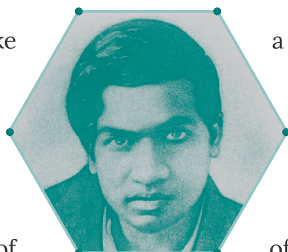
The import of the research is not merely due to the profound result, but also to its power in computer science and its iterative impact back in mathematics. All in all, Ramanujan graphs are maximal examples of how ideas transmit and transform along the increasingly blurry continuum of pure versus applied mathematics.

"I have often described these Ramanujan graphs as the most amazing gift that pure mathematicians have given to theoretical computer scientists," said Spielman at the outset of his talk. He acknowledged that colleagues sometimes counter with, "'Well, what about Fourier analysis?' And, yeah, that's good too. But that's not a gift," he said. Spielman thinks of Fourier analysis as plumbing, or paved roads—it's part of the infrastructure; it's a time-honored staple of the science curriculum.

Ramanujan graphs, by contrast, are a great gift because, first, "we would have never bought it for ourselves," he said. "We wouldn't have known where to find it! I mean, why did they call them Ramanujan graphs? Because the way they proved this is to exploit proofs of the Ramanujan conjecture, and this is not a part of what computer scientists usually learn in their education."

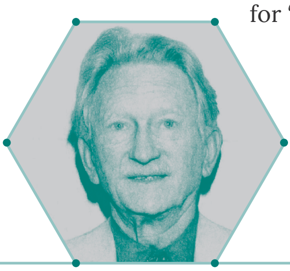


This Ramanujan graph has 80 vertices,which is close to the largest known planar Ramanujan graph of 84 vertices. Its girth is 5, its expansion constant 1/4 (as indicated by the shaded circle), and λ_1 has been calculated by A. Gamburd to be 2.81811… It may be constructed by shrinking pentagons on a dodecahedron.



Rooted in the work of **Srinivasa Ramanujan** (1887–1920), the namesake graphs owe their existence to clever use of proofs of Ramanujan's conjecture. The conjecture is a deceptively simple statement about modular forms, objects in the domain of number theory. It is one of the most important conjectures ever made, articulated by Ramanujan in his 1916 paper "On Certain Arithmetic Functions."

Notably, a half century later, the Norwegian-American mathematician **Atle Selberg**, a 1950 Fields Medalist and Professor in the School of Mathematics (1951–2007), published a related paper "On the estimation of Fourier coefficients ofmodular forms"—which, indirectly, would become a crucial inspiration for "Ramanujan Graphs."



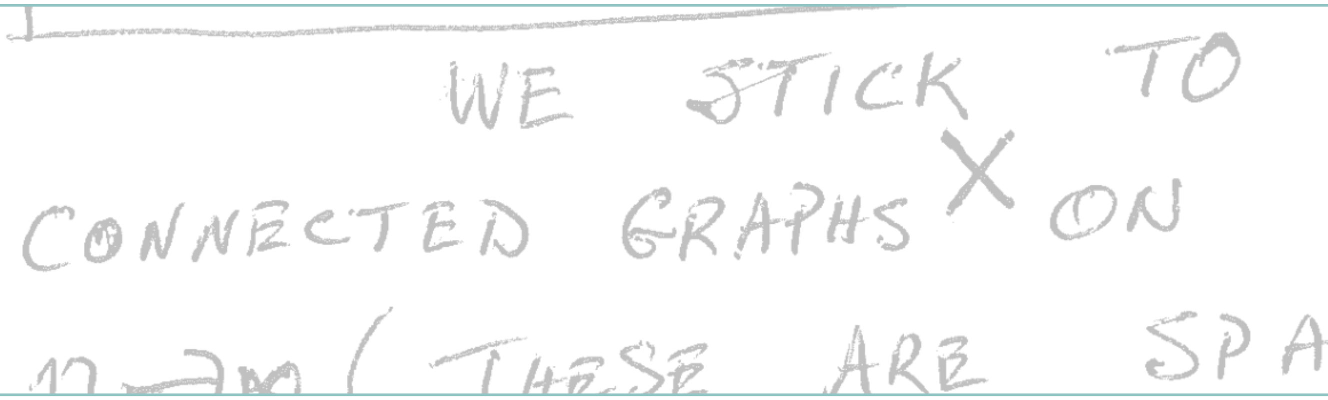
Ramanujan graphs live in the domain of combinatorics: the art of counting, among the oldest subjects in mathematics. In this domain, graphs are all about enumerating connections. A graph is a collection of points and lines, a set of vertices and a set of edges. "Any two vertices are either joined, or they're not," Sarnak said. The edges connect a subset of vertices, and thereby represent a relation. "You have a set of objects, and you have some relations, and you want to prove that those relations are enough to force the existence of some other set." When every vertex has the same number of edges, and thus is connected to the same number of neighbors—that number being "d"—then the graph is said to be "d regular." The first interesting case is d=3. Sarnak added: "Also, d=3 leads to the sparsest graphs, so indeed may be the most interesting case."

The world wide web can be modeled as a graph: a vertex represents a website, and a line indicates a hyperlink. Google's search algorithm, the PageRank algorithm, is based on this kind of graph theory. "You can imagine that many engineering problems, many complexity problems, involve understanding some properties of these graphs," said Sarnak.

When he lectures on Ramanujan graphs, Sarnak begins by spelling out the concept in simple enough terms with his signature handwritten slides:

- RAMANUJAN GRAPHS ARE HIGHLY CONNECTED SPARSE LARGE GRAPHS.
- THE TENSION BETWEEN SPARSE AND HIGHLY CONNECTED IS WHAT MAKES THEM SO USEFUL IN VARIED APPLICATIONS.

Sparsity and high-connectedness are properties that pertain more generally to a larger family of graphs: expander graphs. Expander graphs extend and augment —"expand"—the representation of information or



network connectivity in an efficient and robust way. The sparsity property means that each vertex is only connected to a small number of other vertices; the number of edges, or connections, is much smaller than the maximum possible. Despite the sparsity, the highly connected property means there are many short paths between any two vertices in the graph.

The sparsity-connected interplay and tension facilitates large graphs, making them scalable; and it makes the graphs especially useful because information or signals propagate quickly, and data is efficiently processed and stored.

"The existence of expanders is counterintuitive," said Sarnak. "Very well-known mathematicians made conjectures which, once pruned down and understood, were saying essentially, 'Expanders don't exist.'" And by extension, the existence of Ramanujan graphs is even more counterintuitive: because Ramanujan graphs are a special class of expander graphs that possess optimal sparsity and connectivity. "They are the best possible," Sarnak said. "You cannot do better. That's why they're interesting. And there's a tension between sparse and highly connected. That's what makes them useful in all sorts of applications."

Antecedents of expanders—before they were so named—extend from various directions.

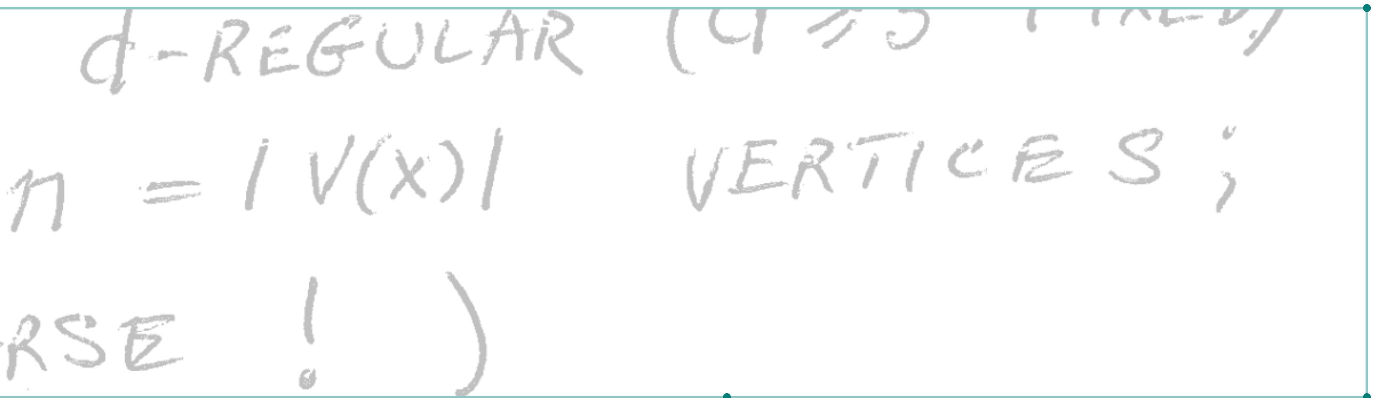
By 1956, **John von Neumann**, Professor (1933–55) in the School of Mathematics, had composed the rudiments of an expander while investigating fault tolerant circuits. He described this work in the paper, "Probabilistic logics and the synthesis of reliable organisms from unreliable components."

In his talk, Spielman reckoned that future developments stem from von Neumann. "I suspect that people studying von Neumann's paper is one of the main ways we got the notion of expansion," said Spielman. "People had read his paper and knew about his paper all around the world."

In 1967, in Russia, Andrey Kolmogorov, among the greatest Russian mathematicians of the twentieth century, published a related paper with Y. M. Barzdin, "On the Realization of Networks in Three-Dimensional Space." By way of example at the outset, they mentioned not only logic networks but also neuron networks—they asked: How many neurons and synapses can fit in a brain? "In the brain, you have a lot of vertices, but a fixed volume," said Alexander Gamburd, a mathematician at The Graduate Center, CUNY; Member in the School of Mathematics (2005–06, 2007–08, 2022); and a longtime collaborator of Sarnak's. "You clearly want the vertices, or neurons, to be highly connected, but there is a sparsity constraint."

"The necessity of sparsity could be seen in the case of the neural network in the brain," said Gamburd. "Identifying synapses with the vertices and dendrites with the edges, one can view the network of neurons in the brain as a graph; since the 'wires' have finite thickness, their total length cannot exceed the quotient of the average volume of one's head and the area of the wires cross-section." Bardzin's contribution was to confirm Kolmogorov's calculation about a neural net under such constraints. It was a crude model of the brain, but in the course of verifying this result, Barzdin constructed the equivalent of an expander.

It wasn't until 1973 that expander graphs were formally defined, and named, by the Russian mathematician Mark Pinsker with the paper, "On the complexity of a concentrator." Pinsker, who worked



in information theory, probability theory, and coding theory, used a probabilistic argument to prove the existence of expanders. And indeed, it seemed that expanders could only be generated randomly. Any deliberate, rational attempt to make one produced a graph that did not possess the coveted properties.

However, Pinsker, in his paper, referred to work (yet unpublished; appearing later in 1973) by his countryman, mathematician **Gregory Margulis**, Member (1991, 2006) in the School of Mathematics. Margulis's feat was to construct an *explicit* expander— that is, to construct a deterministic graph according to a mathematical formula that explicitly sets out which vertices and edges should be connected. As a result, explicit expander graphs could be designed for implementation in any application —in computer science, coding theory cryptography, and other fields that require highly connected, sparse, scalable, and robust graph structures.

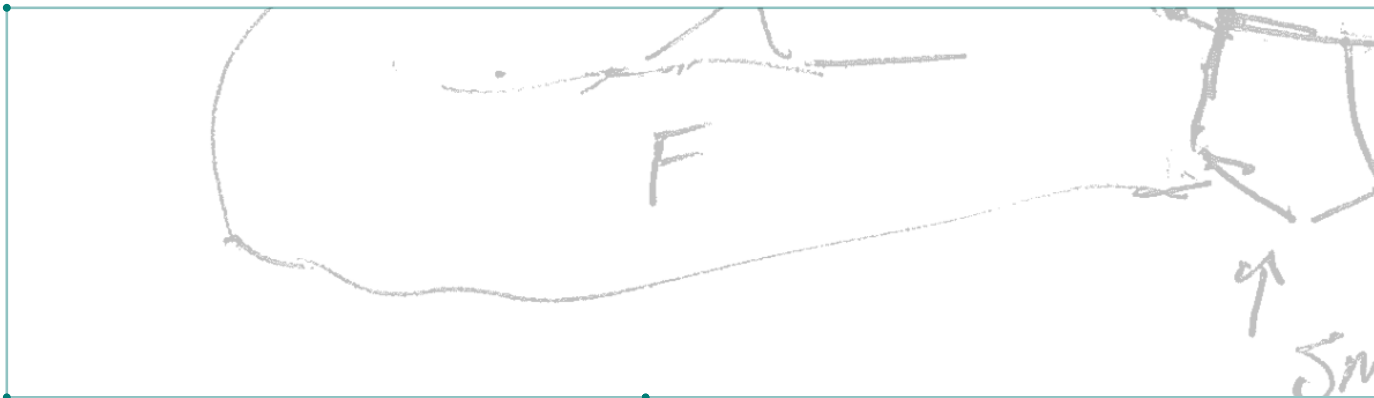
The construction of explicit expanders thereafter became something of an industry.

Sarnak arrived on the mathematical scene in the mid-1970s. He did his Ph.D. in mathematics at Stanford with Paul Cohen, Member (1959–61, 1967) in the School of Mathematics. Cohen had revolutionized set theory by solving the first of David Hilbert's problems from his 1900 list. This work earned Cohen a Fields Medal in 1966, still the only instance of the award for mathematical logic.

Sarnak had intended to pursue logic with Cohen, but when he arrived at Stanford in 1976, his advisor had moved on—he had redirected his attention toward another of Hilbert's problems: the Riemann hypothesis. Posed by German mathematician **Bernhard Riemann** in 1859, the hypothesis addresses the distribution of prime numbers, and in so doing asserts that some nontrivial zeros—zeros of the Riemann zeta function—lie on a critical line. Sarnak happily joined Cohen in bouncing around ideas. Cohen suspected that related work by Selberg might be useful. “So, I had the privilege of learning Selberg's work as an equal of Cohen,” said Sarnak.

In 1984, after a few years at NYU's Courant Institute, Sarnak took up the position of associate professor at Stanford, where he commenced a series of fruitful collaborations with Ralph S. Phillips. One line of investigation they probed was Selberg's compelling contribution, not to the Riemann hypothesis, but rather to the Ramanujan conjecture. And in fact, by this time the Ramanujan conjecture, singular, had evolved into the Ramanujan *conjectures*, plural. The idea proved so compelling that over the years it was reinterpreted—propagated and transformed into various potent reformulations.

The two problems—the Riemann hypothesis and the Ramanujan conjecture, although distinct and dissimilar problems, are not entirely unrelated. The connection comes via those nontrivial zeroes. Selberg had provided a generalization of the Ramanujan conjecture—and Robert Langlands, Professor Emeritus in the School of Mathematics, took it even further. Selberg's general case became known as the Ramanujan-Selberg conjecture. It remains unsolved, but the best results to date are



due to Sarnak and collaborators.

Over the course of their Ramanujan investigations, Sarnak and Phillips became aware, tangentially, of an “order,” of sorts, issued by the combinatorist Noga Alon, frequent Member and Visiting Professor in the School of Mathematics, now at Princeton, and the computer scientist Ravi Boppana, at the Massachusetts Institute of Technology. They had an inkling that their current line of thinking might be relevant.

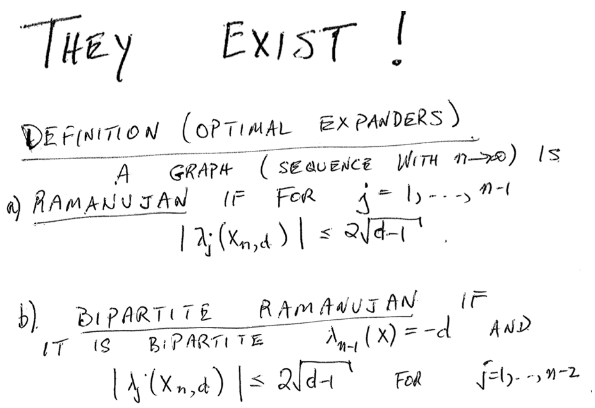
In a 1986 paper, Alon and Boppana showed that there was a limit to how good an expander graph could be. Measuring a graph’s connectivity and expansion properties had become a going and growing concern. The precursors here date back to the early 1970s in the domain of differential geometry, and courtesy of Jeff Cheeger, Member in the School of Mathematics (1972, 1977–78, 1995), now at the Courant Institute. To describe it using technical terms of the art, Cheeger’s contribution was to establish very useful inequalities between an isoperimetric constant *h*—the Cheeger constant, which is difficult to compute—and the spectrum of the Laplacian. The upshot: an analogue of these entities was developed for, and became central in the study of, expander graphs. And the bottom line: “You want *h* to be big,” said Sarnak. “That *h* should be not small implies zillions and zillions of beautiful properties, and one property is there should be no bottlenecks, like a traffic jam. If you’re trying to make an efficient network, you don’t want a bottleneck.”

In an ideal world, there would be no limit on the beautiful properties of an expander graph. Alon and Boppana, however, showed, by a reformulation of the measure of a graph’s structure and expansion properties—the so-called spectral gap measure, which emerged from the domain of linear algebra—that an expander graph could not exceed a certain threshold. There was an upper bound. “You want this gap to be as big as possible,” said Sarnak. “The bigger the gap, the better: the more of an expander your graph will be.”

Alon and Boppana, in delineating the upper bound, put out a call for such an optimal expander graph.

Sarnak and his collaborators delivered. He and Phillips got a start and made some progress. Significant traction on the optimal property came when Sarnak ran it by his friend Lubotzky, then also at Stanford: given the linear algebra reformulation of the graph’s expansion measure, Lubotzky suggested that they explore some seemingly apropos methods in the domain of number theory. “The graphs we made were built out of number theory,” said Sarnak.

The mathematicians exploited a series of results on the namesake Ramanujan conjecture and its reformulations. All they needed in order to construct the graphs were the simplest cases of the Ramanujan conjecture due to the German number theorist Martin Eichler, Member in the School of Mathematics (1964–65). The proof of the original Ramanujan conjecture was due to the Institute’s **Pierre Deligne**, Professor Emeritus in the School of Mathematics. Deligne accomplished this feat by deploying fancy machinery by the German mathematician Alexander Grothendieck, and for this work Deligne won the Fields Medal. Rallying these more sophisticated resources, when all was said and done, Lubotzky, Phillips, and Sarnak were able to verify the existence of an infinite family of optimal expander graphs—the best possible expanders: Ramanujan graphs.



The construction was entirely explicit—the graphs essentially came with a blueprint for application. "You can implement it instantly," said Sarnak. "I give you the vertices," he explained—the names may be numbers, or other mathematical terms of reference. "And I tell you, for example, 'Connect vertex five to vertex seven.' I give you the best configuration with a formula."

In 1988, the researchers published their result in the journal *Combinatorica*. Independently, from behind the Iron Curtain, Margulis delivered the same result, using the same Ramanujan input and a similar construction. He published it the same year and eventually smuggled out a copy to Sarnak via a mutual connection at Stanford.

These days, Lubotzky gets questioned by the younger generation as to why the authors didn't publish their momentous paper in a top journal like the *Annals* or *Inventiones*. "*Combinatorica* is a great niche journal," he said. "We didn't realize the wider import at the time."

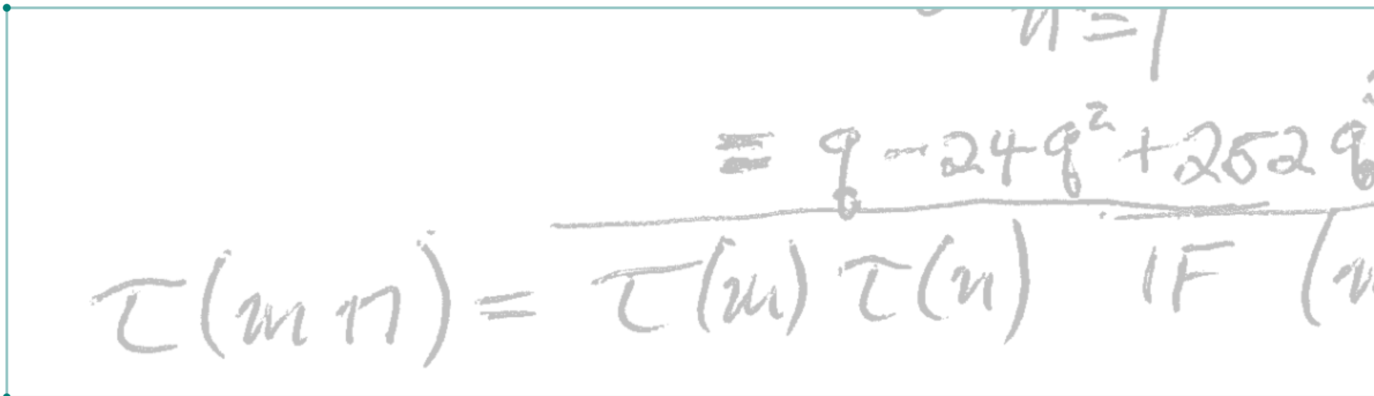
"In computer science, this was sought after," said Sarnak. "But more so than we realized. It became a hit." And it is still very much a going concern.

Sarnak has a bet with Noga Alon about the chances that any regular expander graph generated at random is Ramanujan, i.e., optimal. Alon says that nearly all regular random graphs are Ramanujan; Sarnak says that almost none are. Progress on this front was outlined at the Sarnakfest by the physicist Horng-Tzer Yau of Harvard University, a frequent Member in the School of Mathematics, who lectured on "Spectral Statistics of Random Regular Graphs"—work which he conducted jointly with Jiaoyang Huang, Member in the School (2019–20), and Theo McKenzie. Given what he heard, Sarnak expects a resolution soon. "They are very close to proving that these obey a basic random matrix law," he said.

"It turns out we are both going to lose," said Sarnak. He expanded: "Noga said with probability one that the graph is Ramanujan. I say with probability one that the graph is not Ramanujan. It's going to be that with probability 51% the graph is bipartite Ramanujan, and with probability 27% it is non-bipartite Ramanujan—in the former case he has to pay me, and in the latter case, I have to pay him. We are both wrong, officially."

More tangibly, applications of Ramanujan graphs—a.k.a. L.P.S. Ramanujan graphs, or L.P.S. graphs—abounded back in the day and continue to proliferate: in algorithm design, data storage, and cryptography. And in quantum information theory, quantum expander graphs scramble information.

In 2006, **Avi Wigderson**, Herbert H. Maass Professor in the School of Mathematics, published a 123-page survey, "Expander Graphs and Their Applications," with co-authors Shlomo Hoory



and Nathan Linial. The authors wrote, “It is not surprising that expanders are useful in the design and analysis of communication networks. What is less obvious is that expanders have surprising utility in other computational settings such as in the theory of error correcting codes and the theory of pseudorandomness… they play a key role in the study of Monte-Carlo algorithms in statistical mechanics.” They added, “The list of such interesting and fruitful connections goes on and on with so many applications we will not even be able to mention.” Wigderson estimated that an updated survey today would be triple the size.

Because Wigderson chronicled the abundant utility of expanders, Sarnak calls Wigderson “the expander man.” Wigderson’s survey also includes his own “zig-zag product,” devised with Visitors in the School of Mathematics Omer Reingold (1999–2003) and Salil Vadhan (2000–01). The zig-zag provided a new construction—the first combinatorial (non-algebraic) construction—of explicit expanders that were much easier to understand, and arguably more flexible. Yet, at once, the zig-zag expanders were more difficult to construct and non-optimal. “The originals were not optimal, but later constructions made them near optimal,” Wigderson said.

At any rate, Wigderson doesn’t see the point of evaluating trade-offs or pros and cons. “Math benefits from having different solutions of different natures to the same problem as they reveal connections between fields,” he said, “and sometimes different properties are useful for different applications.”

Wigderson’s epic survey also gathers in Daniel Spielman’s early work, which in part motivated his invitation as the opening speaker at Sarnakfest.

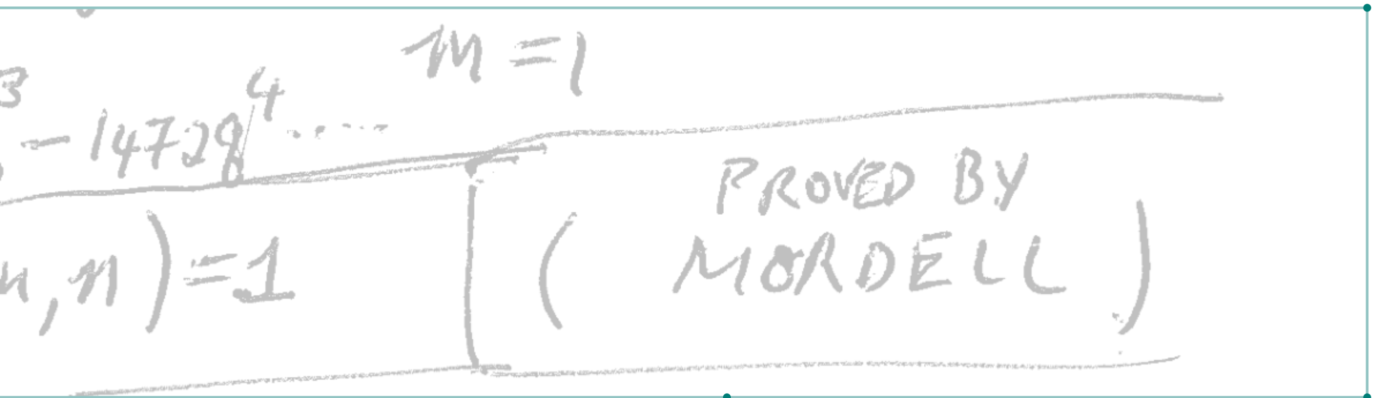
More recent results—with collaborators Adam Marcus, von Neumann Fellow in the School of Mathematics (2016–17), and his former Ph.D. student Nikhil Srivastava, Member (2010–11) and Visitor (2012) in the School, now at UC Berkeley and the Simons Institute for the Theory of Computing—have refined and advanced the construction of Ramanujan graphs, and extended their applications. Notably, one result managed to construct a Ramanujan graph without using number theory.

“Computer scientists didn't like the fact that our proof used such fancy number theory stuff,” said Sarnak. “They wanted to find their own way of understanding.”

But for thirty years, nobody matched it. Spielman and collaborators managed an existence proof—although their constructions were not explicit. In that sense, they did not quite match the Lubotzky-Phillips-Sarnak miracle. But in another sense, as Sarnak pointed out, “They did something better: they do so for all degrees, $d \geq 3$.”

The quantum realm, a space filled with challenges, also makes use of Ramanujan graphs—and notably ones that have migrated into higher dimensions and evolved into Ramanujan complexes, along with other high-dimensional expanders (or “HDXs”). Here, Lubotzky led the way, while Spielman enjoyed being a spectator. “Admittedly, it wasn’t clear to me that this was going to be useful, but it totally was. It recently brought us amazing advances in quantum locally testable codes.”

Another leader in this domain is **Irit Dveer Dinur**, a theoretical computer scientist who joined the Faculty of the School of Mathematics in August



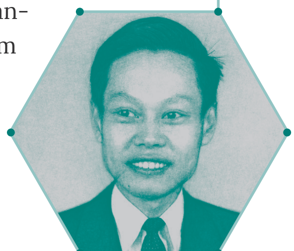
2024. Ramanujan complexes, the higher dimensional analogue of Ramanujan graphs, are “miraculous,” Dinur said. “The construction feels like something that really shouldn’t exist. And if you see something that shouldn’t exist, and you have intuition why it shouldn’t exist, but it does exist, then it is a very powerful thing. It allows you to do things that are almost impossible.”

For a long time, Dinur’s domain was stuck: The technical pursuit, she explained, was “to construct codes and even more sophisticated objects called PCPs, a type of robustified proof, that are both sparse and locally testable, which requires a lot of redundancy”—redundancy is a kind of connectedness, but on a higher level. “Ramanujan complexes and other higher dimensional expanders give you sparsity, and also super redundancy,” Dinur said. “And that’s what allowed people to construct these quantum locally testable codes.” These constructions were not based on Ramanujan complexes, Dinur clarified, but they are part of the theory. “They are based on high-dimensional expansion, which is a property of Ramanujan complexes. Once you study Ramanujan complexes, and understand this property, you can take it aside and modify it in a way that gives you these quantum codes.”

Wrapping up his lecture at the Sarnak conference, Spielman called this quantum line of investigation “one of the more surprisingly successful intellectual endeavors of the last decade in mathematics and computer science.” He said, “Catch me over tea if you want to hear me rave about that.”

During the Q&A that followed the lecture, Sarnak offered more of a retrospective rave. He described the link between Ramanujan graph constructions that looped in an episode in Institute history. He recounted how Spielman and company’s proof uses—as a critical input that does heavy lifting—the Lee-Yang theorem, by the physicists **Tsung-Dao Lee** and **Chen-Ning Yang**, later reformulated by Elliott Lieb, Visitor in the School of Natural Sciences, and Olav Heilmann.

Lee and Yang both served as Faculty in the School in the 1950s while proving that theorem. “It’s not such a great contribution,” Yang once commented, “but I fondly consider it as a minor gem.” (For their work on chirality around the same time, Lee and Yang won the 1957 Nobel Prize in Physics.) While at the Institute, they conversed with von Neumann and Selberg, and they drew directly from the mathematician George Pólya’s attempts at the Riemann hypothesis.



Notably, Sarnak said, the Spielman-et-al proof uses the Lee-Yang theorem —“a theorem which ensures that certain polynomials have all their zeros on a circle.” And similarly, he said, the Lubotzky-Phillips-Sarnak proof uses a proof by the visionary André Weil, Professor in the School of Mathematics (1958–98), “which is known as the ‘Riemann Hypothesis for curves over finite fields’ and asserts that related polynomials have their zeros on a circle.”

Where Sarnak and company had used a number theory theorem, Spielman and company used a statistical physics theorem: “So Lee-Yang is replacing Weil,” said Sarnak. “Both those theorems have the same flavor.”

“Oooh, that I didn’t know,” said Spielman. “Great connection.”

Old and New in the Historical Studies - Social Science Library

Romantic Nationalism and Beyond

In August 2024, the Institute's Historical Studies - Social Science Library (HS-SS) received a gift that sparked a host of new connections to be made between old and new titles in the library's holdings.

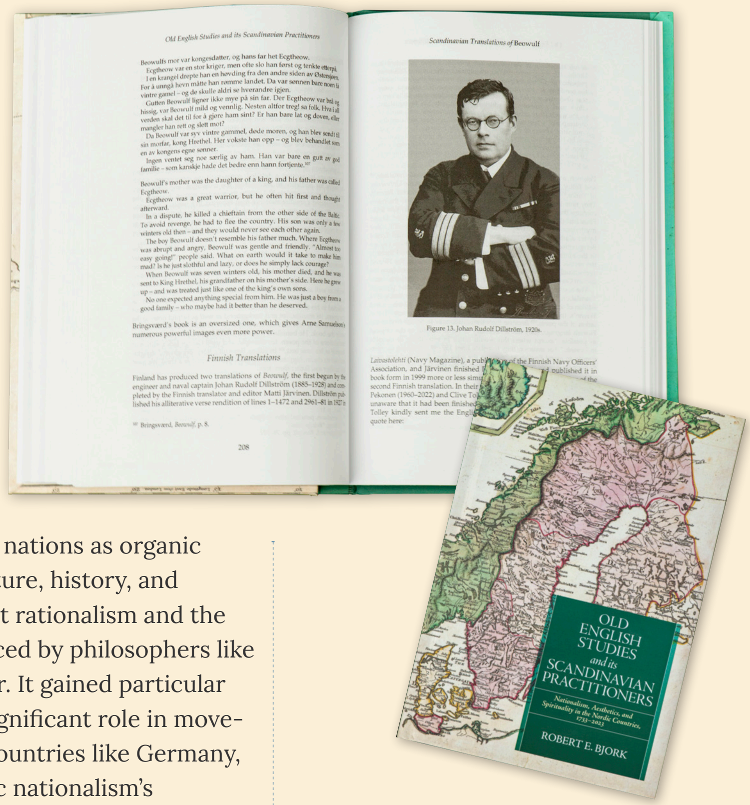
The gift was a copy of *Old English Studies and its Scandinavian Practitioners: Nationalism, Aesthetics, and Spirituality in the Nordic Countries*, 1733–2023, sent by its author Robert E. Bjork, who served as a Member (2004–05) in the School of Historical Studies. Bjork dedicated his IAS Membership to working on the book, and speaks of his "gratitude" to the Institute in the acknowledgements.

His subject is the study of Old English literature, a collection of works written in the earliest recorded form of the English language between approximately 650–1100 C.E., including, most famously, titles such as *Beowulf*. In his book, Bjork outlines how the study of Old English began around 200 years ago, not in England but in Scandinavia, spearheaded by Danish scholar N.F.S. Grundtvig (1783–1872).

Maria O'Leary

Upon receiving the book, Marcia Tucker, HS-SS Librarian, recalls, “It struck me that there was a set of books in the rare book room that might pair well with Bjork’s volume.” The Institute’s rare book room is home to around 3,000 titles. At the core of the collection are a number of first editions of significant works on the history of science, presented to IAS by Trustee and Trustee Emeritus Lessing J. Rosenwald (1940–79), but it has since expanded to cover diverse subject areas, including the Spinoza Research Collection and other titles in early modern history.

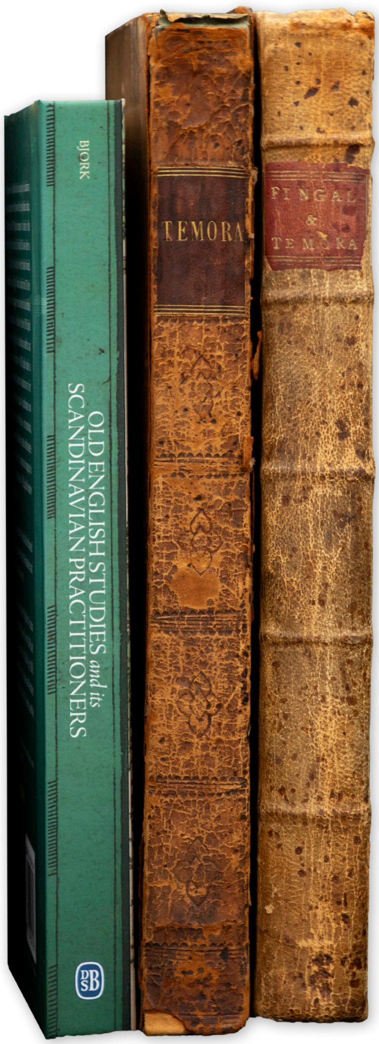
The particular titles from the Rosenwald Room that sprang to Tucker’s mind when she received Bjork’s book were both first editions: *Fingal, An Ancient Epic*, published by James Macpherson in 1761, and *Temora, An Epic Poem*, published by the same author two years later. Like Bjork’s book, these were presented to the Library by a former IAS scholar: Lionel Gossman, Visitor (1978–79, 1983, 1986–87) in the School of Historical Studies. But this was not the only common thread between the publications. They are linked, Tucker points out, by the theme of Romantic nationalism.



Romantic nationalism emerged as a powerful cultural and political force in Europe during the late eighteenth and early nineteenth centuries, entwining closely with the broader Romantic movement in arts and culture. This ideology viewed nations as organic entities, naturally arising from shared language, culture, history, and traditions. It developed in reaction to Enlightenment rationalism and the universalist ideals of the French Revolution, influenced by philosophers like Jean-Jacques Rousseau and Johann Gottfried Herder. It gained particular strength in Central and Eastern Europe, playing a significant role in movements for national unification or independence in countries like Germany, Italy, and various Balkan nations. Crucially, Romantic nationalism’s emphasis on developing and celebrating distinct national identities often saw its proponents looking to idealized versions of the past for inspiration.

It is this element of the Romantic nationalism movement that is exemplified in Macpherson’s texts. *Fingal, An Ancient Epic* and *Temora, An Epic Poem* purport to be authentic translations of ancient Gaelic manuscripts, which preserve poetry composed by the legendary Scottish bard Ossian. These epic poems recount the deeds of the hero Fingal and his son in a mythic Celtic past.

However, in reality, these works were largely of Macpherson’s own fabrication. His critics became suspicious almost immediately upon the publication of the first volume and the authenticity of the books was openly challenged. Eventually, their status as forgeries was confirmed: Macpherson, who was unable to produce the original manuscripts from which his so-called translations were made, had adapted elements from



Celtic mythology, ballads, and folklore to invent the texts, while adjusting the Gaelic names so that they would be easier to read by an English audience. Despite their status as fabrications being exposed, Macpherson still succeeded in creating an idealized vision of Scotland's past that appealed to contemporary Romantic nationalist tastes. His works sparked widespread interest and influenced Romantic writers and even musicians across Europe, from William Blake and Elizabeth Barrett Browning to Franz Schubert and Johannes Brahms.

Romantic nationalism is also an important springboard in Bjork's book. Similar sentiments to those motivating Macpherson to craft his fraudulent epics likewise drove these early Scandinavian studies of Old English: Bjork describes Romantic nationalism as "a first mover" in Old English studies in the Nordic regions. Nationalistic fervor, he argues, arose in response to political turmoil among the countries of Scandinavia, as well as threats of Napoleonic invasion, leading Scandinavians to glorify their ancestral heritage and unique cultural identities. This manifested not only in new constitutions and political movements, but also in art, music, literature, and material culture celebrating Norse and Viking themes.

Nationalism, Bjork contends, is also partially responsible for the relatively obscure status of Scandinavian scholarship on Old English, despite the discipline originating in the region. The language barrier caused Scandinavian contributions to be overlooked, as did "the nationalistic bias in Old English studies," which "has shifted [focus] decidedly away from Scandinavia (and Germany) to England and North America."

Although Romantic nationalism provided an important initial impetus for the study of Old English in the Nordic countries, Bjork indicates that the driving force for continuing those studies has evolved over time. "The qualities Scandinavians now seek in Old English literature—that we all seek," he writes, "are transnational, existential, spiritual, and human." He emphasizes that these texts resonate with fundamental questions about the human experience, marking a shift away from viewing Old English literature as a historical artifact to appreciating its deeper insights and emotions that remain relevant today, extending far beyond national boundaries.

Placing these titles—both Bjork's and Macpherson's—side by side allows the reader to trace the evolution of Romantic nationalism's influence on literary studies from its role in spurring the creation of idealized national epics to its impact on shaping academic disciplines, while also highlighting a recent shift towards a more universal appreciation of the origins of disciplines like Old English studies. The Historical Studies - Social Science library, with its varied collection of old and new works, provides the Institute community with bountiful opportunities for the making of such connections across boundaries and time.

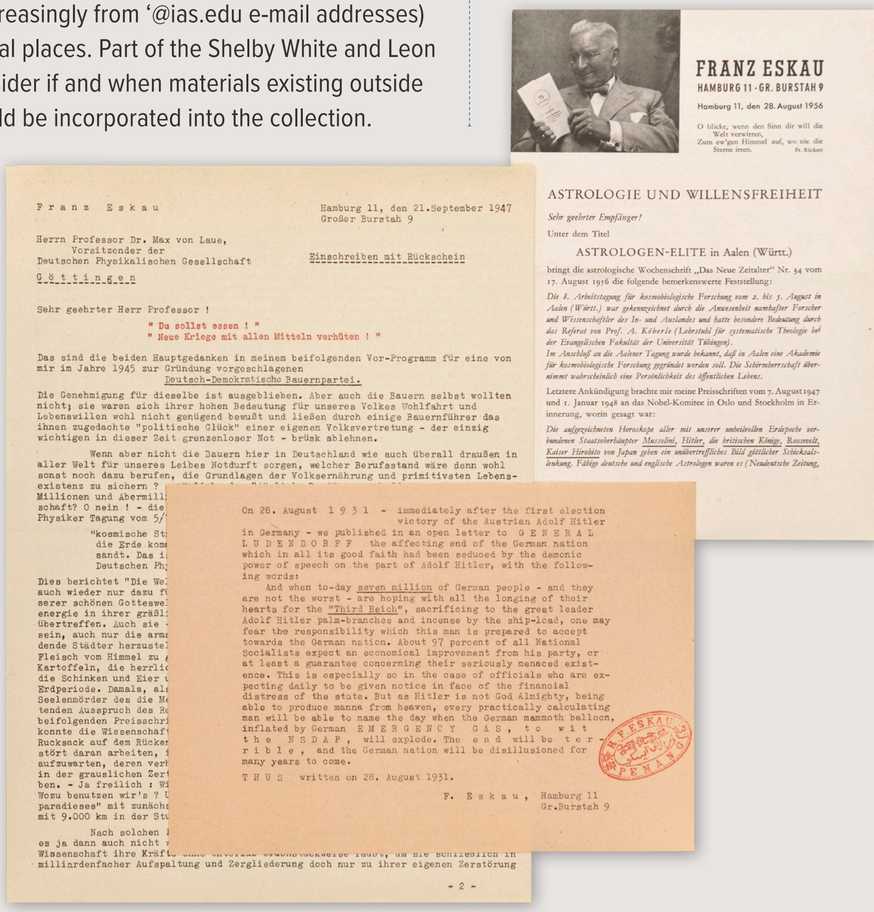
Robert E. Bjork serves as Foundation Professor of English at Arizona State University, specializing in Old English and Old Norse language and literature. His latest book, *Old English Studies and its Scandinavian Practitioners: Nationalism, Aesthetics, and Spirituality in the Nordic Countries, 1733–2023*, will be translated into Russian for publication in 2026 and distributed to libraries and universities in Russia, Armenia, Kazakhstan, Tajikistan, and Kyrgyzstan, among others.

Building Archives of a Mobile Scholar Community

By Caitlin Rizzo

The Institute and its scholarship has a profound global reach, stretching well beyond the confines of its New Jersey campus. Yet this international scope also presents a challenge for archivists. Institute history is difficult to contain: records of scholars' work proves as itinerant as the scholars themselves. Pivotal correspondence, documentation, and scholarship written on Institute letterhead (or increasingly from '@ias.edu e-mail addresses) continually pop up in new and unusual places. Part of the Shelby White and Leon Levy Archives Center's role is to consider if and when materials existing outside the Institute's immediate space should be incorporated into the collection.

A challenge of precisely this nature arose earlier this year, when an archival collection surfaced that contained materials related to two prominent IAS scholars: Max von Laue, Member in the School of Math/Natural Sciences (1935, 1948) and Hideki Yukawa, Member (1948–49) in the same School. The archival materials do not come from a collection accumulated by either Member, but are instead documents received and collected by Friedrich Adolf Paneth (1887–1958), an Austrian-born chemist with no direct IAS affiliation but close contact with the community of IAS scholars. Paneth's archive is wide-reaching. It documents a community of scientists and intellectuals allied against the development of atomic weaponry, providing insight into vital contributions made by IAS scholars in this realm.


FRANZ ESKAU
HAMBURG 11 · GR. BURSTAH 9
Hamburg 11, den 28. August 1956

O blicke, wenn den Sinn dir will die Welt verwirren,
Zum ew'gen Himmel auf, wo nie die Sterne irren. Fr. Rückert

ASTROLOGIE UND WILLENSFREIHEIT

Sehr geehrter Empfänger!

Unter dem Titel

ASTROLOGEN-ELITE in Aalen (Württ.)

bringt die astrologische Wochenschrift „Das Neue Zeitalter" Nr. 34 vom 17. August 1956 die folgende bemerkenswerte Feststellung:

Die 8. Arbeitstagung für kosmobiologische Forschung vom 2. bis 5. August in Aalen (Württ.) war gekennzeichnet durch die Anwesenheit namhafter Forscher und Wissenschaftler des In- und Auslandes und hatte besondere Bedeutung durch das Referat von Prof. A. Köberle (Lehrstuhl für systematische Theologie bei der Evangelischen Fakultät der Universität Tübingen).
Im Anschluß an die Aalener Tagung wurde bekannt, daß in Aalen eine Akademie für kosmobiologische Forschung gegründet werden soll. Die Schirmherrschaft übernimmt wahrscheinlich eine Persönlichkeit des öffentlichen Lebens.

Letztere Ankündigung brachte mir meine Preisschriften vom 7. August 1947 und 1. Januar 1948 an das Nobel-Komitee in Oslo und Stockholm in Erinnerung, worin gesagt war:

Die aufgezeichneten Horoskope aller mit unserer unheilvollen Erdepoche verbundenen Staatsoberhäupter Mussolini, Hitler, die britischen Könige, Roosevelt, Kaiser Hirohito von Japan geben ein unübertreffliches Bild göttlicher Schicksalslenkung. Fähige deutsche und englische Astrologen waren es (Neudeutsche Zeitung,

F r a n z   E s k a u   Hamburg 11, den 21.September 1947
Großer Burstah 9

Herrn Professor Dr. Max von Laue,
Vorsitzender der
Deutschen Physikalischen Gesellschaft
G ö t t i n g e n

Einschreiben mit Rückschein

Sehr geehrter Herr Professor !

" Du sollst essen ! "
" Neue Kriege mit allen Mitteln verhüten ! "

Das sind die beiden Hauptgedanken in meinem beifolgenden Vor-Programm für eine von mir im Jahre 1945 zur Gründung vorgeschlagenen
Deutsch-Demokratische Bauernpartei.

Die Genehmigung für dieselbe ist ausgeblieben. Aber auch die Bauern selbst wollten nicht; sie waren sich ihrer hohen Bedeutung für unseres Volkes Wohlfahrt und Lebenswillen wohl nicht genügend bewußt und ließen durch einige Bauernführer das ihnen zugedachte "politische Glück" einer eigenen Volksvertretung - der einzig wichtigen in dieser Zeit grenzenloser Not - brüsk ablehnen.

Wenn aber nicht die Bauern hier in Deutschland wie auch überall draußen in aller Welt für unseres Leibes Notdurft sorgen, welcher Berufsstand wäre denn wohl sonst noch dazu berufen, die Grundlagen der Volksernährung und primitivsten Lebensexistenz zu sichern ? ...
Millionen und Abermill...
schaft? O nein ! - die ...
Physiker Tagung vom 5/...

"kosmische St...
die Erde kom...
sandt. Das i...
Deutschen Ph...

Dies berichtet "Die Wel...
auch wieder nur dazu fü...
serer schönen Gotteswel...
energie in ihrer gräßl...
übertreffen. Auch sie ...
sein, auch nur die arms...
dende Städter herzustel...
Fleisch vom Himmel zu ...
Kartoffeln, die herrli...
die Schinken und Eier ...
Erdperiode. Damals, al...
Seelenmörder des die M...
tenden Ausspruch des R...
beifolgenden Preisschri...
konnte die Wissenschaf...
Rucksack auf dem Rücke...
stört daran arbeiten, ...
aufzuwarten, deren ver...
in der grauslichen Zer...
ben. - Ja freilich : Wi...
Wozu benutzen wir's ? ...
paradieses" mit zunäch...
mit 9.000 km in der St...

Nach solchen ...
es ja dann auch nicht ...
Wissenschaft ihre Kräft... um sie schließlich in milliardenfacher Aufspaltung und Zergliederung doch nur zu ihrer eigenen Zerstörung

- 2 -

On 28. August 1 9 3 1 - immediately after the first election victory of the Austrian Adolf Hitler in Germany - we published in an open letter to G E N E R A L L U D E N D O R F F the affecting end of the German nation which in all its good faith had been seduced by the demonic power of speech on the part of Adolf Hitler, with the following words:

And when to-day seven million of German people - and they are not the worst - are hoping with all the longing of their hearts for the "Third Reich", sacrificing to the great leader Adolf Hitler palm-branches and incense by the ship-load, one may fear the responsibility which this man is prepared to accept towards the German nation. About 97 percent of all National Socialists expect an economical improvement from his party, or at least a guarantee concerning their seriously menaced existence. This is especially so in the case of officials who are expecting daily to be given notice in face of the financial distress of the state. But as Hitler is not God Almighty, being able to produce manna from heaven, every practically calculating man will be able to name the day when the German mammoth balloon, inflated by German E M E R G E N C Y   G A S , to wit the N S D A P , will explode. The e n d will be t e r r i b l e , and the German nation will be disillusioned for many years to come.

T H U S   written on 28. August 1931.

F. E s k a u , Hamburg 11
Gr.Burstah 9

F. ESKAU PENANG

Correspondence and Printed Ephemera from Franz Eskau to Max von Laue, 1931–1957. Friedrich Adolf Paneth papers, 00128. Shelby White and Leon Levy Archives Center. https://archives.ias.edu/repositories/2/archival_objects/67957

Maria O'Leary

Paneth was born to Jewish parents and educated in Vienna. After gaining his Ph.D. in organic chemistry, he went on to study radioactivity and particularly radiochemistry. After stints in Scotland, England, and the Czech Republic, Paneth held more permanent positions at a series of German universities from 1919–1933, including in Hamburg and Berlin. However, while on a lecture tour in 1933, Paneth learned that Hitler had seized control of Germany and made the decision not to return. Like many other scholars of the time, Paneth would become a scholar forced into exile from the country where he had seen the greatest success in his career and, following the occupation of Austria in 1938, from his native country as well.

In 1938, the University of London appointed Paneth a Reader in Atomic Chemistry and, by 1939, he became a Professor of Chemistry and Director of the Laboratories at the University of Durham. In 1943, he was appointed the head of a joint British-Canadian Atomic Energy team which specialized in chemistry, and moved to Montreal for the duration of the war. At the end of the war, Paneth returned to Durham where he remained until his retirement in 1953, at which point he accepted a prestigious opportunity as the Director of the Max-Planck-Institut für Chemie in Mainz. Paneth remained in the position until 1957, when he became famous in the scientific community for his role as a signatory on what is today remembered as the "Göttingen Manifesto."

no more hiroshimas!

THE NEWS OF JAPAN COUNCIL AGAINST A & H-BOMBS

NO. 3 VOL 5 MARCH 1958

STOP ENIWETOK H-TEST!

BIG TOKYO RALLY OBSERVED ON MARCH 1ST JOINT ACTION DAY

MESSAGES

UNFORGETTABLE DAY

SUPPLEMENT:

NUCLEAR TESTING IS EVERYBODY'S BUSINESS BY DR. K. YUKAWA

Foreign Messages to March 1 Tokyo Rally

— Supplement —

Nuclear Testing is Everybody's Business

BY DR. HIDEKI YUKAWA

Correspondence and Printed Ephemera from the Japan Council Against A and H Bombs, 1957–1958. Friedrich Adolf Paneth papers, 00128. Shelby White and Leon Levy Archives Center

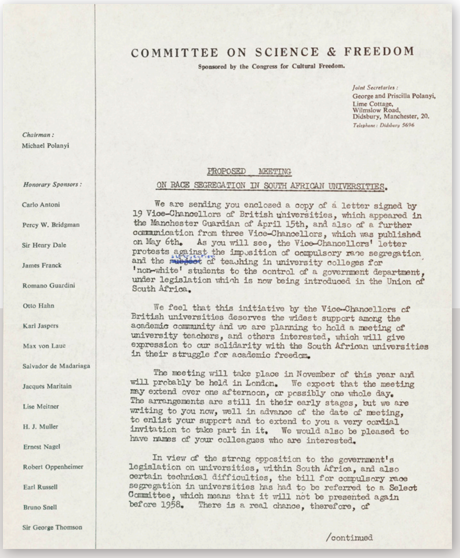
The Göttingen Manifesto is a declaration published on April 12, 1957 by Paneth and seventeen other noted scientists, warning against arming the West German government with tactical nuclear weapons. Significantly, as we might expect given the Institute's commitments to the freedom of expression for academics, the manifesto featured several IAS scholars as signatories, including von Laue and Yukawa.

The Paneth collection documents the exchanges between scholars that took place in the wake of his involvement in the manifesto. It comprises 82 folders of original documents, correspondence, offprints, and printed ephemera, as well as appeals and newsletters from the Japan Council Against A & H-Bombs, including a two-page speech by Yukawa entitled "Nuclear Testing is Everybody's Business."

As one of the original signatories on the manifesto, Paneth—already imbricated in politics because of his efforts in the war—would also become a part of a much different history of scholarship that worked independently of, and in this case, in open opposition to state policy. As well as tying him to his

The collection is a reminder of the inescapable politics of scholarship and, reciprocally, the significance of academic institutions like the Institute that created dedicated space for truly independent forms of inquiry.

co-signatories, von Laue and Yukawa, Paneth's signature linked him to a host of scholars that we celebrate today on this campus, including J. Robert Oppenheimer, Albert Einstein, J. Ernest Wilkins, and many others. Although never holding an IAS position himself, Paneth is inextricably connected to the history of the Institute through its scholars' affiliation and affinity within a broader network.



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Sponsored by the Congress for Cultural Freedom.

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PROPOSED MEETING
ON RACE SEGREGATION IN SOUTH AFRICAN UNIVERSITIES.

We are sending you enclosed a copy of a letter signed by 19 Vice-Chancellors of British universities, which appeared in the Manchester Guardian of April 15th, and also of a further communication from three Vice-Chancellors, which was published on May 6th. As you will see, the Vice-Chancellors' letter protests against the imposition of compulsory race segregation and the ~~subject~~ subjection of teaching in university colleges for 'non-white' students to the control of a government department, under legislation which is now being introduced in the Union of South Africa.

We feel that this initiative by the Vice-Chancellors of British universities deserves the widest support among the academic community and we are planning to hold a meeting of university teachers, and others interested, which will give expression to our solidarity with the South African universities in their struggle for academic freedom.

The meeting will take place in November of this year and will probably be held in London. We expect that the meeting may extend over one afternoon, or possibly one whole day. The arrangements are still in their early stages, but we are writing to you now, well in advance of the date of meeting, to enlist your support and to extend to you a very cordial invitation to take part in it. We would also be pleased to have names of your colleagues who are interested.

In view of the strong opposition to the government's legislation on universities, within South Africa, and also certain technical difficulties, the bill for compulsory race segregation in universities has had to be referred to a Select Committee, which means that it will not be presented again before 1958. There is a real chance, therefore, of

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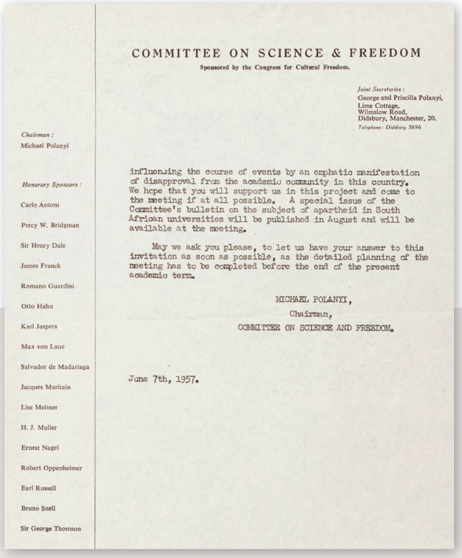

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Lise Meitner
H. J. Muller
Ernest Nagel
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Earl Russell
Bruno Snell
Sir George Thomson

influencing the course of events by an emphatic manifestation of disapproval from the academic community in this country. We hope that you will support us in this project and come to the meeting if at all possible. A special issue of the Committee's bulletin on the subject of apartheid in South African universities will be published in August and will be available at the meeting.

May we ask you please, to let us have your answer to this invitation as soon as possible, as the detailed planning of the meeting has to be completed before the end of the present academic term.

MICHAEL POLANYI,
Chairman,
COMMITTEE ON SCIENCE AND FREEDOM.

June 7th, 1957.

The collection is a reminder of the inescapable politics of scholarship and, reciprocally, the significance of academic institutions like the Institute that create dedicated space for truly independent forms of inquiry. As a historical document, it attests to the international climate out of which the Institute for Advanced Study emerged in the 1930s, and it underscores the necessity of looking beyond immediate IAS scholar archives to piece together the history of a community defined by migration and mobility.

Committee on Science and Freedom Announcement of Proposed Meeting on Race Segregation in South African Universities with Enclosed Statement on Apartheid, 1957. Friedrich Adolf Paneth papers, 00128. Shelby White and Leon Levy Archives Center

DIRECTOR

David Nirenberg, IAS Director and Leon Levy Professor, was elected to the American Philosophical Society.

FACULTY

Nima Arkani-Hamed, Gopal Prasad Professor in the School of Natural Sciences, received a 2024 Frontiers of Science Award from the International Congress of Basic Science.

Wendy Brown, UPS Foundation Professor in the School of Social Science, was announced as the recipient of an honorary doctorate from Södertörn University.

Didier Fassin, James D. Wolfensohn Professor in the School of Social Science, received the Huxley Memorial Medal from the Royal Anthropological Institute of Great Britain and Ireland.

Aaron Naber, Professor in the School of Mathematics, received a 2024 Frontiers of Science Award from the International Congress of Basic Science.

Alondra Nelson, Harold F. Linder Professor in the School of Social Science, was elected to the John D. and Catherine T. MacArthur Foundation Board of Directors. She also co-authored "Governing AI for Humanity," the United Nations High-level Advisory Body on Artificial Intelligence report on global AI governance. She was most recently appointed by President Joe Biden to the National Science Board.

Nathan Seiberg, Charles Simonyi Professor in the School of Natural Sciences, received a 2024 Frontiers of Science Award from the International Congress of Basic Science.

Avi Wigderson, Herbert H. Maass Professor in the School of Mathematics, received an honorary doctorate from the Weizmann Institute of Science.

New Faculty have joined the School of Mathematics

The Institute for Advanced Study has named three new permanent Faculty to the School of Mathematics in the fields of pure mathematics and computer science:

Irit Dveer Dinur (theoretical computer science)
Elon Lindenstrauss (dynamical systems)
Aaron Naber (geometric analysis)

EMERITI

Caroline Walker Bynum, Professor Emerita in the School of Historical Studies, was celebrated in a symposium published in the journal *Common Knowledge*.

Peter Sarnak, while serving as Gopal Prasad Professor in the School of Mathematics, was awarded the 2024 Shaw Prize in Mathematical Sciences.

Joan Wallach Scott, Professor Emerita in the School of Social Science, had a fellowship named in her honor at the University of Wisconsin Madison's Department of History.

Scott Tremaine, Professor Emeritus in the School of Natural Sciences, was presented with an honorary doctorate from the University of Waterloo.

Edward Witten, Professor Emeritus in the School of Natural Sciences, received the Basic Science Lifetime Award in Theoretical Physics from the International Congress of Basic Science.

MEMBERS

Noga Alon, a frequent Visiting Professor in the School of Mathematics, was recognized with the 2024 Wolf Prize in Mathematics.

Uddipan Banik, Member in the School of Natural Sciences, received the Dirk Brouwer Memorial Prize from Yale University.

Ruha Benjamin, Member (2016–17) in the School of Social Science, was awarded a 2024 MacArthur Fellowship.

Penelope Deutscher, Member (2023–24) in the School of Social Science, was presented with a Research Award by the Alexander von Humboldt Foundation.

Tanisha C. Ford, Roger W. Ferguson, Jr. and Annette L. Nazareth Member (2021–22) in the School of Social Science, won a 2024 NAACP Image Award for Outstanding Literary Work in Biography/Autobiography for her book *Our Secret Society: Mollie Moon and the Glamour, Money, and Power Behind the Civil Rights Movement.*

Scott Gaudi, Member (2000–03) in the School of Natural Sciences, was elected a 2023 Fellow of the American Association for the Advancement of Science.

Michał Gawlikowski, Member (1994–95) and Visitor (2016) in the School of Historical Studies, was elected as an Associate Foreign Member of the Académie des Inscriptions et Belles-Lettres, Institut de France.

John J. Hopfield, Visiting Professor (2010–13) in the School of Natural Sciences, was named a recipient of the 2024 Nobel Prize in Physics.

Natalia Komarova, Member (1999–2000) in the School of Mathematics and Member (2000–04) in the School of Natural Sciences, was elected a 2023 Fellow of the American Association for the Advancement of Science.

Michèle Lamont, Visitor (1997) in the School of Social Science, was elected to the American Philosophical Society.

Sebastian Mizera, Member (2019–24) in the School of Natural Sciences, received a Wolfram Innovator Award from Wolfram Research.

Jennifer L. Morgan, Member (2014–15) in the School of Social Science, was awarded a 2024 MacArthur Fellowship.

Amalie "Emmy" Noether, frequent Visitor (1933–35) in the School of Mathematics was posthumously recognized as a "Legacy Honoree" by the American Academy of Arts & Sciences.


Sameer Khan

IAS Launches Jonathan M. Nelson Center for Collaborative Research

The Institute for Advanced Study is launching the Jonathan M. Nelson Center for Collaborative Research, expanding the Institute's capacity for discovery across fields.

The Nelson Center for Collaborative Research is designed to facilitate work on projects and topics that are beyond the reach of a single scholar, discipline, or institution. It will support team-based, theme-based, inter-institutional, and interdisciplinary projects led by Institute scholars in collaboration with researchers across and beyond academia. The Nelson Center will provide seed funding to develop early-stage research ideas, large-scale funding for multi-year research agendas, and the space, infrastructure, and expertise for collaborative projects with partners across the globe.

"Since its founding, the Institute's mission has been to create a research community in which talented individuals from all over the world have been able to realize their highest capacity for discovery, uninhibited by boundaries of dogma or discipline," said David Nirenberg, IAS Director and Leon Levy Professor. "The Nelson Center strengthens our ability to fulfill that mission into our second century, and expands our ability to explore what Director J. Robert Oppenheimer called 'the synapses' between the sciences, humanities and arts, and society."

The Nelson Center for Collaborative Research is made possible by a generous donation from Trustee **Jonathan M. Nelson**, Founder and Chairman of Providence Equity Partners LLC and Co-Founder and Executive Chairman of Dynasty Equity.

"This initiative, which adds a new dimension to study at the Institute by increasing the reach of research by Institute Faculty, builds on our historic record of excellence, and expands our relationships with thought leaders around the world," said Nelson, continuing "along with others, I am proud to support this new Center and its important goals."

The Nelson Center for Collaborative Research has also received generous support from the Gerard B. Lambert Foundation. It is being led by executive director **David Zielinski**, who was formerly the executive director of Harvard Catalyst and associate dean for clinical and translational research at Harvard Medical School. Zielinski joined the Institute on August 1, 2024.

Karl H. Palmquist, Martin A. and Helen Chooljian Member in Biology in the School of Natural Sciences, received the 2024 Harold M. Weintraub Graduate Student Award from the Fred Hutchinson Cancer Center.

Amin Pérez, Member (2017–18) in the School of Social Science, received the History of Sociology and Social Thought Distinguished Scholarly Publication Award from the American Sociology Association for his book *Bourdieu and Sayad Against Empire: Forging Sociology an Anticolonial Struggle*.

Rubina Raja, Member (2019) in the School of Historical Studies, received one of the Carlsberg Foundation's Research Prizes for 2024.

Martin Rees, frequent Member in the School of Natural Sciences and IAS Trustee Emeritus, was announced as the winner of the 2024 Wolf Prize in Physics.

Sara Seager, Long-Term Member (1999–2002) in the School of Natural Sciences, was one of the winners of the 2024 Kavli Prize in Astrophysics.

Asheesh Kapur Siddique, Member (2021–22) in the School of Historical Studies, won the 2024 College Outstanding Teaching Award from the College of Humanities & Fine Arts at the University of Massachusetts Amherst.

Pierre Sikivie, Member (2005) in the School of Natural Sciences, was elected a 2023 Fellow of the American Association for the Advancement of Science.

Geordie Williamson, Distinguished Visiting Professor (2020–21) in the School of Mathematics, won a 2024 Max Planck–Humboldt Research Award.

INSTITUTE

Paul DiMaggio, Princeton Foundation for Peace & Learning Founders' Circle Member (2017–18) in the School of Social Science, was appointed to the Board of Trustees.

Anoop Prasad, Managing Director and member of the Executive Committee of D. E. Shaw & Co., who served on the Friends Executive Committee (2018–24), was appointed to the Board of Trustees.

Sofía Torallas Tovar has joined the School of Historical Studies as a long-term Distinguished Visiting Professor.

Pauline Yu, IAS Trustee and Director's Visitor (2014), was officially presented with a 2022 National Humanities Medal from the National Endowment for the Humanities.

Nine Past Scholars Win 2024 Guggenheim Fellowships

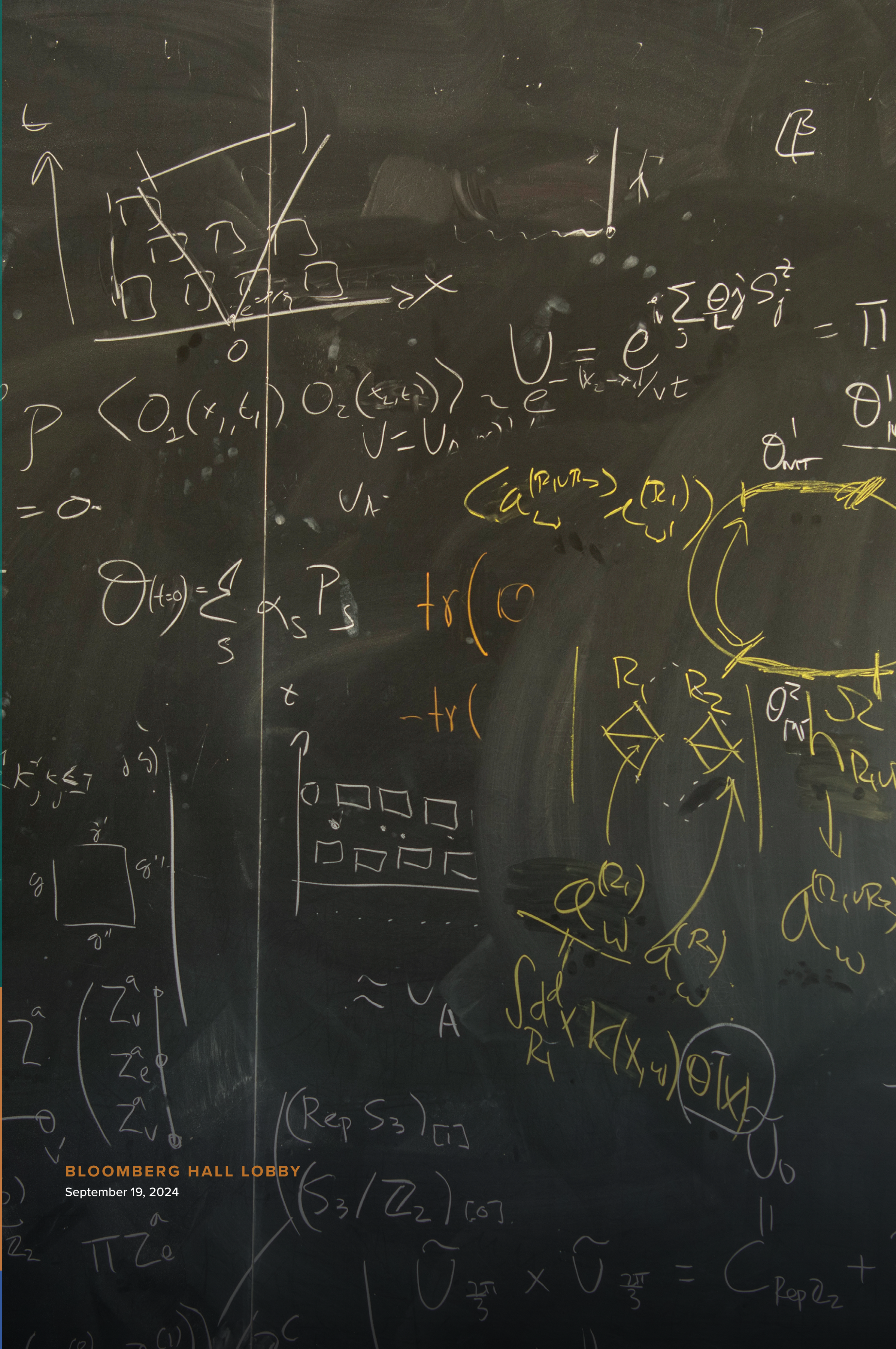
Nine past scholars across three IAS Schools—Natural Sciences, Historical Studies, and Social Science—have received 2024 Guggenheim Fellowships, one of the most remarkable honors for mid-career researchers, artists, and writers.

From the School of Natural Sciences, **Marc Kamionkowski** (Member, 1991–95) and **Tracy Slatyer** (Member, 2010–13; Junior Visiting Professor, 2018–19), two physicists who study dark matter, received fellowships.

From the School of Historical Studies, the new Fellows were Members **Emily Wilcox** (2023), **Alexander Nagel** (2017), **Jan-Werner Müller** (2013), and **John Connelly** (2002–03). Together, their work spans from studies of Italian art and Christianity to East European and Chinese history.

From the School of Social Science, Member **Carola Suárez-Orozco** (2009–10), who studies the immigration system, also received a fellowship.

And from both the Schools of Social Science and Historical Studies, Member **Kim Lane Scheppele** (2013–14) and Visitor **Angela N.H. Creager** (Social Science, 1996–97; Historical Studies, 2002–03) were supported by the foundation for their work on authoritarianism and biomedical research respectively.



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September 19, 2024

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