IAS | THE INSTITUTE LETTER

Fall 2022

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IAS | THE INSTITUTE LETTER Fall 2022

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Illustrator turned designer turned physics student turned science visualizer, **Olena Shmahalo** enjoys 'visualizing invisible things,' like the abstract and imperceptible subjects in theoretical and experimental science. She joined *Quanta Magazine* in 2014, eventually becoming its first Art Director.

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IAS Welcomes Over 250 Scholars for 2022–23 Academic Year

On September 19th, the Institute for Advanced Study (IAS) celebrated the formal start of the 2022–23 academic year. 281 new and returning scholars arrived on campus—from postdoctoral fellows at the beginning of their research careers to distinguished senior academics and 24 permanent Faculty. The 2022–23 scholarly community hails from 36 countries, representing approximately 107 academic institutions worldwide.

"I have the joyful responsibility of welcoming more than 250 of the planet's most interesting scholars to our community," stated David Nirenberg, Director and Leon Levy Professor. "As a past IAS Visitor, I have myself experienced the riches of the Institute's research environment, and know the intellectual transformations it produces. I look forward to the discoveries they will offer the world."

Bhargav Bhatt, Fernholz Joint Professor in the School of Mathematics, is the most recent Faculty appointment. Previously a Member (2012–14) and Visitor (2020), Bhatt is one of the leading figures of the recent revolution in *p*-adic geometry.

Wei Ho, a former Visitor (2020), returns to IAS as a Visiting Professor and as the first Director of Women and Mathematics (WAM). Established in 1993 and first held at IAS in 1994, the annual program aims to recruit and retain more women in mathematics, supporting female scholars at various stages of their careers.

The School of Mathematics's special year, led by Distinguished Visiting Professor Tamar Ziegler, will probe the still-evolving interfaces between ergodic theory, additive combinatorics, multiplicative number theory, and algebraic geometry. It will build on spectacular advancements that have been made in interlacing these fields over the past two decades.

The 2022–23 theme seminar of the School of Social Science, "Climate Crisis Politics," will explore how questions raised by the climate crisis reorient twenty-first century political, social, and economic thought and practice, and examine theories that will rise to meet these challenges.

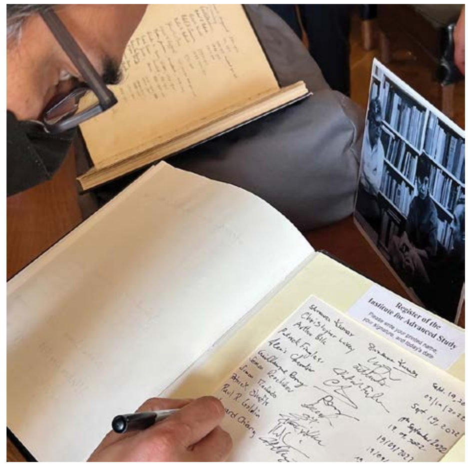
The theme seminar will be led by Wendy Brown, UPS Foundation Professor (IAS) and Timothy Mitchell, William B. Ransford Professor of Middle Eastern, South Asian and African Studies (Columbia University), in collaboration with Didier Fassin, James D. Wolfensohn Professor (IAS) and Alondra Nelson, Harold F. Linder Professor (IAS). ■

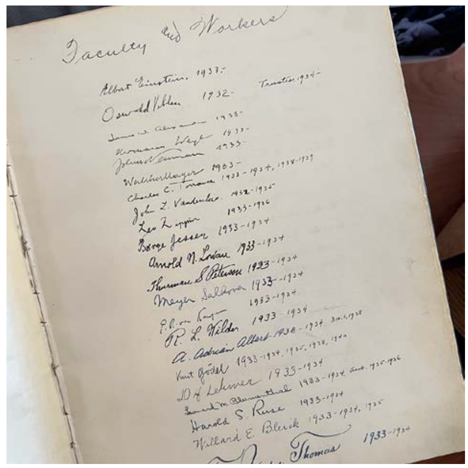
ABBEY ELLIS

Fuld Hall on September 19th, first day of term.

IAS ON Instagram

instituteforadvancedstudy





The first day of term saw new scholars gather in the Fuld Hall common room to sign the #IASRegistry. This tradition dates back to the Institute's founding, when members were referred to as "Workers."

Original signatories include Albert Einstein, John von Neumann, and Anna Stafford. Although it is customary for each scholar to sign the registry only once, those returning for a second term can add their name again. The signature of Kurt Gödel, who was associated with the Institute from 1933 until his death in 1978, appears in the registry on multiple occasions.

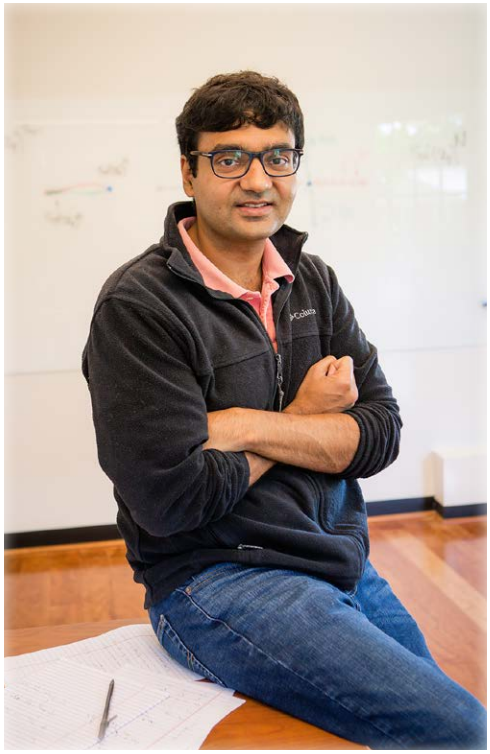
Can you spot any other famous names?

For the latest news, research, and campus updates, follow IAS on Instagram: @instituteforadvancedstudy.

Bhargav Bhatt Joins Mathematics Faculty at IAS

Bhargav Bhatt, an internationally renowned expert in arithmetic algebraic geometry and commutative algebra, has joined the Institute for Advanced Study as Fernholz Joint Professor in the School of Mathematics, effective July 1, 2022. His new position is a joint appointment with Princeton University, with IAS serving as his home institution. Bhatt joins from the University of Michigan, where he is currently on leave as the Frederick W. and Lois B. Gehring Professor.

Among Bhatt's principal achievements is the introduction—with frequent collaborator Peter Scholze, building on their previous joint work with Matthew Morrow—of the theory of prismatic cohomology. This fundamental discovery in arithmetic algebraic geometry is widely regarded for its simplicity and many applications. His original research, coupled with his skill as an expositor of ideas, have established Bhatt as a driving force of the field.


ANDREA KANE

"Bhargav combines mathematical creativity with a penchant for collaboration and the ability to perceive analogies across seemingly dissimilar fields," stated David Nirenberg, IAS Director and Leon Levy Professor. "His presence at the Institute will surely facilitate discovery, not only in his own work, but for many others in our mathematical community."

Bhatt first came to IAS as a Member (2012–14) in the School of Mathematics and returned as a Visitor (2020). Primarily focused on algebraic geometry and its interactions with number theory, commutative algebra, homotopy theory, Bhatt's work complements current research conducted in the School of Mathematics by fellow Faculty members Frank C. and Florence S. Ogg Professor Jacob Lurie and Robert and Luisa Fernholz Professor Akshay Venkatesh.

"There has been a real revolution in p-adic geometry over the last few years, with Bhargav Bhatt as one of its leading figures," remarked Lurie. "I'm thrilled that he'll be joining the Faculty of the School of Mathematics."

Initially an engineering student, Bhatt worked to understand bridges from a physical standpoint. He ultimately found his calling in the bridges he built between disparate areas of mathematics, including commutative algebra, derived geometry, birational geometry, and p-adic Hodge theory.

In the field of commutative algebra, Bhatt has made several important contributions to the circle of ideas surrounding Hochster's direct summand conjecture. Following a formal proof of the conjecture by Yves André, Bhatt proved a much stronger version of Hochster's conjecture based on the Cohen–Macaulay property and Kodaira vanishing up to finite covers. His proof makes essential use of the theory of prismatic cohomology.

His work on extensions of de Rham (and crystalline) cohomology to singular algebraic varieties using derived methods builds on the work of Luc Illusie and Alexander Beilinson. Bhatt's efforts resulted in new proofs of comparison theorems in p-adic Hodge theory, namely the crystalline comparison conjecture of Fontaine and the semi-stable comparison conjecture of Fontaine-Jannsen.

A prolific collaborator, Bhatt advances the mathematics community through the power of his ideas and the ease with which he communicates them. He is also a generous mentor, willingly sharing his time and insights with other researchers. Such interactions will enrich the collaborative atmosphere that is crucial to the Institute's mission: to support the development of scholars and inspire research at the highest levels.

"I'm deeply honored (and frankly a bit daunted) by this appointment," commented Bhatt. "The Institute and Princeton University have been home to many remarkable breakthroughs in mathematics in the last century. On a personal level, both institutions have played decisive roles in my own development. It is a privilege to be back, and I look forward to contributing to the intellectual community here."

Bhatt earned a B.S. in Applied Mathematics from Columbia University (2005) and went on to receive his M.A. and Ph.D. in Mathematics from Princeton University (2010) under the advisement of Aise Johan de Jong.

Bhatt's achievements have received wide international recognition. He received the 2021 New Horizons in Mathematics Prize from the Breakthrough Prize Foundation "for outstanding work in commutative algebra and arithmetic algebraic geometry, particularly on the development of p-adic cohomology theories." He is also the recipient of the 2021 Clay Research Award of the Clay Mathematics Institute. Bhatt received a Packard Fellowship (2015), was named Eilenberg Chair at Columbia University (Fall 2018), and was elected as a Simons Investigator (2019) and Fellow of the American Mathematical Society (2021). He delivered a plenary talk at the International Congress of Mathematicians on July 11, 2022. ■

Wei Ho Named Director of Women and Mathematics

Wei Ho, Visiting Professor in the School of Mathematics, has been named as the first director of the "Women and Mathematics" (WAM) program at IAS. During her five-year appointment she will lead the annual, award-winning program, which has the mission to recruit and retain more women in mathematics.

A renowned mathematician, Ho is currently a tenured Associate Professor of Mathematics at the University of Michigan and both a Research Scholar and Visiting Lecturer with Rank of Professor at Princeton University. As part of her research, Ho explores statistical questions about objects in number theory, a subfield recently dubbed arithmetic statistics. She is particularly interested in finding arithmetic applications of classical algebro-geometric constructions. Her numerous papers have been highly regarded and are expected to have widespread applications.

ABBEY ELLIS

In 2020, Ho was a Visitor in the School of Mathematics. She was previously a participant, teaching assistant, and lecturer at WAM and will be able to bring her prior experience with the program to her role as director. She will be the first academic resident to lead the activities of WAM, offering a fresh perspective and strengthening its impact.

"Over the last 28 years, the IAS Women and Mathematics program has made a tremendous impact on many mathematicians, including myself," stated Ho. "I am excited and grateful for the opportunity to join the leadership of this storied program and to continue this important work while part of the vibrant mathematical community in Princeton. I thank all of those who have worked so hard on this program over the years, and I hope to continue their legacy of inspiring young mathematicians."

The WAM curriculum includes an intensive multi-day workshop, hosted on the IAS campus, featuring lectures and seminars on a select topic. Participants engage in networking events, community discussions, and explore various career opportunities. The coming academic year will also feature the Inaugural Emmy Noether Lecture Series, "100 Years of Noetherian Rings" research conference, and a joint mathematics meeting in Boston with WAM alumnae.

Ho has also been involved in both mentoring and outreach outside of WAM. Currently, she organizes multiple mathematical conferences, including one of the recent Women in Numbers workshops, which are coordinated by Women in Number Theory. A resource for women number theorists, the group also aims to showcase the many contributions women have made to the field. Ho is co-organizing the Stacks Project Workshop—an initiative of the Stacks Project—where graduate students, postdocs and senior mathematicians collaborate on a topic in algebraic geometry in small groups. She is also organizing a Mathematical Sciences Research Institute semester for spring 2023.

Ho received her Ph.D. in 2009 from Princeton University, where she was supervised by IAS Trustee (2017–22) and Member (2001–02) Manjul Bhargava, with whom she has published on core questions in arithmetic statistics. Her paper with Member (2012–13) Arul Shankar and Ila Varma has also had a profound impact on the field, in addition to papers on applications to questions in number theory, like her work with Levent Alpöge.

Her work has earned her regular funding from the National Science Foundation, including a CAREER grant, and a Sloan Research Fellowship.

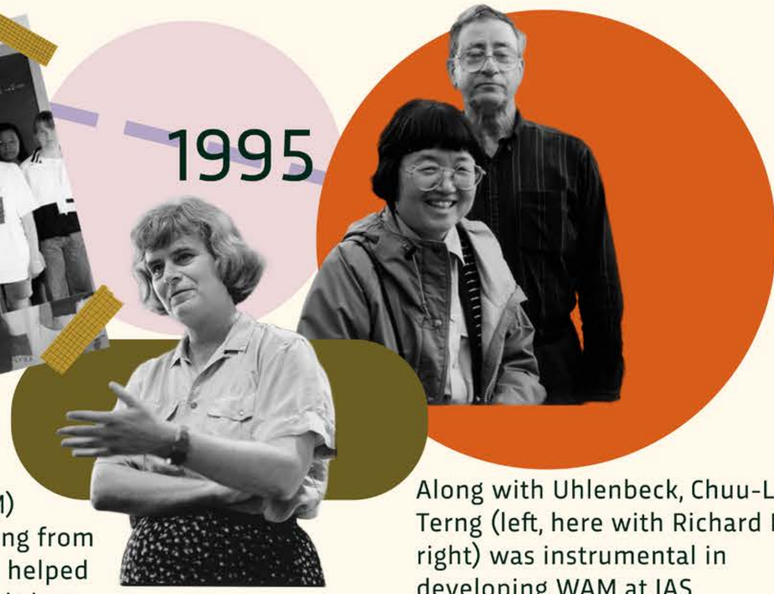
"It is an exciting and historic time for the Women and Mathematics Program with the appointment of Wei Ho as the first director," said Michelle Huguenin, Program Manager in the School of Mathematics. "Wei brings great energy, ideas, and experience to the role. I look forward to working with her and seeing how the program evolves under her leadership."

WAM continues its mission to recruit and retain more women in mathematics through new and sustained initiatives with generous support from the Minerva Research Foundation, National Science Foundation, Lisa Simonyi, and Princeton University Department of Mathematics. ■

WOMEN AND MATHEMATICS *A Timeline*

1995

In 1994, the Women and Mathematics Program (WAM) made its home at IAS, after moving from Park City, Utah. Karen Uhlenbeck helped grow WAM from the original workshop into a full-fledged program.



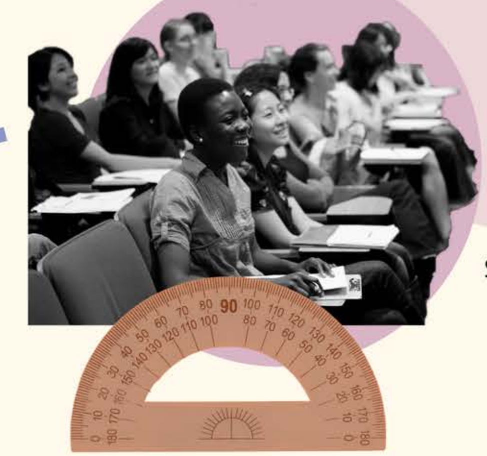
Along with Uhlenbeck, Chuu-Lian Terng (left, here with Richard Palais, right) was instrumental in developing WAM at IAS.

2004

Participants discuss an idea at the blackboard. The theme in 2004 was Analysis and Non-linear PDEs.

Participants, including current Trustee Gigliola Staffilani, talk over tea.

2011



Karamatou Yacoubou Djima joins other participants for WAM's year on Sparsity and Computation.

2012

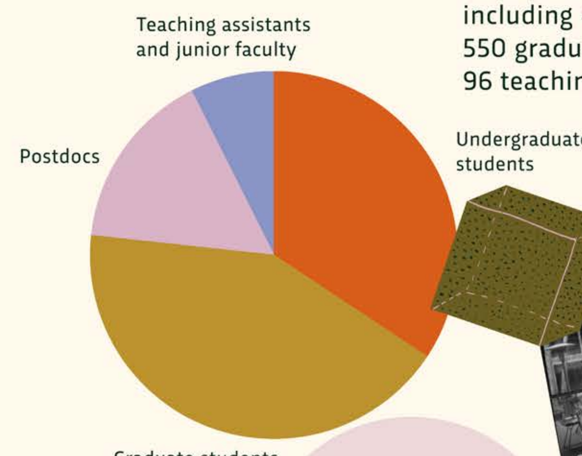
Drawing of Seifert surfaces of Legendrian knots for 21st Century Geometry.

2018

Margaret Readdy, Antonella Grassi, Nancy Hingston, Dusa McDuff, Karen Uhlenbeck (back row), Alice Chang, Lisa Traynor, Chuu-Lian Terng, Christine Taylor, and Michelle Huguenin (front row), important figures in the development of WAM, celebrate WAM's anniversary.

The Women and Mathematics program celebrated its 25th anniversary in 2018. The following year, it was awarded the American Mathematical Society prize "Mathematics Programs that Make a Difference."

WAM has had a total of 1,297 participants, including 445 undergraduate students, 550 graduate students, 206 postdocs, and 96 teaching assistants and junior faculty.



2022

The upcoming program year on Patterns in Integers: Dynamical and Number Theoretical Approaches will be held in May 2023.

ANNA LAQUA

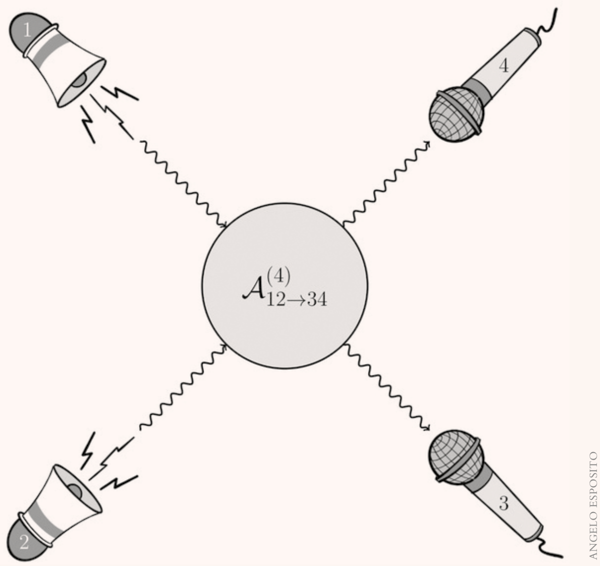
The Strange Behavior of Sound Through Solids

Not everything needs to be seen to be believed; certain things are more readily heard, like a train approaching its station. In a paper, published in *Physical Review Letters* in early June, researchers have put their ears to the rail, discovering a new property of scattering amplitudes based on their study of sound waves through solid matter.

Be it light or sound, physicists consider the likelihood of particle interactions (yes, sound can behave like a particle) in terms of probability curves or scattering amplitudes. It is common lore that, when the momentum or energy of one of the scattered particles goes to zero, scattering amplitudes should always scale with integer powers of momentum (i.e., p^1, p^2, p^3, etc.). What the research team found however, was that the amplitude can be proportional to a fractional power (i.e., $p^{1/2}$, $p^{1/3}$, $p^{1/4}$, etc.).

Why does this matter? While quantum field theories, such as the Standard Model, allow researchers to make predictions about particle interactions with extreme accuracy, it is still possible to improve upon current foundations of fundamental physics. When a new behavior is demonstrated—such as fractional-power scaling—scientists are given an opportunity to revisit or revise existing theories.

This work, conducted by Angelo Esposito (IAS), Tomáš Brauner (University of Stavanger), and Riccardo Penco (Carnegie Mellon University), specifically considers the interactions of sound waves in solids. To visualize this concept, picture a block of wood with speakers placed on both ends. Once the speakers are powered on, two sound waves—phonons—meet each other and scatter, similar to collisions in a particle accelerator. When one speaker is adjusted to a certain limit, such that the momentum of the phonon is zero, the resulting amplitude can be proportional to a fractional power. This scaling behavior, the team explains, is likely not limited to phonons in solids, and its recognition may help the study of scattering amplitudes in many different contexts, from particle physics to cosmology.

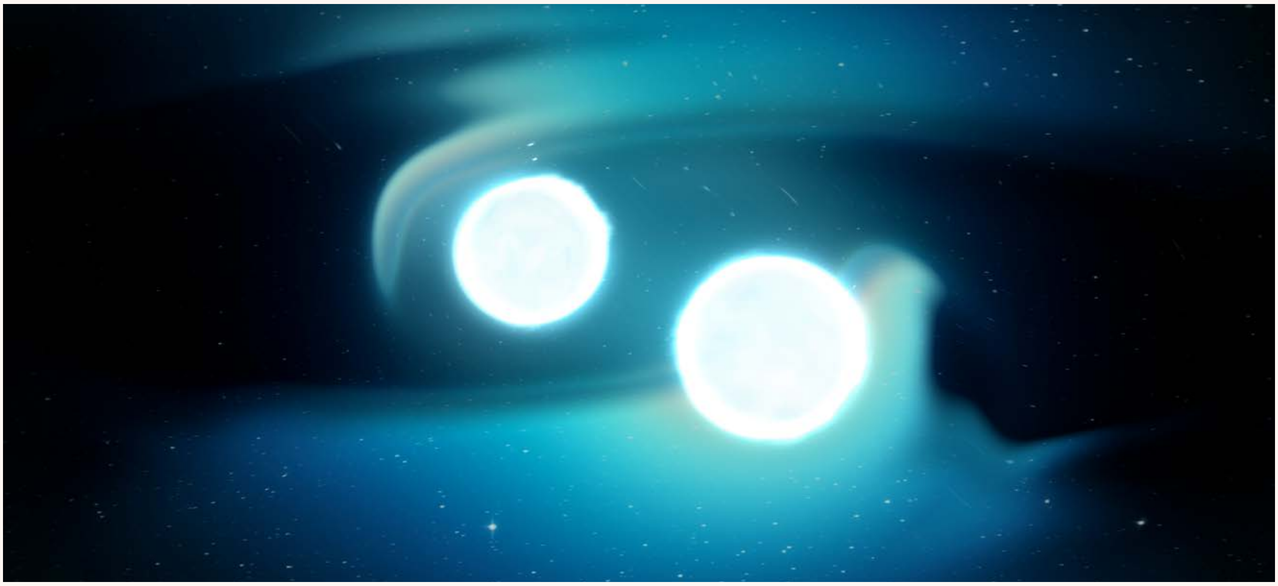


Two sound waves (1 and 2) are produced, scattering into two other sound waves (3 and 4), which are then detected. The probability for this process is described by a 4-point scattering amplitude.

"The detailed properties of scattering amplitudes have recently been studied with much vigor," stated Esposito. "The goal of this broad program is to classify possible patterns of behavior of scattering amplitudes, to both make some of our computations more efficient, and more ambitiously, to build new foundations of quantum field theory."

Feynman diagrams have long been an indispensable tool of particle physicists, yet they come with certain limitations. For example, high accuracy calcu-lations can require tens-of-thousands of Feynman diagrams to be entered into a computer, to describe particle interactions. By gaining a better understanding of scattering ampli-tudes, researchers may be able to more easily pinpoint particle behavior rather than relying on the top-down approach of Feynman diagrams, thus enhancing the efficiency of calculations.

"The present work reveals a twist in the story, showing that condensed matter physics displays much richer phenomenology of scattering amplitudes than what was previously seen in fundamental, relativistic physics," added Esposito. "The discovery of fractional-power scaling invites further work on scattering ampli-tudes of collective oscillations of matter, placing solids in the focus." ■



NASA/GODDARD SPACE FLIGHT CENTER

New Tool Allows Scientists to Peer Inside Neutron Stars

Imagine taking a star twice the mass of the sun and crushing it to the size of Manhattan. The result would be a neutron star—one of the densest objects found anywhere in the universe, exceeding the density of any material found naturally on Earth by a factor of tens-of-trillions. Neutron stars are extraordinary astrophysical objects in their own right, but their extreme densities might also allow them to function as laboratories for studying fundamental questions of nuclear physics, under conditions that could never be reproduced on Earth.

Because of these exotic conditions, scientists still do not understand what exactly neutron stars themselves are made from, their so-called "equation of state" (EoS). Determining this is a major goal of modern astrophysics research. A new piece of the puzzle, constraining the range of possibilities, has been discovered by a pair of scholars at IAS: Carolyn Raithel, John N. Bahcall Fellow in the School of Natural Sciences; and Elias Most, Member in the School and John A. Wheeler Fellow at Princeton University. Their work was recently published in *The Astrophysical Journal Letters*.

Ideally, scientists would like to peek inside these exotic objects, but they are too small and distant to be imaged with standard telescopes. Scientists rely instead on indirect properties that they can measure—like the mass and radius of a neutron star—to calculate the EoS, the same way that one might use the length of two sides of a right-angled triangle to work out its hypotenuse. However, the radius of a neutron star is very difficult to measure precisely. One promising alternative for future observations is to instead use a quantity called the "peak spectral frequency" (or f_2) in its place.

But how is f_2 measured? Collisions between neutron stars, which are governed by the laws of Einstein's Theory of Relativity, lead to strong bursts of gravitational wave emission. In 2017, scientists directly measured such emissions for the first time. "At least in principle, the peak spectral frequency can be calculated from the gravitational wave signal emitted by the wobbling remnant of two merged neutron stars," says Most.

It was previously expected that f_2 would be a reasonable proxy for radius, since—until now—researchers believed that a direct, or "quasi-universal," correspondence existed between them. However, Raithel and Most have demonstrated that this is not always true. They have shown that determining the EoS is not like solving a simple hypotenuse problem. Instead, it is more akin to calculating the longest side of an irregular triangle, where one also needs a third piece of information: the angle between the two shorter sides. For Raithel and Most, this third piece of information is the "slope of the mass-radius relation," which encodes information about the EoS at higher densities (and thus more extreme conditions) than the radius alone.

This new finding will allow researchers working with the next generation of gravitational wave observatories (the successors to the currently operating LIGO) to better utilize the data obtained following neutron star mergers. According to Raithel, this data could reveal the fundamental constituents of neutron star matter. "Some theoretical predictions suggest that within neutron star cores, phase transitions could be dissolving the neutrons into sub-atomic particles called quarks," stated Raithel. "This would mean that the stars contain a sea of free quark matter in their interiors. Our work may help tomorrow's researchers determine whether such phase transitions actually occur." ■

NASA, ESA, CSA, AND STSCI

The James Webb Space Telescope: What's Next?

An interview with Nadia Zakamska

The launch of the James Webb Space Telescope (JWST) on December 25, 2021, and the release of its first images in July, has generated impassioned discussion across the IAS campus and beyond. The telescope has stunned the world with its images of never-before-seen astrophysical phenomena, captured in exquisite detail. Its ability to obtain such images stems from its capacity for observing in the infrared spectrum, which is invisible to the human eye.

Infrared telescopes can see things that visual-wavelength observatories like NASA's Hubble Space Telescope, launched in 1990, cannot. For one, galactic dust clouds obscure many astrophysical objects from the view of telescopes like Hubble. However, most infrared light can pass straight through this dust, like X-rays passing through the body to create an image of a patient's bones, allowing us to see more of the universe. Moreover, like the change in pitch from a receding siren, light from distant receding galaxies is stretched—or "redshifted"—away from visible wavelengths and into the infrared. The James Webb Space Telescope is primed to collect images of precisely those faraway galaxies that would have escaped the view of Hubble.

LEE SANDBERG

Since infrared light is not visible to the naked eye, the data from JWST had to be processed and turned into a false color image before it could be put on the front page of the *New York Times*. The beautifully colored images that we see on TV and in press releases have been colorized by scientists on Earth. The colors are carefully chosen to give a "realistic" view of what the images would look like if we had infrared eyes, but also highlight particularly important features and make striking pictures for the media.

In its first five months of operation, JWST will collect data for a total of thirteen Early Release Science programs. During each program's allotted observation time, scientists will decide what the telescope is "pointed at." Exactly 17.4 hours of observation time has been allocated to a project co-led by Dominika Wylezalek (University of Heidelberg), Sylvain Veilleux (University of Maryland), David Rupke (Rhodes College), and former IAS Member and Visiting Professor Nadia Zakamska (Johns Hopkins University). The project is titled "Q-3D: Imaging Spectroscopy of Quasar Hosts with JWST Analyzed with a Powerful New PSF Decomposition and Spectral Analysis Package."

On July 18th, we spoke to Zakamska, whose research group has been involved with JWST since 2017, to gain a deeper understanding of the telescope's significance.

What new science will you be able to do with JWST?

I have a very broad range of scientific interests in astrophysics. Currently, all of my group's accepted programs for the first year of JWST observations are focused on supermassive black holes and their host galaxies. For example, we will be observing pairs of quasars which our group discovered a couple of years ago using data from the Gaia Mission and the Hubble Space Telescope in collaboration with Yue Shen (University of Illinois Urbana-Champaign). Such pairs of quasars form when two massive galaxies collide and start merging, and the supermassive black holes in their centers both start swallowing gas and get activated as quasars—extremely bright sources of radiation emitted by the accreting gas. At least, this is our current hypothesis for the nature of the close pairs of quasars we have discovered, and with JWST observations we will be able to detect the host galaxies in the throes of the merger and test whether these ideas are correct.

The rest of my group's programs focus on the so-called galactic winds. Quasars can produce so much radiation during the matter's final plunge into the supermassive black hole that the radiation pressure can push out much or all of the gas available in the quasar's host galaxy. This would have the effect of stopping star formation in the host galaxy for a long time, so quasar-driven galactic winds are thought to limit the maximal stellar mass of galaxies in the universe. About ten years ago, our group made some of the first observations of this process from the ground, and I spoke about some of the early results in a public talk at the Institute in 2013. Using JWST, we can now observe some of the most extreme galactic winds in the universe that were not observable from the ground. For the first time, we can study their impact on star formation, which has only been hypothesized so far.

In the future, I am planning to propose for JWST to observe a variety of other types of astronomical sources. Right now, I am excited about all kinds of exotic stars in our own galaxy, for example double white dwarfs that will merge due to emission of gravitational waves, anomalous white dwarfs that could be remnants of type Ia supernova donors, and powerful outflows from star-forming clouds.

How have you been involved in JWST before the image release?

In 2017, my research group participated in the very first general call for telescope proposals and were successful against greater than ten to one odds. This first proposal was co-led by my former postdoc Dominika Wylezalek—now a group leader at the University of Heidelberg—myself, Prof. Sylvain Veilleux, and Prof. David Rupke. The advantage of this early start is that my group has long been familiar with the technical capabilities of the facility and has been developing tools for the scientific analysis of JWST data. On the flip side, we are now under enormous pressure to deliver the results and the software to the scientific community as quickly as possible, so this is what will be occupying me for the next few months.

What do you think the significance of JWST will be for the field of astrophysics as a whole?

I see two avenues for lasting impact. One, of course, is the sheer importance of scientific discoveries. By their nature, discoveries are somewhat unpredictable, but if I were to speculate, the most significant achievements of JWST will be in understanding of exoplanets and in studies of the very distant universe.

Following the ground-breaking discovery of the first exoplanet in 1995 by [Michael] Mayor and [Didier] Queloz (joint winners of the 2019 Physics Nobel Prize), thousands of planets outside of the solar system are now known. Many of them were discovered by NASA's Kepler Mission and more are now being found by NASA's TESS mission. JWST will shortly be providing the first glimpses into the atmospheres of these planets, allowing scientists to understand planet composition. On the distant universe side, the infrared capabilities of JWST will allow us to probe unprecedented cosmological redshifts, offering a tantalizing possibility of discovering the very first stars and galaxies in the universe. These objects are so distant that their light has taken most of the time since the Big Bang to reach us, and therefore we are seeing them as they appeared at the dawn of the universe.

In addition to tackling these fascinating topics, JWST will impact astrophysics and society as a whole in another important way. JWST was built as a general-purpose observatory, rather than to answer a particular scientific question. Furthermore, the scientific program of JWST, just like that of any other of NASA's Great Observatories, is determined by peer review on a competitive basis. And finally, the proposal process for JWST is open to anybody in the world. Thus, JWST will perform its observations in the true spirit of common human enterprise, where the whole community participates in defining the most exciting applications for this amazing new facility.

Do you think $10 billion multi-decade space telescope projects are the way forward in astrophysics research?

Interesting modern astrophysics is pursued on a very wide range of financial scales, from billion- and multi-billion-dollar facilities like Keck and JWST to multi-million-dollar satellites dedicated to a particular science goal, to university-owned smaller telescopes and radio dishes, to amateur astronomers with telescopes in their own back yards, to theorists with their paper and pens and fast computers. However, the frontiers of research and the

NASA, ESA, CSA, AND STSCI

The James Webb Space Telescope observes in infrared to capture exquisitely detailed images. The Carina Nebula is shown here, as viewed through the Hubble and Webb telescopes.

scale of ambitions for American astrophysics are undoubtedly set by our flagship facilities. So what are some of the exciting, ambitious goals that may be worthy of such investment in the future?

Many years ago, when I was a Member at IAS and Professor Peter Goldreich was presiding over our daily journal club discussions, he said something that made an indelible impact on me, and I'll try to reproduce it as close to his original words as I can remember: "Life on other planets will be discovered in your lifetime," he said, and took a pause while we all stared at him. Then he added, "Not in mine, but in yours." I think the statement struck me because Peter had never seemed a dreamer, so this came through as a realistic prediction.

One of the most profound, most fundamental quests of humanity is to understand our place in the universe and to determine whether there is life on other worlds. Looking beyond JWST, one of the most exciting frontiers for humanity would be to detect and characterize so-called habitable exoplanets. These planets are just the right mass to have a solid core and a thin atmosphere, like Earth, and are precisely at the right distance from their host star (and are therefore at the right temperature) to have liquid water on their surfaces.

Whether we are technologically and scientifically within reach of this goal was recently evaluated by the 2020 Astronomy and Astrophysics Decadal Survey. The report concluded that an $11 billion ultraviolet + optical + infrared telescope set to be launched in 2040 has "the potential to change the way that we as humans view our place in the universe" by being able to characterize habitable planets outside of the solar system. Furthermore, "This is a quest at the technical forefront, and of an ambitious scale that only NASA can undertake," thanks to its prior leadership in space astrophysics.

Of course, I would like to see many other—perhaps more pressing—problems of humanity addressed on this timescale as well. But curiosity about our world and the creativity required to solve challenges in this quest are what makes us human, and what has often driven technological progress. There should be no reason why a wealthy country such as the U.S. cannot both tackle practical issues such as public health and well-being and invest in fundamental astrophysics research, to continue and enhance U.S. leadership in science and higher education. ■

Q&A with D. Dominique Kemp

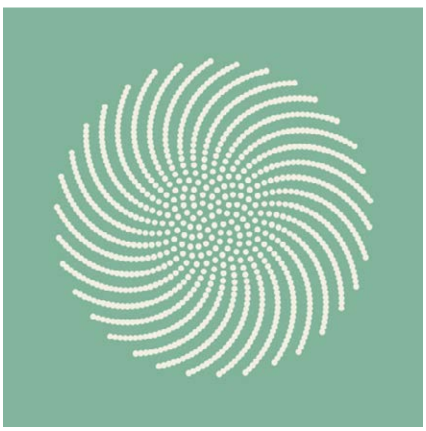
D. Dominique Kemp, a Shiing-Shen Chern Member in the School of Mathematics, is interested in problems that connect harmonic analysis with geometry. In particular, he explores decoupling, restriction and Kakeya theory, and Böchner-Riesz theory. He obtained his Ph.D. in mathematics from Indiana University-Bloomington, being the first black student ever to do so. Before arriving at IAS, Kemp held a postdoctoral appointment at the University of Wisconsin-Madison, funded by the National Science Foundation.

How do you describe your work to friends and family?

Typically, I describe it as an endeavor to understand the interactions of oscillating waves (in the physical realm) and more broadly any mathematical phenomena that exhibit oscillatory behavior. Because multidimensional waves are not excluded, geometry and topology naturally arise as essential considerations and tools, a detail that greatly enriches the study.

What is one way you would like to impact your field?

I would like to play my part in pushing the frontier of what we know in the field. Currently, much is known about those waves with frequencies adhering to a nice geometric behavior, i.e. those exhibiting curvature. However, the territory between the two extremes of curvature and no curvature is vast and largely unknown. The beginning of my research career has been a series of small steps into this realm.



Scale-based analysis obtains different views of an object's geometry, rendering a systematic understanding of the complexity.

What motivates you as a researcher?

I think the challenge, creativity, and (purposeful) rigor of mathematical discovery and expression appeal to me. I enjoy the incredible scope of structured freedom to explore; the challenge of finding precise, systematic language to communicate concepts; the diversity of solutions possible for a single problem; and hidden connections between different realms of the science.

Where is your favorite place to think?

I enjoy thinking about mathematics in any reasonably quiet room that has a pleasant interior with bookcases and artwork, good lighting, and broad windows facing a park, meadow, or garden.

Why IAS?

I accepted the postdoctoral position at IAS because of the wonderful opportunities for research and intellectual development here. In one way or another, the Institute attracts the world's leading experts across the mathematical sciences, and I desire to learn and grow from their expertise. As well, I look forward to joining and living among a community of broad, innovative scholarship, a residential experience that I'm sure I will savor for years to come.

What other activities or pastimes do you enjoy?

I enjoy playing piano, fitness, attending music and theater performances, visiting art museums and gardens, and hiking.

What is your favorite part about your career and work?

My favorite part about my career and work is the humanity of it. Mathematics, at its core, is like music in that it is the attempt of a human being to express a complex idea comprehensibly to other human beings. The struggle that such an endeavor requires, in terms of attaining a correct view of the concept and communicating it precisely, is a joy to experience and also, I think, inspiring to others to behold. ■

Q&A with Verena Krebs

Verena Krebs is a medieval historian working on Christian Ethiopia and the Horn of Africa, who draws on archaeology, art, and written sources for her scholarship. Following the publication of her first book, *Medieval Ethiopian Kingship, Craft, and Diplomacy with Latin Europe* (Palgrave Macmillan, 2021), she was awarded a 2022 David Dan Prize for "overturning traditional narratives of African-European relations and cultural exchange, and painting a vivid picture of the role of art, artisans and relics in state-building and diplomacy in medieval Ethiopia."

At IAS, Krebs will work on her second monograph, "Africa Collecting Europe: Patronage and Power in Christian Ethiopia, 1468–1530," which centers long-neglected material culture sources from Christian Ethiopia to tease out an untold story about the assertion of power in a pre-colonial African kingdom.

VERENA KREBS

How do you describe your work to friends and family?

I tend to say that I look at how people in the medieval past encountered one another over very long distances, and how they thought about the world they lived in, and their place in that same world.

What is one way you would like to impact your field?

I'd be very happy if my research could help broaden the (geographic) scope of medieval history, reassess commonly held paradigms about European-African interactions, and push people to re-think the importance of African polities in a larger pre-modern world.

What motivates you as a researcher?

Trying to figure out the many (often very surprising, and rather marvelous!) ways in which the pre-modern world was interconnected. So many things seem inexplicable at first glance—like this one small painted enamel found in a now-remote monastery in the Ethiopian province of Gojjam. It was made in early sixteenth-century France, yet there's writing on it in the old Ethiopian literary and liturgical language of Ge'ez. Its rather wonky letters indicate that the inscription was painted in Europe by a Latin Christian artisan who did not know what they were writing. How and why did this enamel come to be made? Who commissioned it, and

VERENA KREBS

Painted enamel, commissioned in France in the early sixteenth century by an Ethiopian Queen mother to ensure the succession of her son to the Solomonic throne

for what purpose was it brought to early sixteenth-century Christian Ethiopia? Turns out there's a larger story of courtly intrigue, and a queen mother's attempt to get her young son on the throne all hiding behind the history of this one small object. It opens up a whole world, if we care to look.

Where is your favorite place to think?

I do my best thinking on long hikes in the remote German countryside … in moments when I'm actively trying not to think. By a quirk of fate, I wrote both my big research projects in a rural village, staying at my parents' house at the edge of a low forest mountain range—first to save money when I ran out of funding the last year of my Ph.D., and then again when I wrote my first book from scratch during the Covid lockdowns of spring and summer 2020.

Why IAS?

From everything I've heard, IAS offers a peaceful place to work and wonderful opportunities to interact with other scholars. Also, I've never had a sabbatical, and I've never spent much time in the U.S., so I'm quite excited about both.

What other activities or pastimes do you enjoy?

Hiking, running, kickboxing—anything that forces me to clear my mind, really. I also really love cooking, and I am a huge sci-fi and fantasy nerd.

What is your favorite part about your career and work?

That it gives me the freedom to pursue something I'm truly excited and passionate about—and that it has enabled me to travel far and wide, forming lasting connections with friends and colleagues in places far from where I grew up. I'm the first in my family to attend high school (not to even speak of obtaining any further education!), so I'm constantly reminded that this work, this career, and the rather mind-blowing fact I'm paid to think, read, write, or travel—it's just an immense privilege. ■

OLENA SHMAHALO

Black Holes as Laboratories

How We Use Event Horizon Telescope Data to Test Our Understanding of Black Holes and Gravity Itself

BY LIA MEDEIROS

Black holes are fascinating objects that capture the imagination of the general public and scientists alike. And yet, they are remarkably simple. According to Einstein's theory of gravity—general relativity—black holes can be fully described by only three basic parameters: mass, angular momentum, and electric charge. Unlike most objects we commonly encounter, black holes of all masses have the same fundamental shape (or geometry), given the same spin and electric charge. A more massive black hole will have the same geometry as a less massive one, but scaled up in size. It is, therefore, no surprise that the first image of the black hole at the center of our own galaxy, published on May 12, 2022 by the Event Horizon Telescope (EHT) Collaboration, seems remarkably familiar.[1]

The now famous "orange donut" image of the black hole at the center of the M87 galaxy was first published by the EHT in April of 2019. The black hole at the center of our galaxy, called Sagittarius A* (Sgr A*)—revealed in May 2022—is approximately 1,500 times less massive than the black hole in the M87 galaxy. It's also about 2,000 times closer to Earth, which results in an "orange donut" of similar size from our point of view. The fact that the two black hole images look so similar—both with a ring of emission (the bright donut) and a central brightness depression (the empty donut hole)—is a remarkable confirmation of general relativity. These two black hole images, together with gravitational wave detections, show that black holes of vastly different masses are all consistent with the predictions of Einstein's theory. The unparalleled resolution of the EHT images allows us to use black holes in space to test assumptions, predictions, and alternatives—bringing to the fore an era of astrophysics where astrophysical black holes can finally be used as laboratories to test our understanding of gravity itself.

Why Use Black Holes as Laboratories?

Einstein developed the theory of general relativity between 1907 and 1915. According to his theory, what we experience as gravity is actually a geometric effect—mass tells spacetime how to curve, and the curvature of spacetime in turn tells mass how to move. The orbits of the planets are not caused by the gravitational "pull" of the sun, but rather, the mass of the sun curves the spacetime around it. The planets are trying to move in straight lines but are unable to, due to the curvature of the space they are moving through.

General relativity was first tested over 100 years ago and since then has been tested numerous times, with, for example, pulsar observations, cosmological studies, and measurements within the solar system. One might wonder, then, why we still test this theory, when it has already been tested for over a century. When testing a fundamental theory, it is important to keep in mind that validating one prediction of the theory does not guarantee that other predictions will also hold. For example, Newtonian mechanics had passed many tests before general relativity was developed, but we now know that, while Newtonian mechanics is a great

1 The images of these two black holes, in addition to their geometry, are also affected by the details of the accretion flows around them. Both of these black holes are in the same accretion regime, resulting in very similar images.

approximation in many cases, it is not complete. In particular, it is important to test theories in different regimes. For gravity, this means performing tests in very weak gravitational fields (low curvature)—such as tests at large cosmological scales—as well as in incredibly strong gravitational fields (high curvature)—such as tests with black holes. The first detection of gravitational waves from merging black holes by LIGO in 2016 provided the first strong-field test of general relativity. The EHT's images of M87 and Sgr A* provide new tests in the strong-field regime.

Tests with black hole images are complementary to those with gravitational waves; the latter are primarily sensitive to the dynamical aspects of the theory, while the former are sensitive to the geometry of the black hole itself. The black holes observed in the detection of gravitational waves have masses on the order of tens-of-times the sun's mass, while Sgr A* and the black hole in M87 have masses on the order of one-million- and one-billion-times the mass of the sun respectively. Although both tests probe the curvature of spacetime very close to a black hole, the curvature around a small black hole is much higher than that around a large black hole (curvature scales as inverse of mass squared). This means that these black holes can each be used as a laboratory to test general relativity at vastly different curvatures.

Testing with Sgr A* and M87

If general relativity is correct, and if a few physically motivated assumptions hold, then astrophysical black holes must be consistent with a very specific geometry. This specific black hole can rotate (can have spin), but does not have a significant electric charge.[2] This spinning but chargeless black hole is called "Kerr," after Roy Kerr who discovered its geometry in 1963. If we find that black holes in space are inconsistent with the Kerr geometry, then either general relativity is incomplete, or one of our physically motivated assumptions is violated. In particular, a violation of Kerr would likely violate the "No Hair Theorem," which, in colloquial terms, states that a black hole is completely determined by only three numbers: its mass, spin, and charge. A violation of the No Hair Theorem would have important implications for our understanding of gravity.

In the recent EHT publications on Sgr A*[3] we use the measured size of the ring of emission in the image of Sgr A* to show that this black hole is consistent with the Kerr geometry, as well as to place constraints on alternative geometries. To do this, we calibrate the measurement of the size of the observed ring of emission to the size of the black hole shadow.[4] The boundary of the black hole shadow is defined as the critical impact parameter between light-ray trajectories that fall into the black hole and those that escape to infinity, as seen by a distant observer. The black hole curves spacetime and the light rays trace out curved paths through the curved space. Because of this, photons that originally were not directed at the black hole can be curved towards it and fall into the event horizon. Due to the curved trajectories of light rays, the black hole shadow, as seen by a distant observer, will be approximately 2.6 times larger than the event horizon of the black hole. The Kerr geometry predicts a specific shape and size for the black hole shadow, which depend only weakly on the spin of the black hole.

Both Sgr A* and the black hole in the center of the M87 galaxy have very low accretion rates, meaning that a small amount of mass is falling into these black holes relative to their total mass. Due to these low accretion rates, theoretical models predict that the accretion disks around these black holes will be thick—more like a donut than a disk. For such models, the ring of emission in black hole images at short radio wavelengths (i.e., the wavelength at which the EHT observes) coincides with the black hole shadow. In the new EHT results, we use hundreds of thousands of models and simulations to calibrate between the black hole shadow and the ring of emission we observe in the EHT images. The size of the ring of emission seen in the EHT image of Sgr A* is completely consistent with the predictions for a Kerr black hole, and we can measure the size of the black hole shadow with an uncertainty of about ten percent. We consider several geometries that deviate from Kerr in a parametric manner, as well as geometries that are solutions to specific alternative theories. We even consider geometries that are frequently in the realm of science fiction, such as wormholes. Our ten-percent error bound is able to completely rule out several geometries (including a wormhole), and constrain the free parameters of several others.

Testing Whether Sgr A* Has an Event Horizon

One of the most iconic features of a black hole is its event horizon, sometimes referred to as "the point of no return." The event horizon is not a material surface but rather a mathematically defined boundary. Anything that comes closer to the black hole than this distance can never escape the black hole, not even light itself. The event horizon is crucial to our understanding of black holes, as it censors the singularity from the rest of the universe, avoiding possible unphysical phenomena; one such example of unphysical phenomena predicted around some theoretical naked singularities (singularities not shielded by an event horizon) is the possibility of walking in a circle and running into yourself from a few minutes ago.

Although most physicists and astrophysicists were

2 Black holes in space are not expected to have significant electric charge, since they should be able to attract the opposite charge and neutralize themselves.

3 The Event Horizon Telescope Collaboration et al 2019 ApJL 875 L6 https://doi.org/10.3847/2041-8213/ab1141.

4 The black hole shadow has a precise mathematical definition that depends only on the geometry of the black hole itself, and not on what is happening to the matter around the black hole.

already confident before the recent EHT observations that Sgr A* was in fact a black hole (and should, therefore, have an event horizon), it is still compelling to directly rule out alternatives. The first alternative is an object with a surface outside of the event horizon and in thermodynamic equilibrium, which absorbs and is heated by incident radiation, and which then re-emits the energy thermally. This model has been developed in the literature for several years; however, one of its free parameters is the size of the emitting region, and the new EHT results provide very stringent constraints on this. The model is further constrained by the measured accretion rate onto Sgr A*, also measured by the EHT. Lastly, this thermal model predicts a significant increase in infrared flux, which is inconsistent with previous infrared observations of Sgr A*. We therefore rule out a thermally emitting surface for Sgr A*.

The second alternative we consider is a surface (outside of the event horizon) that reflects incident radiation. The EHT observations are uniquely suited to constrain such an alternative, since a reflective surface results in additional emission within the center of the ring of emission. Although our exploration of this model is not as extensive as the thermal model discussed above, the depth of the brightness depression in EHT images of Sgr A* can already rule out a completely reflective surface, as well as place constraints on partially reflective surfaces.

THE FUTURE LOOKS BRIGHT FOR BLACK HOLE ASTROPHYSICS, BOTH FOR TESTS WITH BLACK HOLE SHADOWS AND TESTS WITH GRAVITATIONAL WAVES.

Finally, a naked singularity is also a potential alternative to an event horizon, and we consider several examples of naked singularities. Some naked singularities can be completely ruled out or constrained by the measured size of the black hole shadow. However, despite the remarkable high-resolution image, some naked singularities are still able to mimic the expectations of a Kerr black hole and cannot be ruled out. Although these new EHT results have proven very powerful in ruling out several alternatives to an event horizon and, therefore, significantly increased our confidence that event horizons enshroud singularities in space, we cannot conclusively reject all alternatives to an event horizon.

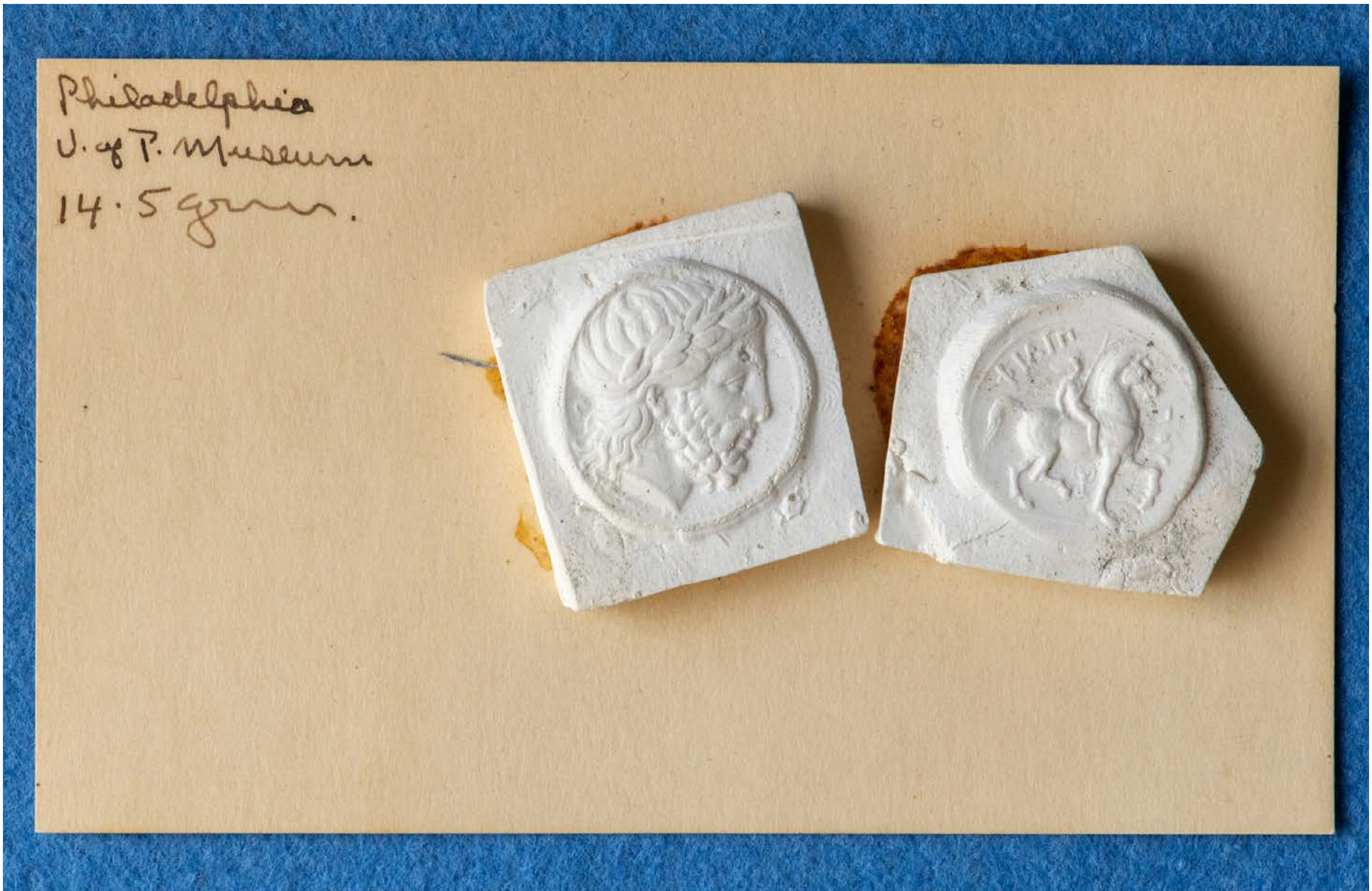
The Future of Testing with Black Holes

Strong-field tests of gravity—those with gravitational waves and those with black hole shadows—are complementary to each other, probing vastly different masses, and, therefore, curvature scales. We can directly compare the constraints between the two experiments and show that, since we are probing very similar gravitational radii, we can achieve comparable constraints on deviations. Before the publication of the first detection of gravitational waves in 2016, there was not a single test of general relativity in the strong-field regime. Only a few years later, we now have several strong-field tests that span over 10 orders of magnitude in black hole mass. This is still only the beginning.

The future looks bright for black hole astrophysics, both for tests with black hole shadows and tests with gravitational waves. In fact, the next generation of gravitational wave detectors are already being planned. Two such instruments, the Einstein Telescope and LISA, will provide a higher rate of detections (due to improved sensitivity) and probe different mass scales. The 2017 observations with the EHT were unprecedented as they were the first very long baseline interferometry observations with a global array. Since then, the EHT has successfully observed targets in 2018, 2021, and 2022 with additional telescopes which have significantly improved image fidelity and modeling constraints. All gravitational tests published by the EHT thus far have used only the size of the emission ring and not its shape. Due to the limited number of telescopes used, the 2017 observations do not provide a strong constraint on the shape of the ring. However, with 2022 data, constraints on the asymmetry of the shape of the ring may finally be possible, which would lead to a new constraint on a different part of the Kerr metric.

Observations at a shorter wavelength are also planned for 2023. Since the resolution scales with wavelength, a shorter wavelength will result in significantly improved resolution. Coupled with the improvements in our observational capabilities, new imaging and model fitting algorithms are continuously being developed. Advancements in analysis methods will further improve constraints on the size and shape of the black hole shadow, and depth of the flux depression resulting in further constraints on alternative geometries, as well as alternatives to an event horizon. With these advancements, astrophysical black holes will become better and better laboratories, providing greater insights into our fundamental theories. ■

Lia Medeiros is an NSF Astronomy and Astrophysics Postdoctoral Fellow and has been a Member of the School of Natural Sciences since 2019. She is an active member of the EHT collaboration and has held key leadership roles. She is currently developing a new algorithm for EHT data analysis, based on machine learning techniques that use a large high-fidelity simulation library as a training set. In addition to her research, she leads an outreach and education initiative teaching astronomy to students in Princeton High School's English Language Learners program—many of whom recently immigrated from Guatemala.



MARIA O'LEARY

MARIA O'LEARY

Casting a New Light on the History of Archaeological Research at IAS

BY ABBEY ELLIS

The role of reproductions in facilitating the study of the ancient Mediterranean has long been recognized at IAS. Upon his appointment as the Institute's first professor of Greek epigraphy in 1935, Benjamin D. Meritt petitioned then-Director Abraham Flexner to create a collection of "squeezes": paper reproductions that recorded the text of ancient Greek inscribed stones. An epigraphic library comprising nearly thirty thousand copies of inscriptions was the result, a collection that is further supplemented by photographic records of inscribed stones excavated at the Athenian Agora. Until relatively recently, the majority of the Institute's reproductions were believed to be of this paper variety; however, a recent find in the epigraphic library has quite literally lifted the lid on a whole new collection of copies.

THAT SUCH DETAILED IMAGERY WAS DEPICTED ON ANCIENT COINS MEASURING JUST A FEW CENTIMETERS ACROSS IS ALREADY AN IMPRESSIVE TECHNOLOGICAL ACHIEVEMENT, AND THAT THIS SAME IMAGERY HAS BEEN SO PRECISELY REPLICATED USING PLASTER IS EQUALLY REMARKABLE.

In their ongoing work to catalogue and digitize the Institute's squeezes, Dr. Aaron Hershkowitz and Dr. Esen Ogus of the Krateros Project made a surprising discovery: inside a battered box believed to contain squeezes, they uncovered more than one hundred plaster casts of ancient coins. The coin casts were nestled in the box alongside a mix of scrap paper, photograph cutouts, and other ephemera, and secured in place by a thick wadding of fiberglass. They had to be meticulously cleaned before any research into their origin could take place. Fortuitously, the casts were uncovered just days before the arrival of a new Visitor to the Institute's School of Historical Studies: myself! I had just submitted my Ph.D. thesis on plaster reproductions of another variety—a collection of casts taken from famous ancient Greek and Roman sculptures, held at the Ashmolean Museum of Art and Archaeology in Oxford, England—and was delighted to lend my expertise to the project.

The miniature plasters reproduce coins from across the ancient Mediterranean; some were originally produced in Lucania, southern Italy, others at Ephesus on the coast of Turkey, and more still in Syracuse on the island of Sicily. The original coins were minted at the behest of some of the ancient world's most famous figures, including Augustus, Rome's first Emperor, and Philip II of Macedon, the father of Alexander the Great. Some are of interest for their mythological imagery: one cast reproduces a coin that features the goddess Athena with the sea-monster Scylla (described in Homer's epic poem *The Odyssey*) positioned atop her helmet. Another particularly detailed example preserves an image of a four-horse chariot known as a quadriga, driven by a charioteer who brandishes a goad. Nike, the personification of Victory, is shown flying toward him with a crown.

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That such detailed imagery was depicted on ancient coins measuring just a few centimeters across is already an impressive technological achievement, and that this same imagery has been so precisely replicated using plaster is equally remarkable. The success of the replication is a consequence of the cast-making technique. They were likely created using clay molds: each original ancient coin would have been pressed into a smooth piece of clay in order to make an

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exact impression. The coin would then be extracted from the clay and a small amount of liquid Plaster of Paris would be poured into the resulting cavity. Once the plaster had been left to set, the clay would be peeled away, leaving a 1:1 plaster reproduction of the coin's imagery in its place. Each cast preserves one face of an ancient coin, with two separate casts being required to duplicate each coin in its entirety. On a cast representing the Emperor Augustus, one can even identify how the ancient die used to strike the image onto the original metal disk slipped during the minting of the coin. As a result, the design is not centrally aligned on the disk but off-center, leaving a large section on the right-hand side of the coin blank. The plaster cast replicates this perfectly. Near-perfect replication is not unusual: research published in 2019, which involved the 3D scanning of both original marble sculptures from Athens' Parthenon and plaster casts created from them, revealed that the latter replicated the former to within a millimeter of accuracy.

Upon discovery, many of the IAS casts were without identification; however, some of them were accompanied by a scant amount of documentation, giving me a starting point for tracking down their precise original referents. A few plasters were adhered to index cards, labelled with details of the original coin's weight and the museum collection in which they were housed at the time of casting. Some of the coins still reside within those same museum collections (I saw some of the originals on display during a visit to the Penn Museum, Philadelphia). However, the vast majority of the casts were undocumented. The few clues that were available have allowed me to develop an understanding of the objects' use and significance.

Also preserved alongside the casts was an envelope addressed to Professor Paul A. Clement at Johns Hopkins University, Baltimore. The envelope is a fascinating piece of history in its own right, attesting to the political climate in 1930s Germany on the eve of World War II. It bears a *Briefstempel* (letter stamp) from the Berlin's Akademie der Wissenschaften (Academy of Sciences) that is complete with Nazi symbolism: an eagle clutching a sword and a pair of lightning bolts. The name "Berlin" is flanked by a pair of swastikas. It is unlikely that casts were transported in this envelope, however: a note at the top reveals that Professor Clement had received a delivery of photographs, not plaster reproductions, from the Academy. Nevertheless, the presence of Professor Clement's name on the envelope was immensely helpful in identifying some of the casts. After initially joining the Institute as a Member in the School of Historical Studies from 1938 to 1949, Clement continued as a frequent Member in the 1950s. In 1938, he published a volume alongside colleague Professor David M. Robinson in which he catalogued the ancient coins discovered at the site of Olynthus in ancient Macedonia. Many of the coins illustrated in the volume are represented in the cast collection. I have been engaged in the lengthy task of comparing the cast coins to those illustrated in the volume in order to attribute the reproductions to their originals.

The reproductions likely allowed Clement to draw comparisons between original coins that were not immediately available to him, enabling him to carry out his analysis without making in-person visits to museums and private collections across the globe. Even after photography became the most popular method for documenting archaeological finds, casts were still very useful for this

This envelope, discovered alongside the casts, names Paul Clement, the IAS scholar who used them in his research

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kind of study as they reproduced their originals at 1:1 scale, unlike photographs which can distort the scale of objects when viewed in isolation. Casts also possessed another advantage: when photographing coins for use in publications, casts were preferable over the shiny metal originals because their less reflective plaster surfaces were easier to illuminate.

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Although the casts likely fulfilled an important role in his research, Professor Clement is unlikely to have had a hand in making the objects himself. The variable quality of the casts' workmanship and the many different types of plaster used indicates that they were not the work of a single maker. Instead, they were made by the private collectors and museums that held the originals. These individuals and institutions are acknowledged by Clement in the preface to his publication. Some of the private collectors made an even more direct note of their contribution, inscribing their names on the reverses of the casts that they produced. Other casts even preserve the fingerprints of those who made them.

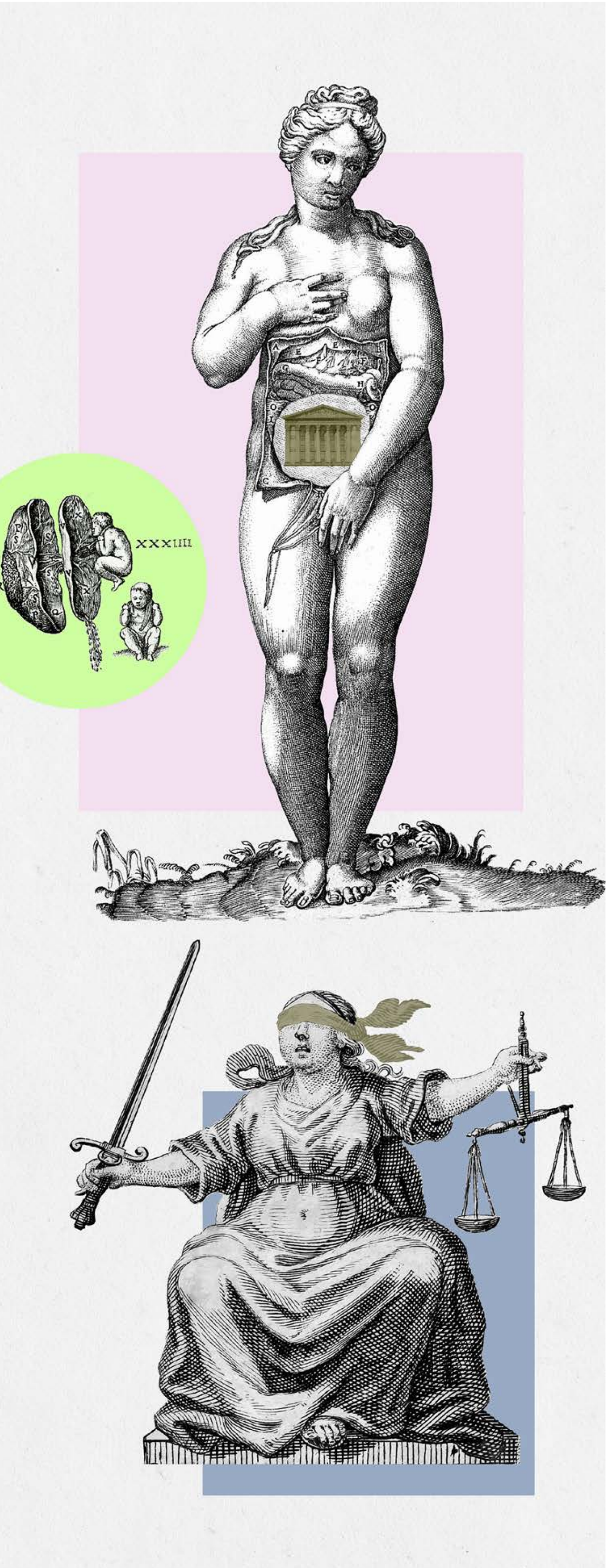
While the casts might initially seem small and insignificant, the Institute is very lucky to have these objects in their collection. In the early twentieth century, plaster casts of ancient subjects were removed from display at many major museums. At this time, reproductions in general were perceived as lacking in value compared to original objects. Many casts were left to disintegrate in dank warehouses or were even deliberately destroyed. The Institute's casts are fortunate survivors of this tumultuous time.

Today, scholars are beginning to recognize the significance that casts hold as historic objects in their own right, and reproductions are enjoying something of a renaissance. In 2018, the plaster cast courts at London's Victoria & Albert Museum reopened with great fanfare, and *Chroma*, an exhibition that is currently on display at the Metropolitan Museum of Art, New York, presents brightly painted 3D-printed reproductions of ancient statues to give an impression of their original polychrome appearance. I view the casts not as mere copies but as fascinating historical documents that can enhance our understanding of how the study of classical antiquity has developed over time. ■

MARIA O'LEARY

Abbey Ellis is a past Visitor (2021–22) and Research Associate (2022) in the School of Historical Studies. She has a background in Classical Archaeology, gaining her Bachelor's and Master's degrees in the subject from the University of Oxford. She graduated with her Ph.D. in Museum Studies from the University of Leicester in 2021.

The coin casts featured here, and the reproductions of ancient pinakia described in the Spring 2022 Institute Letter, are currently the subject of a pop-up exhibition titled *Original Copies?*, available to view in Fuld Hall.



ANNA LAQUA

After Dobbs: Biolegalities of Fetal Personhood

BY SONJA VAN WICHELEN AND MARC DE LEEUW

There is a uniquely U.S. story to the legal undoings following *Dobbs v. Jackson Women's Health Organization*. The American divide on abortion finds its contested space reinvigorated by the recent majority decision from the U.S. Supreme Court that overturned *Roe* and *Casey*. This distinctly American institution of politically appointed judges is unparalleled to any other top courts in other liberal democracies. Besides important debates on the constitutional order, the erosion of women's reproductive rights, and the de-democratization of American society, the *Dobbs v. Jackson* case also reignites deliberations on fetal personhood. Already, states are newly engaging how to engross the fetal person. Georgia, for instance, renders the fetus tax-deductible; once doctors can detect heartbeat, fetuses are legal persons in Georgian law, making them claimable as dependents in tax returns.[1] Arizona and Alabama, too, have recently passed abortion bans that define the legal personhood of the fetus. In contrast, the U.S. Supreme Court just rejected the petition to claim personhood status for a fetus after conception which was brought out of Rhode Island.[2]

It is notable that laws regarding fetal personhood also mushroomed following *Roe* itself in 1973, including inquiries regarding the status of frozen embryos.[3] While these instances of reinstating fetal personhood appear mostly as an ideological side-show, uses of legal personhood reflect a more complex contending of law vis-à-vis matters of life. Our contribution here focuses less on the current contested politics behind *Roe* and *Dobbs*, and more on the question of how fetal personhood attaches to or detaches from forms of life and the contemporary biological, technological, and relational nature of reproduction. Beyond the justified outrage over the *Dobbs* ruling,

1 Ava Sasani, "Georgia Abortion Law Says a Fetus Is Tax Deductible," *The New York Times*, August 4th, 2022, https://www.nytimes.com/2022/08/04/us/georgia-abortion-law-fetus-tax-dependent.html

2 Samira Asma-Sadeque, "US supreme court declines to take up fetal personhood case," *The Guardian*, October 11, 2022, https://www.theguardian.com/world/2022/oct/11/us-supreme-court-fetal-personhood-appeal-case

3 See Cromer, Risa. 2019. "Making the Ethnic Embryos: Enacting Race in US Embryo Adoption." *Medical Anthropology* 38 (7): 603–619.

the tension between law and life was an already existing legal affair with complex, and often unresolved, debates about the boundaries of the natural and the artificial, the social and the technological. The articulation of fetal rights brings about foundational puzzles within the domain of legal persons, deliberations on which may form opportunities to reorganize life in new ways—albeit vigilantly—including those that account for reproductive justice.

Legal Personhood: Past and Present

The topic of legal personhood is a richly debated area in legal theory and the anthropology of law. Integral to Western legal thought, the early history of legal personhood captures the inventive ways in which law deploys legal fictions to organize, resolve, or re-order social problems. Roman law, for instance, invented legal techniques of personhood to find resolutions to practical dilemmas in society and its institutions, operating primarily as a juridical placeholder to accommodate relationships with the city, estates, or kin.[4]

Legal personhood in Rome did not embody any reference to a natural or human person; it was not shaped according to biological understandings of human beings. Instead, the biological was adapted by law to fit the function of a person, thereby "fictionalizing biology so as to provide the necessary warrant for each of the transactional personae that it invented."[5] A good example is Roman adoption, where one could adopt adults, or could adopt grandsons to the status of sons regardless of biological order of reproduction. Scholars refer to this as *artificial* personhood, denoting the fictional ways personhood has been imagined. But this early iteration of legal personhood—as an invented artificial intervention—was soon to be destabilized by Christianity and the human sciences.

The concept of the natural person as attached to the human being occurred over an extended period, starting from the influence of Christianity on law in the Middle Ages and reaching through to the rise of the human and life sciences in the nineteenth century. Biology played a particularly vital role in constituting the naturalized person, illustrative in the legal assumption that natural persons are either male or female. Apart from the rudimentary facts of biology that have organized law foundationally in the realms of family and inheritance (such as birth, death, sex, and reproduction), the biological and psychological sciences helped constitute the natural person by providing scientific knowledge of humanity and human behavior. The strong influence of human rights in legal systems around the world further emphasized the legal subject's reference as a naturalized human being.

Throughout modern history, the bio-legal configuration of personhood has functioned by means of dichotomous division—between persons and things, life and law, mind and body, human and the non-human—and the natural person in modern law tightly references the natural body, through birth and death, the division of the sexes, and metaphysical human (and liberal) traits such as autonomy, integrity, and agency.[6] This bounded human has received due critique from feminist scholars, who point out discrepancies of the natural person when turning to the pregnant body.[7] Anthropological theory, too, subjected law's natural person to reproach by pointing to the Eurocentric constructions of personhood, including metaphysical understandings of autonomy and bodily integrity. Rather than the bounded self, individuality in non-western societies is relational—"dividual" as the anthropologist Marilyn Strathern calls it.[8] Moreover, the relational includes non-human and inanimate others, which disturb the vital modern distinction between a person and a thing.

The introduction of biomedical technologies in contemporary times has complicated disputes around personhood, particularly fetal personhood. Take, for instance, obstetric ultrasound imaging and Prenatal Genetic Diagnosis (PGD), which have become routinized in medical practice and even legally required in specific U.S. jurisdictions. Scholars have shown how requiring women to undergo ultrasound imaging make them more empathetic to the fetus, and less-inclined to carry out a planned abortion.[9] On the other side, the routinization of PGD testing causes higher frequency of terminations following the diagnosis of intellectual and physical disability, prompting advocates of disability rights to resist mainstreaming such testing.

While such biomedical technologies impact society at large, they specifically influence the boundaries and limitations of fetal personhood in law. Here, juridical persons and natural persons are often collapsed, compounding not only moral claims on the fetus, but also the apparent paradoxical situation that the law allows both abortions and tort suits for pre-birth injuries.[10]

It is, in fact, the conceptual work of disentangling this presumed paradox that allows fetal personhood to be more than the politicized version it begets from the U.S. abortion debate. Moving beyond a pro-life/pro-choice dichotomy, personhood can be put to work to ignite its possibility and reconfigure itself to a definition more amenable to emerging forms of justice.[11]

4 See Mussawir, E., & Parsley, C. 2017. The law of persons today: At the margins of jurisprudence. *Law and Humanities*, 11(1), 44–63, p. 49.

5 See Pottage, A., 2002. Unitas personae: on legal and biological self-narration. *Law & Literature*, 14(2), pp. 275–308, pp. 289–290.

6 See Van Wichelen, S. and De Leeuw, M., 2022. Biolegality: How Biology and Law Redefine Sociality. *Annual Review of Anthropology*, 51, pp. 383–399.

7 See for instance Karpin, I., 1992. Legislating the female body: reproductive technology and the reconstructed woman. Colum. J. *Gender & L.*, 3, p. 325–350.

8 See Strathern, M., 1988. The gender of the gift. In *The Gender of the Gift*. University of California Press, p. 13.

9 See Mills, C., 2018. Seeing, Feeling, Doing: Mandatory Ultrasound Laws, Empathy and Abortion. *Journal of Practical Ethics*, 6(2): 1–31.

10 For instance, when so-called wrongful birth or wrongful life claims are invoked where medical negligence has led to the birth of an unwanted or disabled child, respectively.

11 See also Gündoğdu, A., 2021. At the margins of personhood: Rethinking law and life beyond the impasses of biopolitics. *Constellations*, 28(4), pp. 570–587.

Futures of Legal Personhood

Arrangements of fetal personhood in society today can be interpreted in two ways. On a political level, fetal personhood demonstrates the ideological deployment of the fetus (turning the fetus into a tax-deductible entity as a pro-life gesture). On a more legal-theoretical plane, however, it can also be seen as a demonstration of how legal forms and biological knowledge coalesce to transform legal representation (personhood) into a biological "faction" (fiction as legal fact). Beyond the issue that some states assign personhood to the fetus while others do not, a complication occurs as personhood (as biological faction) becomes attached to specific rights.

Clashes emerge once the right of the fetus is pitted against a pregnant person's life; which rights should prevail over the other? Here, the pregnant body is not one that fits in the individual protection of human rights. The individualized concept of rights works against a body that is "multiplied"; while it invites the protection of one life (the fetus), it does so within the body of another life (of the gestator). Hence, assigning legal personhood to a fetus living inside another legal person creates a conflict between a naturalized legal personhood (the biological status of the fetus attached to the legal representational status of personhood) and the rights claims of a citizen (the state granting rights to legal persons as citizens). Deliberations over these legal problems are important in moving forward the social and political discussion around fetal personhood, and in preparing for further social and technological challenges on legal understandings of "life," "persons," and "birth."

The pluralization of personhood becomes a necessity when considering biomedical technologies that determine disease and disability from the point of conception. Wrongful life claims—in which parents (or the children themselves) sue third parties for damages for a life of preventable disabilities—are proliferating in many jurisdictions. Children can now legally contest their own conception.[12] Moreover, the legal status of the fetus becomes more pressing with pending technologies that allow ectogenesis: the gestation of embryos outside the uterus in artificial environments. Here, not just reproductive material, but the actual gestational process is detached from the human body, thereby bringing the body/life question central to the puzzle of fetal personhood/fetal rights.

A latent way to engage these complexities is to divert attention to potentialities enacted through "the body." According to Strathern, the oscillation between person and thing is a core mechanism through which we actualize the body in modernity and modern law. The potentiality of personhood in the case of an embryo, for example, varies according to whether the embryo is frozen or thawed, implanted in utero or discarded.[13] The body can actualize as a different "form," according to the relation that is actualized by the claim.

Strathern notes that the question of whether body parts can be seen as property is dependent not only on biological relations (the detachment of parts from the whole), but also conceptual relations (the conceptual capacities to detach parts from wholes). We can imagine for instance that the frozen embryo (as gestationally detached from, while genetically attached to, the original biological parents), can, conceptually, be detached from the original biological parents when the embryo is donated to "intended" gestational/adoptive parents. Hence, the emergence of biomedical and reproductive technologies further complicates the biology of parts and wholes, as well as the concept of detachment—concepts which do not have a space in existing perspectives of legal personhood.[14]

The conception of a personhood tightly attached to nature—contrasting the varied definitions of personhood throughout history and complicated by current disputes —has caused scholars to criticize the concept for subsuming the singularity of life it purports to represent: a false technique to sustain a universalized form of human character.[15] However, rather than concluding from such a critique that law subsumes life with its ominous power, exploring constructions of personhood potentially opens opportunities to articulate new avenues of thinking personhood beyond rights and interests.[16]

Besides resisting how the U.S. Supreme Court has overturned *Roe*—namely by creating new legal factions around the interpretation of the constitution—here lies a task for legal scholars and the broader public: to imagine and re-imagine the relation between law and life. ■

The views expressed in this opinion and analysis article are the authors' own and do not necessarily reflect those of the Institute Letter*'s editorial staff.*

Sonja van Wichelen is Associate Professor in Sociology with the School for Social and Political Sciences at the University of Sydney, Australia. She is a former IAS Member (2020–22) in the School of Social Science. Her most recent book is Legitimating Life: Adoption in the Age of Globalization and Biotechnology *(Rutgers University Press, 2019).*

Marc de Leeuw is Senior Lecturer in Legal Philosophy with the Law School at the University of New South Wales, Australia. He is a former IAS Visitor (2020–22) in the School of Social Science. His most recent book is Paul Ricoeur's Renewal of Philosophical Anthropology: Vulnerability, Capability, Justice *(Rowman and Littlefield, 2021).*

12 Van Beers, B., 2017. The Changing Nature of Law's Natural Person: The Impact of Emerging Technologies on the Legal Concept of the Person. *German Law Journal*, 18(3), pp. 559–594.

13 Strathern, M., 1999. *Property, substance, and effect: anthropological essays on persons and things* (pp. 248–260). London: Athlone Press, p. 175.

14 See Esposito, R., 2015. *Persons and things: from the body's point of view.* John Wiley & Sons.

15 See also Esposito ibid.

16 See also Vatter, M. and De Leeuw, M., 2019. Human rights, legal personhood and the impersonality of embodied life. *Law, Culture and the Humanities*, https://doi.org/10.1177/1743872119857068.

AMIAS In Focus

Leslye Obiora, Visitor (1998) in the School of Social Science, came to the Institute to work on a project examining the UN-determined international human rights agenda and how well it has travelled across cultures and structures (both how it has been adopted by various cultures, as well as how it is developed with new cultures in mind), specifically in relation to gender equality. Following her time at IAS, she gained further experience in public service; she has served as the Minister of Mines and Steel Development for the Federal Republic of Nigeria, as Manager of the World Bank Gender and Law Program, and has held several teaching positions. She has also been a Trustee of various Boards, including the Association of Members of the Institute for Advanced Study (AMIAS).

Thinking back to your time at the IAS, where were you in your career at that point?

For me, coming to the IAS was a great turning point. I have eleven years of post-graduate studies, but all of them are in law. So, while I'd always wanted to do social sciences and interdisciplinary work, none of my training was in that. When I think of my time at IAS, I think very fondly within the framework of the metaphor of a child learning to walk: you take your baby steps amidst the watchful eyes of your parents, you stumble, you get up, and they keep encouraging you.

Did you have fruitful encounters with other Members and Faculty while at the IAS, and did these encounters impact your work?

I came here looking for a place to deepen or advance my studies, and I [found] a village in every sense of the word—a village where you had every demographic cohort, from one-year-olds to octogenarians, who all interacted in a way that was very mutually enriching, very respectful, and very encouraging. You hear of the famed Faculty—Clifford Geertz, Michael Walzer, Albert Hirschman, and Joan Scott—but you don't realize how approachable and how really devoted they are in mentoring and nurturing you, and in investing in your career. What I did there would have been infinitely different had I not sat at the feet of these great people and my fellow scholars to reflect much more deeply on the implications of what I was arguing about. You would have people fiercely disagreeing with you, but it was in the spirit of camaraderie; it was always—always—invariably enriching.

What did your time as an IAS scholar enable you to accomplish?

I went from the Institute back to my home institution at the time, which was the University of Arizona. Within a year of returning there, I got an offer to go to the World Bank to manage their standalone Gender and Law program. So, I got to take my scholarship to a policy arena. I had thirteen countries in my portfolio, all of them in Africa, and would reach out to policy makers there to figure out how they could use their law reform program to improve the status, well-being, and agency of women in those countries. I came from IAS and then my eyes were opened to the real world at the World Bank, and my life has never been the same because, after that, I felt a burning sense of obligation to really roll up my sleeves and devote my intellectual capital to help improve on policy outcomes. I can say, without a shadow of doubt, that after more than two decades, becoming a member of IAS is a gift that has just given perpetually in my life.

What was the most important aspect of your stay?

I guess the ambiance. It may have been something in the air or in the water, or it may have been the social events that they integrated into what we were doing, but it was the most relaxed sanctuary that I have found, anywhere. The whole campus is beautiful, including the woods. This was my first encounter with wildlife, up-close and personal; the deer would just be impervious to your presence and walk straight up to you. And the very first time I saw a cloud of fireflies (which were actually my favorite), I couldn't quite figure out what they were and had to go investigate. When it turned out to be these fireflies, it was almost like the heavens had come down. It was so picturesque, and each of these little, very unique things added to the beauty—if not the magic—of the place. ■

From the Reading List:

Singing Like Germans

Black Musicians in the Land of Bach, Beethoven, and Brahms.

An excerpt from the debut book of Kira Thurman, Member (2019–20) in the School of Historical Studies.

The award-winning *Singing Like Germans* tells the story of Black musicians in German-speaking Europe and how their performances of classical music challenged ideas about who could perform such works, as well as concepts of identity—both racial and national.

[Roland] Hayes had a small voice. He was an expert in singing softly, creating vocal coloring, and shaping vocal lines with minute detail. Like [Theodor] Lierhammer, Hayes also remained adamant throughout his career that the best way to learn German lieder was through the music of Schubert. "I like the Schubert music for the quality which suggests improvisation and spontaneity, and for its highly colored, imaginative feeling," he explained in his memoir. "It lends itself to emotional re-creation and can be made to sound endlessly fresh and inspired."[1] Hayes's training in 1920s Vienna with Lierhammer fit perfectly with his own vocal abilities and perceptions of German lieder.

Perhaps for those reasons, when Hayes premiered on the European continent, he stunned Viennese critics. Although he was to their minds unmistakably foreign—one critic described him in primitivist terms as "a small, agile Negro with crisp hair, thick lips, and shining white teeth"—to some, his expert execution of German lieder suggested a cultivation far removed from what they imagined to be his primeval Blackness.[2] Hayes's diction, pronunciation, and lyricism were apparently evidence of that great Austro-German musical tradition that many believed created a unique German sound. A critic for the popular newspaper *Wiener Allgemeine Zeitung* wrote, "No German could sing Schubert with more serious or unselfish surrender. Do not imagine that it is sufficient to be white to become an artist. Try first to sing as well as this Black man did."[3] His observation is a remarkable example of what critical race theorists call marking/unmarking in historical discourse. This author critiqued the popular assumption that one had to be white in order to be an authentic singer of German lieder. The critic admitted that he too has assumed that classical music and German national identity were anchored in whiteness—until he heard Hayes sing. Thus, the critic's comments revealed the invisibility of whiteness as a racial position," as Richard Dyer describes it, for only after Hayes had performed the German lied did the music and its performers become marked in racial terms.[4] But much to the critic's surprise, he discovered that German musical identity was not irrevocably bound to whiteness after all. The relationship between appearance and sound, between race and culture, could be severed.

Hayes's performance in the spring of 1923 was the first of

1 Christopher Small, *Musicking: The Meanings of Performing and Listening* (Hanover, NH: University of New England Press, 1998), 10.

2 By "musical Germanness," I mean the discourse that developed in the late eighteenth century by which Germans were described as the "people of music" and a particularly German essence was attributed to musical composition and/or expression. As scholars such as Applegate and Potter have argued, no one could define what musical Germanness actually was. But by the mid-nineteenth century many believed that Germans "understood the deeper sources of music more fully and intuitively than others." Applegate, "Saving Music: Enduring Experiences of Culture," *History and Memory* 17, nos. 1–2 (2005): 217–37. In the 1930s, Potter writes, "many studies simply accept[ed] musical Germanness as a given without defining it." See Potter, *Most German of the Arts: Musicology and Society from the Weimar Republic to the End of Hitler's Reich* (New Haven: Yale University Press, 1998), 211.

3 Hoi-eun Kim, "Made in Meiji Japan: German Expatriates, German-Educated Japanese Elites, and the Construction of Germanness," *Geschichte und Gesellschaft* 41, no. 2 (April–June 2015): 291–92.

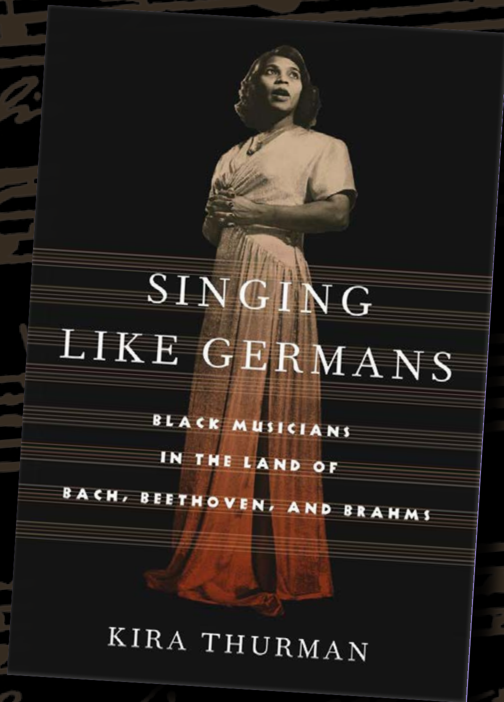
4 Ibid.

many that challenged audiences' notions of what constituted authentic performance practice. Following his successful debut in Vienna, Hayes embarked on a tour through Central Europe that took him to Graz, Budapest, Karlsbad, and Prague. Hayes credited Countess Colloredo-Mansfeld with helping him learn how to sing lieder with authority. Together in Prague they read definitive biographies of historical German figures including Johann Wolfgang van Goethe, Friedrich Schiller, and Otto von Bismarck, and played through the music of Bach, Handel, Mozart, Schubert, Schumann, Beethoven, Brahms, and Wolf.[5] The countess suggested numerous changes to Hayes's performance style that also transformed his singing. From her he learned to elongate or double the consonants on specific words (such as the *l* in *liebe*), thus giving him a more authoritative grasp of lieder performance practice.[6]

Following his time in Prague, Hayes headed to Berlin in May 1924 where, as I discussed in the previous chapter, he subdued an angry crowd with his performances of lieder. Much of Hayes's success in Berlin has to do with his choice of repertoire. His decision to begin his Liederabend with Schubert's "Du bist die Ruh" turned out to be the best possible choice for that moment for several reasons. First, singing softly forced the crowd to stop shouting at him in order to hear him. Second, the lied's sweetness, warmth, and quiet (the primary dynamic markings are pianissimo) were disarming; its performative qualities did not present Hayes as a threatening stranger. Rather, the piece gave the opposite impression: the performer of "Du bist die Ruh" sounds gentle and patient. Third, "Du bist die Ruh" was one of Schubert's more well-known lieder, and its comforting familiarity may have also helped subdue Hayes's audience.

What Hayes offered the crowd on that evening in 1924 was ultimately something intimate, familiar, and beloved. Expecting scandal, exotic curiosity, minstrelsy, and indecency (which they associated with Blackness), the audience encountered a soothing, simple, and beloved Schubert lied. Instead of sounding like other African American singers of spirituals and popular music, Hayes resembled musically the native German-speaking performers the audience was accustomed to hearing.

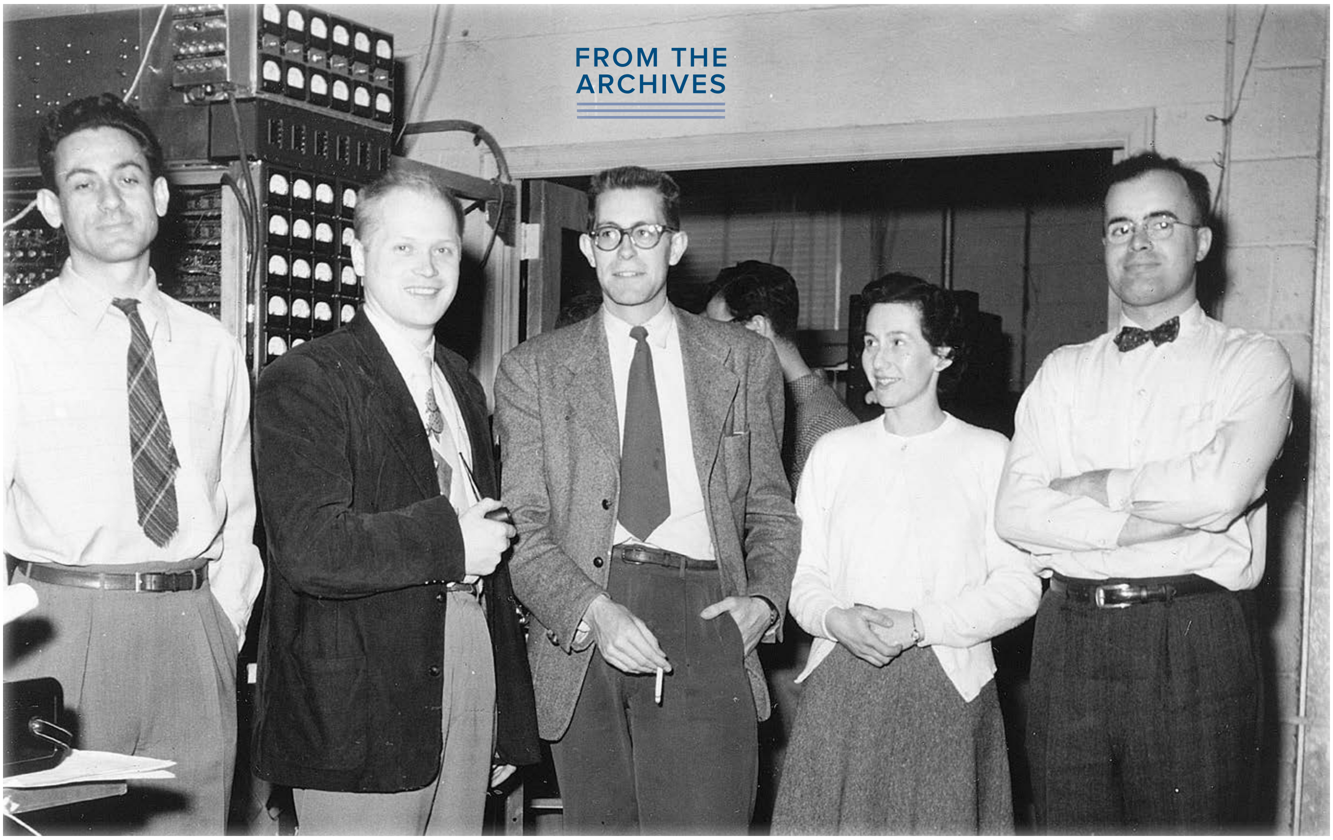
After their initial resistance, most Berliners were impressed by how expertly Hayes had mastered the German lied. Several newspapers called him a "true artist" who had captured the feeling and sentiment of German lieder with breathtaking accuracy and warmth. In the right-leaning nationalist newspaper *Deutsche Tageszeitung*, the musicologist Hermann Springer called Hayes a "Negro who shows dedication in singing Schubert and Brahms for us in the German language."[7]



The seriousness of Hayes's musical purpose found approval in Berlin. In fact, it was "specifically in these songs by Schubert, Schumann, Brahms, and Wolf that one noticed that Roland Hayes is a real artist, not just a singer but rather a musician," wrote a critic for the conservative German People's Party (DVP)-backed *Deutsche Allgemeine Zeitung*.[8] Like the critic for the *Wiener Allgemeine Zeitung*, the writer claimed that real artistry was located in the purity and universality of German music. In their eyes, Hayes had transitioned from being a Black entertainer to a more "universally" appealing artist of classical music. ■

Thurman, Kira. *Singing Like Germans: Black Musicians in the Land of Bach, Beethoven, and Brahms*. Ithaca, NY: Cornell University Press, 2021.

5 Inga Clendinnen, *Dancing with Strangers: Europeans and Australians at First Contact* (Cambridge: Cambridge University Press, 2005), 11.
6 James H. Johnson, *Listening in Paris: A Cultural History* (Berkeley: University of California Press, 1995).
7 See Christian Thorau and Hansjakob Ziemer, *The Oxford Handbook of Music Listening in the 19th and 20th Centuries* (New York: Oxford University Press, 2019), accessed online November 11, 2019, https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190466961.001.0001/oxfordhb-9780190466961-e-1; Daniel Morat, ed., *Sounds of Modern History: Auditory Cultures in 19th and 20th Century Europe,* (New York: Berghahn, 2014); Jan-Friedrich Missfelder, "Period Ear: Perspektiven einer Klanggeschichte der Neuzeit," *Geschichte und Gesellschaft* 38, no.1, (January–March 2012): 21–47.
8 See Nina Sun Eidsheim, *The Race of Sound: Listening, Timbre, and Vocality in African American Music* (Durham, NC: Duke University Press, 2019); Grace Wang, *Soundtracks of Asian America: Navigating Race Through Musical Performance* (Durham, NC: Duke University Press, 2015).



SHELBY WHITE AND LEON LEVY ARCHIVES CENTER

The Politics of Climate Crisis, Then and Now

This year, UPS Foundation Professor Wendy Brown will lead the Institute's School of Social Science theme seminar on the politics of climate crisis. In her own words, Brown describes the theme seminar as an investigation of the emergent politics that arise "from the crisis's emergency quality, its global dimensions yet unequally distributed effects, and its severe indictment of existing ways of human life." In preparation for this historical work, the Shelby White and Leon Levy Archives Center is engaged in a reciprocal effort to uncover the legacy of climate research and climate politics at the Institute.

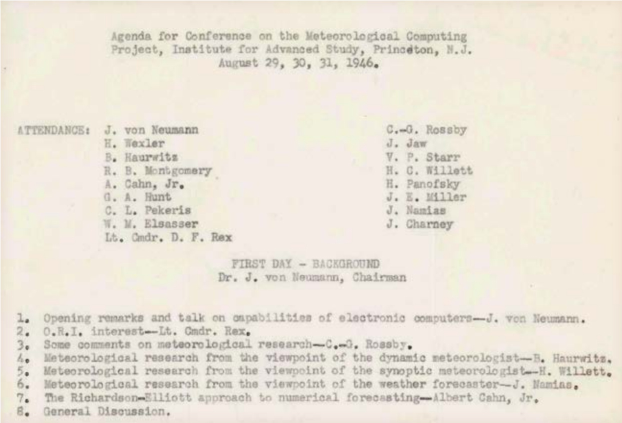
The Institute's involvement with the advancement of climatology begins over seventy-five years ago. On August 29, 1946, IAS Professor John von Neumann welcomed a group of sixteen experts in the field of meteorology to the Institute campus. The attendees included two official representatives from the federal government: Lieutenant Commander D. F. Rex of the United States Department of the Navy Office of Research and Inventions, and Harry Wexler, Chief of the Scientific Services Division of the United States Weather Bureau (now the National Weather Service). The United States maintained an active interest in the work of the conference—bringing together a group of meteorologists and mathematicians that might be able to leverage von Neumann's new Electronic Computer Project to create the first successful numerical predictions to forecast the weather.

Two decades earlier, the first attempts to predict the weather by Lewis Fry Richardson proved unsuccessful. But geopolitical conflict is often the impetus for scientific and technological advancement; the pressures of creating state systems that could effectively predict and leverage meteorological and climate data heightened at the outset of World War II. Beginning with United States involvement in the war, von Neumann and many of the meteorologists attending the conference had been involved in efforts to resolve what the United States saw as a gap in the resources of the Allied powers. In 1940, President Franklin D. Roosevelt called for the construction of 50,000 military aircraft and 10,000 meteorology-trained officers. Suddenly, meteorologists had become a key part of the politics of warcraft.

Von Neumann himself had already joined the effort to combat the Nazi government—whose rise had pushed him to immigrate to the United States from his native Europe and settle at the Institute for Advanced Study—and his work on the Manhattan Project had fueled an interest in the mathematical problems of weather prediction and control. For von Neumann, the Electronic Computer Project provided the necessary government funding and calculation power to address many of the problems of Richardson's first attempts.

The list of participants and consultants for the three-day conference included mathematicians and meteorologists of global renown, including the following:

- Bernhard Haurwitz, a University of Göttingen specialist in atmospheric and ocean dynamics, then based out of the Massachusetts Institute of Technology (MIT)



Agenda for Conference on the Meteorological Computing Project, Institute for Advanced Study, Princeton, N.J.
August 29, 30, 31, 1946.

ATTENDANCE:

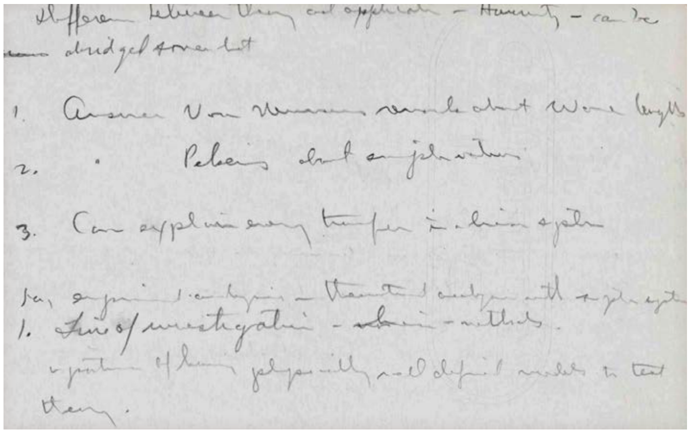
J. von Neumann	C.-G. Rossby
H. Wexler	J. Jaw
B. Haurwitz	V. P. Starr
R. B. Montgomery	H. C. Willett
A. Cahn, Jr.	H. Panofsky
G. A. Hunt	J. E. Miller
C. L. Pekeris	J. Namias
W. M. Elsasser	J. Charney
Lt. Cmdr. D. F. Rex	

FIRST DAY - BACKGROUND
Dr. J. von Neumann, Chairman

1. Opening remarks and talk on capabilities of electronic computers—J. von Neumann.
2. O.R.I. interest—Lt. Cmdr. Rex.
3. Some comments on meteorological research—C.-G. Rossby.
4. Meteorological research from the viewpoint of the dynamic meteorologist—B. Haurwitz.
5. Meteorological research from the viewpoint of the synoptic meteorologist—H. Willett.
6. Meteorological research from the viewpoint of the weather forecaster—J. Namias.
7. The Richardson-Elliott approach to numerical forecasting—Albert Cahn, Jr.
8. General Discussion.

SHELBY WHITE AND LEON LEVY ARCHIVES CENTER

Conferences and Seminars: Conference on the Meteorological Computing Project, Institute for Advanced Study, Princeton, New Jersey, August 29 to August 31, 1946



Notes from the Jule G. Charney Papers at the Massachusetts Institute of Technology

- **Raymond B. Montgomery**, former physical oceanographer employed by the Woods Hole Oceanic Institute, then based out of MIT
- **Albert Cahn, Jr.**, a junior physicist at the University of Chicago's Metallurgic Laboratory who was involved with von Neumann on the Manhattan Project
- **Gilbert A. Hunt**, one of the forecasters who had been responsible for weather prediction in advance of the Allied invasion of Normandy on D-Day
- **Chaim L. Pekeris**, an Israeli-American geophysicist and mathematician who left MIT to join the Hudson Laboratories of Columbia University for the duration of World War II
- **Walter M. Elsasser**, the German-born American physicist known for developing the geodynamo theory presently used to explain Earth's magnetic fields
- **Carl-Gustaf Rossby**, a Swedish-born American meteorologist who organized the training of military meteorologists at the University of Chicago and first explained the fluid mechanics of the Earth's atmosphere
- **Jeung Jang Jaw**, a pioneering Chinese meteorologist and physicist now known as the father of China's satellite program
- **Victor P. Starr**, American meteorologist and professor at MIT known for his contributions to atmospheric science
- **Hurd Curtis Willett**, an American meteorologist who headed the development of the polar front theory of five-day weather prediction for the U.S. Weather Bureau
- **Hans Panofsky**, son of Erwin Panofsky and one of the first meteorologists to study the structure of the lowest 300 feet of atmosphere for such purposes as learning how pollutants could be controlled
- **J. E. Miller**, the meteorologist and researcher known for his creation of the Miller Techniques used to classify nor'easters
- **J. Namias**, Chief of the Extended Forecast Division of the U.S. Weather Bureau and one of the meteorologists responsible for weather forecasting in Northern Africa for the Allies during World War II
- **Jule G. Charney**, American meteorologist credited with the 1979 "Charney Report" of the National Research Council, which documents some of the first scientific assessments on the relationship between carbon dioxide and climate change

The conference generated work that would lay the foundation for an understanding of climatology that is only becoming familiar to most individuals now, over seventy-five years later. The Meteorology Project that proceeded from the conference not only succeeded in developing the first short-term numerical predictions of the weather, it also brought together some of the most important meteorologists to work on the development of an atmospheric approach to understanding the climate. Under the influence of co-chair Carl-Gustaf Rossby, later workers on the project would develop a sophisticated understanding of the climate as a geofluid dynamic system, a mathematical calculation that could account for the impacts of the ocean and the atmosphere on the weather as global phenomena. These later workers, like Joseph Smagorinsky and Jules Charney (noted above), would leverage this experience to reconceptualize the study of the weather as the study of the global climate—as exemplified in the 1979 report that bears Charney's name.

Following the project in 1953, von Neumann published in *Fortune* magazine, for the American public, an article that confronted the progress and politics of the research. In his essay titled "Can We Survive Technology," von Neumann predicted the political effects of meteorological interventions, comparing the human manipulation of weather to a kind of biological weapon of the state. Two years later, a separate conference reconvened the various members to discuss the success of the first weather forecasts made at the Institute, and within a few short years, former member of the Meteorology Project Joseph Smagorinsky went on to found the Geophysical Fluid Dynamics Laboratory that remains in Princeton, NJ. Today, the legacy of this work is all around us, and the material evidence remains a treasure of the Shelby White and Leon Levy Archives Center. ■

News of the Institute Community

Faculty

BHARGAV BHATT, Fernholz Joint Professor in the School of Mathematics, has been awarded the 2022 Frederic Esser Nemmers Prize in Mathematics.

DIDIER FASSIN, James D. Wolfensohn Professor in the School of Social Science, has been appointed as a professor at Collège de France, holding the chair Moral Questions and Political Issues in Contemporary Societies, and has been elected to the American Philosophical Society.

Members

ANA LUCIA ARAUJO, Member (2022) in the School of Historical Studies, has received a senior scholar grant at the Getty Research Institute for the academic year 2022–23.

ANA CARAIANI, Member (2013–16) in the School of Mathematics, has been awarded a 2023 New Horizons in Mathematics Prize.

HOWARD CHIANG, Member in the School of Historical Studies, has received the 2022 Bonnie and Vern L. Bullough Book Award from the Society for the Scientific Study of Sexuality, for his book *Transtopia in the Sinophone Pacific* (Columbia University Press).

PETER CHRISTENSEN, Member (2021–22) in the School of Historical Studies, has been named Humanities Center director at the University of Rochester.

RONEN ELDAN, Member (2021–22) in the School of Mathematics, has been awarded a 2023 New Horizons in Mathematics Prize.

JUNE HUH, Member (2014–20) in the School of Mathematics, won a 2022 Fields Medal, and was also awarded a 2022 MacArthur Fellowship.

WEBB KEANE, Member (1997–98 and 2019–20) in the School of Social Science, has been named Distinguished University Professor at the University of Michigan.

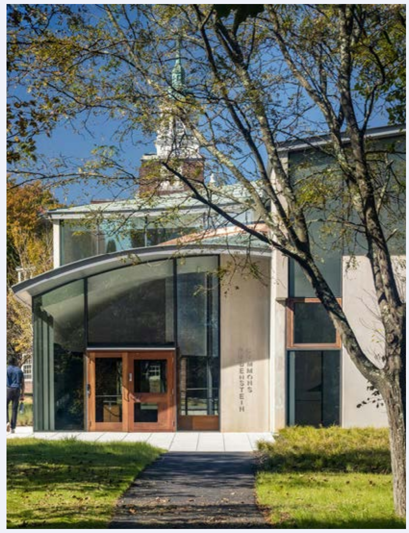
Grand Opening of Rubenstein Commons at IAS:
A Space for Sciences, Humanities, and Nature to Intertwine by Steven Holl Architects

The Rubenstein Commons building at IAS has opened its doors, providing a nexus of flexible gathering spaces to support enhanced communication and collaboration among scholars, and forming an inviting social hub for the wider IAS community. Enabled through a visionary gift from businessman and philanthropist David M. Rubenstein, the Commons will have a transformative impact on intellectual and communal life at IAS, one of the world's leading centers for curiosity-driven basic research.

"With the opening of this forum for curiosity, discovery, and critique, we celebrate the Institute's enduring commitment to the nourishment of the global collective intellect," stated David Nirenberg, IAS Director and Leon Levy Professor. "This is a place whose beauty will stimulate contemplation and whose space will invite the dialogue necessary for questioning at its most profound."

Through its design, Rubenstein Commons will support community and academic life on the IAS campus by promoting communication and collaboration with a variety of social spaces and meeting rooms. Conceived as a "social condenser," the building provides a communal and flexible gathering place for the Institute's research community across all four Schools—Historical Studies, Mathematics, Natural Sciences, and Social Science. The Commons will also offer a space for the display of images and materials that tell the story of the Institute's heritage and extraordinary scholarly community, from Einstein to today.

"By having the ability to come together, the great human brain can be improved because all brains, all humans benefit from talking to



PAUL WARCHOL

others," remarked Rubenstein at the groundbreaking ceremony on March 14, 2018. "What the Commons is designed to do is to bring people together, who are the great brains of our society, and have them interact; and also, people who visit can meet with the scholars. So that's really what it's designed to do."

Tasked with creating a new building with long-term architectural significance, the design by Steven Holl Architects—selected as the winner of an international competition in March 2016—integrates with the surrounding landscape and campus, including the Institute's flagship building, Fuld Hall, designed by Jens Fredrick Larson in his characteristic Colonial Revival style.

"It has been an honor and a joy to work on such an extraordinarily important project for the Institute for Advanced Study," said Steven Holl. "We only hope that the inspired feelings we had in creating and making these spaces can contribute to the future social life of the Institute." ■

MONICA KIM, Member (2015–16) in the School of Social Science, has been awarded a 2022 MacArthur Fellowship.

JAMES MAYNARD, Member in the School of Mathematics, has been awarded a 2022 Fields Medal and a 2023 New Horizons in Mathematics Prize.

LIA MEDEIROS, Member in the School of Natural Sciences, was shortlisted for Nature's 2022 Inspiring Women in Science Award for Scientific Achievement and received the Scientific Achievement Judges Special Commendation.

REUBEN JONATHAN MILLER, Member (2016–17) in the School of Social Science, has been awarded a 2022 MacArthur Fellowship.

JINYOUNG PARK, Member (2020–21) in the School of Mathematics, has been awarded the 2023 Maryam Mirzakhani New Frontiers Prize.

AARON POLLACK, Member (2017–18) in the School of Mathematics, was awarded a Faculty Early Career Development (CAREER) award from the U.S. National Science Foundation.

DANIEL THOMAS POTTS, Member (2008–09) in the School of Historical Studies, was elected a Corresponding Member of the British Academy.

LÁSZLÓ SZÉKELYHIDI, Member (2003–04) and Distinguished Visiting Professor (2021–22) in the School of Mathematics, has been appointed a director at the Max Planck Institute for Mathematics in the Sciences in Leipzig.

KIRA THURMAN, Member (2019–20) in the School of Historical Studies, has received the 2021 Marfield Prize for Outstanding Writing about the Arts, the 2022 Rock and Roll Hall of Fame Ralph J. Gleason Music Book Award, and the American Historical Association's 2022 George L. Mosse Prize for her book *Singing Like Germans: Black Musicians in the Land of Bach, Beethoven, and Brahms* (Cornell University Press), which was also listed by NPR as one of the best books of 2021.

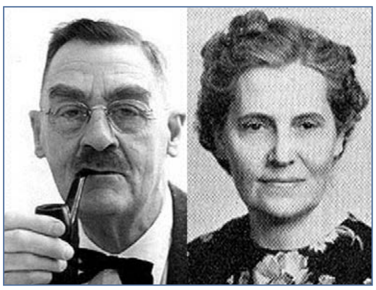
RACHEL WARD, Member (2019) in the School of Mathematics, has been selected as the 2022 recipient of the Peter O'Donnell Distinguished Researcher Award by the Oden Institute for Computational Engineering and Sciences.

ANNA WIENHARD, Member in the School of Mathematics, has been appointed a director at the Max Planck Institute for Mathematics in the Sciences in Leipzig.

Institute

WENDELL WEEKS and **GIGLIOLA STAFFILANI** have joined the IAS Board of Trustees.

Frank C. and Florence S. Ogg Professorship Established at IAS



VIA BGSU

The Institute for Advanced Study is delighted to announce the establishment of the Frank C. and Florence S. Ogg Professorship in the School of Mathematics, thanks to the generosity of former Mathematics Member (1968–69), Andrew Ogg. The new professorship is named in honor of Ogg's parents. Jacob Lurie, Professor in the School, has been selected as the inaugural Frank C. and Florence S. Ogg Professor.

"It is always especially meaningful when an alumnus of our program and a distinguished scholar is moved to support the research of future generations at the Institute. The Ogg family has been contributing to mathematics and to the transmission of knowledge for nearly a century, and through the Frank C. and Florence S. Ogg Professorship, it will continue to do so for centuries more," stated David Nirenberg, IAS Director and Leon Levy Professor.

Frank Ogg received a Bachelor of Arts degree from the University of New Mexico in 1922. He gained a Master of Arts and Ph.D. from the University of Illinois, both in mathematics, in 1924 and 1927 respectively. He joined the department of mathematics at the then-Bowling Green State College in 1931. He became a professor in 1939 and was chairman of the department from 1948 until 1965. In honor of his decades of service, Bowling Green State University (BGSU), as it is now known, dedicated the Frank C. Ogg Library of Mathematics and Science after his retirement in 1969.

His wife, Florence Ogg, entered Eastern Illinois State University in 1919, having achieved the highest score on the entrance examination in the school's history. She majored in astronomy and minored in mathematics. After graduating in 1923, she began graduate study in mathematics at the University of Illinois, earning her master's degree in 1926. She completed the course work for her doctorate in 1931. For many years, she taught mathematics for elementary and secondary teachers at BGSU.

Following in his parents' footsteps, Andrew Ogg received his undergraduate degree in the 1950s at BGSU. He received his Ph.D. in 1961 from Harvard University, under the supervision of former Mathematics Member (1959–60), John Tate. Ogg himself joined IAS as a Member in the School of Mathematics in 1969. During his time at IAS, he was mentored by Faculty member André Weil. His scholarship touches on the fields of number theory, elliptic curves, and modular forms. He currently serves as Professor Emeritus at UC Berkeley.

"I'm honored to be the first to hold the Frank C. and Florence S. Ogg Professorship in the School of Mathematics," remarked Lurie. "Andrew Ogg is a terrific mathematician, who has made valuable contributions to algebra and number theory. I am grateful for his generous support of the Institute and the work we do here." ■

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