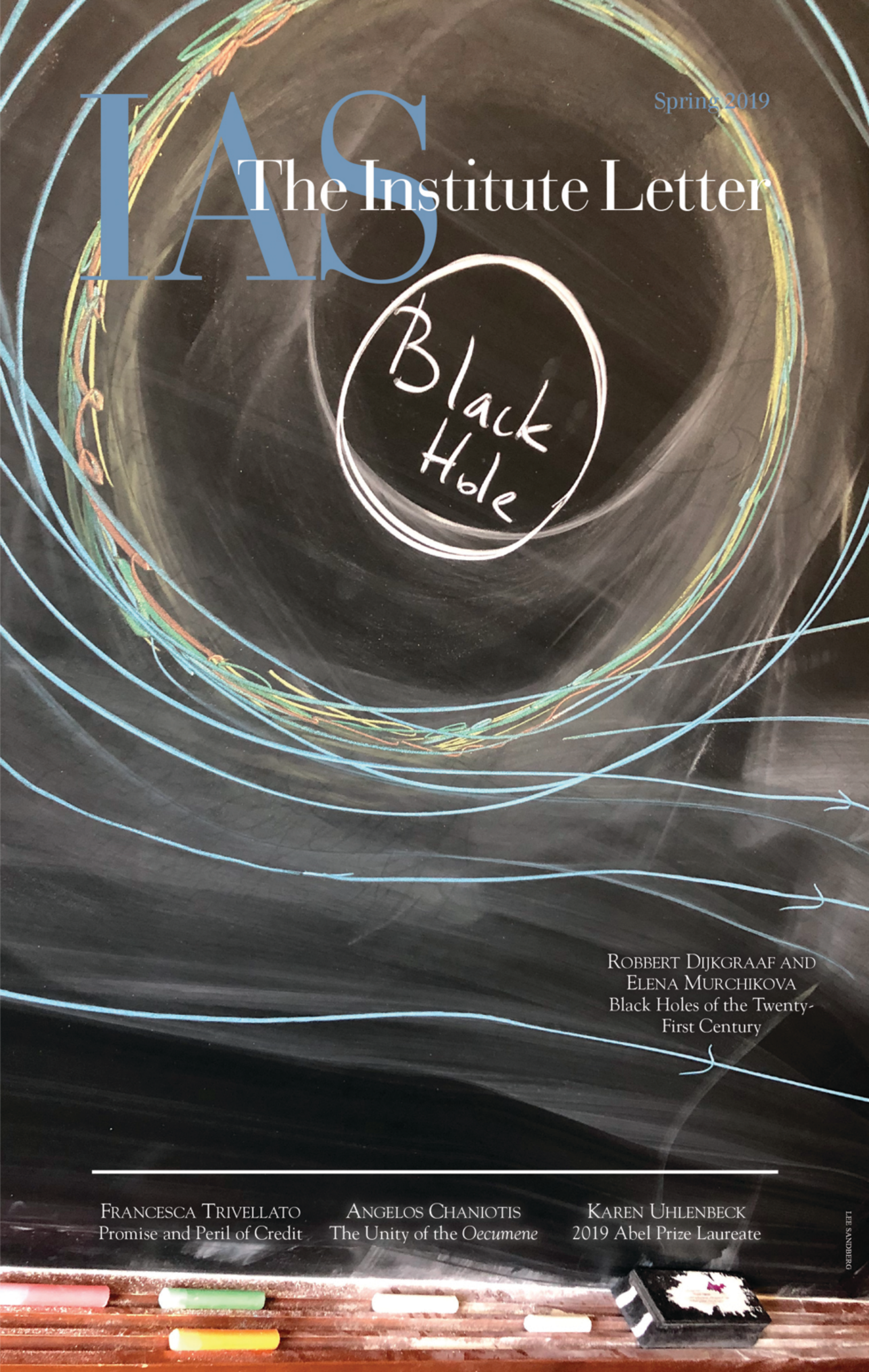
IAS
Spring 2019

The Institute Letter



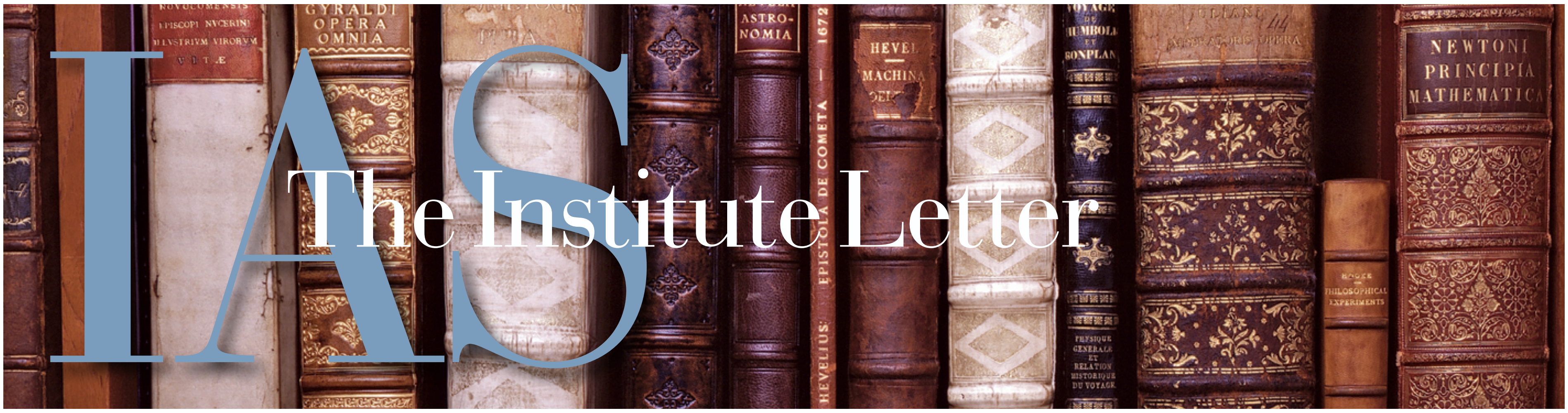
LEE SANDBERG

Robbert Dijkgraaf and Elena Murchikova
Black Holes of the Twenty-First Century

Francesca Trivellato
Promise and Peril of Credit

Angelos Chaniotis
The Unity of the *Oecumene*

Karen Uhlenbeck
2019 Abel Prize Laureate



The Institute Letter

Institute for Advanced Study Spring 2019

James Stone Appointed to Faculty

Developing and applying codes to important astrophysical problems and ushering in a new era of precision simulations

KEREN FEDIDA

James Stone

James Stone, a world-renowned computational astrophysicist whose research focuses on fluid dynamics—in particular numerical solutions to the equations of magnetohydrodynamics (MHD) in an astrophysical context—has been appointed to the Faculty of the School of Natural Sciences at the Institute for Advanced Study, effective July 1, 2019.

"Jim is an innovator and problem solver, whose novel numerical algorithms have shaped the field of computational astrophysics and contributed greatly to our understanding of the universe," said Robbert Dijkgraaf, IAS Director and Leon Levy Professor. "He will be a wonderful addition to the Institute's astrophysics program. With a broad research scope and a commitment to mentorship, Jim's position at the IAS will facilitate wide dispersal and application of knowledge, providing insight into longstanding questions concerning a variety of cosmic systems. With this appointment the Institute also reaffirms the increasing importance of the computational approach to research."

Stone is currently Lyman Spitzer, Jr. Professor of Astrophysical Sciences, Professor of Applied and Computational Mathematics, and Chair of the Department of Astrophysical Sciences at Princeton University. His research interests

(Continued on page 3)

Alondra Nelson Appointed to Faculty

Exploring the intersection of racial formation and social citizenship and emerging scientific and technological phenomena

CHI-CHI AGBIM

Alondra Nelson

Alondra Nelson, an acclaimed sociologist, author, and researcher who explores questions in science, technology, and social inequality, has been appointed Professor and Harold F. Linder Chair in the School of Social Science at the Institute for Advanced Study, effective July 1, 2019.

"In light of her pathbreaking work, her exceptional achievements, and her recognition across multiple fields and beyond academia, it is difficult to imagine a better candidate for the Linder Chair than Professor Nelson," said Didier Fassin, James D. Wolfensohn Professor in the School of Social Science. "She will bring her innovative and multidisciplinary work to the School of Social Science, and she will certainly be in conversation with the other Schools as well."

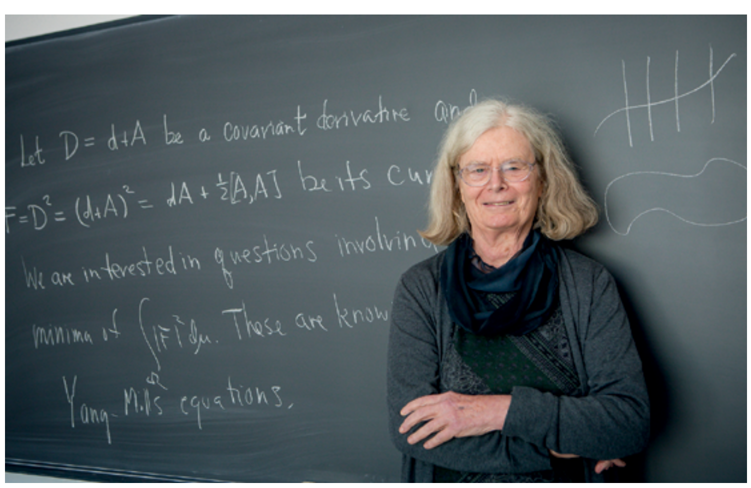
Nelson is currently Professor of Sociology at Columbia University, where she served as the inaugural Dean of Social Science. She is also President of the Social Science Research Council. In addition to her numerous contributions to anthropological and sociological journals and historical studies, Nelson is exceptional for her intellectual versatility that extends to scholarship in the worlds of

(Continued on page 17)

Karen Uhlenbeck Awarded 2019 Abel Prize

Long-Time IAS scholar is first woman to receive prestigious award

The Norwegian Academy of Science and Letters has awarded the 2019 Abel Prize to Karen Keskulla Uhlenbeck whose affiliation with the Institute for Advanced Study spans four decades, as a current Visitor in the School of Mathematics and a former Member and Visiting Professor in the School. Professor Emerita of Mathematics and Sid W. Richardson Regents Chair at the University of Texas at Austin, Uhlenbeck was cited by the Abel Committee "for her pioneering achievements in geometric partial differential equations, gauge theory, and integrable systems, and for the fundamental impact of her work on analysis, geometry, and mathematical physics."



ANDREA KANE

Karen Uhlenbeck

"The Institute is thrilled that Karen Uhlenbeck has been recognized with the 2019 Abel Prize for her transformative work across various mathematical disciplines, from minimal surfaces to gauge theory, and for her foundational contributions to the field of geometric analysis," said Robbert Dijkgraaf, IAS Director and Leon Levy Professor. "A leading mathematician of our time and a member of the IAS community since 1979, Karen has played a leading role in advancing mathematics research, championing diversity, and inspiring the next generation of women to become leaders in the field."

Helmut Hofer, IAS Professor in the School of Mathematics, commented, "Quite frankly: it is about time. Karen has had a tremendous impact on the development of modern geometric analysis, particularly the calculus of variations. Her contributions to minimal surface theory and Yang-Mills theory have changed the subjects and started some of the most exciting developments in mathematics. Karen has had a long affiliation with IAS, and we are very happy that after retiring from the University of Texas at Austin she continues to contribute to the vibrancy of IAS as a Visitor. Besides her scientific impact, Karen has been an extraordinarily good citizen, making numerous contributions to the mathematical profession at large. She is a role model for all of us."

The Abel Prize is an international award that acknowledges outstanding scientific work in the field of mathematics and comes with a monetary award

(Continued on page 16)

News of the Institute Community

The Ionian University has awarded Angelos Chaniotis, Professor in the School of Historical Studies, the title of doctor honoris causa. Additionally, Chaniotis has coedited *Epigraphicum Graecum LXIV* (Brill, 2018) with Thomas Corsten, Eftychia Stavrianopoulou, and Nikolaos Papazarkadas, Member (2018) in the School.

Choice has named *Empires and Exchanges in Eurasian Late Antiquity: Rome, China, Iran, and the Steppe, ca. 250–750*, edited by Nicola Di Cosmo, Luce Foundation Professor in East Asian Studies in the School of Historical Studies, and Michael Maas, Member (2000–01) in the School, an Outstanding Academic Title.

Patrick J. Geary, Andrew W. Mellon Professor in the School of Historical Studies, was honored at "Visions of Medieval Studies in North America: A Conference in Honor of Patrick J. Geary" at the Center for Medieval and Renaissance Studies at the University of California, Los Angeles. A number of current and former Members in the School of Historical Studies spoke at the conference. Additionally, Geary and Narayana Murthy, IAS Trustee, have been elected to the American Academy of Arts and Sciences, along with five former Members.

The National Institute for Nuclear Physics, in collaboration with the Galileo Galilei Institute, has awarded Juan Maldacena, Carl P. Feinberg Professor in the School of Natural Sciences, the inaugural Galileo Galilei Medal.

Francesca Trivellato, Professor in the School of Historical Studies, has authored *The Promise and Peril of Credit: What a Forgotten Legend about Jews and Finance Tells Us about the Making of European Commercial Society* (Princeton University Press, 2019).

Akshay Venkatesh, Professor in the School of Mathematics, and Manjul Bhargava, IAS Trustee and Member (2001–02) in the School, have been elected Fellows of the Royal Society.

Avi Wigderson, Herbert H. Maass Professor in the School of Mathematics, has been awarded the 2019 Donald E. Knuth Prize by the ACM Special Interest Group on Algorithms and Computation Theory and the IEEE Technical Committee on the Mathematical Foundations of Computing. Additionally, Wigderson and Toniann Pitassi, Visiting Professor in the School, have been named 2018 ACM Fellows by the Association for Computing Machinery.

Irving Lavin (1927–2019), Professor in the School of Historical Studies for forty-five years, is to be named *Cavaliere di Ordine della Stella d'Italia* (Knight of the Order of the Star of Italy) in June.

Joan Wallach Scott, Professor Emerita in the School of Social Science, has authored *Knowledge, Power, and Academic Freedom* (Columbia University Press, 2019).

The Women and Mathematics Program at the Institute for Advanced Study has received the 2019 Award for Mathematics Programs that Make a Difference by the American Mathematical Society.

Vrije Universiteit Brussel has awarded Robbert Dijkgraaf, Director and Leon Levy Professor, an honorary doctorate. Additionally, Dijkgraaf has been elected a Foreign Member of the Royal Flemish Academy of Belgium for Science and the Arts.

David M. Rubenstein, IAS Trustee, has been elected to the American Philosophical Society, along with two former Members.

The Institute for Advanced Study has awarded Jim Simons, IAS Trustee Emeritus and Member (1972) in the School of Mathematics, the inaugural IAS Bamberger Medal.

The A.M.N. Foundation for the Advancement of Science, Art, and Culture in Israel, under the auspices of and in cooperation with the Prime Minister of Israel, has awarded Eva Illouz, Member in the School of Social Science, a 2018 EMET Prize for Science, Art, and Culture in Social Sciences.

The Georg-August-Universität Göttingen has awarded the 2018 Christian-Gottlob-Heyne-Preis to Christian Mauder, Member in the School of Historical Studies. Additionally, the Middle East Studies Association has awarded Mauder the 2018 Malcolm H. Kerr Dissertation Award in the Humanities.

The Friends of the Museum of Cluny have awarded Muriel Debié, Member (2016–17) in the School of Historical Studies, a 2018 Prix de la Dame à la Licorne for *Le Monde Syriaque: Sur les Routes d'un Christianisme Ignoré* (Les Belles Lettres, 2017), cowritten with Françoise Briquel-Chatonnet.

A research team including Members in the School of Historical Studies Mercedes García-Arenal (1988–89) and Roberto Tottoli (2016–17) has been awarded a 2018 ERC Synergy Grant for "The European Qur'an."

The Franklin Institute has awarded John J. Hopfield, Visiting Professor in the School of Natural Sciences (2010–13), the 2019 Benjamin Franklin Medal in Physics.

A research team including Edward van den Heuvel, Visitor in the School of Natural Sciences (1974), has been awarded the 2018 Viktor Ambartsumian International Science Prize by the Republic of Armenia.

Maria de Lurdes Rosa, Member (2015) in the School of Historical Studies, has been awarded a 2018 ERC Consolidator Grant for "VINCULUM."

The Association for Africanist Anthropology has named *Matatu: A History of Popular Transportation in Nairobi* (University of Chicago Press, 2017) by Kenda Mutongi, Member (2004–05) in the School of Social Science, a finalist for the 2018 Elliott P. Skinner Book Award.

The Islamic Republic of Iran's Ministry of Culture and Islamic Guidance has awarded Maurice Alex Pomerantz, Member (2015–16) in the School of Historical Studies, its World Award for Book of the Year for *Licit Magic: The Life and Letters of al-Ṣāḥib b. ʿAbbād (d. 385/995)* (Brill, 2017).

The German Research Foundation has awarded a 2019 Gottfried Wilhelm Leibniz Prize to Ayelet Shachar, Member (2000–01) in the School of Social Science and a Trustee of the Association of Members of the Institute for Advanced Study.

CONTENTS

2 News of the Institute Community
R. Martin Chavez Appointed to Board of Trustees
3 Jim Simons Awarded IAS Bamberger Medal
4 The Black Hole is the Atom of the Twenty-first Century
Evidence of Six New Binary Black Hole Mergers Discovered by IAS Team
5 How the Event Horizon Telescope Showed Us a Black Hole
6 The Universe Speaks in Numbers
8 Interstellar Magnetism
9 The Promise and Peril of Credit
10 A Brave New World: Hellenism from Alexander to Hadrian
12 Democracy in an Age of Lies
13 The Yellow Vests Movement, an Unidentified Political Object
14 A Continuing Engagement with Endangered and Excluded Scholars
17 Karen Uhlenbeck on Being the First Woman to Receive the Abel Prize
18 Jean Bourgain, Pioneering Mathematician, Dies at 64
19 Irving Lavin (1927–2019), Iconic Art Historian, Dies at 91

Questions and comments regarding the *Institute Letter* should be directed to Kelly Devine Thomas, Editorial Director, via email at kdthomas@ias.edu or by telephone at (609) 734-8091.

Issues of the *Institute Letter* and other Institute publications are available online at www.ias.edu/publications.

Articles from issues of the *Institute Letter* are available online at www.ias.edu/ideas.

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R. Martin Chavez Appointed to Board of Trustees

GOLDMAN SACHS

R. Martin Chavez

The Institute for Advanced Study has appointed R. Martin Chavez to its Board of Trustees, effective October 27, 2018.

R. Martin Chavez is a Vice Chairman of the Goldman Sachs Group Inc. and Global Co-Head of its Securities Division. Prior to assuming his current role, Chavez was Executive Vice President and Chief Financial Officer. He was named Partner in 2006.

Chavez is a member of the Goldman Sachs Management Committee, Firmwide Capital Committee, Firmwide Risk Committee, and Steering Committee on Regulatory Reform. He is also a member of the Firmwide Hispanic/Latino Network and the Lesbian, Gay, Bisexual, and Transgender Network.

Chavez earned a Ph.D. in Medical Information Sciences from Stanford University in 1990, an S.M. in Computer Science from Harvard University in 1985, and an A.B., magna cum laude, in Biochemical Sciences from Harvard College in 1985. He serves on the Harvard Board of Overseers and is a Fellow of the New York Academy of Medicine.

Jim Simons Awarded IAS Bamberger Medal

In recognition of visionary philanthropy in the spirit of IAS founders Louis Bamberger and Caroline Bamberger Fuld

On March 14, 2019, Albert Einstein's 140th birthday, the Institute for Advanced Study held the inaugural IAS Einstein Gala to honor trailblazing mathematician, investor, and philanthropist Jim Simons. A former Member in the School of Mathematics, founder of Renaissance Technologies, and Chair of the Simons Foundation, Simons was recognized with the IAS Bamberger Medal for his extraordinary service on the Institute's Board of Trustees, his visionary support of the Institute's mission, and his deep awareness of the essential need for basic research across the sciences and humanities.

Simons is the first recipient of the IAS Bamberger Medal, which recognizes visionary philanthropy in the spirit of Louis Bamberger and Caroline Bamberger Fuld, the brother and sister who founded and endowed the Institute in 1930, providing for its lasting and essential independence. Simons was honored for his active engagement in the intellectual life and development of the Institute, and his generous support of basic research around the world.

The New York event, which raised $3.5 million to support basic research at IAS, was attended by more than 550 leaders from the worlds of business, philanthropy, technology, art, and academia, among them Ellen Futter, Larry Gagosian, Vartan Gregorian, Jeff Koons, Eric Schmidt, Diana Taylor, James and Merryl Tisch, and Sir James and Elaine Wolfensohn. The program featured an interview with Simons by Master of Ceremonies and IAS Trustee David Rubenstein, Co-Founder and Co-Executive Chairman of The Carlyle Group and host of *The David Rubenstein Show: Peer-to-Peer Conversations* on Bloomberg TV and PBS; a musical performance by cellist Zoë Keating curated by IAS Artist-in-Residence and Pulitzer Prize–winning composer David Lang; and "Einstein's Dream," a multimedia presentation by Robbert Dijkgraaf, IAS Director and Leon Levy Professor. ■

The IAS Einstein Gala in honor of IAS Trustee Emeritus Jim Simons (top left, center) was attended by more than 550 leaders from the worlds of business, philanthropy, technology, art, and academia, including (clockwise, and from left to right): IAS Board Chair Charles Simonyi, Simons, and IAS Director Robbert Dijkgraaf; IAS Trustee Eric Schmidt and Christine and Rafael Reif; Simonyi and Sir James Wolfensohn, IAS Board Chair Emeritus; Diana Taylor, IAS Trustee Emerita Shelby White, and IAS Board Vice Chair Nancy Peretsman; IAS Trustee David Rubenstein with Simons; Zoë Keating; IAS Trustee John Overdeck and Akshay Venkatesh, Professor in the School of Mathematics; and Annette Nazareth and IAS Trustee Roger Ferguson.

STONE *(Continued from page 1)*

include star formation, accretion flows, interstellar gas dynamics, and the development of numerical algorithms for MHD and radiation hydrodynamics.

"Jim is the preeminent authority in numerical astrophysics. He has developed methods to address some of the most challenging problems in the field and through his work has ushered in a new era of precision simulations with a wide range of applications," said Matias Zaldarriaga, Professor in the School of Natural Sciences. "His field-spanning work combines a deep knowledge of the physics involved with cutting-edge mathematics and computational science to achieve unrivaled success."

Stone is a world leader in MHD largely because he is equally influential in code development and in applying his codes to important astrophysical problems. The public codes ZEUS-2D, released in 1992 by Stone and Michael Norman, and Athena, released in 2008 by Stone and his collaborators, are among the most powerful and widely used astrophysical codes today.

"I am thrilled to be joining the Faculty at the IAS," said Stone. "The opportunity to focus full-time on research and to collaborate with the Members and other Faculty, is what makes the IAS so special. It gives me the chance to think about the big problems that are hard to work on at other places."

Stone's work has provided groundbreaking insight into the nature of giant molecular clouds, using three-dimensional simulations to provide the first realistic high-resolution models of these dense, massive systems that give rise to the majority of star formation in galaxies. Stone has also elucidated many of the physical processes that determine the evolution of the accretion disks that power quasars, micro-quasars, and accreting neutron stars. With his students, he has explored numerical models of the spiral waves and shocks created by planets orbiting in protoplanetary disks and the critical but poorly understood process of planetary migration in the disk. Furthermore, Stone has made many contributions to the difficult subject of radiation transport, including the first numerical studies of the effects of radiation fields on accretion disks and of line-driven disk winds, and the first global models of radiation-dominated disks.

Stone earned a B.Sc. and M.Sc. from Queen's University in Canada (1984 and 1986) and a Ph.D. from the University of Illinois (1990). He was named a Fellow of the American Physical Society (2013) and received the organization's Aneesur Rahman Prize for Computational Physics (2011) and the Dirk Brouwer Career Award from the American Astronomical Society (2018). During his academic career, Stone has held academic positions at Princeton University, the University of Cambridge, and the University of Maryland. He is also a Member of the American Astronomical Society, the American Physical Society, and the International Astronomical Union. ■

The Black Hole Is the Atom of the Twenty-First Century

A black hole is the simplest and the most complex object that we know.
The iconic photo of the black hole published recently shows that a resolution of this paradox exists.

BY ROBBERT DIJKGRAAF

Move over Brexit. For a brief moment on April 10, the attention in the European Commission's headquarters in Brussels was not focused on Theresa May, but on the first photo of a black hole. As European Commissioner Carlos Moedas said during the presentation—one of five simultaneous announcements around the world—it is not often that someone is applauded during a press conference in that bureaucratic black hole, let alone gets a standing ovation. But that was exactly what happened to this cosmic heavyweight.

Scientists have obtained the first image of a black hole, using Event Horizon Telescope observations of the center of the galaxy M87. The image shows a bright ring formed as light bends in the intense gravity around a black hole that is 6.5 billion times more massive than the Sun. This long-sought image provides the strongest evidence to date for the existence of supermassive black holes and opens a new window onto the study of black holes, their event horizons, and gravity.

The iconic black hole image released by the Event Horizon Telescope collaboration has gone viral these days. The anticipation started days earlier. In the taxi ride to the airport, the driver questioned me intensely about the upcoming announcement. Suddenly, the whole world was focused on a bit of universal positive news. The cosmos must have chuckled, because black holes are the biggest bad boys among the celestial bodies. They easily devour millions, if not billions of stars. In fact, this specific black hole in the galaxy M87 is one of the most massive in our neighborhood of the universe. So, it was the blurry mugshot of a cosmic super villain that made us all feel so good.

It is difficult to overestimate the importance of this discovery. There is only one moment in human history when we will have seen a black hole for the first time. And that moment is April 10, 2019. We are getting spoiled, because this decade has already produced a number of such "five-star discoveries," such as the detection of the Higgs particle in 2012 and the first direct observation of gravitational waves announced in 2016.

It is amazing that these discoveries that touch all of us so closely, are so far removed from everyday experience. This particular black hole is at a distance of 55 million light-years—so we gaze in wonder at an image from the time just after the extinction of the dinosaurs. The gravitational waves were the distant sounds of a huge collision that was 1.5 *billion* light-years away. And to find the Higgs particle we had to travel equally far into the interior of an atom.

These three spectacular discoveries have something else in common. They all started with a simple idea in the minds of a few visionary scholars and required many generations of technological innovations and worldwide collaborations to ultimately be measured. That grand intellectual adventure appeals to the general public. But why are scientists so enthusiastic? There are at least three reasons that make the black hole photo so special.

First of all, it confirms, again, Einstein's theory of relativity. In a wonderful cosmic coincidence, this announcement came almost exactly a hundred years after the first experimental verification of his theory, the measurement of the sun's deflection of stellar light during the solar eclipse of May 29, 1919—an event that launched Einstein as the first modern scientific celebrity.

Secondly, through these measurements, we learn much more about the formation of black holes and their role in the history of the cosmos. In recent years, black holes have made the transition from theoretical textbooks and science fiction movies to central characters in modern astronomy.

But perhaps the most important reason for all this excitement is that we now know for certain that black holes exist. They live at the very edge of scientific knowledge and remind us of the greatest challenge in modern physics: how to reconcile our understanding of the largest structures of the universe with the smallest structures.

Inside a black hole, nature has hidden its deepest secrets. Matter is compressed into a single point, the famous singularity, and time actually stops. That is just as inconceivable as the fact that all matter originates and time finds its beginning in the Big Bang. The late Princeton physicist John Wheeler, who gave the black hole its name (it was previously known as a "gravitationally completely collapsed object"), formulated it powerfully, "The existence of spacetime singularities represents an end to the principle of sufficient causation and so to the predictability gained by science. How could physics lead to a violation of itself—to no physics?"

Black holes thus play a similar role as atoms did a hundred years ago. According to the laws of nature known at that time, they simply could not exist. They would self-destroy. But experiments taught us that nature had found a solution. The resolution of this paradox eventually led to the advent of quantum theory and a radical break in our understanding of reality, including a fundamental role of probability in physical processes.

The black hole is just such a paradox, the atom of the twenty-first century. From the perspective of gravity, it is the simplest object we know of, no more than a hole in space. At the same time, according to quantum theory, it is the most complex object, the most compact way to store matter and information. Compressed into a black hole, planet Earth would be as small as a marble. We know that ultimately the merging of these two perspectives—maximal simplicity and maximal complexity—must offer a solution, undoubtedly again with far-reaching consequences for our view on space and time.

The iconic image is therefore so exciting because it tells us that there is a solution for our homework. Nature has found a way to make black holes exist. Now it is up to us to find out what nature knows and we do not yet. Back to work! ■

Robbert Dijkgraaf, Director of the Institute for Advanced Study and Leon Levy Professor since July 2012, is a mathematical physicist who has made significant contributions to string theory and the advancement of science education. This article is a translation of a column that first appeared in NRC Handelsblad *and* De Standaard. *He is an author, with founding IAS Director Abraham Flexner, of* The Usefulness of Useless Knowledge *(Princeton University Press, 2017).*

Evidence of Six New Binary Black Hole Mergers Discovered by IAS Team

Public release of observational data leads to better understanding and pioneering methods

Six new binary black hole mergers that exceed the detection thresholds defined by the LIGO-Virgo Collaboration (LVC), the group responsible for the first direct observation of gravitational waves on February 11, 2016, have been discovered by IAS researchers Matias Zaldarriaga, Professor in the School of Natural Sciences; Members Tejaswi Venumadhav, Barak Zackay, and Liang Dai; and Javier Roulet of Princeton University's Department of Physics. These discoveries mark the first time that a group outside of the LVC has been able to analyze gravitational wave data to detect binary black hole mergers not previously identified by the LVC.

Taking data made public by the LVC, the IAS team applied a unique set of signal processing techniques to detect these cataclysmic events, nearly doubling the total number of binary black hole mergers found during LVC's second observing run (O2) from 7 to 13. A previous paper by the team, released in March 2019, found one new merger in addition to the three identified in the original LVC observing run (O1).

By increasing the number of observations, researchers will be better able to understand the formation, specific properties, evolution, and ultimate demise of these systems through the ripples they send across the fabric of spacetime. The team's results also reveal diversity among these systems, from the rate of spin to the direction of spin relative to the orbit.

LVC recently announced its third observing run (O3), which began on April 1, 2019. In addition to hardware upgrades implemented between observing runs that allow scientists to peer deeper into the universe, the methods pioneered by IAS researchers now provide another vital tool to maximize the return on data analysis, while increasing the total observable volume within the universe by a factor of two. "I think one important consequence of this analysis is that it illustrates the importance of making this type of observational data public," said Zackay, Peter Svennilson Member in the School. "Doing so acknowledges that the broader scientific community can bring significant innovations to the table and that the internal analysis of the data does not mark the end of discovery." ■

A link to the paper regarding the team's analysis of data from O2 is available at https://arxiv.org/pdf/1904.07214.pdf. On April 24, Zaldarriaga and Zackay gave a talk describing the results for an audience at IAS, which may be viewed at www.ias.edu/ideas/gravitational-wave-searches-ligovirgo.

How the Event Horizon Telescope Showed Us a Black Hole

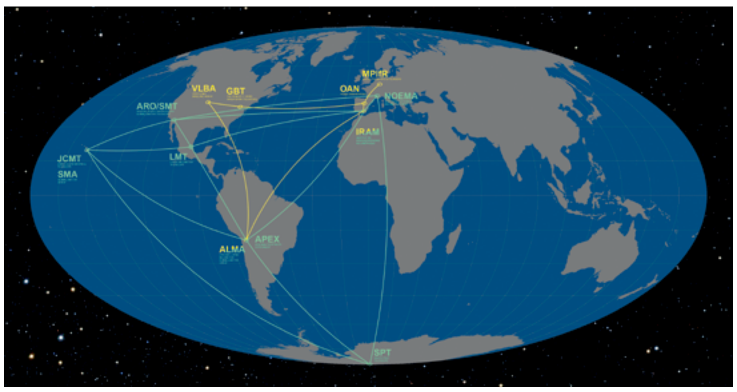
And what we may expect from the observations of the black hole in the center of our galaxy

BY ELENA MURCHIKOVA

On April 10, 2019, we were presented with the first-ever close-up image of a black hole by the Event Horizon Telescope (EHT). This remarkable technological achievement was made possible by the collective efforts of hundreds of astrophysics, engineers, and computer scientists. They arranged for simultaneous observations of their target with multiple telescopes around the globe and correlated the data between the instruments to effectively achieve the creation of a planet-sized telescope. The data was then processed to make the image we saw in the news.

But did we really "see" a black hole when we were shown "just" a digital image? And how is it possible to create an Earth-sized telescope?

Let me start by explaining why EHT really needed an Earth-sized telescope. An abundance of dust exists between our telescopes and the observed black holes. This dust absorbs electromagnetic radiation of short wavelengths such as visible light (about 5.5 x 10^{-7} m), infrared light (about 10^{-6} m), and so on. However, the radiation of wavelengths of about 1 millimeter (10^{-3} m) and larger is not affected by the dust. The angular resolution of a telescope is proportional to the observed wavelength divided by the diameter of the telescope. A longer wavelength results in lower resolution, while a bigger telescope mirror ensures higher resolution. ETH, therefore, had to observe a wavelength of around 1 mm. (They observed at 1.3 mm.) However, this wavelength also implied that they needed a telescope similar in size to the diameter of our planet to resolve the black hole shadow. It is not practically possible to construct a mirror of such a size, but we can still achieve the required resolution, using the interferometer technique. To explain it, we will use a series of analogies.



EUROPEAN SOUTHERN OBSERVATORY/O. FURTAK

This illustration shows the location of the telescopes used in the 2017 EHT observations of M87, which together effectively achieve the creation of a planet-sized telescope.

First analogy: Imagine a real telescope mirror equivalent to the size of planet Earth and then placing over it a black cloth with several holes. The cloth would limit the telescope's capabilities and reduce its light-collecting area, but we still would have a mighty planet-sized telescope with high-resolution capabilities.

Second analogy: Imagine a handful of small mirrors. One can place them together tightly and construct a nice medium-sized telescope mirror. But one can also choose to scatter them across a larger area. Each small mirror represents a place where the fabric from the first analogy has a hole. Thus, if one finds a smart way of connecting the small mirrors and analyzes the data collected by each of them together, one may be able to reproduce the capabilities (in particular, the resolution) of the large mirror similar in size to the area across which the mirrors were scattered. Additionally, in moving the small pieces around, one would cover more and more of the surface of the large mirror and thus get closer and closer to its full capabilities.

This is a toy illustration of how an interferometer works. EHT simultaneously collects the data from multiple telescopes spread across our planet and then correlates and analyzes the data from them jointly. The involved telescopes also change their relative positions with respect to the target due to the Earth's rotation covering larger parts of the Earth-sized mirror.

Over the history of astronomical observations, we have learned to employ and trust technology to help us study the sky. The first observations were done with unaided eyes only. Then optical telescopes magnified the image and increased the light-collecting area from the pupil size to the size of the lens (and later the mirror) so smaller and fainter objects became visible in detail. The films (and other receivers) afforded us much longer exposures than capable by the human eye. The films and receivers also allowed us to look outside the range of visible spectra, which was extremely useful to the study of celestial objects. (As the product of evolution on our particular planet, our eyes are strategically designed to be sensitive to the radiation from the Sun with a complete disregard of whether it is a good frequency range for the study of the rest of the universe.) Interferometers are just the next step in the evolution of visual aids. Therefore, we indeed "saw" a black hole although we were shown "just" a post-processed digital image.

It is true that science-wise the image of M87's black hole did not teach us anything unexpected. It looked exactly as predicted. But perhaps this is not a bad thing. When the Large Hadron Collider in CERN started operating, it had to rediscover all the previously discovered particles. Only then, could it be trusted to search for unknown particles and to probe new physics. The first EHT image was proof of the value of new technology, and it passed the test. Should the subsequently released image show something unexpected and new, we will be more inclined to dive into its physical implications rather than questioning what went wrong with the observation. (Such a discovery, which matches predictions so well, has also, hopefully, demonstrated to the world in this age of anti-science that experts likewise should be trusted.)

What is next for the EHT? The other long-anticipated, and I would argue, more exciting target, is our own black hole in the center of our Milky Way galaxy known as Sagittarius A★ (Sgr A★)—the subject of my own research at the Institute. Sgr A★ is the closest supermassive black hole to Earth. It is located 26,000 light years away and has a mass 4,000,000 times that of the Sun. In contrast, M87's black hole is 2,000 times further away and is 1,600 times more massive, but the sizes of the shadows of the black holes are similar. The mass of Sgr A★ was deduced from the orbits of the nearby stars, which were tracked for twenty-five years, and scientists concluded that the object around which they orbit is so massive and so small that it can be nothing but a black hole. (Professor Scott Tremaine wrote more on this subject in his article "The Odd Couple: Quasars and Black Holes" for the *Institute Letter* in 2015; see www.ias.edu/ideas/2015/tremaine-blackholes-quasars).

A puzzling side of the behavior of Sgr A★ is its accretion, namely, the behavior of in-falling gas. Here I would like to point out that the black hole does not suck in any material. The material falls into it by itself. In the same way, Earth does not suck up the International Space Station, which closely orbits it. The station experiences friction with the outer layers of the planet's atmosphere, which slows it down causing its orbit to sink lower; in order to stay in space, it has to be re-boosted, i.e., moved to a higher orbit, regularly. The gas clouds orbiting the black hole also experience the same kind of friction, get heated, slow down, and move closer and closer to the back hole, until they fall in. They, so to say, accrete onto or feed the black hole. The gas clouds also radiate the excessive heat while spiraling down, thus producing the emission we call black hole radiation. (The Hawking radiation from the black holes is hopelessly overwhelmed by the radiation of the accreting gas.)

The amount of the hot gas (about ten million Kelvin), which is bound to Sgr A★, is well constrained by X-ray observations. If this gas fed the black hole in the usual way, we would see a few orders of magnitude more radiation than we actually observe. It was therefore concluded that it spirals into the black hole faster than it can radiate the heat, because the density of the gas is low, and thus the amount that is getting fed to the black hole can be larger than we would normally infer from the amount of observed radiation. The particular details of the process, however, are still uncertain. We still do not know whether there is a radial outflow from Sgr A★; whether it has jets; what the velocity of the gas flow around it and the direction of the flow are at the various radii; whether the flow forms a disk or not; how the density and temperature of the gas and the strength of magnetic fields change with the distance from the black hole; and how much of the gas, which is too cool to emit X-rays, is present near the black hole. The last area is the subject of my own studies.

There are several unresolved questions concerning the feeding of our supermassive black hole, which EHT observations will be able to help answer. For instance, we will learn about the presence or absence of Sgr A★ jets and confirm the direction of the gas flow rotation and its inclination (it was recently claimed to be face-on). Overall, it would open a completely new chapter in studying black hole physics. All in all, it is a true privilege to live in such an exciting and dynamic time for this wonderful field.

No one can predict where the deeper understanding of fundamental laws that rule this world will lead us and what doors they will open, but it is always unexpected and exciting. It is worth remembering that the study of electricity was once considered a completely impractical endeavor, which would never have any useful applications. Now we tax it. ■

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The Universe Speaks in Numbers

Unearthing the quantum jewel

by Graham Farmelo

"Multi-faceted gems, each with crystalline symmetry that gives them an unexpected mathematical beauty"—that is how the physicist Lance Dixon describes the mathematical objects used to predict what happens when nature's fundamental particles scatter off each other. These particles—including the subnuclear quarks and gluons—have no shape or size, so such scatterings might be regarded as one step up from nothingness.

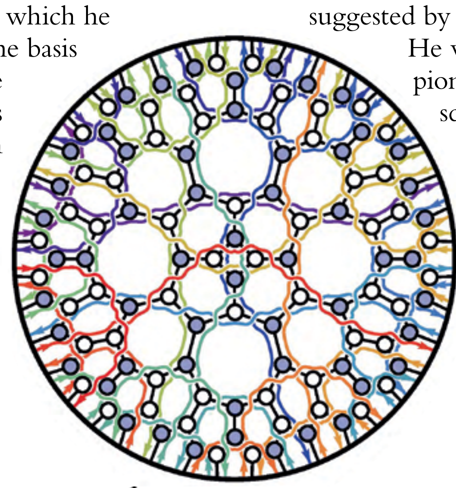
Interest in scattering amplitudes among physicists has increased rapidly in recent decades. Theoreticians need a clear understanding of these amplitudes to interpret data from the ultra-high-energy collisions between protons at CERN's Large Hadron Collider—in essence, these collisions involve scatterings of the quarks and gluons inside the protons. The improved understanding of these collisions helped to enable the experimenters' great discovery of the Higgs particle in 2012.

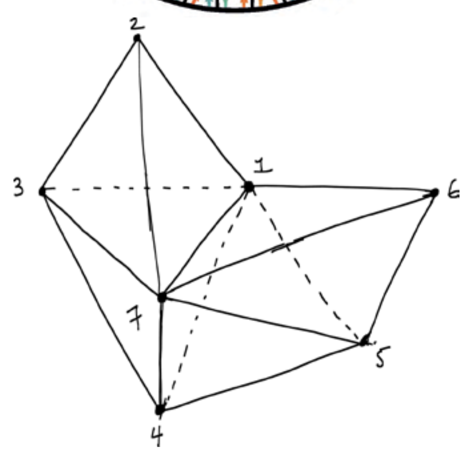
One of the biggest leaps forward in our understanding of these amplitudes took place at the Institute for Advanced Study in the fall of 2003, when Edward Witten discovered a new approach to the subject, based on Roger Penrose's twistors. Penrose still believed that these mathematical objects, which he had discovered in the 1960s, offer the best hope of supplying the basis of a fundamental theory of nature. But they had yet to become part of mainstream physics, and most theorists regarded them as merely a mathematical curiosity. Witten's work propelled them into the mainstream of theoretical physics, generated new lines of research, and opened up new ways of thinking about scattering in the subnuclear domain.

Using Penrose's twistors, Witten set up a new type of string theory. Each twistor describes the history of a massless particle as it moves through spacetime—a challenging concept that Witten had been struggling with for several years and occasionally used in his papers. Witten had now used twistors to come up with a new string theory that did not apply in higher dimensions but was framed in terms of ordinary, four-dimensional spacetime.

By mid-December 2003, when many people in the West were following the capture of Saddam Hussein, many theoreticians were—for the first time—fixated on twistors. Although Penrose didn't "completely buy" the new theory, he was delighted to see twistors propelled into the mainstream of science. Among the readers who wolfed down Witten's paper was the Harvard-based theorist Nima Arkani-Hamed. "The twistor-strings paper was wilder and more transgressive than most 'Edward-style' presentations we're used to, where everything is laid out logically and understood perfectly." It was as if, out of the blue, Bach had written a piece of bebop.

One of the first physicists to appreciate the power of this method was Freddy Cachazo, an impressively talented young Venezuelan field theorist who had an office on the same corridor of the Institute as Witten. "We all knew Edward was on to something," Cachazo recalls. "He was working alone, crazy hours, late into the night, at weekends, but none of us knew what he was doing." Cachazo found out after Witten walked into his office one afternoon and asked him whether he "would give him a hand with a few calculations that required the use of the Mathematica software program." Within a week, Cachazo's number crunching was producing a stream of dazzling results.





A mathematical structure known as the positive Grassmannian (top) was used by Professor Nima Arkani-Hamed and collaborators to develop a scattering process for particles known as the amplituhedron (bottom), the latest tool for calculating how particles interact.

For a few months, twistor string theory was a red-hot topic—after decades in the dark wings of theoretical physics, Witten had thrust it into the limelight. Among the converts to the twistor approach at the Institute were Ruth Britto and Bo Feng, two young researchers who had known Cachazo since their student days. Building on Witten's edifice, the three theorists quickly developed a new set of mathematical relationships between the scattering amplitudes in the theory.

Sensing that there was more to learn from this approach, Witten joined the trio of young theorists. Within a few weeks, they had a resounding success: they discovered a surprisingly neat way to calculate complicated scattering amplitudes by "building" them up from much simpler ones, using a set of straightforward rules, with twistors apparently less central to the formalism than most physicists had first believed. Central to the method was a clever application of a classic theorem of complex functions first proved almost two centuries earlier, by the French mathematician Augustin-Louis Cauchy. Witten and his colleagues used a famous theorem discovered by Cauchy to develop a set of elegant formulae that applied not only to quarks and gluons but, surprisingly, to all the other subatomic particles in the Standard Model, and even described their motion in higher spacetime dimensions. Experts in scattering amplitudes regarded the formulae as a sensation, a genuine breakthrough. In a lively seminar given by Cachazo at Harvard, he caught the attention of Arkani-Hamed, who later said, "I was blown away. I had no idea that scattering amplitudes were teaching us so much about field theory." Within a few days, he had decided "to become a graduate student all over again" and learn the subject from Cachazo. Within a few months, they had begun a collaboration that eventually led not only to new insights into collisions between subatomic particles but also, unexpectedly, to some of the frontiers of mathematics that had previously been of little or no interest to physicists.

In early 2008, when Nima Arkani-Hamed joined the Faculty at the Institute for Advanced Study in Princeton, he and Cachazo were deep into their collaboration. By the end of the year, a few weeks after Barack Obama's election to the U.S. presidency, they were exploring a new approach to scattering theory suggested by Oxford theoretician Andrew Hodges.

He was best known for his classic biography of the computer science pioneer Alan Turing, a book that later inspired the Oscar-winning script for *The Imitation Game*. Hodges had begun to write the book in 1977, two years after he had completed his Ph.D., advised by Penrose, on twistor diagrams. These diagrams were, roughly speaking, the analogue in twistor theory of Feynman diagrams in conventional field theory and were another of Penrose's innovations. No particle physicist took much notice of Hodges's diagrams, partly because they were bedeviled by mathematical difficulties. Almost two decades later, Hodges claimed that twistor diagrams supplied by far the easiest way of understanding the relationships between scattering amplitudes written down by Witten and his three young collaborators. Hardly anyone took Hodges seriously—for almost two years, his paper lay unread on the desk of Arkani-Hamed, who could not make up his mind whether it "was the work of a crank or a genius."

But only a few months after Arkani-Hamed began working in earnest on scattering amplitudes, he was clear that Hodges was anything but a crank. "By bending our way of thinking to fit his," Arkani-Hamed later said, "Freddy and I found ourselves making pretty good progress understanding how twistors can help understand scattering amplitudes."

On the morning of April 30, 2009, Arkani-Hamed received what he later described as "a bolt from the blue." It was an email from David Skinner informing him of several breakthroughs by him and his colleagues, notably one by Hodges, who had proposed a new way of calculating scattering amplitudes for gluons. Instead of adding together a series of contributions, each generated by a Feynman diagram, Hodges suggested that in some cases the amplitude might be interpreted as the volume of a type of abstract object. This object is known as a polytope, an assembly of abstract "triangles" that fit together to form a volume in higher-dimensional space. In ordinary three-dimensional space, these objects are analogous to popular Christmas decorations shaped like a multipointed star.

Arkani-Hamed and Cachazo had a hunch that they needed some new mathematical perspective to make progress. In late spring of 2009, they consulted a few books that they guessed might be relevant, including *The Principles of Algebraic Geometry*, a tome written thirty years before by the mathematicians Phillip Griffiths and Joe Harris. On the morning of June 10, Cachazo made a breakthrough. While reading the first chapter of Griffiths and Harris's book—one of only two mathematics books he owned—he saw a simple matrix—an array of mathematical variables—that looked exactly like the one he and Arkani-Hamed were working on. This object, Cachazo read, is an expression of what mathematicians describe as the Grassmannian, familiar to few theoretical physicists but well known among pure mathematicians. This mathematical construction was first written down in 1844 by the school teacher and ordained minister Hermann Grassmann in his book *Ausdehnungslehre*, largely ignored at the time, though subsequent generations of mathematicians regarded it as a visionary masterwork.

"I was so excited that I wanted to tell everyone," Cachazo later recalled. But he kept his excitement to himself for a few hours, studied the pages of Griffiths and Harris's book, and convinced himself that this was just the mathematics he

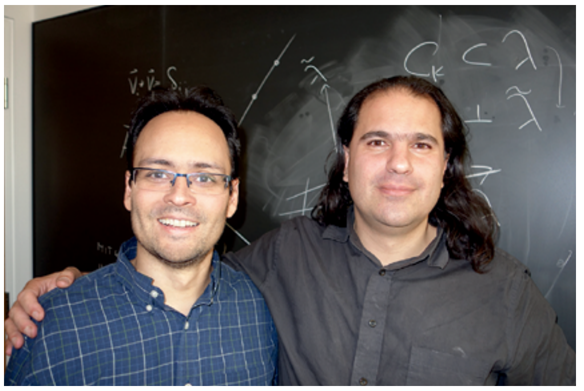
(Continued on page 7)

 (Continued from page 6)

and Arkani-Hamed needed. "I wanted Nima to feel the same thrill as I had, so I decided to send him a cryptic email" that afternoon, he remembered: "Look at page 193 of Griffiths and Harris!" Three hours later, Arkani-Hamed emailed his reply: "Well now!! This is amazing. . . ." The Grassmannian appeared to be perfectly suited to describing what happens when gluons scatter off each other. In the case of two gluons producing five gluons, the motion of all the particles can be described using an array of numbers—a matrix—with seven rows (one for each gluon) and four columns (one for each dimension of spacetime). Grassmann's mathematics enables physicists to handle all the quantities in the matrix with ease. Even better, the method was completely general: it didn't apply to a particular number of gluons but to any number of them. As Arkani-Hamed says, "This 160-year-old mathematics was sitting there on the shelf, as if Grassmann had wanted to help us describe gluonic scattering in the most general possible way, about 125 years before anyone had even conceived of gluons."

Arkani-Hamed, Cachazo, and their colleagues were elated. Within a few days, the Grassmannian had enabled them to generate mathematically every one of the main contributions to the scattering amplitude that describes gluonic scattering. In one fell swoop, this mathematical framework enabled a unified method of describing gluonic scattering—including twistor string theory, Hodges's recent discoveries, and even the formula discovered by Witten and his three young collaborators.

Soon thereafter, Arkani-Hamed, Cachazo, and their collaborators posted online a paper that demonstrated how Grassmannian mathematics supplied a unifying understanding of all of Hodges's twistor diagrams. Arkani-Hamed knew he and his colleagues had only scratched the surface of the subject. One serious problem with the Grassmannian method was that it yielded too much information: it contained all the mathematical contributions needed to describe the gluonic scattering amplitudes, but no rule for how to combine them into the separate amplitudes. It was as if physicists had all the pieces they needed to solve a jigsaw puzzle without knowing the puzzle's shape.



Freddy Cachazo, Member (2002–05, 2009–10) in the School of Natural Sciences, with IAS Professor Nima Arkani-Hamed

Lost again, Arkani-Hamed and his colleagues changed tack. They decided to try to understand the behavior of the gluons via the simplest viable description, using what is sometimes known as the Superglue Model. This mathematical construction did not attempt to describe gluons in the real world to high accuracy but gave a means of studying the most important aspects of their behavior using mathematics with an exceptionally high degree of symmetry, which made calculations relatively easy. This model's predictions for scattering at ultra-high energies are identical to those of the experimentally well-established gauge theory of strong interactions, thus providing a secure link with the real world.

By applying Grassmannian mathematics to the Superglue Model, Arkani-Hamed and his collaborators hoped to be rewarded by a revelation. But they got nowhere and decided that it was time they sought help to come to grips with the mathematics, which looked forbiddingly complicated. In a series of meetings, Arkani-Hamed and his colleagues discussed their mathematical challenges with some of the Institute's mathematicians—including Pierre Deligne and Bob MacPherson—and Sasha Goncharov, a Yale expert in algebraic geometry. To help get the conversation moving, Witten attended the first meeting, partly to help translate between the languages of scattering amplitude physics and the mathematical concepts that might be relevant. Afterwards, the mathematicians and theoreticians met regularly, with Deligne regularly placing a wodge of clarifying mathematical notes in Arkani-Hamed's mailbox—"They were solid gold for us," Arkani-Hamed later said.

In the early summer of 2011, the penny finally dropped. To understand what happens when gluons scatter off each other, the theorists did not need to use the entire Grassmannian object but only a part of it, the so-called positive Grassmannian. For months, Arkani-Hamed and his collaborators tried to incorporate Hodges's idea that scattering amplitudes could be calculated as "volumes" into the positive-Grassmannian framework. They struggled to make headway. One of Arkani-Hamed's students, Jacob Bourjaily, remembers that the group's working practices were as exhilarating as they were exhausting: "Nima likes to pull quite a lot of 'all-nighters,' fueled by espressos, Diet Cokes, and nachos. . . . The sessions often ended at dawn when we fetched up in a local diner for a communal breakfast, though we were still talking physics, non-stop."

Convinced that they still needed a better understanding of the underlying mathematics, in the autumn of 2011, Arkani-Hamed, Bourjaily, and their colleagues secured a meeting with Alexander Postnikov, the blue-chip Grassmannian expert at the Massachusetts Institute of Technology. The encounter turned out to be a revelation. During the intense discussions in Postnikov's shambolic office, and later over lunch in the nearby canteen, it gradually emerged that they were working on the same thing. At one point, Postnikov pulled out some diagrams of a type that he had not previously mentioned, only for Arkani-Hamed and his colleagues to see—to their astonishment—that they were identical to ones that they had been using for months.

In a rally of instant messages on a summer Saturday afternoon in 2013, Arkani-Hamed and his graduate student Jaroslav Trnka decided on a name for the new object: the amplituhedron, which they used in December 2013 as the title of the paper in which the object first appeared. The "amplituhedron picture" of predicting what happens when two gluons collide is potentially revolutionary. In Feynman's method, the interactions between gluons take place only at points in spacetime (so-called locality), and it is assumed at the beginning that the total probability of all outcomes of a collision between two gluons must be precisely one (unitarity). But, in Arkani-Hamed and Trnka's amplituhedron method, the scattering is described in a completely different way: the locality and unitarity emerge from the mathematical formulae in the final stage of the calculation. Arkani-Hamed and Trnka had discovered the first example of a structure in which "space and time" and quantum mechanics are not fundamental. Arkani-Hamed later told me, "This is a concrete example of a way in which the physics we normally associate with spacetime and quantum mechanics arises from something more basic."

The amplituhedron—sometimes referred to as a quantum jewel—caused quite a stir among theoretical physicists. Some critics, however, cautioned that the amplituhedron might just be an artefact of the Superglue Model, an approximation to reality, and may have nothing to do with the scattering of real particles. Time will tell. Arkani-Hamed later told me that he is increasingly confident that the significance of the amplituhedron has yet to be fully understood. One sign of this is that, since the object's discovery in scattering-amplitudes theory, it has also cropped up in three other parts of physics: cosmology, quantum theories of gravity, and very general classes of field theory. No one understands why, Arkani-Hamed says, though he is confident that the reason for this will eventually become clear. He is convinced that the mathematics that he and his colleagues are using—much of it rarely (if ever) before used in fundamental physics—will be of fundamental importance to describing nature. "This is not the mathematics of smooth surfaces that works so well in string theory, for example," he says. "It's mathematics much more closely linked to whole numbers."

The amplituhedron was a gift for mathematicians. One of the reasons it was so fascinating to them was that they could have discovered it long before, by building logically on Grassmann's idea and with no reference to the real world. But it fell to physicists to unearth the object, steered by a wish to understand gluonic scattering and using the twin constraints of quantum mechanics and the special theory of relativity. These theories have been the sturdy guiderails of theoretical physics for almost a century and have generated a wealth of new physical ideas, together with fascinating connections with advanced mathematics. The field of scattering amplitudes exemplifies the symbiosis between physics and mathematics at the frontiers they share. ■

Graham Farmelo, a frequent Director's Visitor at the Institute, is a fellow at Churchill College at the University of Cambridge, an affiliated professor at Northeastern University, and author of several books, including The Strangest Man, *which won the Los Angeles Times Book Prize. This article is an edited excerpt from his most recent book* The Universe Speaks in Numbers *(Basic Books, 2019). Reprinted with permission.*

From the *New Yorker*: A Different Kind of Theory of Everything

"Some researchers are attempting to wean physics off of spacetime in order to pave the way toward this deeper theory. Currently, to predict how particles morph and scatter when they collide in spacetime, physicists use a complicated diagrammatic scheme invented by Richard Feynman. The so-called Feynman diagrams indicate the probabilities, or "scattering amplitudes," of different particle-collision outcomes. In 2013, Nima Arkani-Hamed and Jaroslav Trnka discovered a reformulation of scattering amplitudes that makes reference to neither space nor time. They found that the amplitudes of certain particle collisions are encoded in the volume of a jewel-like geometric object, which they dubbed the amplituhedron. Ever since, they and dozens of other researchers have been exploring this new geometric formulation of particle-scattering amplitudes, hoping that it will lead away from our everyday, spacetime-bound conception to some grander explanatory structure."
—IAS Director's Visitor (2017) Natalie Wolchover, writing for the New Yorker, *explores the puzzles and paradoxes of contemporary science, highlighting the work of Nima Arkani-Hamed, Professor in the School of Natural Sciences, www.newyorker.com/science/elements/a-different-kind-of-theory-of-everything.*

Interstellar Magnetism

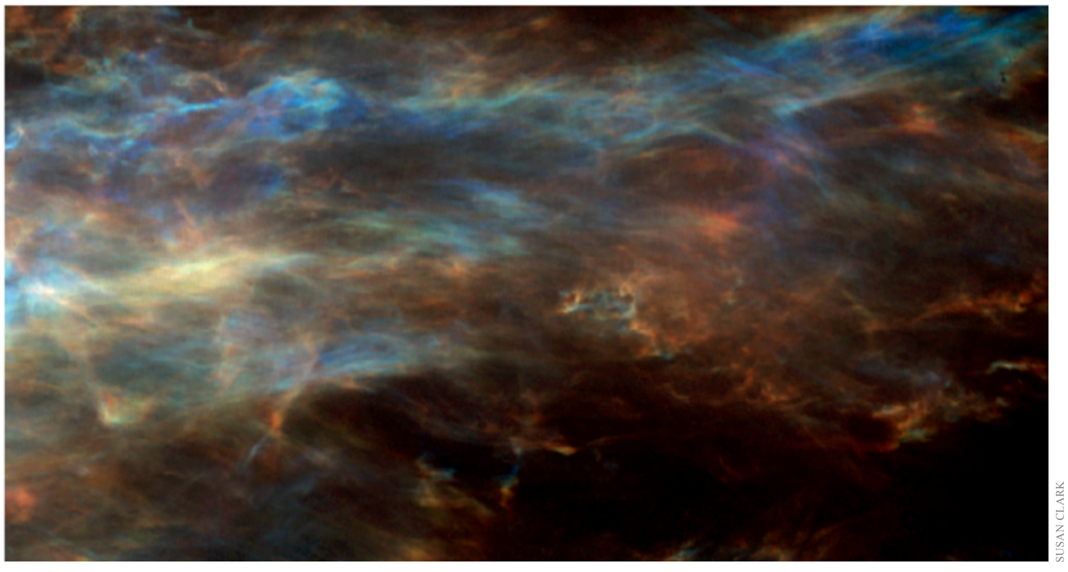
New ways to trace the galactic magnetic field, and why it matters to cosmology

BY SUSAN CLARK

You may have done this experiment as a child: spread a bunch of iron filings on a table, a heap of insouciant metal dust. Now place a bar magnet in their midst, and ah! The iron filings snap to attention, as if endowed with a sudden sense of purpose. They align their lengths with the local magnetic field orientation, and suddenly an invisible presence is revealed: the curving contours of the magnetic field.

I want to pull off a similar revealing act. I want to see, and understand, the magnetic field that permeates our Milky Way galaxy.

From our perch here on Earth, we primarily learn about the magnetic field through its influence on light. One of the techniques we use is somewhat analogous to the iron filings experiment. Interstellar space is vast, tenuous, and dusty. Tiny dust grains float in the great expanses between stars. These dust grains are in general aspherical, and, torqued hither and yon by ambient radiation, they find a preferred orientation: they align their short axes with the local magnetic field. As starlight filters through interstellar dust, the aligned dust grains absorb a particular polarization of light, such that the starlight that finally arrives at our telescopes is linearly polarized in a direction determined by the orientation of the intervening magnetic field. The dust grains themselves radiate thermal emission at infrared wavelengths that is likewise polarized. So by observing starlight polarization and polarized dust emission, we measure a component of the interstellar magnetic field.



SUSAN CLARK

An image of emission from neutral hydrogen in our galaxy. The red, green, and blue components of the image show neutral hydrogen emission at different Doppler-shifted frequencies. Fine filamentary structure is visually evident.

How else does interstellar magnetism reveal itself? My collaborators and I discovered a new way to trace the orientation of the magnetic field, through its influence on the structure of interstellar gas. Like dust, neutral hydrogen gas is pervasive in the interstellar medium—the stuff between the stars. With the unparalleled sensitivity of the Arecibo radio telescope in Puerto Rico, we revealed an imprint of the interstellar magnetic field on the texture of the diffuse interstellar medium.

Long, thin tendrils of neutral hydrogen stretch for parsecs across interstellar space. My colleagues and I showed that these "fibers" of neutral hydrogen are well aligned with the local magnetic field.[1,2] The galactic magnetic field creates order in the turbulent space between the stars, and we can use the morphology of neutral gas to trace the magnetic field orientation. Importantly, these structures are seen projected onto the plane of the sky; stuck in our little corner of the galaxy, we view the Milky Way from a single vantage point. Neutral hydrogen orientation, like dust polarization and starlight polarization, can only tell us about a single component of the three-dimensional magnetic field we seek to map. However, in my first year at the Institute, I found a way to probe the line-of-sight component of the magnetic field using neutral hydrogen. I showed that measuring the orientation of the gas structures at different Doppler-shifted velocities probes how tangled the magnetic field is along the line of sight.[3] Line-of-sight magnetic field tangling—differently oriented magnetic fields at different distances in a given direction—gives rise to phenomena like depolarization of the dust emission. This new probe of the coherence of the magnetic field lets us better understand how the field, and the gas and dust it permeates, are distributed in the galaxy.

We have also recently made progress in understanding what these magnetically aligned neutral hydrogen structures are. After our initial discovery, some researchers proposed that the observed magnetic alignment was a trick of the velocity field: that these were not real, three-dimensional neutral hydrogen structures in space, but simply a coincidence of turbulent velocity fields shifting emission to different frequencies. My collaborators and I recently published a paper showing that in fact these structures are "real": dusty, three-dimensional features that seem to be colder on average than their surroundings.[4] Much remains to be explored about how and why these cold neutral hydrogen structures are so anisotropic, and so deeply coupled to the magnetic field.

Understanding galactic magnetism is an exciting goal unto itself, but there lurks another motivation for this work, one that takes us far beyond our home galaxy. The question: what happened during the first trillionth of a trillionth of a billionth of a second after the Big Bang? It is currently thought that in this fraction of a second after popping into existence, the universe underwent a growth spurt: a period of extremely rapid expansion called inflation. While a number of observations are consistent with inflation, we have yet to detect a "smoking gun": a signal uniquely predicted by an inflationary cosmology. The search is on for just such a signal: a pattern of polarization imprinted in the cosmic microwave background (CMB), the residual radiation from the formation of the universe. Measuring this signal, inflationary gravitational wave B-mode polarization, is the chief goal of many current and proposed experiments.

UNDERSTANDING GALACTIC MAGNETISM IS AN EXCITING GOAL UNTO ITSELF, BUT THERE LURKS ANOTHER MOTIVATION FOR THIS WORK, ONE THAT TAKES US FAR BEYOND OUR HOME GALAXY. THE QUESTION: WHAT HAPPENED DURING THE FIRST TRILLIONTH OF A TRILLIONTH OF A BILLIONTH OF A SECOND AFTER THE BIG BANG?

The principal difficulty in finding this polarization signal in the CMB is that we have to look through our galaxy. The tiny dust grains that let us probe the galactic magnetic field emit polarized radiation at the same frequencies where we observe the polarized CMB. The primordial signal is buried under a galactic signal that is far stronger. Or, as the saying goes, one person's treasure is another person's contaminating foreground. Our hope in solving the puzzle of inflation thus hinges on our ability to measure the polarized dust signal as precisely as possible, in order to separate it from the polarized CMB. To this end, I am now collaborating with Brandon Hensley, a postdoc at Princeton University and an expert in the microphysics of interstellar dust. We are using all of the insights gleaned over the past several years about how neutral hydrogen traces the magnetic field to build new, data-driven models of the polarized dust signal. Our model uses neutral hydrogen to probe both the plane-of-sky magnetic field and the variable magnetic field along the line of sight. It's a new way of linking the magnetized gas in the interstellar medium to the dust foreground that obscures our view of the polarized CMB. We're in pursuit of the invisible: mapping the elusive magnetic field between the stars. And the better we understand the magnetized interstellar medium, the better we will be able to peer back to the beginning of time. ■

Susan Clark has been a Member and NASA Hubble Fellow in the School of Natural Sciences since 2017. Her research focuses on the magnetic interstellar medium, magnetohydrodynamic processes, and the polarized foreground to the cosmic microwave background.

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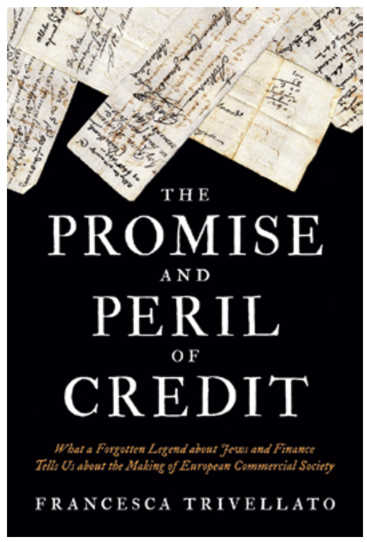
The Promise and Peril of Credit

What a forgotten legend about Jews and finance tells us about the making of commercial society

BY FRANCESCA TRIVELLATO

It would be misleading to say that this book "found me." But the impetus behind it came as much from what was happening around me as from my academic interests. In September 2008, an endless stream of breaking news relayed bleaker and bleaker economic reports on the future of millions of ordinary people. Lehman Brothers collapsed. Home foreclosures became a daily event. Talk of greed resurfaced in public conversation. Even *usury* and *usurious*, words that I had not heard uttered outside of the classroom, reentered everyday vocabulary, alongside *loan shark* and *pawnbroker*. As financial mogul John Alfred Paulson admitted in April 2010, "We believed that the two-year adjustable rate mortgages made to lower income borrowers with poor credit history, little or no documentation, no downpayment and rates that would shortly reset at usurious interest rates set the stage for significant delinquencies and foreclosures, thus eroding the value of these securities."[1]

As a citizen, I was angry and anguished. As a historian of early modern European market organization and market culture, I was intrigued and felt slightly vindicated. Since the fall of the Berlin Wall, scholarly interest in the slow-paced economies of the preindustrial period had waned, and faith in the upward trajectory of modern financial capitalism had become nearly gospel. Now, it seemed, we were back to square one. No easy solution was in sight. In fact, the daily reports did not seem much clearer than seventeenth-century merchant manuals, which were filled with advice on how to make money as well as warnings against avarice and shady dealers.



While the global financial system stood on the brink of collapse after years of speculative frenzy, an old excerpt from Warren Buffett's 2002 annual letter to Berkshire Hathaway shareholders resurfaced and went viral. Sounding like Cassandra amid a cheerful crowd of Wall Street investors, Buffett had described credit default swaps as "financial weapons of mass destruction" carrying "dangers that, while now latent, are potentially lethal."[2] The statement remains controversial. Not everyone agrees with Buffett's judgment, and this skepticism affects the work of government and private agencies charged with regulating the industry to this day. What is remarkable about Buffett's warning is that the man who offered it was not a fierce opponent of corporate finance or a future leader of the Occupy Wall Street movement, but the richest man in the world at the time of its writing.

I mention these recent events not to suggest that we can link today's rapid "financialization" to earlier transformations of Europe's economy in simple terms, but to point out that even those who believe in the positive effects of expanding private and public credit, now as in the past, cannot easily agree on where to draw the boundaries of that expansion and what kind of oversight might best prevent fraud and the emergence of oligopolies. *The Promise and Peril of Credit* examines key episodes in the West's millennium-long struggle to delineate the place that finance ought to occupy in the social and political order. It does so by introducing readers to modes of thinking about the morality of credit that have become increasingly alien to us even as the questions that animated those early modern discussions remain as vital now as they were then.

After decades of retreat from the mainstream, economic history is making its way back to college curricula and scholarly publications. Today as always, present concerns stimulate academics' choice of subject matter and approaches to historical inquiry. Income and wealth inequality, the connection between slavery and capitalist modes of production and consumption, the impact of cultural traditions on economic performance, and the timing and consequences of globalization top the list of current research topics pursued by economic historians of various persuasions. A sense of urgency infuses this research—a welcome and energizing change after decades during which North American history departments' interest in economic history lay dormant. However, one should not forget that each of these themes has its own long and distinguished scholarly pedigree; nor should we risk falling into the old trap of searching for the origins of contemporary phenomena—Marc Bloch's "idol."[3] While I readily admit, and indeed embrace, the influence that present concerns exert on my scholarly work, my aim in this book is to bring back to life ways of thinking about the economy that have become increasingly foreign to the mainstream of the academy and to interrogate the sources of our amnesia about topics and problems that not long ago occupied a central place in debates about the development of European capitalism.[4]

In Anglophone historiography in particular, the demotion of the preindustrial period to second-rank importance in examinations of Europe's economic takeoff has often been compounded by the enduring legacy of the Protestant Black Legend, according to which Catholic societies after the Reformation eschewed profit and indulged in idleness. This twin tendency has affected even serious scholarship and detracted from the study of economic transformations in Catholic Europe from the medieval commercial revolution to the industrial revolution. To be sure, one can always find staunch enemies of all forms of commercialization among Catholic authors, but more interesting—and, by the sixteenth century, often more influential—were those theologians, lawyers, judges, philosophers, statesmen, merchants turned writers, and polymaths who did not oppose financial dealings as such but disagreed on the written and unwritten rules that ought to govern the marketplace for the benefit of Christian and polite commercial society.

Credit was central to those intellectual debates. Derived from the Latin verb *credere*, "to believe" and "to trust," the noun *credit* and its cognates during this period had economic, legal, political, social, and cultural connotations. Used less frequently, *finance* referred primarily to government finances. The more capacious and common *commerce* was adopted by early modern commentators not only in reference to the activities of retail and wholesale merchants, but also to describe the economic policies governing those activities. But commerce had even wider meanings that transcended the economic realm. In the Italian city-states of the fifteenth century, the Latin word *commercium* denoted the material transactions conducted for the purpose of earthly gain and gratification, but it was used just as often in reference to the relationship between believers and the divine, the exchange of ideas among humanists, the social bonds linking all humans (or at least those men who saw each other as peers), and even prostitution (carnal commerce). Although the word commerce had a somewhat narrower meaning by the eighteenth century, it continued to be applied to the entire gamut of human activities and beliefs. It follows that technical disquisitions about credit instruments, and what might make them go astray, were never abstracted from moral, political, and social considerations.

Thus framed, the subject of my inquiry would be boundless, since the search for a well-tempered commercial society was at the heart of too many consequential intellectual and political projects in preindustrial Europe to be examined in any depth in a single study. In this book, I turn to one little-known but revealing chapter in these heated debates about the morality of credit: a narrative that for a good 250 years, from the mid-seventeenth to the early twentieth century, attributed to medieval Jews the invention of marine insurance and bills of exchange, two key instruments of European private finance. There is no truth to this tale, since both financial tools emerged slowly out of previous arrangements, and Jews had no special role in the process, yet it proved surprisingly resilient—which is why I believe it warrants the designation of *legend*. Over time, this unfounded and today largely forgotten origin story punctuated many and varied literatures about commerce. By working with and around this narrative about Jews and credit, I discuss how numerous Christian authors—some famous, some fallen into oblivion—articulated their vision for a morally acceptable and productive commercial society.

I take representations of Jews' economic roles to be symptomatic of larger claims: implicitly or explicitly, they conveyed hard-to-define ideals of a Christian-inflected marketplace rather than describing the actual involvement of Jews in the economy. This approach has been adopted almost exclusively in reference to the Middle Ages because of the widely held assumption that in the mid-seventeenth century, the "science of commerce" began to shed its religious concerns about merchants' moral integrity.[5] Here, I show instead that late medieval representations of Jews and their alleged modes of handling credit, recast in new guises at various junctions, continued to be central to the definition of European commercial society through the French Revolution and that the founders of modern social thought—Karl Marx, Max Weber, and Werner Sombart—incorporated these representations of medieval Jews' economic roles into their grand narratives.

In the pages of this book, readers will encounter familiar names and famous moments in European history, such as those I just mentioned, but will also be introduced to a host of unknown figures and unpredictable connections across themes and periods. In trying to make sense of fragments of the past that our blind spots have led us to neglect, I weave together strains of scholarship that have been growing further and further apart. That is why this book does not fall squarely into any single field of historical inquiry but is rather an exercise in demonstrating the potential (and, no doubt, the pitfalls) of roaming across times

(Continued on page 12)

A Brave New World: Hellenism from Alexander to Hadrian

The "big bang" for the unity of oecumene

BY ANGELOS CHANIOTIS

In 327–326 B.C.E., Alexander the Great, after having defeated the Persian King and conquered the Persian Empire, crossed eastern Iran, Afghanistan, and Bactria, testing the limits of his abilities. He attacked the fortress of Aornos, on Mount Pir-Sar in Pakistan, which was regarded as unconquerable. Even his ancestor Heracles had failed to conquer it, so the myth went. At about the same time that Alexander attempted to surpass Heracles, where the hero had failed in his easternmost adventure, another Greek undertook a daring enterprise at the place marking Heracles's westernmost deed: the Pillars of Hercules, or modern Gibraltar. Around 325 B.C.E., the geographer and mariner Pytheas of Massalia embarked on an expedition to explore the western ocean. After breaking the Carthaginian blockade of the Straits of Gibraltar, he sailed along the coast of Portugal in an attempt to circumnavigate Europe. In the course of his journey, he discovered the British Isles, possibly reached Norway or Iceland—depending on where one locates the place the ancients called Thule—and sailed deep into the Baltic Sea. Although it is unlikely that Alexander ever learned of Pytheas's enterprise, it is not by chance that these adventures were more or less contemporary. Both Pytheas and Alexander were motivated by the same inquisitive spirit and fascination with the unknown. Around this time, in the more comfortable venue of the Athenian Lyceum's shady gardens, Aristotle and his pupils were pursuing a plan to map, analyze, and classify the entirety of the visible world and all aspects of human behavior. Pytheas in the West, Alexander in the East, and Aristotle in Greece's intellectual center are parallel culminations of decades of Greek scientific exploration, which in the late fourth century B.C.E. was breaking new paths.

After Alexander had opened up new horizons in the East, others followed, guided by plans or fortune. The universal scholar Poseidonios, while visiting Gades (modern Cadiz in Spain) and studying the tides on the Atlantic coast in the early first century B.C.E., heard about the adventures of a certain Eudoxos of Kyzikos a few years earlier. His work *On the Ocean* is lost, but an account of Eudoxos's expeditions is preserved in the *Geography* of Strabo. Eudoxos came to Egypt as an envoy. He joined up with the king in his voyages up the Nile. During one of these journeys, an Indian was brought to the king by the garrison of the Red Sea, who reported that they had found him shipwrecked. The Indian was handed over to people to teach him Greek. Once he had learned it, his story was that he was sailing from India when he happened to lose his way and ended up safely after his fellow sailors had died of starvation. He was taken at his word and promised to act as guide for the route to India to a crew selected by the king. Eudoxos was one of them. So, he sailed off with presents and returned with a cargo of perfumes and precious stones. He was soon deceived in his hopes as the king appropriated the whole cargo.

The grave epigram of a traveling pig gives an unusual insight into the mobility of the era. Having traveled all the way from Dyrrhachion on the Adriatic Sea to Edessa in Macedonia, the pig was run over by a wagon on its way to a festival of Dionysus. Pella, Ephorate of Antiquities, AKA 1674.

What Eudoxos learned from the Indian sailor was the use of the monsoon winds that permitted a direct journey from Ethiopia to India through the Indian Ocean, avoiding the long, expensive, and dangerous journey along the southern coast of Arabia and through the Gulf of Oman. In 116 B.C.E., the king died and Eudoxos was sent on a new expedition, which again filled his ship with luxuries—probably spices, perfumes, and precious stones. The return journey was adventurous; the ship was stranded somewhere between Cape Guardafui in Somalia and Zanzibar. Eudoxos managed to return to Alexandria, only to see his cargo confiscated, again, by the new king. Then Eudoxos tried his luck in the West. He went to Gades in Spain, with the plan to circumnavigate Africa and reach India through an alternative route. He failed, and the king of Mauritania delivered him to the Roman general Sulla. He attempted a fourth journey, from which he never returned. The way this story is narrated by Poseidonios corresponds to Hellenistic taste: fortune stages an encounter between a shipwrecked Indian, a curious Greek, and an avaricious king. And as in many Hellenistic stories, there are unexpected twists of fate and thwarted expectations. The adventures of Eudoxos exemplify, to an extreme level, the new possibilities that the Hellenistic world created for trade in exotic products and the dissemination of information. This was in part endorsed by royal patronage, unknown before Alexander.

A travel handbook known as the *Circumnavigation of the Erythraean Sea (Periplous Maris Erythraei)*, probably composed in the mid-first century C.E., provides detailed information about the harbors, trading posts, and products to be found along the coasts of the Red Sea, the Persian Gulf, and the Indian Ocean. For instance, merchants interested in importing frankincense from the Arabian Peninsula learned that

> after Arabia Felix there is a continuous length of coast, and a bay extending two thousand stadia or more, along which there are Nomads and Fish-Eaters living in villages. Just beyond the cape projecting from this bay there is another market-town by the shore, Kana, of the Kingdom of Eleazos, the Frankincense Country; and facing it there are two desert islands, one called Island of Birds, the other Dome Island, one hundred and twenty stadia from Kana. Inland from this place lies the metropolis Sabbatha, in which the King lives. All the frankincense produced in the country is brought by camels to that place to be stored, and to Kana on rafts held up by inflated skins after the manner of the country, and in boats.

This text shows in the most impressive way how far knowledge of these regions had advanced since the time of Nearchos, the admiral of Alexander who traveled from India to the Persian Gulf in 327 B.C.E. Under Nero, when the Roman emperor enjoyed diplomatic relations with rulers in Arabia, his subjects risked trading journeys along the coast of the Arabian Peninsula and as far east as India and Sri Lanka. Trading activity with these regions was quite diverse. For instance, the important harbor of Barygaza in northwest India was a place where Roman and Greek traders could profitably sell wine, textiles, and silver vessels, as well as singing boys and beautiful girls for the king's harem, receiving in exchange semi-precious stones, herbs, spices, and exotic animals.

A certain Sophytos, a man who died in Alexandria Arachosia (today's Kandahar) in the late first century B.C.E., may be one of the traders who visited Barygaza. In the elaborate grave epigram that he composed for himself, he gives an account of his achievements. His ancestral fortune having been lost, Sophytos sought ways to raise the ancestral home high again. He took a loan and left his city, determined to return only as a rich man. His maritime enterprises must have been in the Indian Ocean. From Kandahar he could have easily reached the harbor of Barygaza, and from there his trips may have brought him as far as Egypt. He returned a wealthy man, rebuilt the ancestral house, erected a new grave for his ancestors and himself, and composed a poem in Greek for the Greek population that must have still been living in Alexandria Arachosia. The archaeological exploration of harbor sites in southern India and the discovery of Roman coins and wine jars there corroborate the advancement of Greek trade with these areas in the early imperial period.

The impetus for such connections came from Alexander. His campaign was the "big bang" of Hellenistic "globalization," as it were.

"Six degrees of separation": an ancient "globalization"

The film *Babel*, released in 2006, shows how the fate of a handful of people in Morocco, Japan, Mexico, and the United States—people who are strangers to one another—is connected because of certain circumstances. This drama,

(Continued on page 11)

directed by Alejandro González Iñárritu and written by Guillermo Arriaga, is one of many films, plays, and television series that are based on the theory that everyone is six or fewer steps away, by way of relationships or acquaintances, from any other person in the world. This concept was first formulated by the Hungarian author Frigyes Karinthy in his 1939 short story "*Láncszemek*" ("Chains"). It became known through the work of the social psychologist Stanley Milgram, author of "The Small-World Problem," published in *Psychology Today* in 1967. In the words of a character in the 1990 play *Six Degrees of Separation* by John Guare: "Six degrees of separation between us and everyone else on this planet. The President of the United States, a gondolier in Venice, just fill in the names." In the age of the internet, Facebook, and Twitter, this concept seems archaic.

It cannot be seriously claimed that when Alexander the Great ascended the throne of Macedonia in 336 B.C.E. there were six degrees of separation between him and any individual living in the areas that would, ten years later, comprise his empire. By contrast, it is not unreasonable to assume that when Hadrian ascended the throne of Rome 453 years later there were six, or fewer, degrees of separation between the emperor and any individual in his empire and in the adjacent states. Even a simple *fellah* in south Egypt knew a village secretary, who communicated with the village chief, who had a contact with the governor of the district, who knew the governor of Egypt, who had been appointed by the emperor. The developments that Alexander's campaigns set in motion ultimately led to the creation of a complex network of political, administrative, economic, and cultural connections that came close to the modern phenomenon of globalization. Of course, this network did not extend over the entire globe, but it did cover the region that contemporaries knew as the *oecumene*, "the inhabited earth." One might more appropriately speak of "ecumenization."

> THE DEVELOPMENTS THAT ALEXANDER'S CAMPAIGNS SET IN MOTION ULTIMATELY LED TO THE CREATION OF A COMPLEX NETWORK OF POLITICAL, ADMINISTRATIVE, ECONOMIC, AND CULTURAL CONNECTIONS THAT CAME CLOSE TO THE MODERN PHENOMENON OF GLOBALIZATION.

The conquests of Alexander destroyed the Persian Empire but did not create a lasting empire to replace it. Nonetheless, they did engender a huge political network of kingdoms, semi-independent dynasts, and *poleis* extending from the Adriatic Sea to Afghanistan and from the north shore of the Black Sea to Ethiopia. These states also had relations with Italy, the Greek *poleis* of Magna Graecia and Rome, the Greek colonies in the south of France, Carthage in North Africa, and the Mauryan Empire in India. Thus, the world of Alexander's successors constituted a network that comprised the entire known world, with the exception of East Asia. But if we also consider various population movements—for instance, the migration of the Gauls into Greece and Asia Minor in the early third century B.C.E., the invasion of the Yuezhi and other nomadic tribes into Bactria in the second century B.C.E., and the repeated raids of Scythians and other tribes into the territories of the Greek cities—the world of Alexander's successors was also connected with central Europe, central Asia, and the western borders of China. The Roman expansion from the late third century B.C.E. onwards gradually enlarged the borders of this network of interconnected regions to include the Iberian Peninsula, central and western Europe, Britain, and north Africa. By the time of Hadrian's death, a large part of the *oecumene* was within the borders of one single empire.

People (and animals) on the move

The development of a network of interconnected regions was accompanied by an unprecedented movement of populations. This ranged from the voluntary movements of mercenaries, artists, merchants, entertainers, itinerant orators and educators, students of oratory and philosophy, pilgrims journeying to sacred places, and athletes to the forced migration of exiles after civil wars, captives, slaves, and diaspora Jews. Some movements were periodical, as in the trips of the "sacred envoys," who announced festivals, the visits of audiences to the great athletic contests in Olympia and Delphi, and the maritime journeys through the Indian Ocean that were determined by the monsoon winds. More often, they were determined by ad hoc needs, such as the trips undertaken by ambassadors to cities, kings, Roman authorities, and emperors. Movements could be massive, as with the settlement of Hellenistic new city foundations or Roman colonies, the Gallic invasions of Greece and then of Asia Minor, or the resettlement of Jews after their revolts. The movement of large groups was usually permanent, resulting in dramatic changes in the ethnic composition of the population and contributing to cultural diversity.

At the same time, the individual and temporary movements of people, especially of traders and scholars, had a significant impact on culture. Orators, philosophers, and historians traveled around the world, giving lectures in major cities and sanctuaries. *Akroasis* (public lecture) is the word that designates their main activity: visiting a city, a sanctuary, or a court, staying there for a few days or months, and giving lectures in gymnasia, theatres, town halls, and palaces. They read excerpts from historiographical works, presented philosophical and delivered encomia of cities and emperors, and offered advice on social and political issues. From the second century B.C.E. on, intellectuals came to Rome as ambassadors of their cities, others as friends of Roman statesmen, and yet others tried their fortune in the new metropolis of the world. A turning point in this respect was the "embassy of the philosophers" from Athens to Rome in 155 B.C.E., which was sent to appeal against the decision of the senate to impose a fine on the city. The lectures of Karneades, one day focusing on the defense of justice and the next against it, became famous; although Cato the Elder, a conservative Roman senator, made sure that the philosophers left the city immediately, their influence remained, and in the following decades the number of Greek intellectuals visiting Rome multiplied. The activities of itinerant historians, orators, grammarians, and philosophers—scholars who combined expertise in these fields were known as "sophists"—continued into the Imperial period, culminating in a time known as the "Second Sophistic," lasting roughly from the reign of Nero to the early third century C.E.

"Go east" was the advice for most of the Greeks under those who succeeded Alexander, and it remained so for centuries. As Rome consolidated its position at the center of the *oecumene* and the *pax Romana* made journeys relatively safe, individuals and groups from Greece and the Hellenized provinces found their way to Rome, Italy, and the western provinces. Men of letters, actors, and athletes were a minority of such people, over-represented in our sources; most were slaves, traders, artists, and skilled workers. Occasionally, grave inscriptions tell these people's stories, such as the sad case of Hyle from Thessalonike, who died alone in Bonn around 200 C.E.: "Thessalonike was my fatherland and Hyle was my name. Aisos, the son of Batallos, conquered me with love potions, although he was a eunuch. And so my wedding bed was ineffectual. And now I lie here, so far away from my fatherland." In the small world of the Roman Empire, a woman from Thessalonike who followed her husband to Germany could still think of her fatherland with nostalgia.

Movement in this period involved not only the movement of people, but also the movement of objects. Looted works of Greek art decorated Roman houses and villas, and Roman clay lamps lit the houses of Asia Minor. Isolated objects of Greek and Roman manufacture even reached China, Thailand, and Korea, suggesting contacts, if not regular trade. And there was the movement of animals: horses and dogs from areas renowned for their special breeds, but also exotic creatures displayed in processions and triumphs or killed in the arena. The grave epigram of a traveling pig gives us an unusual insight into the mobility of this era. Probably trained to perform acrobatic tricks or to compete in races in festivals, the pig came all the way from Dyrrhachion on the Adriatic Sea to Edessa in Macedonia. On its way to a festival of Dionysus it was run over by a wagon (see image, page 10):

> Here lies "the Pig," beloved by all, a young quadruped, having left the land of Dalmatia, brought as a present. I reached Dyrrhachion and wishing to see Apollonia I crossed every land with my own feet, alone, undefeated. But now I have left the light because of the violence of the wheels. I wished to see Emathie and the wagon of the phallus, but now here I rest, although I was too young to pay my tribute to death.

It is not possible to think of an earlier period in recorded human history in which movement was so intense, massive, and wide-ranging. However, the gradual political and cultural convergence of the *oecumene* that started with Alexander and continued advancing under the Roman emperors never uprooted local identities and allegiances. ■

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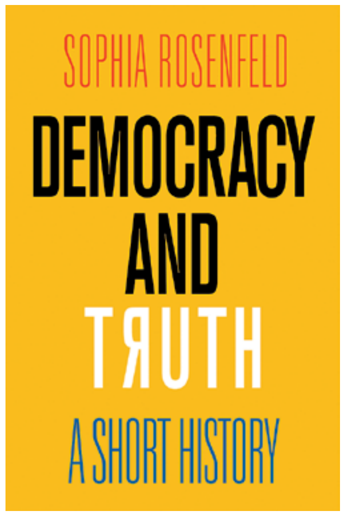
Democracy in an Age of Lies

On collecting and hearing the (often conflicting) evidence of experience or lived truth from all sides

BY SOPHIA ROSENFELD

Conventional wisdom today says that the sciences—natural, physical, and even the quantitative social sciences like economics—are especially good for teaching effective truth practices. That is surely right to a degree. But just as much, we might (unfashionably) think about stressing the humanities and, especially, history. Historians of all kinds depend on the existence of facts. Even those most taken with postmodernism do not accept that there is no such thing as an untruth or argue that it is the same to make it all up as to build on verified documentation. Yet historical facts are also the kinds of basic truths that are most easy to manipulate and also often the most politically sensitive and contested. That's why Truth Commissions have, since the 1980s, been established all over the globe, from postdictatorship Chile and Peru, to postapartheid South Africa, to contemporary American universities grappling with their own racist pasts. The idea behind them all is that, in order to come to terms with prior political violence and to begin the process of finding some basic consensus on which to build, the public needs an opportunity to collect and hear the (often conflicting) evidence of experience, or a kind of lived truth, from all sides, including those that have previously gone unheard. For only with this exposure, no matter how uncomfortable it may be, can a new, truly democratic national or local narrative be forged. There is a lesson here for all efforts to construct accounts of what *really* happened.



However, that's not all that history's good for. For what historians, like their colleagues in literature, art, and philosophy, actually teach—and which is equally vital as a form of training—is not just "what are the facts" and "where do we find them." They teach interpretation. That means learning how to read and to analyze for meaning. It also means grasping the complexity of any form of truth beyond the most elemental, from how a policy can simultaneously hurt some people and help others, to how complex truths can themselves look so different to two people who hail from the same place. This is ultimately how students learn how to be citizens: people who understand what came before but who can also weigh and consider alternate visions of the future.

Support for a democratic truth regime should thus also lead us to uphold and encourage a tradition of non-violent (but not necessarily "civil" in the sense of polite) protest, a tradition that well predates modern democracy but that had a real revival in the 1960s and into the 1970s across much of the world. Such protests put people in the streets, largely apart from formal institutions and their speech rules, offering critiques but also applying pressure on them to reform their ways. Citizens can and should again join forces to protest against forms of lying and corruption as ethical violations. Citizens should also seize the opportunity to agitate publicly for revised and updated methods and standards of truth determination now that epistemology has reemerged as a critical political battleground. Getting cops to wear cameras that accurately record their interactions with civilians, and especially black civilians, is one recent successful outcome of demonstrations of this sort orchestrated by the grass-roots organization Black Lives Matter. The 2017 March for Science, which took shape in response to the seeming anti-science bent of the early days of the Trump administration, is another. It has now morphed into an organization that supports rallies around the globe designed to convey the message that "science is real" (as protestors in Oklahoma put it) and that we need "evidence-based policy that serves all communities" (according to the organization's homepage). This is one place where experts and citizens should also find common purpose.

And one could go one step further too. As Mahatma Gandhi made clear in the very different context of late-colonial India, truth, or *satya*, is ultimately both the condition and the consequence of all politics. Action is political in the positive sense only insofar as it challenges or disturbs ordinary, conventional understandings of the world and ultimately reveals the truth beneath the surface, changing self-conceptions in the process. Truth-seeking and truth-telling are, in other words, inextricably linked to all liberation movements as well.

Yet there is a final risk here. All this pro-truth evangelizing and reinforcement of various democratic traditions might well ultimately be moot if we remain totally divided from one another by every material or psychic measure. Pierre Rosanvallon, writing recently about strategies for combating populism in France, proposed that, in the end, what matters is that people from all walks of life possess a shared language of politics, a common platform for starting a wide-ranging conversation. Hannah Arendt, our intermittent guide through this tricky terrain, would probably have agreed. Neither, though, has much to say about if or how such a thing could be possible in a world defined so thoroughly by economic inequality and stratification as the present one. Could empirically minded, plain-speaking, fact-checking journalists, bulked-up suffrage, court and educational systems, a tradition of street demonstrations, and the development of a new kind of First Amendment jurisprudence that paid more attention to maintaining facticity and reversing silencing techniques be enough to revitalize the democratic take on truth? Could any of the elements of the democratic imaginary, including liberty, equality, and dignity as well as truth become, once again, a widely shared goal? It is hard to say yes to either question as long as people seem to be living in such different worlds, economically and psychologically.

There are, of course, no direct lines between economic hardship and any particular ideological position. Places around the world hard hit by the downturn of 2008 have today placed in power very varied kinds of leaders and parties, alone and in coalitions. Even in the United States, household income, as opposed to geography or cultural identifiers, is generally a poor indicator of voting preferences. That's because so much of politics today is about questions of identity, lifestyle, and respect, unconnected to pocketbooks (something the very wealthy have, in different ways, encouraged across party lines). Nevertheless, to reach a consensus about what constitutes truth requires agreeing in some minimal way about what reality looks like and, even more, how we can know or represent this reality and why it matters—ethically, epistemologically, politically—how we do so. That's going to be difficult when not even schools or the military provide for a common experience across economic differences and when money seems to create distinctions in almost every aspect of American life, including perceptions, trust, and the rest. All of which makes one wonder if the preservation of the democratic conception of truth will not ultimately require a considerably more substantive fix. ■

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PROMISE AND PERIL OF CREDIT *(Continued from page 9)*

and places, blending economic and religious history, approaching the history of economic thought from new angles, and integrating Jewish history more fully into the narrative of Europe's past.

In piecing together the traces left by the legend that attributed to medieval Jews a foundational role in the creation of modern private finance, my ultimate aim is to demonstrate that throughout European history, debates about the market's reach have been inseparable from the construction of legal and symbolic hierarchies of inclusion and exclusion. The impersonality of the market is a recent ideal and remains an elusive reality. ■

Francesca Trivellato, who joined the Faculty of the School of Historical Studies in 2018, is a leading historian of early modern Italy and continental Europe who has made significant and groundbreaking contributions to our understanding of the organization and culture of the marketplace in the pre-industrial world. Trivellato's original and imaginative research has revitalized the study of early economic history, and her influential work on cross-cultural trade intersects the fields of European, Jewish, Mediterranean, and global history, religion, and capitalism.

1 *Financial Times*, April 21, 2010, emphasis mine.

2 Buffett's letter to his shareholders can be read in full at http://www.berkshirehathaway.com/letters/2002pdf.pdf (accessed July 9, 2018). The phrase had appeared in prominent media sources years before, but only after September 2008 did it go viral. See, e.g., "Buffet's 'time bomb' goes off on Wall Street," BBC News, September 18, 2008, http://news.bbc.co.uk/2/hi/2817995.stm (accessed July 9, 2018). The noted CBS News program 60 Minutes aired an episode entitled "Financial Weapons of Mass Destruction" on October 26, 2008.

3 Marc Bloch, *The Historian's Craft*, trans. Peter Putnam (New York: Vintage Books, 1953 [1949]), 29–35.

4 Throughout the book, I purposefully avoid the casual use of the term *capitalism*, in spite of the new purchase it has acquired since 2008 and, especially, since the publication of Thomas Piketty's *Capital in the Twenty-first Century*, trans. Arthur Goldhammer (Cambridge: Harvard University Press, 2014 [2013]). I fear that to call the money markets of premodern Europe capitalistic would interfere with my quest to identify their specificities and link them to the cultural clashes that they generated. Consequently, in referring to the economy of the late medieval and early modern periods, I often resort to the label *preindustrial* because structural conditions that affected the working of credit markets, notably poor information technologies and the absence of notions of legal and political equality, can be found throughout the history of Europe from 1000 to 1800. Only in the last chapter do I readily use the term *capitalism*, because there I engage with nineteenth- and early-twentieth-century social theories aimed at defining modern capitalism as a distinctive historical phenomenon.

5 Notable exceptions are Jonathan Karp, *The Politics of Jewish Commerce: Economic Ideology and Emancipation in Europe, 1638-1848* (Cambridge: Cambridge University Press, 2008) and David Nirenberg, *Anti-Judaism: The Western Tradition* (New York: W.W. Norton, 2014), in particular ch. 8, which is an abridged version of Nirenberg, "Shakespeare's Jewish Questions," Renaissance Drama, 38 (2010): 77–113.

The Yellow Vests Movement, an Unidentified Political Object

Interpreting a mobilization fueled by accumulated grievances against neoliberal reforms

BY DIDIER FASSIN AND ANNE-CLAIRE DEFOSSEZ

On November 22, five days into the *gilets jaunes* protests, with some 2,000 roads and roundabouts barricaded across the country and 280,000 demonstrators having taken to the streets in the major cities, Emmanuel Macron welcomed journalists from *Le Monde* to the Élysée. It was not to give them his analysis of this extraordinary outburst but to take them on a tour of the presidential palace, where he had undertaken a costly renovation of its sumptuous ballroom. He told them that Brigitte, the First Lady, was supervising the project, and praised her choice of a €300,000 carpet woven at the Royal Manufactory of Aubusson. "We are at a moment in the life of the nation when it is necessary to invest," he declared, and since the Élysée was the showcase of France, it had to be a priority. For a President who regards the King's death during the Revolution as a permanent trauma for the French people, and considers it his mission to occupy the vacated space, this disconnect between the preoccupations of the nation and its head of state—the yellow vests were initially supported by 75 percent of the population, according to opinion polls—could be called a Louis XVI moment, comparable to the Bourbon monarch's laconic diary entry for July 14, 1789, the day the Bastille fell: "Nothing."

SEBASTIEN BOZON/AFP/GETTY IMAGES

VALERY HACHE/AFP/GETTY IMAGES

(Left) A roundabout near Colmar, birthplace of the sculptor Frédéric Auguste Bartholdi, designer of the Statue of Liberty, March 2018. (Right) Demonstration in Paris, on the Champs-Élysées, December 15, 2018

The executive had simply not taken stock of the magnitude of the yellow-vest mobilization, nor of the accumulated grievances that lay behind it. The insurgency was regarded as one more episode of futile protest against its neoliberal reforms. The experience of Macron's first two years in office—the repeated failure of massive demonstrations to prevent his revisions of the labor code, overhaul of the state rail operator, and cuts to pensions—led Paris to believe that it could ride out this latest unrest. It deemed trivial the yellow vests' main complaint: an increase in fuel tax of 6.5 cents per litre for diesel and 2.9 cents for petrol, scheduled for January 1, 2019, and coming on top of similar rises implemented in 2018. The stated purpose of the carbon tax was to reduce fossil-fuel consumption, an ecological gesture intended to dispel the negative impression created by the resignation of Nicolas Hulot, the popular environment minister, who had declared himself frustrated by the government's lack of political will on green issues.

Truth be told, very few politicians or commentators had anticipated such disturbances, or proved able to interpret them once they became entrenched—despite a burgeoning literature on the subject. How could a leaderless grassroots movement, involving often quite small groups of protesters, monopolize the national news, capture the attention of the wider world, and destabilize a government that had swept to power by a landslide victory in 2017? As Jacques Rancière has suggested, it is as difficult to understand why some people mobilize when confronted with situations they regard as unacceptable, as it is to understand why others in similar or even worse circumstances do not. The *gilets jaunes* upsurge appears all the more remarkable when one considers that most of its adherents had never participated in a demonstration before and refuse any political or union affiliation.

Commentators who derided the initial grievance of the *gilets jaunes* ignored the fact that opposition to the fuel-tax increase had a deeper meaning, rooted in the social transformations of the past decades, which recent measures have merely aggravated. Worsening economic inequality since the 1980s was relatively well tolerated as long as living standards continued to improve for everyone, even if not at the same pace. But since the 2008 financial crisis, the income of the bottom 40 percent of the population has dropped. Pauperization has mainly afflicted those who were already the most disadvantaged, among whom joblessness and under-employment became increasingly rife. At the same time, the cost of housing, energy, insurance, and school meals has risen faster than the overall rate of inflation. These trends have left the lowest segment of the population with a reduced budget to meet all their other needs.

In parallel, rising rents and house prices, especially in large cities, have forced more and more people on tight incomes to move further away from urban centers, where many of them work. Public transport remains chronically underdeveloped in these hinterlands, so owning a car is essential. The soaring cost of fuel has therefore eaten into household budgets. In rural areas the problem is even more acute. There, the atrophy of public services—from post offices to train stations, hospitals to schools—obliges people to drive into larger towns to access any sort of amenity. Thus, whereas the tax increases had little impact on privileged social layers, since fuel represents only a small proportion of their budgets, they constituted a real financial burden for people living at a distance from the cities. It is estimated that the carbon tax weighs five times more heavily on the bottom decile than on the top, even though the former produces much less pollution than the latter. Besides, the car industry itself was exempted from this environmental levy. On top of these injustices, drivers of diesel cars saw the extra tax hike for their vehicles as being particularly unfair, because the government has encouraged the use of this type of engine for decades, and so it is found today in more than 60 percent of all personal vehicles in France—mostly the older ones owned by lower-income road-users.

The contemptuous attitude of the elite has reinforced the sense of social relegation among the disregarded classes. The President himself has made multiple disparaging or condescending public interventions of this kind: dismissing his critics as "slackers and cynics"; describing women laid off from a slaughterhouse as "mostly illiterates"; drawing a contrast between "people who succeed and people who are nothing"; deploring that "we are putting crazy amounts of dough into minimum social benefits"; telling a young jobseeker that "I'll cross the street and I'll find you something"; and commenting, in reference to the yellow vests, that "we must make those who suffer hardship take responsibility because some behave well but others screw around." These incendiary statements, which a late act of contrition in his television address of December 10 could not erase from collective memory, probably explain why the January polls showed that 68 percent of the French population find Macron arrogant and that he is the most unpopular French President in the history of the Fifth Republic, with only 23 percent holding a positive opinion of him. As the historian Gérard Noiriel notes, "popular struggles almost always involve the denunciation of the disdain of the powerful, and that of the yellow vests only confirms this rule." But Macron's verbal haughtiness is not the only cause of the spectacular collapse in his approval ratings. For the protesters, his deeds, more than his words, manifest his scornful indifference to their condition.

The first actions of the newly elected President left no doubt about his political orientation. To the applause of business leaders, the former Rothschild banker abolished the solidarity tax on wealth, replacing it with a levy on real estate from which financial assets were exempt, and cut corporation tax as well as employer payroll charges. Conversely, to balance the state's budget, housing benefit, family allowances, and pensions were all reduced. Not surprisingly,

(Continued on page 15)

A Continuing Engagement with Endangered and Excluded Scholars

Confronting political barriers that hinder the progress of knowledge

BY ALICE CRARY, JOHAN HEILBRON, AND IAN JAUSLIN

Institutions can flourish by finding innovative methods to affirm the most admirable ideals articulated at their foundings. Some of IAS's greatest ideals reflect its origins in the 1930s, at the time of the Great Depression and the emergence of totalitarian and other non-democratic governments around the globe. When, in 1933, Germany's National Socialists passed a law excluding non-Aryans and political dissidents from civil service jobs, the ensuing cataclysm resulted in a flood of German university professors seeking positions abroad. Urged on by Faculty members such as Oswald Veblen, the Institute ultimately responded by supporting assistance projects to help scholars endangered by Europe's political upheaval. These initiatives were, as then-Director Abraham Flexner conceded in correspondence, partly self-interested steps for an institution committed to developing, at the highest levels, not only mathematics but fields of humanistic studies, politics, and economics. IAS was poised to take advantage of the situation created by the political crises abroad, but pragmatism was accompanied by idealism, and a dedication to challenging political barriers that hinder the pursuit of knowledge, as well as to providing a haven for individuals confronting such barriers, played a decisive role.

Early in 2017, after the issuance in the U.S. of an executive order banning immigration from seven predominantly Muslim countries, a group of Members from across IAS formed the "History Working Group" to research these early moments in the Institute's existence and to affirm its "founding ethos in our precarious present." The essay of which the current article is an excerpt continues the work of this group, by surveying outreach efforts in the Institute's recent history. Attention to the less distant past is helpful for understanding how to uphold its finest ideals going forward, and, notably, it reveals that the Institute's endeavors to support individuals hampered in their work by political obstacles has extended not only to endangered scholars but to scholars confronting structural forms of bias—including bias that is gender-, race-, class-, and geography-based—and who are for this reason at risk of exclusion from the pursuit of knowledge. This commitment to excluded or underrepresented scholars dates to the institution's first years. Documents from the early 1930s, such as the Institute's Certificate of Incorporation, assert that "in the appointments to the staff and faculty as well as in the admission of workers and students, no account shall be taken directly or indirectly, of race, religion, or sex." This longstanding devotion to non-discrimination is reflected in the Institute's continuing efforts to meet the challenges of reaching out to underrepresented groups.

THE INSTITUTE'S ENDEAVORS TO SUPPORT INDIVIDUALS HAMPERED IN THEIR WORK BY POLITICAL OBSTACLES HAS EXTENDED NOT ONLY TO ENDANGERED SCHOLARS BUT TO SCHOLARS CONFRONTING STRUCTURAL FORMS OF BIAS—INCLUDING BIAS THAT IS GENDER-, RACE-, CLASS- AND GEOGRAPHY- BASED—AND WHO ARE FOR THIS REASON AT RISK OF EXCLUSION FROM THE PURSUIT OF KNOWLEDGE.

Among the most notable challenges are those related to gender and race. Of the 112 individuals who have been appointed to the Faculty since 1930, eight have been women. The first woman member of the IAS Faculty was the archaeologist Hetty Goldman (1936–47). Half a century later, Joan Scott (1985–2014) in the School of Social Science was the second. More recently, these appointments have been complemented by those of Danielle Allen (2007–15) in Social Science and by Patricia Crone (1997–2014) and Caroline Walker Bynum (2003–2011) in Historical Studies. In the past years, two out of four Faculty appointments in Historical Studies have been women, Sabine Schmidtke (2014) and Francesca Trivellato (2018), as is the newest appointment in Social Science, Alondra Nelson (2019). Allen was the first African-American to serve on the IAS Faculty, and, when Nelson arrives at the Institute in July, she will be the second.

Summer schools as steps toward inclusion

Some of the Schools' most visible and successful initiatives have been summer programs like Women and Mathematics (WAM), a residential summer program with outreach objectives, which recently received the American Mathematical Society's Award for Mathematics Programs that Make a Difference. Now in its twenty-fifth year, WAM was founded and, for many years, organized by Chuu-Lian Terng, a Member (1979, 1997–98) in the School of Mathematics, and Karen Uhlenbeck, a current Visitor in the School who first met Terng as a Member in 1979. Uhlenbeck is the recipient of the 2019 Abel Prize in mathematics, the first woman to win this prestigious award, in recognition of the fundamental impact of her work on analysis, geometry, and mathematical physics. WAM, the summer program she cofounded, originally grew out of the Park City Mathematics Institute (PCMI), itself an IAS outreach program that started when Phillip Griffiths, now Professor Emeritus in the School of Mathematics, was Director of the Institute, and it targeted, among others, secondary and post-secondary mathematics educators. The inspiration for WAM came partly from the fact that, at PCMI, the percentage of women undergraduate students, graduate students, and mathematics researchers was very low, especially when compared to the number of women high school teachers of mathematics.

Uhlenbeck explains that, when WAM started, it struck her that the number of women in mathematics had grown during the 1960s and 1970s but had stagnated since. She wanted to design a program with an atmosphere welcoming of interactions among women in the profession and of conversations about careers and work-life balance. From its inception, WAM has been committed to reaching out to candidates, especially undergraduates, from smaller universities and colleges, with an eye to honoring and assisting those with excellent promise from less privileged backgrounds. The program, which consists of lectures, colloquia, and panels that are organized annually around a core topic in mathematics, brings together research mathematicians and women studying math at undergraduate, graduate, and postdoctoral levels. Some participate more than once, resulting in significant community building. Having grown from an initial cohort of fifteen participants to more than seventy, WAM recently launched an Ambassador Program to extend the network. This program will annually fund up to three postdoctoral or advanced graduate "ambassadorships" and up to six graduate "ambassadors" to organize conferences. Additionally, as Uhlenbeck notes, "a large percentage of women mathematicians who receive recognition has been associated with [WAM] in some way either as participants or lecturers" (for details, see www.math.ias.edu/wam/news).

Outreach efforts aimed at regional diversity

With an eye to fostering regional diversity in particular, the Institute has supported a number of projects in the sciences. This includes the Science Initiative Group (SIG), established at IAS in 1999. Cofounded by Director Griffiths, SIG aspired to provide guidance for the Millennium Science Initiative (MSI). This project supported centers of scientific excellence in the developing world by helping to fund master's and doctoral programs at regional, university-based networks in sub-Saharan Africa. Nor is SIG the Institute's only contribution to regional diversity in the sciences. IAS provides support to initiatives such as the recent Institute for Theoretical Physics in São Paulo, and, earlier, it supported the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste. Since its founding in 1962 by the late Nobel Laureate Abdus Salam, ICTP has been a leader in efforts to advance scientific expertise in the developing world.

Some of IAS's initiatives to overcome obstacles to geographic diversity have been launched by the School of Social Science under the guidance of Didier Fassin. Since his 2009 appointment as James D. Wolfensohn Professor, Fassin has been troubled by the disproportionate number of Members from North America and Europe. He has led the School in broadening its recruitment efforts, reaching out to scholars in Africa, the Middle East, and South America, with the result that, since 2015, the School has been able to host at least one scholar from each of the six major continents every academic year. But the success of the endeavor has been partial, and Fassin has taken seriously hurdles for scholars coming from the developing world, including a lack of funding for sabbaticals. He organized a more accessible Institute experience in the form of a summer program, inaugurated in 2015, with nineteen scholars from Latin America, the Middle East, and Africa. The program—funded in major part by the Riksbankens Jubileumsfond—ran over three years, with the same participants meeting for two weeks, each time in a different location, from 2015–17. The Mellon Foundation has now agreed to fund the program for at least six more years, to be organized in three two-year cycles. In each case, the first session will be hosted by Fassin at IAS, and, for the second, the group will be split, with one set hosted by Sarah Nuttall at the University of the Witwatersrand in Johannesburg, South Africa, where the proceedings will continue in English, and a second set hosted by Mara Viveros at the Universidad Nacional de Colombia in Bogotá, where the proceedings will be in Spanish.

(Continued on page 15)

ENDANGERED SCHOLARS *(Continued from page 14)*

Endangered scholars at IAS today

The Institute's programs for reaching excluded scholars have coexisted with the continuation of its historical commitment to endangered scholars. The School of Social Science has played a guiding role, recruiting Members whose livelihoods, or lives, are threatened by authoritarian and repressive governments. Under Fassin's leadership, the School has hosted five at-risk scholars. Three were co-funded by the Scholar Rescue Fund (SRF), an organization run by the Institute of International Education (IIE) that provides fellowships for endangered scholars.

Since its founding in 1919, the IIE has provided assistance to endangered scholars from Europe, Russia, Asia, and Africa. In 1933, the IIE founded the Emergency Committee in Aid of Displaced German (later: Foreign) Scholars, on which sat both Flexner, the first Director of the IAS, and Veblen, a founding Professor of the Institute, who were driving forces behind the institution's outreach to endangered scholars. The Emergency Committee assisted 330 scholars in moving to the United States, including IAS Professor Kurt Gödel, Visitor Emmy Noether, and many other prominent academics, like Richard Courant, founder of the Courant Institute of Mathematical Sciences at New York University, and novelist Thomas Mann. In 2002, the IIE founded the SRF to formalize its commitment to endangered scholars. SRF awards fellowships of one to two years to threatened academics, providing funds up to $25,000 to cover scholars' stipends. The SRF has awarded more than a hundred fellowships to Syrian scholars since the Syrian civil war broke out in 2011. Before Trump banned the issuance of visas to Syrian nationals, more than half of these scholars used their funding to come to the U.S.

The first at-risk scholar in the School of Social Science was selected in 2015. Inspired partly by the fruits of this first experience, Fassin brought in a second scholar at risk in 2016. A year later, three endangered academics from, respectively, sub-Saharan Africa, East Asia, and a former Soviet Republic followed. One was affiliated with SRF, and the other two were funded by the School of Social Science. Recognizing the success of this project, the School of Historical Studies admitted a scholar at risk in 2017. Both Social Science and Historical Studies have taken steps to bring in more endangered scholars.

Looking forward in light of the past

In surveying IAS's legacy of dedication to excluded and endangered scholars, we should bear in mind that the individual Schools face distinctive challenges. It is true that a diversity not only of regional perspectives but of perspectives related to race-, gender-, and class-based social identity can internally inform the kind of understanding sought by social and historical researchers. Although structural features of the disciplines affect the way scholars in different fields approach issues of inclusion, IAS's Schools resemble each other in being heirs to an eminent tradition of preserving scholars' safety and combatting region-, gender-, race-, class-, and religion-based obstacles that derail the progress of knowledge. However proud we are to claim this heritage—and we should be proud—carrying it forward will require not only hard work, good judgment, courage, and an openness to risk, but also the humility to learn from missteps. ■

Alice Crary, Johan Heilbron, and Ian Jauslin were members of the Institute's History Working Group. Crary and Heilbron were Members in the School of Social Science in 2017–18, Jauslin in the School of Mathematics in 2016–18. Crary is Professor of Philosophy at the University of Oxford and the New School for Social Research. Heilbron is Director of Research at the Centre National de la Recherche Scientifique and member of the Centre Européen de Sociologie et de Science Politique. Jauslin is a Postdoctoral Research Fellow in the Physics Department at Princeton University. The longer version of this article is available at www.sss.ias.edu/history-working-group.

YELLOW VESTS *(Continued from page 13)*

Macron soon earned the sobriquet "President of the rich." His justification for these policies rested on the hackneyed trickle-down theory, according to which reduced taxes on the wealthy and corporations stimulate investment, create jobs, and eventually prove beneficial to all. But this did not convince the majority of the population, who understood that the man they had elected because he claimed to be neither right nor left was in fact a typical neoliberal. Far from rejuvenating the political world, as he had promised during his campaign, Macron seemed merely to represent the old politics in new garb. This is probably why the yellow vests immediately obtained such an extraordinary measure of public support, despite the disruption they are causing to many people's daily lives. Although the number of protesters on the streets on any given day has rarely exceeded 100,000, the majority of the population who expressed sympathy with them in the polls should be regarded as demonstrators by proxy.

But is it even legitimate to call the protests of the yellow vests a movement? Several features of those protests run against this characterization, particularly if one considers how the mobilization developed in the closing weeks of 2018. First, rather than being a coordinated demonstration, it is a spontaneous uprising. Blockades are agreed upon between neighbors and friends. Improvised protests take place at venues chosen at the last minute via social media. Most of the time, no permission is solicited from the authorities, which have been all too ready to declare these rallies illegal and proceed to make arrests among anyone gathered in a group. Second, no leaders or spokespersons emerged from their ranks. Those who put themselves forward to liaise with the authorities or accepted invitations on talk shows were immediately criticized, and sometimes even threatened. Third, no single watchword or program unified the participants. Although certain themes recurred, on tax justice in particular, the most frequent slogans heard were against Macron himself, confirming the general mood of disaffection with the President.

It is certainly the case that the very form taken by the mobilization renders any analysis of its sociodemographic composition problematic. However, studies have been done *in situ* at the roundabouts, via social media, and through opinion polls. The observations gleaned so far by journalists and sociologists across the country do suggest some general traits. First, the yellow vests are a very heterogeneous group. Most have no experience of engagement in social movements, organized labor, or political parties. Second, they combine men and women—the latter unusually well represented, at 45 percent of the total—pensioners and workers, craftsmen and tradesmen, nurses and housekeepers, students and unemployed. Most adherents come from the upper-working class or the lower-middle class, drawn together by the shared experience of their income being progressively squeezed by tax hikes and rising expenses. Third, most reside in the distant outskirts of cities, as well as in depopulated rural areas, where there is a painful sense of abandonment by the state. The expression "peripheral France," so often used to characterize them, should thus be taken in the polysemous sense of those who occupy—or regard themselves as occupying—a political, social, and spatial periphery. In the opinion of sociologist Serge Paugam, the yellow-vest movement represents "the revenge of the invisible" against the "social contempt" of the elites.

So close to the start of the yellow-vest mobilization, it is difficult to draw definitive conclusions about its meaning and future. The movement has too often been treated as *sui generis*, when in fact useful comparisons can be drawn with mobilizations that have occurred in Spain, Italy, and Greece over the past decade. There are undoubtedly similarities: anger at diminished purchasing power and at the dysfunction of representative democracy; social and political heterogeneity of the protesters, with a significant role played by precarious workers and newcomers to militancy, especially women; occupation of public spaces and utilization of social media; absence of leaders and formal structures, at least in the early phases of these movements. Two factors might nevertheless singularize the French case: the channeling of people's rage against the figure of the President, who has become the symbol of an arrogant and authoritarian neoliberalism, and the country's history of struggles over the social state, which remains part of the collective imaginary.

Whereas these hypotheses will need to be confirmed, what can be said with some confidence is that the *gilets jaunes* mobilization constitutes an event in the strong sense of the term—that is, a moment which imposes a temporal rupture in the course of things, with a before and an after. No one knows whether this movement will evolve toward a more recognizable form, but it has at least reminded French politicians of the existence of a category that had disappeared from their vocabulary: *les classes populaires*. ■

An anthropologist, sociologist, and physician, Didier Fassin has been James D. Wolfensohn Professor in the School of Social Science since 2009. His current work is on the theory of punishment, the politics of life, and the public presence of the social sciences. A sociologist, Anne-Claire Defossez, Visitor in the School since 2015, conducts research on the question of women's political participation and representation by exploring the trajectory and experience of women formally involved in politics at local and national levels in France. This article is a shortened and revised version of their article "An Improbable Movement? Macron's France and the Rise of the Gilets Jaunes*," published in the January/February edition of the* New Left Review*, available at http://bit.ly/fassin-defossez.*

 (Continued from page 1)

equivalent to about $700,000. The Prize will be given to Uhlenbeck by H.M. King Harald V at an award ceremony in Oslo on May 21. Since the Abel Prize was first bestowed in 2003, 18 of the 20 recipients have been affiliated with the Institute as present and past Faculty or Members, including the 2018 honoree, Robert Langlands, and the 2013 honoree, Pierre Deligne, Professors Emeriti in the School of Mathematics.

Uhlenbeck, the first woman to receive the Abel Prize, initially came to the Institute as a Member in the School of Mathematics in 1979. She returned as a Member in 1995, served as a Visiting Professor in 1997–98 and 2012, and has been a Visitor since 2014. She is a founder of the Institute's Park City Mathematics Institute (PCMI), a summer program that brings together mathematicians and math teachers to study and exchange ideas, providing immersive educational and professional development opportunities.

Uhlenbeck also cofounded the IAS Women and Mathematics program (WAM) with fellow IAS Member Chuu-Lian Terng in 1993 as part of PCMI, and then established the program on the Institute's campus in 1994. The purpose of WAM is to address gender imbalance and success rates among women in the mathematics field. Both Uhlenbeck and Terng have mentored hundreds of young women mathematicians through the program they founded, resulting in a powerful network of nearly 1,500 participants to date. In April, WAM was recognized with the American Mathematical Society's 2019 Award for Mathematics Programs that Make a Difference.

"What Karen has done for the mathematical community and in particular for the WAM program would not fit in the margin of a book. It will not fit in a whole book either," observed Antonella Grassi, Member (2000-01) in the School of Mathematics, on the occasion of the twenty-fifth anniversary of the program last May. "Karen has a contagious passion and enthusiasm for mathematics. She is warmly welcoming towards all sorts of creatures, beginning and more established mathematicians, and stray cats alike. She is driven by a strong intellectual curiosity and an equally strong drive to do her best, and beyond, to give everyone an opportunity to strive. She is also fun. The program, and all of us who have been involved with it, have greatly benefited from her presence."

Of her forty-year association with the Institute, Uhlenbeck commented, "The Institute was actually very important in my career. The year I spent in 1979–80, which was a year organized by S. T. Yau, was just eye opening for me. It really brought me into the math community and made me feel like a member of the math community."

On March 19, when the Abel Prize was announced, the Institute community gathered to celebrate Uhlenbeck at a reception in her honor. Among those who spoke at the event were Daniel Freed, Professor of Mathematics at the University of Texas at Austin, Member (1996–97 and 2015) in the IAS School of Mathematics, and Member (1997–98) in the School of Natural Sciences; Sun-Yung Alice Chang, Eugene Higgins Professor of Mathematics at Princeton University and a Distinguished Visiting Professor (2008–09) and Member (1976–77, 1993, and 2004) in the IAS School of Mathematics; and Edward Witten, Charles Simonyi Professor in the School of Natural Sciences.

"I think of Karen as a real maverick. She's someone who can go into a new area, something quite unexplored, and somehow hone in on just the core issue," said Freed. "And in that unexplored territory she proves these amazing fundamental theorems with incredible technical expertise. In turn, those theorems open up new pathways. Her beautiful mathematics is the guiding light that others follow down these pathways, where they discover riches of more and more beautiful mathematics. These reverberations speak to the depth of Karen's insights."

On March 19, 2019, the IAS community gathered to celebrate Karen Uhlenbeck (top). Uhlenbeck is one of many Abel Prize laureates with a long history at IAS, among them Robert Langlands (middle, left) and Pierre Deligne (middle, right), Professors Emeriti in the School of Mathematics. Speakers included Helmut Hofer (bottom, left), Professor in the School.

Chang, a member of the Abel Prize selection committee, spoke in detail about the work for which Uhlenbeck received the award, particularly her contributions in three main directions: bubbling analysis and minimum surfaces; the study of Yang-Mills equation gauge theory; and integrable systems. "The conclusion of our citation is that Karen Uhlenbeck's pioneering results have had fundamental impact on contemporary analysis, geometry, and mathematical physics," said Chang. "Her ideas and leadership have transformed the math landscape as a whole. On a personal note, I have long admired the work of Karen Uhlenbeck and think of her as my role model in my career. As you have heard from other speakers, Karen's achievement is not limited to research."

In addition to her influence in mathematics, Witten spoke about her contributions to physics, particularly gauge theory and especially non-abelian gauge theory, which provided the framework in the 1970s for how physicists learned to understand the elementary particles in the form of the Standard Model of particle physics. "When Karen became involved in the late '70s, non-abelian gauge theory was a scarcely known subject mathematically and she was one of the most important pioneers in developing it as a mathematical subject," said Witten. "Karen's important results in math, some of which in part were inspired by physics, have in turn had a lot of influence in physics."

Uhlenbeck was born in Cleveland, Ohio, in 1942. Her father, Arnold Keskulla, was an engineer, and her mother, Carolyn Windeler Keskulla, an artist and school teacher. Having a curious mind, she developed a lifelong love of the outdoors, read incessantly, and dreamed of becoming a research scientist. Planning to major in physics, she enrolled at the University of Michigan, where she discovered the intellectual challenge of pure mathematics, guiding her future academic path. Graduating in 1964, she went on to study at Brandeis University, earning her Master's degree in 1966 and Ph.D. in 1968.

In 1990, in Kyoto, Japan, Uhlenbeck became the second woman to give a Plenary Lecture at the International Congress of Mathematicians, the largest and most important gathering of mathematicians in the world. The first woman to deliver the lecture was Emmy Noether in 1932; the following year, Noether joined the Institute's School of Mathematics as a Visitor from 1933–35. In 2016, a series of lectures at the Institute celebrated the life and work of Noether, during which Uhlenbeck explored Noether's fundamental insight into the conservation law in modern theoretical physics.

Uhlenbeck has held academic positions at the University of Texas at Austin; Institute Des Hautes Études Scientifiques; the University of Chicago; Max-Planck-Institut für Mathematik; Harvard University; University of California, Berkeley; University of Illinois at Chicago; University of Illinois at Urbana-Champaign; and the Massachusetts Institute of Technology.

Uhlenbeck is a Fellow of the American Mathematical Society, and a Member of the National Academy of Sciences, the American Academy of Arts and Sciences, the American Philosophical Society, the Mathematical Association of America, the National Association of Mathematicians, and the Association for Women in Mathematics. Her honors include the Steele Prize from the American Mathematical Society (2007); the National Medal of Science (2001); the Noether Lecture award from the Association for Women in Mathematics (1988); and a MacArthur Prize Fellowship (1983–88). ■

Karen Uhlenbeck on Being the First Woman to Receive the Abel Prize

The following is a slightly edited excerpt of the remarks that Karen Uhlenbeck gave at the reception held in her honor at the Institute for Advanced Study on March 19, 2019.

I think many of the people who are interested in congratulating me on the Abel Prize are doing so because I'm a woman and I'm the first woman to get it.

And I can't help resist telling the story that actually it isn't quite as unnerving as being the second woman to give a plenary address at the International Congress of Mathematicians. That was in 1990. The first woman was Emmy Noether in 1932, which is a pretty frightening fact when you're in the middle of it. Now it doesn't seem so bad.

But, anyway, it's not so easy being a role model. One of the things you learn when you're going through life and so forth is that you need role models, but you don't need perfect role models. You need role models who fall down and pick themselves up. You need role models who show how even though you can't do everything, you can do some things. You need role models to keep you going.

GEORGE M. BERGMAN/MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH GGMBH

Karen Uhlenbeck at Berkeley in 1969

One of the things that interviewers have been asking me is, "Did I have a role model?" And I've thought about it, and I can tell you who my role model was. It was Julia Child. She had these fantastic television programs, and she was a real person. She could pick the turkey up off the floor and serve it.

People also ask me if things have changed for women, and I want to say, "Boy, have they." And that's because most of you are young. You don't know what it was like. It wasn't until the '60s and '70s that the laws that prevented women and minorities from getting jobs were taken off the books. I was really at that first stage when it became possible that you could make your way into mathematics and become a mathematician.

Of course, there were still some laws on the books, but some universities hired women without worrying about it too much and it was a great moment. And I do have to say that, along with a lot of the other women who took advantage of this, we thought that—now that the laws are changed and the doors are no longer locked—women and minorities would just march through the doors and take their rightful place in academia. And sad to say it was not that simple. But it is a lot better now, and I hope that I have helped to make it a better place.

A recording of the reception in Karen Uhlenbeck's honor is available at www.ias.edu/ideas/2019-abel-prize-reception.

I also want to say one last thing and that's thanks to the Norwegian government for recognizing pure mathematics. It's a wonderful subject, a lot of fun. And I feel very privileged not only to have been a research mathematician but to have enjoyed it and to be rewarded for it. Thank you very much. ■

NELSON *(Continued from page 1)*

biology, medicine, and public health. She is a renowned and influential scholar in the field of the social studies of science and technology, most especially the sociopolitical dimensions of genetics and artificial intelligence.

"A remarkably dynamic and creative scholar, with an exceptionally broad view of the social sciences, Alondra has revealed facets of our society previously overlooked or hidden, diving deeply into the complexities of humanity and illuminating the gray areas of our past and present," said Robbert Dijkgraaf, IAS Director and Leon Levy Professor. "On behalf of the Institute, we are proud to welcome Alondra to our IAS family and recognize the unique perspective and opportunity her work brings to our community."

Nelson's work offers a critical and innovative approach to the social sciences that is conducive to a fruitful dialogue with the many disciplines represented among IAS Faculty and Members. Her major research contributions are situated at the intersection of racial formation and social citizenship, on the one hand, and emerging scientific and technological phenomena, on the other.

"I'm honored beyond measure to have been invited to join this distinguished intellectual institution and to have the opportunity to carry forward my research as a part of this exceptional community of scholars," Nelson said.

Her groundbreaking work brings together several research traditions: political sociology; racial and ethnic studies; the sociology of science, knowledge, and technology; medical sociology; and social and cultural theory. She applies qualitative methodology—principally ethnography, historiography, and ethical inquiry—to the study of how conceptualizations of human difference shape lived experience, social relations, and life chances.

While sociologists have long devoted attention to how race is socially constructed, Nelson distinctly also explores how social groups both engage with and contest anthropological and biomedical concepts of race. She explores and connects these dimensions in her two major books, *Body and Soul: The Black Panther Party and the Fight Against Medical Discrimination* (University of Minnesota Press, 2011) and *The Social Life of DNA: Race, Reparations, and Reconciliation after the Genome* (Beacon Press, 2016).

In *Body and Soul*, she argues, based on archival research and interviews, that the Black Panther Party was not only a radical political movement, but also a public health movement. The activists established a national network of neighborhood clinics, providing basic health services and implementing screening and counseling programs for genetic disease. Nelson's work also shows how the group intervened in debates over the medicalization of violence, and challenged theories about the alleged inherent biological inferiority of people of African descent. This highly original book garnered several scholarly awards, including the 2013 Mirra Komarovsky Book Award for the best sociological monograph from the Eastern Sociological Society.

In *The Social Life of DNA*, Nelson imaginatively excavates a constellation of endeavors initiated by members of the African diaspora, who embark upon journeys to uncover information about their ancestral origins with the aid of genetics and then use this information to varied ends that she terms "reconciliation projects." Nelson is currently preparing a new book that explores the centrality of science to the practice of governance through an exploration of the Obama administration's Office of Science and Technology Policy and its navigation of the ethical, legal, and social implications of the initiatives and regulations it would promote.

Nelson has coedited two important collective volumes that take up the central themes of her research in a broader context and from a comparative perspective. The first book, *Technicolor: Race, Technology, and Everyday Life* (with Thuy Linh Tu; NYU Press, 2001), investigates the emergence of then-new information technologies and considers the ways they were informed by prevailing racial ideologies. *Technicolor* is widely cited as one of the first works on the intersection of race and technology, laying the groundwork for a now-burgeoning area of study. The second book, *Genetics and the Unsettled Past: The Collision of DNA, Race, and History* (with Keith Wailoo and Catherine Lee; Rutgers University Press, 2012), considers the alignment of genetic science with commercial genealogy, with legal and forensic developments, and with pharmaceutical innovation to examine how these developments promise to lend new authority to biological understandings of both race and history. Nelson's publications also include a recent special issue of the *British Journal of Sociology* on the use of genetics and genealogy in a project of historical and political reckoning at Georgetown University.

Nelson is a Phi Beta Kappa graduate of the University of California, San Diego, with a B.A. in anthropology. She earned her Ph.D. in American studies from New York University in 2003. She was first appointed in 2003 as Assistant Professor and later Associate Professor in Sociology and African American Studies at Yale University, where she received the Poorvu Family Award for interdisciplinary teaching excellence. She was then recruited in 2009 to the Department of Sociology and the Institute for Research on Women, Gender, and Sexuality at Columbia University.

The recipient of numerous honors and fellowships, Nelson has been a visiting scholar at the London School of Economics, the Max Planck Institute for the History of Science in Berlin, the International Center for Advanced Studies at New York University, and the W. E. B. Du Bois Institute for African and African American Research at Harvard University. She has received fellowships from the Andrew W. Mellon Foundation, the Ford Foundation, and the National Science Foundation.

Nelson is presently Chair of the American Sociological Association's Section on Science, Knowledge, and Technology. She is an elected Fellow of the American Academy of Political and Social Science and of the Hastings Center, and an elected Member of the Sociological Research Association. She was formerly a Member of the World Economic Forum Network on Artificial Intelligence, the Internet of Things, and the Future of Trust, and of the National Science Foundation–sponsored Council for Big Data, Ethics, and Society. ■

Jean Bourgain, Pioneering Mathematician, Dies at 64

Jean Bourgain, IBM von Neumann Professor in the School of Mathematics at the Institute for Advanced Study, revered for the exceptional range, depth, and power of his mathematical work, passed away in Bonheiden, Belgium, on December 22 at the age of 64. Despite a long battle with cancer, his resilient and dauntless approach to challenges remained undeterred. He continued working through the end of his life, with great generosity and grace, while building upon a prolific career in mathematics.

"One of the most fearless and important mathematicians of our time, Jean had an extraordinary ability to bring a new perspective to longstanding questions in numerous areas of mathematics, including number theory, probability theory, and statistical physics, which have been permanently shaped by his contributions," said Robbert Dijkgraaf, Director and Leon Levy Professor. "Greatly admired for his daring originality and intellectual power, Jean will continue to inspire future generations with his generosity and brilliance. He will be deeply missed at the Institute and by colleagues and friends around the world."

Bourgain joined the Institute's School of Mathematics as a Professor in 1994, the same year he received a Fields Medal, and served as IBM von Neumann Professor since 2010.

"Jean had an unequaled analytic brilliance, which together with his positive outlook allowed him to resolve many long-standing problems in a broad range of areas of mathematics," said School of Mathematics Professor Peter Sarnak, a friend, collaborator, and colleague of Bourgain. "His breakthroughs came with unexpected novel techniques and theories which drive and define the contemporary field of mathematical analysis. The same clarity and optimism characterized his very effective service over many years as the Chair of the School of Mathematics. His premature passing is a major loss to the Institute and to mathematics."

Jean Bourgain

Bourgain's work touches on many central topics of mathematical analysis, such as the geometry of Banach spaces, ergodic theory, spectral problems, and nonlinear partial differential equations from mathematical physics. His early solution and advancement of longstanding problems include Rudin's Lambda-p set problem in harmonic analysis, and Mahler's conjecture in convex geometry. He made major advances in other areas such as theoretical computer science, group theory, and in number theory, including a complete solution of Vinogradov's Mean Value Theorem, which stood for more than eighty years. In Hamiltonian dynamics, he developed the theory of invariant Gibbs measures and quasi-periodicity for the Schrödinger equation.

In awarding the 2018 Steele Prize for Lifetime Achievement to Bourgain, the American Mathematical Society recognized him as "a giant in the field of mathematical analysis, which he has applied broadly and to great effect. In many instances, he provided foundations for entirely new areas of study and in other instances he gave mathematics new tools and techniques."

A widely celebrated mathematician, Bourgain's influence has been acknowledged with many awards, including the Breakthrough Prize in Mathematics (2017); the Antonio Feltrinelli International Prize for Mathematics from the Academia Nazionale dei Lincei (2016); the Crafoord Prize in Mathematics (2012); the Shaw Prize in Mathematics (2010); the Vernadsky Gold Medal from the Ukraine Academy of Sciences (2010); the Ostrowski Prize (1991); the Élie Cartan Prize (1990); the Langevin Prize from the Académie des Sciences, Institut de France (1985); the A. De Leeuw-Damry-Bourlart Prize (1985); and the Empain Prize from the National Fund for Scientific Research, Belgium (1983).

Bourgain was born on February 28, 1954, in Ostende, Belgium. He received his Ph.D. from the Free University of Brussels in 1977 and his Habilitation in 1979. He was awarded the Alumni Prize from the Belgium National Fund for Scientific Research (NSF), then served as Professor (1981–85) at the Free University of Brussels, receiving great honors for his research work. He was awarded the Empain Prize by the Belgium NSF in 1983, and, in the same year, he also received the Salem Prize.

In 1985, Bourgain was awarded the highest science honor from Belgium, the De Leeuw-Damry-Bourlart Prize. Bourgain then left Belgium and accepted two appointments, one as J. L. Doob Professor of Mathematics at the University of Illinois and the other as Professor at the Institut des Hautes Études Scientifique at Bures-sur-Yvette in France. The French Academy of Sciences awarded Bourgain its Langevin Prize in 1985 and its highest award, the Élie Cartan Prize, in 1990.

In 2012, Bourgain was awarded the Crafoord Prize in Mathematics with Terence Tao, Visitor (2005) in the School of Mathematics, for having made important contributions to many fields of mathematics—from number theory to the theory of nonlinear waves. Bourgain's ability to change perspective and view problems from new angles has led to many remarkable insights, attracting a great deal of attention among researchers worldwide.

Bourgain's work has impacted how we live our everyday lives, from applications such as the production of structures that exhibit randomness—an essential contribution to theoretical computer science—to defining the relationship between such familiar operations as addition and multiplication.

Bourgain had an extraordinary ability to invent new analytical techniques for exploring, and ultimately resolving, a variety of seemingly intractable problems. In this way, he has changed the nature of what can be achieved and the nature of what is known to be true. Bourgain's techniques have proven so powerful that they have found numerous applications beyond those for which they were originally developed, allowing other mathematicians to achieve their own unrelated goals.

Prior to his appointment to the Faculty of the Institute, Bourgain served as Lady Davis Professor of Mathematics (1988) at the Hebrew University of Jerusalem and, subsequently, Fairchild Distinguished Professor (1991) at the California Institute of Technology.

He was a Foreign Member of the Polish Academy of Sciences, the Academia Europaea, the Royal Swedish Academy of Sciences, and the Royal Flemish Academy of Belgium for Science and the Arts, and he was a Foreign Associate of the National Academy of Sciences and the Académie des Sciences, Institut de France. Bourgain was bestowed the title of Baron by the Belgian government in July 2015. In association with the honor, Bourgain designed a coat of arms with the inscription "In hope against hope." In May 2016, the Institute celebrated Bourgain's work and impact with the conference "Analysis and Beyond," videos of which are available at www.ias.edu/ideas/2016/bourgain-analysis-and-beyond.

Bourgain is survived by his wife, Mei-Chu Chang; their son, Eric Bourgain-Chang; his sister, Claire Bourgain; and brother-in-law Bart Dierickx. ■

"BOURGAIN LIVED AND BREATHED MATHEMATICS. A NIGHT OWL WHO TRAVELED FREQUENTLY BACK AND FORTH BETWEEN THE IAS AND CALIFORNIA, WHERE HIS WIFE AND SON LIVED, HE WOULD OFTEN, WHEN AT PRINCETON, SHOW UP AT THE IAS SHORTLY BEFORE AFTERNOON TEA AND WORK WITH COLLABORATORS UNTIL WELL PAST MIDNIGHT. THEN, AFTER THE OTHERS HAD GONE TO BED, HE WOULD CONTINUE INTO THE NIGHT. HIS COLLABORATORS WOULD OFTEN WAKE UP TO AN EMAIL FROM BOURGAIN SENT AT 4 A.M., CONTAINING THE SOLUTION TO A PROBLEM THAT, THE NIGHT BEFORE, HAD SEEMED AS IF IT WOULD TAKE WEEKS TO CRACK."

—*Erica Klarreich in* Nature, *http://bit.ly/bourgain*

The Institute will honor the life and work of Jean Bourgain on May 31 and June 1. The event will take place in Wolfensohn Hall on the Institute's campus and speakers will include Vitali Milman, Gigliola Staffilani, Larry Guth, Svetlana Jitomirskaya, and Elon Lindenstrauss with special remembrances by colleagues, friends, and collaborators. To register, please visit www.ias.edu/events/honoring-bourgain.

Irving Lavin (1927–2019), Iconic Art Historian, Dies at 91

Irving Lavin, Professor Emeritus in the School of Historical Studies at the Institute for Advanced Study, passed away in Princeton on February 3 at the age of 91.

Lavin was an art historian distinguished by his charismatic and challenging teaching, rigorous search for the relationship between form and meaning in the visual arts, and the conviction that the study of the history of art was the study of the history of ideas. He was renowned for his tenacious explorations of difficult subjects, and his willingness to see all the facets and possibilities of their solutions.

"Irving exemplified the characteristics of a world leading scholar and humanist in his generosity, enthusiasm, and curiosity, which spanned diverse disciplines," said Robbert Dijkgraaf, Director and Leon Levy Professor. "The Institute community, where Irving made his intellectual home for 45 years, was enriched by his presence, his insights, and his dear friendship. He will be greatly missed here and around the world."

Irving Lavin

Lavin's deep knowledge of Italian art and culture was the result of over fifty years of study, particularly in Rome, where he embraced the city and encouraged Italian art history to move into the world of intellectual creativity. For this gift, the city offered him many honors, including the Tercentennial Medal, commemorating the death of Gianlorenzo Bernini (1980), and the Premio Daria Borghese (1981), and appointed him Honorary Member of the Corporation of Sculptors and Marble Workers of Rome as well as Membro Straniero della Accademia Nazionale dei Lincei. He also received the Premio Internazionale "Galileo Galilei," from the University of Pisa (2005), the Sescentennial Medal, commemorating the birth of Donatello, from L'Accademia delle Arti del Disegno, Florence (1986) and was made Accademico d'Onore by Accademia Clementina, Bologna (1986). He died as he was about to fulfill his last invitation: to be plenary speaker at the Fondazione Caetani colloquium on sixteenth-century Roman sculpture (March 2019). His last article on "The Silence of *David* by Gianlorenzo Bernini" will be published posthumously in the periodical *Artibus et Historiae,* in the Spring 2019 issue.

THE BREADTH OF HIS KNOWLEDGE ON THE HISTORY OF ART AND CULTURE WAS PHENOMENAL, AS WAS HIS ABILITY TO RECOGNIZE CONNECTIONS BETWEEN SEEMINGLY DISPARATE PHENOMENA.

"Irving Lavin continued to be part of the life of the School of Historical Studies until a few weeks before his passing. The breadth of his knowledge on the history of art and culture was phenomenal, as was his ability to recognize connections between seemingly disparate phenomena," said Angelos Chaniotis, Professor of Ancient History and Executive Officer of the School of Historical Studies. "With an alert mind and youthful curiosity, he took a genuine interest in the projects of the Members, created bridges between the disciplines, and stimulated discussions."

Lavin began his career studying philosophy at Washington University in St. Louis, Missouri, and at the invitation of Bertrand Russell went to Cambridge University to become his tutee. He soon became aware that such a theoretical field was not for him and took up more practical studies, namely the history of art. Within ten years he had degrees from New York University and Harvard University, and had won the prestigious Arthur Kingsley Porter Prize for Scholars under 40 three times ('59, '62, and '68)—so often, in fact, the paradigm for the prize was changed. In 1966, Lavin began a series of discoveries, the first of which brought to light the earliest marble portrait bust made by the young prodigy Gianlorenzo Bernini at the age of 14 years. That discovery was only the first of many previously unknown Bernini busts made throughout his career. Lavin's last contribution was a black-and-white marble sculpture of the famous Roman lawyer Prospero Farinacci (d. 1619), published in the spring of 2018.

Lavin was born on December 14, 1927, in St. Louis, Missouri. He received his B.A. from Washington University (1948), his M.A. from the Institute of Fine Arts, New York University (1951), and an M.A. (1952) and Ph.D. (1955) from Harvard University for his dissertation, "The Bozzetti of Gianlorenzo Bernini." He taught on the faculties of Washington Square College, New York University (1957–59; 1963–66); Vassar College (1959–61); the Institute of Fine Arts, New York University (1967–73); and Princeton University (1974–90). Lavin joined the Institute's School of Historical Studies as a Professor in 1973 and became a Professor Emeritus in 2001.

Reflecting on Lavin's appointment and early years as a Professor in the School, the late Carl Kaysen, IAS Director 1966–76, observed in an Oral History interview, "I found it interesting that Irving could talk about nineteenth-century English art as well as about Bernini and as well about Tunisian mosaics. [...] Irving fulfilled the notion of real intellectual interaction across the faculty boundary." With John Elliott, Professor in the School from 1973–90, Lavin worked to make the School more cohesive in the 1970s, with a focus on actively encouraging the appointments of younger Members. As Elliott recalled in an Oral History interview, Lavin viewed the Institute as an international center with an international message and as "a place of refuge for younger people to get on with their own work as visiting Members."

Lavin's publications show his wide-ranging intellectual interests: from late antique architecture (Triclinia) to North African, particularly Tunisian, floor mosaics, the Renaissance (Donatello, Michelangelo, Pontormo, and Giovanni Bologna), the Baroque (Caravaggio and Bernini), to the twentieth century, with essays on Picasso and Jackson Pollock. He also communicated easily with practicing artists and was close friends with George Segal, Mel Bochner, Frank Stella, and traveled with and wrote about Frank O. Gehry.

His books include *Bernini and the Crossing of St. Peter's* (1968); *Bernini and the Unity of the Visual Arts* (1980); *Past–Present: Essays on Historicism in Art from Donatello to Picasso* (1993); *Santa Maria del Fiore: Il Duomo di Firenze e la Vergine Incinta* (1999); and *Caravaggio e La Tour: La Luce Occulta di Dio* (2000). The first two volumes of a projected six-volume edition of his collected works have been published as *Visible Spirit: The Art of Gianlorenzo Bernini* (2007–09), while the third volume has appeared as *Bernini at St. Peter's: The Pilgrimage* (2012). A gathering of his essays on modern and contemporary art, *The Art of Art History*, has also appeared in Italian as *L'Arte della storia dell'arte* (2008).

Lavin was a celebrated lecturer: he gave the Franklin Jasper Walls Lecture at the Pierpont Morgan Library in New York (1975); the Slade Lectures at Oxford University in 1985; the Thomas Spencer Jerome Lectures at the University of Michigan and the American Academy in Rome, 1985–86; the Una's Lectures in the Humanities, University of California, Berkeley, 1987; and the Andrew W. Mellon Lectures in the Fine Arts, National Gallery of Art, Washington, D.C., in 2004. In 1993, Lavin hosted a centennial symposium on the work of Erwin Panofsky at the Institute for Advanced Study, where Panofsky had been a Professor.

In addition to his scholarly production, he gave considerable efforts to shaping the directions of art historical research in North America. He was a founding member of the committees charged with the creation of three new institutes dedicated to research in the history of art and architecture in America and abroad: The J. Paul Getty Research Center (Los Angeles); The Center for Advanced Study in the Visual Arts (CASVA), the National Gallery, Washington, D.C.; and the Canadian Centre for Architecture (CCA), in Montreal, Canada.

In 2011, he and his wife, Professor Marilyn Aronberg Lavin, co-authored a small book titled *Truth and Beauty at the Institute for Advanced Study*, in which they explore the origin and historical framework of the Institute and its seal, designed in 1931 by French artist Pierre Turin. Lavin writes in the introduction, "It is our joint hope that, to some extent, this perhaps excessively academic study expresses the gratitude we both feel for the precious gifts we have received over the years from this wondrous place."

Lavin is survived by his wife of 66 years, Marilyn Aronberg Lavin, a distinguished art historian, their daughters, Amelia Lavin and Sylvia Lavin, her husband Greg Lynn; and grandchildren, Sophia Lavin Lynn and Jasper Lavin Lynn. ■

On April 26, the Institute celebrated the life and work of Irving Lavin with an all-day event that began with a series of scholarly discussions in the morning, followed in the afternoon by personal remembrances by Horst Bedekamp, Professor of Art History, Humboldt University; Nicola Courtright, Professor of Art History, Amherst College; Jack Freiberg, Professor of Italian Renaissance Art & Architecture, Florida State University; architect Frank Gehry; architect Phyllis Lambert; David Levine, Professor of Art History, Southern Connecticut State University; and art historian Charles Scribner III. A recording of the event is available at www.ias.edu/ideas/lavin-remembrance.