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APS NEWS

A PUBLICATION OF THE AMERICAN PHYSICAL SOCIETY

GOVERNMENT AFFAIRS

APS Members Honored for Outstanding Science Policy Advocacy

BY TAWANDA W. JOHNSON

Every year, APS honors a select group of members with the 5 Sigma Physicist Award for performing outstanding advocacy that is crucial to maintaining the strength of the U.S. scientific enterprise. And throughout 2018, the awardees partnered with the APS Office of Government Affairs (OGA) to write op-eds and participate in meetings that helped advance the Society's policy goals.

"It is terrific that APS can recognize individual efforts to advocate for science, but of course such work is done in strong collaboration with OGA, as well as other APS members and leadership, so the recognition is shared praise for teamwork," said APS Physics Policy Committee Chair Roger Falcone, a physics professor at the University of California in Berkeley and 2018 APS President.

Falcone received the 5 Sigma Physicist Award for his work with OGA in leading dozens of meetings with congressional staffers and executive branch officials on the topics of scientific mobility and education policy.

Regarding the importance of science policy, Falcone said, "science policy, like other issues that the government deals with, are generally much more complex than most of us first imagine, so we need to provide the relevant data to help decision making."

2017 APS President Laura Greene, who also led numerous meetings with congressional staffers and executive branch officials, said she was "speechless" when she received the award and mentioned that "it was really the complementary skills of Roger and me, working with the APS OGA, that set the standard."

Greene, who is a physics professor at Florida State University and chief scientist at the National High Magnetic Field Laboratory, added, "Science policy advocacy is crucial. We need to help our politicians (and the public) understand the great benefit fundamental and applied science brings to society, and our nation."

Justin Powell, a graduate teaching assistant at the University of Tennessee, Knoxville, and Shua Sanchez, a PhD candidate at the University of Washington, both authored key op-eds that were part of a nationwide campaign by the APS OGA concerning student loans. The effort successfully killed a federal legislative proposal that would have eliminated loan provisions that are crucial to physics undergraduates and graduate students.

"I am honored to be recognized by APS," Powell said. "There is an ever-growing need for scientists to be a part of the conversation in policy decisions. If we don't advocate for policies that help

ADVOCACY CONTINUED ON PAGE 6

EDUCATION AND DIVERSITY

Second Group of PhysTEC Fellows Chosen

BY THOMAS HONE

The Physics Teacher Education Coalition (PhysTEC) has selected its second cohort of PhysTEC Fellows. Teams from five different institutions were recognized as Fellows and will receive support to build and enhance high school physics teacher education programs. The PhysTEC Fellows come from Bridgewater State University (BSU), Clemson University, Colgate University, The University of Texas Rio Grande Valley (UTRGV), and the University of Washington Bothell. Each of these institutions showcased a strong desire to grow and improve their physics education programs and provided compelling plans to do so.

The PhysTEC project will support the implementation of planned activities at these institutions as part of a larger effort to combat a shortage of qualified physics teachers. PhysTEC will offer tools and strategies to improve their programs, recognition from APS and AAPT to help build institutional support, connections with national leaders in physics teacher education, and advice on external resources to support physics teacher preparation activities. Fellows will also receive travel support to attend the national PhysTEC conference in 2020 and 2021 and will participate in video conferences to exchange ideas and updates with the entire cohort.

FELLOWS CONTINUED ON PAGE 7

APRIL MEETING

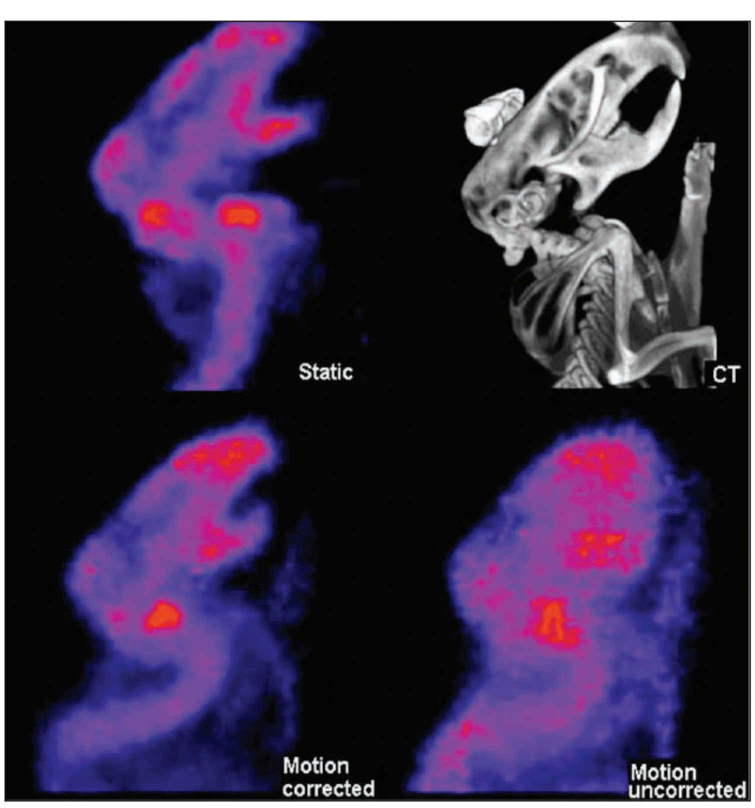
Better Biological Imaging with Nuclear Physics

BY LEAH POFFENBERGER

Physics has long been a contributor to medical imaging, dating back to the discovery and use of x-rays in 1895. And thanks to nuclear medicine, physics continues to play a role in improving how we are able to see inside the human body.

Paul Lecoq (CERN) and Andrew Weisenberger (Thomas Jefferson National Accelerator Laboratory) presented new ideas for detectors in medical imaging at the 2019 APS April Meeting, as part of the first session sponsored by the APS Topical Group on Medical Physics (GMED). Lecoq proposed a method of increasing positron emission tomography (PET) scan sensitivity by improving timing resolution, and Weisenberger discussed a number of projects at Jefferson Lab exploring new uses for radioisotopic imaging.

Imaging with radioactive nuclear isotopes is a valuable diagnostics technique, often used to detect cancer and investigate organ function. These isotopes, radioactive versions of compounds involved in metabolic processes, are injected into the body and concentrate in tumors or organs of interest. PET scans measure gamma ray photons that are produced when positrons emitted by the isotope collide and annihilate electrons in tissue. Because the compounds are chosen to bind to specific biomolecules, the bright 3D gamma ray images indicate biological activity.



Single-photon emission CT scans of an awake mouse in motion: (clockwise from top left) static image, conventional CT scan, smeared image of mouse in motion, and motion-corrected image. IMAGE: JEFFERSON LAB

Lecoq is on a quest to further improve PET scanners as part of a team at CERN developing technology that would increase scan sensitivity by a factor of 200. A

BIOIMAGING CONTINUED ON PAGE 5

COMPASS Points to Effective Mentoring Practices

BY LEAH POFFENBERGER

From April 25 to 27, physics and chemistry faculty came together for a workshop aimed at improving career mentoring for students in the physical sciences. APS, the American Chemical Society (ACS), and the Research Corporation for Science Advancement (RCSA)'s Cottrell Scholars Collaborative joined forces for the event, hosted at the American Center for Physics (ACP) in College Park, Maryland.

The Career and Occupational Mentoring for the Professional Advancement of Science Students (COMPASS) Faculty Workshop paired up 30 early to mid-career faculty members from institutions around the country. In 10 sessions over three days attendees received guidance on career mentoring, promoting professional development, and changing departmental culture at their respective institutions.

Crystal Bailey, APS Head of Career Programs, spoke at the first session about the importance of being an effective career mentor. She emphasized the need for mentors to consider industry options when guiding students towards future careers. Physics education researcher and Rutgers University professor Geraldine Cochran presented on culturally-aware mentoring to address equity and inclusion within the physical sciences.

Other speakers and the participating Cottrell Scholars at the COMPASS workshop (sites.trinity.edu/compass/2019-workshop) challenged attendees to research the current professional development opportunities available to their students and create a plan to improve these programs at their respective universities.

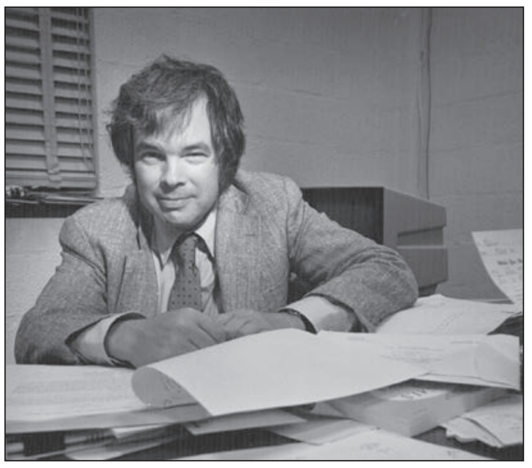
APS and ACS provided logistics support to the conference by finding expert speakers, while APS hosted the workshop at ACP and funding came from RCSA. The workshop was an effort organized by the Cottrell Scholar Collaborative, a program instituted by RCSA for early career faculty members in chemistry, physics, and astronomy to promote innovation in teaching at a university level.

Physics and chemistry faculty met at the American Center for Physics to attend a COMPASS workshop on mentoring.

THIS MONTH IN

Physics History

June 15, 2013: Death of Kenneth Wilson



Kenneth Geddes Wilson

Phase transitions can be found in almost every aspect of our daily lives, perhaps something as simple as ice melting or water boiling. But physicists had long puzzled over how to calculate the behavior of a system at the critical point in detail until a man named Kenneth Geddes Wilson created a powerful general theory that could do just that.

Born on June 8, 1936, Wilson was the son of a prominent Harvard University chemist, E. Bright Wilson. His mother Emily had studied physics before her marriage. A precocious child, especially in mathematics, the young Wilson used to compute cube roots while waiting for the school bus. He was bored by his high school classes and skipped several grades, entering Harvard College at 16. He majored in math, became a collegiate track and field athlete, and worked at the Woods Hole Oceanographic Institution during the summers. Legend has it that he proved one of Freeman Dyson's conjectures while waiting around for a computer to finish processing.

Wilson attended Caltech for his graduate studies, opting to switch his focus from math to physics because of its connection to the real world. His father recommended he approach either Richard Feynman or Murray Gell-Mann as a thesis advisor, and Gell-Mann's work with Francis Low in 1951 on a mathematical tool known as the renormalization group appealed to Wilson. He completed his PhD in 1961 and was a postdoc at Harvard and at CERN before he joined the faculty of Cornell University in 1963, where he remained for most of his physics career. (His brother David, a molecular biologist, was also a Cornell faculty member.)

His wife, Alison—whom he met while folk dancing—once observed that Wilson was "the most lacking in small talk of anyone I ever met." He wanted his words to count. His early publications were also sparse, because of the difficult nature of the problems he chose to wrestle with. He wanted to develop tools that could be applied broadly to entire classes of problems. "My very strong desire to work in quantum field theory did not seem likely to lead to quick publications," he wrote in his Nobel autobiography. "But I had already found out that I seemed to be able to get jobs even if I didn't publish anything so I did not worry about publish or perish."

Wilson's experience with the renormalization group as a graduate student ended up having a profound influence on his work with phase transitions and critical points. The variation of the fundamental properties of particles and forces depended on the scale over which they were measured, and Wilson realized that this scaling was also crucial for phase transitions. He showed that it was possible to divide the problem up into many smaller, simpler pieces, making it possible to describe was happening at the critical point of a system one scale at a time. He received the 1982 Nobel Prize in physics for this work, with the deceptively simple citation, "for his theory for critical phenomena in connection with phase transitions."

He applied a similar approach to his work on the relatively new discipline of quantum field theory, which was plagued by mathematical infinities at the time. His new technique resolved those issues. His ideas were also crucial to the development of quantum chromodynamics, notably his invention of lattice gauge theory, imaging space as an interconnected lattice of bars, in which every intersection represents a point in spacetime.

According to Paul Ginsparg, who was mentored by Wilson at Cornell, Wilson was far ahead of his physics colleagues when it came to computing and networks, largely out of frustration. "After inventing lattice gauge theory in 1974, he found he didn't have adequate computing power to solve the theory numerically, so he wanted easy ways to use large numbers of parallel processors," Ginsparg wrote in a memoir. Wilson was involved with the building of five national scientific supercomputing centers by the National Science Foundation. In 1985, Cornell named him as director for its new Center for Theory and Simulation in Science and Engineering (now known as the Cornell Theory Center).

Late in his career, he and Alison moved to Ohio State University, where she had been hired to run its supercomputer center. (Wilson joked that he was the "spousal hire.") There, he turned his efforts toward improving education. He was an early champion of the "active involvement" approach to K-12 science and math education, focusing on science by inquiry. "If you want to have an impact on science literacy, you need to rivet your attention on the 46 million students in our public schools, not on graduate students in our universities," he once said. "And you need to understand the challenges confronting K-12 teachers." Wilson

WILSON CONTINUED ON PAGE 3

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John Hopfield and Eli Yablonovitch Named Benjamin Franklin Medalists

BY DAVID VOSS

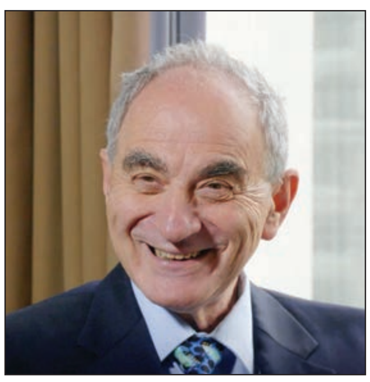
At a ceremony on April 11, former APS President John J. Hopfield (Princeton University) and APS Fellow Eli Yablonovitch (University of California Berkeley) were honored as 2019 Benjamin Franklin Medal awardees. Awarded by The Franklin Institute, the Benjamin Franklin Medal seeks to recognize excellence in science and technology.

Hopfield, professor of molecular biology at Princeton, began his scientific career as a physicist, obtaining his bachelor's degree at Swarthmore in 1954 and his PhD in solid-state physics at Cornell University in 1958. He joined Bell Labs after completing his doctoral work, and while there, his attention turned to biology. In the 1970s he worked on error correction in genetics, and in the 1980s began researching neural networks and storage of memory in the brain. Hopfield served as President of APS in 2006.

His medal citation reads "For applying concepts of theoretical physics to provide new insights on important biological questions in a variety of areas, including neuroscience and genetics, with significant impact on machine learning, an area of computer science."

Yablonovitch, professor of electrical engineering at Berkeley, is widely known for his work in optics and lasers. He obtained his Bachelor of Science from McGill University in Montreal in 1967 and his PhD at Harvard in 1972. While at Bell Laboratories in the 1970s, he was a pioneer in the field of photonic crystals—structured materials that exhibit photonic bandgaps. In addition, he has made a number of key contributions in solar cell and semiconductor laser research.

John J. Hopfield



Eli Yablonovitc

Yablonovitch has also co-founded a number of companies in optical technology and was named an APS fellow in 1990.

His medal citation reads "For widely-used scientific improvements to radio- and light-based technologies in wireless communications and solar energy applications."

The latest awards were announced in December 2018 by The Franklin Institute in Philadelphia, which began awarding the Franklin Medal in 1915, renamed the Benjamin Franklin Medal in 1998.

For more on the awards, visit fi.edu/awards.

WILSON CONTINUED FROM PAGE 2

died on Jun 15, 2013, just one week after turning 77, from complications associated with lymphoma.

"Wilson's great legacy is that we now regard nearly every quantum field theory as an effective field theory," Caltech physicist John Preskill wrote when news broke of Wilson's passing. "We don't demand or expect that the theory will continue working at arbitrarily short distances. At some stage it will break down and be replaced by a more fundamental description. More than anyone else, we have Ken Wilson to thank for this indispensable wisdom. Few ideas have changed physics so much."

Further Reading:

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APRIL MEETING

What Next for Gravitational Wave Detection?

BY SOPHIA CHEN

Since the day humans first directly detected a gravitational wave—September 14, 2015—Nobel Prizes have been doled out, the Laser Interferometer Gravitational-Wave Observatory (LIGO) researchers have upgraded their detectors twice, and they've confirmed ten more detections.

The first generation of post-detection physicists has also arrived. "I joined LIGO right after the first discovery," says Maya Fishbach, a fourth-year graduate student from the University of Chicago, who presented her research at the APS April Meeting in Denver this year.

She remembers another landmark moment—the first signals from a neutron star merger in August 2017—when she was "still a baby grad student." This event was the first in which electromagnetic observations from radio wavelengths to gamma rays all came together to herald the new era of multi-messenger astronomy. Now, researchers can observe electromagnetic and gravitational waves in tandem to study astrophysical events in richer detail than ever before [see *Physics* **10**, 114 (2017)].

Coordinating largely online, the thousand-person collaboration sprinted to publish around a dozen papers in the month following the neutron star merger. "It's really exciting, but also really exhausting to work with so many people," says Fishbach. "I feel like I've aged so much."

Future facilities will include KAGRA (Kamioka Gravitational Wave Detector) in Japan, designed to be the first underground gravitational wave observatory. IMAGE: ICRR UNIVERSITY OF TOKYO

LIGO, working with its European counterpart, Virgo, has kept up the pace of detection, analysis, and scientific debate. The collaboration turned on their three gravitational wave observatories for a third observing run on April 1. Prior to this, they'd improved the sensitivity of their detectors—one in Livingston, Louisiana, one in Hanford, Washington, and one near Pisa, Italy—by 40 percent. By May 23, the detectors had already registered 13 more candidate signals. They are currently confirming the signals and preparing for more detections in a year-long observing run.

The confirmed detections so far: 10 gravitational waves from binary black hole mergers and one gravitational wave from a binary neutron star merger. The candidate signals include 10 possible black hole mergers, two neutron star mergers,

LIGO CONTINUED ON PAGE 7

MARCH MEETING

Cell-sized Robots Start to Explore the Microscopic World

BY LEAH POFFENBERGER

Robots have been created to explore the remote and harsh environments of the deep sea and the surface of Mars. Now, Marc Miskin and his colleagues at Cornell have developed tiny robots that can explore new environments closer to home, including the human body, at the fundamental scale of biology—the cell.

These cell-sized robots at their largest are the width of a human hair but come equipped with an arsenal of microelectronics for moving around and sensing their environment—and each one costs less than a cent. Miskin, now an associate professor at the University of Pennsylvania, presented results of his post-doctoral research involving the creation of these tiny tools at the 2019 APS March Meeting in Boston.

"There's this alien, bizarre universe that we know exists in drops of water and blood and all over, but we can't participate in it—we have to just watch it," said Miskin. "What I love about this research is that we are building things can now go into that world, explore, perform tasks, move things around, and you can do this with precision that is accorded to you by robotics."

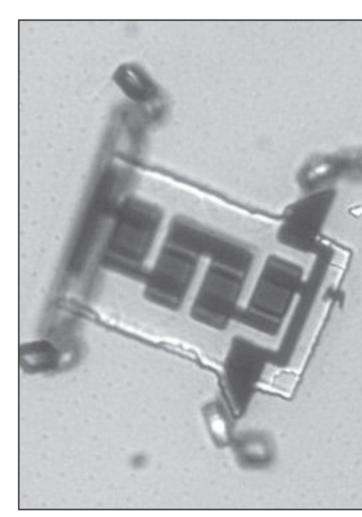
Miskin's microbots incorporate photovoltaics for power and can move around thanks to nanometer-thick legs built into the body that activate in response to laser light. The legs are small in comparison to the size of the robotic body, but the bots can scoot an impressive distance: The longest recorded excursion—the length of a microscope slide—is the equivalent of a person walking 10 kilometers. Future versions will harbor silicon sensors for projects like mapping the brain or delivering drugs inside the body.

Fortunately, manufacturing each robot doesn't require a microscopic assembly line: Using nanofabrication techniques, the components for the robots are etched onto a 4-inch silicon wafer. One wafer can yield up to a million individual robots.

"They cost less than a cent each, so unlike a macroscopic robot, these robots are disposable," says Miskin. "They're like medicine or like microorganisms. You can throw any individual robot away. And most importantly, all of this functionality is not at some arbitrary length scale, but at the fundamental size of biology, the size of the cell."

Thanks to their small size and tough constitutions, these robots are incredibly robust, allowing them to be injected into new and sometimes corrosive environments—including the body. Miskin is currently working on providing these robots with ways to sense their environment, like voltmeters and thermometers, and ways for the robots to report back information about their world.

"One of the applications we like most is neural recording and recording what's going on inside the body," said Miskin. "Let's say you want to measure what's going on with someone's spinal cord—you don't want to be poking around in there. It might be nicer to inject robots in your body and have them crawl over to that location."



Robots no bigger than a biological cell are taking baby steps. IMAGE: MARC MISKIN

Figuring out how to control these tiny robots inside the body is still a challenge, since the robots are powered by light. If the robots are more than a millimeter deep in tissue, they lose their power source. As a result, Miskin and his colleagues are working on alternative methods of powering the robots, such as magnetic fields.

These robots could have other uses outside of biology too: Miskin is also interested in seeing how these robots could be used in conjunction with chemistry and material growth. Another of his colleagues is working on ways to use these tiny robots to scrub out poisons from lithum ion batteries to extend battery life.

"The big advantage here is if they're manufacturable and they're cheap, they're like a chemical," said Miskin. "And then you can start to treat them that way and really push the edge of the envelope."

LETTERS

Members may submit letters to letters@aps.org. APS reserves the right to select letters and edit for length and clarity.

Harassment in Physics

Blatant sexism in any professional area does expose an unhappy deficiency in the human condition. Although scientists are mere mortals, we in the APS should expect a higher ethical standard from our members. I can only hope that the small statistical sample presented in the April 2019 *Back Page* feature is an aberration and not the norm.

As a PhD student and through a long career as a national laboratory scientist, I personally saw many contrary and very constructive examples. Hopefully, subsequent articles will expose the more positive interactions that current and future female scientists had with their mentors.

Robert G. Lanier
Danville, California

The author of "Yes, Sexual Harassment Still Drives Women Out of Physics" (*APS News*, May 2019) presents a convincing case that the pervasiveness and inappropriateness of harassment of women is a blight on our profession, and needs to be addressed more seriously. Of the three types of this unwelcome behavior cited in the study, the first—"*sexist* gender harassment," including disparaging remarks such as, "Women cannot do physics"—was mentioned by 91.3% of women reporting some form of sexual harassment.

This being the largest complaint by far, compels me to give an example that may subject that 91.3% figure to reconsideration. When I was graduate student, my male nuclear physics professor in the privacy of his office said to me, "In pursuing a career in physics, you are deluding yourself." Pretty heavy stuff!

But not sexist. I am male, always have been—and a white male, at that. The prof just didn't like me. I completed his class, but chose for a thesis advisor a different professor who saw promise in me. Years later, I received from the APS the Tom W. Bonner Prize for "outstanding experimental research in nuclear physics."

So there is likely a component of that 91.3% that has naught to do with sexism. If you are a woman experiencing such treatment, consider that possibility. In any case, don't let it derail your plans. If you know in your bones that physics is your destiny, make it so.

Michael Moe
Rancho Santa Fe, California

Thank you for publishing the April 2019 Back Page article "Impressions from the DNP Fall Meeting." I know APS could be concerned about publishing these sorts of negative reports, but I think the benefit of articles like this is quite substantial. I'm not a member of DNP but I can easily imagine this sort of behavior happens at the APS meetings I attend; and I hope that raising the awareness of these issues will result in improvements over the long term. So again, thank you for the courage to publish this.

Eric Weeks
Atlanta, Georgia

FYI: SCIENCE POLICY NEWS FROM AIP

Congress Bolstering Its Access to S&T Expertise

BY JONATHAN BEHRENS

Congress has faced increasing pressure, from inside and out, to improve its ability to act on matters in which science and technology (S&T) play a critical role. To meet the demand, the House Appropriations Committee recently advanced legislation that would provide $6 million to reestablish the Office of Technology Assessment (OTA), a research group that provided S&T advice to Congress before it was defunded in 1995.

Meanwhile, the Government Accountability Office (GAO) is currently increasing its S&T analysis capabilities in response to separate legislation enacted last year. That legislation also asked the Congressional Research Service (CRS) to commission a study of other ways Congress could augment its advice channels, including by reestablishing OTA.

While the CRS study has not yet been released, the new legislation reflects the conviction of some House Democrats that the further step of restoring OTA is warranted. Whether the Republican-controlled Senate will support the proposal remains to be seen.

GAO expanding S&T assessment team

Following the dissolution of OTA, GAO became a newly important source of S&T advice to Congress and has undertaken technology assessments in addition to its usual audits of federal S&T programs.

Earlier this year, GAO created a new Science, Technology Assessment, and Analytics (STAA) team that consolidated its S&T-related activities, and last month it released a plan for expanding the unit. GAO intends to increase the STAA staff from 49 to 70 by this October and have up to 140 employees in subsequent years, depending on the level of demand from Congress.

The head of GAO, Gene Dodaro, has said expanding the STAA team is a high priority for the agency. Acknowledging the options before Congress at a recent budget hearing, he remarked, "I know there's been a debate in the past about whether to reinstate OTA or provide more resources to GAO. I'm here to assure you that we're prepared, if you decide to go that way, to handle those additional responsibilities."

OTA advocates seek 'anticipatory' advice

Congress established OTA in 1974 to serve as a source of nonpartisan S&T expertise. The office had about 150 staff and an annual budget of

S&T CONTINUED ON PAGE 6

Goldwater Foundation Names its 2019 Scholars

BY PHOEBE SHARP

The Goldwater Scholarship was established in 1986 to honor the late Senator Barry Goldwater (R-AZ), who served the United States for 56 years in the military and the Senate. Since 1989, the Goldwater Foundation has awarded 8,628 scholarships to promising college sophomores and juniors for a grand total of $68 million invested in these individuals' futures.

To be a Goldwater Scholar, a student must be ranked among the best and brightest future scientists. All are ambitious and determined, and their research is expected to have a lasting impact in the scientific community.

This year, 496 scholarships were given to college students nominated by 443 academic institutions in all fields. Most of these students are majoring in natural science, together with 74 engineering majors and 62 mathematics and computer science majors. This year, the Foundation chose 84 awardees in physics and astronomy.

Receiving a Goldwater Scholarship shows these students' commitment to research and leadership in their fields. The scholarship application requires excellent written communication skills, many hours of effort, and diverse scientific research experiences. Three of the individuals awarded this prestigious scholarship are featured below.

Haley Bowden

Jonathan Lu

Chris Moore

Haley Bowden

Haley Bowden, a junior at the University of California-Santa Barbara (UCSB), learned about the Goldwater Scholarship through the encouragement of her academic advisor, Sathya Guruswamy.

Since high school, Bowden has known physics was her passion. Participating in the Science Olympiad for K-12 students, she enjoyed the physics portion of the competitions so much she would study the subject even after the event.

Given her background, Bowden had no trouble completing the research portion of the Goldwater application. Involved in research for most of her summers, she participated in Eureka, a program at the Center for Science and Engineering Partnership at the University of California, Santa Barbara. She went on to UC LEADS, a network for students that offered mentoring from UC professors as well as paid summer research experiences. From there, Bowden landed in Guruswamy's group.

Bowden credits her support network for her success. Her mom, a woman in STEM herself, encouraged her to "embrace math and science." Her professors and department pushed her to explore a variety of physics topics.

This is not the first year Bowden applied to the Goldwater, however. Her most important advice was to ask professors to provide feedback when preparing the application. Reactions from those not in physics can be beneficial as well, since the technical aspects of the application need to be understood by those in other fields. She had a better understanding of how to improve her application in the second try, and it paid off.

Nick Alward-Saxon is a staff member at UCSB who helps students applying to national awards and coordinates their nominations. "Haley's application stood out both in that her project PI had given her significant independence as a member of the research team and that she had thrived in that context and achieved results," he said.

Alward-Saxon added that three important points of a Goldwater application are independence in research, development and use of problem-solving skills in addressing challenges, and an ability to think creatively and investigate alternative approaches.

Bowden looks forward to conducting research on galaxy formation in her doctoral work and continuing on to academia.

SCHOLARS CONTINUED ON PAGE 5

APRIL MEETING

RMP Celebrates 90th Anniversary at Plenary Session

On April 16, three distinguished researchers spoke at a plenary session marking the 90th anniversary of the founding of the APS journal *Reviews of Modern Physics* (RMP). The session was chaired by RMP Lead Editor Randall Kamien (University of Pennsylvania) and covered advances in laser-based particle accelerators, the search for dark matter, and the astrophysics of black holes.

Wim Leemans (DESY) discussed progress in building a new generation of particle accelerators in which electrons surf on plasma waves created by intense lasers. The technology has the potential for accelerating particles along tens of centimeters to energies that would require conventional accelerators that are hundreds of meters long.

Elena Aprile (Columbia University) reviewed the status of experimental searches for dark matter in underground laboratories. Although there have been no confirmed signs of dark matter to date, the highest sensitivities to date have been achieved with direct detection schemes based on interactions in large volumes of liquid xenon.

Andrea Ghez (UCLA) talked about the center of the Milky Way, which is known to contain a supermassive black hole thanks to more than a decade of observations with high resolution ground-based telescopes.

Videos of all three presentations are available on the APS YouTube channel: youtube.com/apsphysics.

Wim Leemans

Elena Aprile

Andrea Ghez

SCHOLARS CONTINUED FROM PAGE 4

Jonathan Lu

Jonathan Lu, a sophomore-equivalent at the University of North Texas (UNT), has no shortage of research experience. Starting at the age of 13, Lu began developing his research skills, and he now contributes to three different labs all centered around biophysics and material science.

Lu says he is driven by three goals: expanding his intellect, making practical contributions to human life and health, and exploring his passions. With those aims in mind, Lu hopes to advance the science that supports medicine.

One of his research projects was developing materials to repair broken bones in the lab of Nahendra Dahotre. An important goal was to keep the patient in mind by shortening healing times or reducing pain. Lu's ability to zoom out of the immediate research task at hand to see the bigger picture explains his success when moving between research projects.

William Acree, a chemistry professor at UNT, has worked with Lu on simulating reactions between organic solutes and finding safer solvents for industry. Acree said he was impressed with Lu's research experience. Having published three papers and with others in the works, Lu can, "go from one project to another pretty quickly," without losing sight of his other projects.

For the Goldwater application, Acree said the Foundation wants "to see that the person is a team player and can contribute to society," two characteristics which Lu possesses. Lu struggled with condensing his aspirations into the word limit set by the application, but it helped him more concisely explain his goal. Acree recommends getting a wide variety of research experience when applying to the Goldwater Scholarship.

Lu hopes to get a PhD in biophysics with a concentration in materials science.

Chris Moore

Chris Moore, a physics and astronomy major at the University of Washington (UW), comes to the Goldwater Scholarship with a diverse background. For nine years prior to college, Moore served as a U.S. Navy SEAL. Rising through the ranks to become an instructor, he knew he wanted to study science after his service, and physics was the perfect fit.

Serving in the Navy gave Moore a head-start in many of the skills that physics departments want their students to graduate with: leadership, networking, and ambition.

"Leadership is difficult to foster, and something you have to learn," he said. Coming to UW with well-developed leadership skills naturally led him to the Society of Physics Students (SPS), and eventually to becoming a leader within his SPS chapter.

For networking, Moore credits the Lunchbox Seminars sponsored by SPS for exposing him to cutting edge research in the physics community. This seminar series hosts a wide range of colloquium speakers from all fields of physics. In these settings, students are able to communicate directly with leading scientists, Moore said. He noted that it's also a great opportunity for practicing his elevator pitch, a useful tool when working to "support the intersection of science and policy."

Drive was the third key to Moore's success. Physics majors have to be highly motivated, and receiving a Goldwater Scholarship was a national recognition of Moore's effort. He started in cosmology but moved to condensed matter physics and now studies the dynamics of nitrogen vacancy centers in diamond. Moore is going to an REU (Research Experiences for Undergraduates) program at MIT this summer.

When considering his next steps after the Navy, he knew he wanted to "continue having a positive impact." Moore plans to get a PhD in condensed matter physics.

The author is the Education and Diversity Programs Coordinator at APS.

BIOIMAGING CONTINUED FROM PAGE 1

more sensitive scan produces a better image, but also improves the practicality and applications of the PET scan; greater sensitivity means a patient can be subjected to a lower dose of radiation, which allows more frequent, more comprehensive, or much gentler scans.

"PET is the imaging modality that has the highest sensitivity, however there are a number of medical challenges that we have to face which require further increasing the PET sensitivity," said Lecoq at a press conference at the meeting. "There is more and more need for the ability to track a smaller number of cells, especially in the study of stem cells, and most importantly to allow a reduction of the dose in PET scans, which opens PET scans to new categories of patients including pregnant women, children, and even fetuses."

To reach this improved sensitivity involves improving the timing resolution—the PET scan equivalent to increasing the shutter speed on a camera, leading to crisper images. When a photon pair is emitted during a scan, each traveling in opposite directions, they reach the detectors at roughly the same time, but the tiny differences in their times of flight hold information about where they were emitted. Current state of the art PET scans have time-of-flight (TOF) resolutions around 200 picoseconds, but Lecoq is part of an ambitious effort to achieve a 10 picosecond TOFPET scanner. Creating new metamaterials to act as improved scintillators in a PET scan would be a big step towards reaching this goal.

"We believe that this 10 picosecond target will be achievable because of a number of emerging technologies in order to speed up this process. [CERN] decided to set up a challenge, the so-called 10 picosecond challenge," said Lecoq. "The idea is to have the maximum number of people working in this field, in order to speed up this development and to eventually reach this very ambitious target of 10 picoseconds…Our idea is to make possible the impossible."

Weisenberger, a leader of the nuclear research group at Jefferson Lab, shared new ways radioisotopic imaging can be harnessed. Researchers at Jefferson Lab have created new ways to use PET and SPECT (single photo emission computed tomography) for imaging plants, unanesthetized animals, and tumors during surgery and improving mammography.

"We take a radioisotope and it's attached to a molecule that has some feature or some function within the body, which is the biological function of interest—these tiny molecules can be injected in vivo into biological systems such as people, animals, plants or microbes," said Weisenberger. "It's very similar to what biologists have been doing for years with looking at features on a cell…we're using radioisotopes like a stain to make visible features in the body that we're interested in following."

In collaboration with Duke University, Weisenberger's group at Jefferson Lab has developed a plant imaging technique they call PhytoPET that uses a radioisotope of carbon dioxide to visualize photosynthesis in a live plant. They have also worked with Johns Hopkins University to develop a method of imaging unanesthetized live animals in motion with SPECT, which is important in studies wherein anesthesia may impact the results.

"We came up with a method in which you can track the motion of the mouse, and then use that information to computationally reconstruct what the uptake distribution [of a radioisotope] looks like," said Weisenberger.

This computational movement correction is also being used in a hand-held gamma ray camera so that surgeons can identify specific locations of tumors or diseased lymph nodes. This device is currently undergoing clinical trials and should prevent unnecessary removal of healthy portions of the lymphatic system.

"In breast cancer surgery, the surgeons are interested in which lymph glands are involved in the tumor that's in the breast—the whole lymphatic system is your second circulatory system," said Weisenberger. "In the past they used to remove all the glands that are near [the tumor], but that was certainly overkill. By using a radioisotope, they're actually able to figure out where it actually will be absorbed into the lymph nodes."

Weisenberger's group has also worked on developing a compact camera for breast imaging that can provide a detailed scan of even very dense breast tissue using a new type of collimator made up of tungsten plates that slide to provide precise direction of gamma rays.

"Just doing basic nuclear physics research creates an environment in which we can then look for other applications and discoveries that are uses just outside of nuclear physics," said Weisenberger.

ADVOCACY CONTINUED FROM PAGE 1

support the next generation of science students and researchers, then we can't expect our fields to grow and flourish. Organizations like APS are instrumental in providing a platform for scientists to be heard."

"I am proud that I was able to work with other physicists to encourage our government to make smart investments in graduate education," Sanchez said. "The scientific advancements made by academic research is dependent on a government that values science and scientists, and it's important that we get out of our labs once in a while to meet with our representatives and make positive change in society."

Don Q. Lamb, professor emeritus in the Department of Astronomy and Astrophysics at the University of Chicago, wrote about the importance of making the F-1 visa "dual intent," enabling international students to simultaneously study and apply for citizenship in the United States.

"I was surprised and honored to receive the award. Receiving it means a great deal because addressing important issues that involve science is something I care deeply about. Members of APS and the APS Office of Government Affairs make a great team in advocating for policies the APS thinks are important."

Scientists have an important role to play in advocating on science policy issues, explained Lamb.

"The challenges involving science that the U.S. and the world face seem greater than ever. Scientists have a special understanding of these challenges. I feel we, therefore, have a responsibility to share our knowledge and our judgment about policies and address them with the public and key decision makers."

Sarit Dhar, associate professor of physics at Auburn University, also wrote an op-ed on the F-1 visa issue.

"I am extremely delighted and honored," he said about receiving the 5 Sigma Physicist Award.

On the importance of science policy advocacy, he said, "I believe having formal pathways for dialogue between the science community and policymakers is crucially important for prioritizing resource allocation and directions

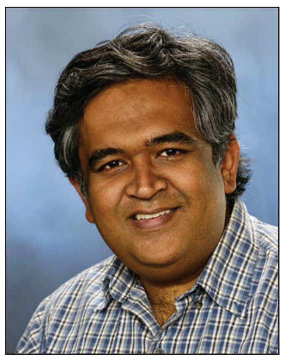

Roger Falcone


Laura Greene


Justin Powell


Shua Sanchez


Don Q. Lamb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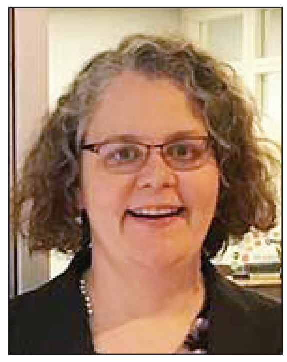

Kristan Corwin


Julia Phillips


Eliot Kapit


Ivan Deutsch

of science and technology research to meet the demands of the socio-economic and security needs of our country's future."

Kristan Corwin, former physics professor at Kansas State University, was elated to be honored for her advocacy roles as a participant in the APS Congressional Visits Day and author of an op-ed on the link between science and the workforce.

"I very much enjoyed my visit to Capitol Hill with fellow physicists to explain the importance of certain key issues to the offices of both my senators and my congressman at the time. The conversations were both challenging and stimulating, and I would encourage others to participate in Capitol Hill visits," she said. "Afterward, I prepared an op-ed on the importance of educating new scientists from a young age, and I very much appreciate the help and support I was given by my colleagues at Kansas State University and APS in navigating that process."

Corwin added, "I have recently become a federal employee, with less opportunity for advocacy. However, I encourage APS members to contact their elected representatives and take advantage of the opportunities for advocacy available to them."

Julia Phillips, retired vice president and chief technology officer at Sandia National Laboratories, was a co-author of an op-ed outlining recommendations in the report, "Neutrons for the Nation," a study by the APS Panel on Public Affairs. In addition, she participated in key meetings to promote the report.

"I was so surprised and honored," said Phillips. "I do things because I think they are important, and the recognition is an unexpected but much-appreciated bonus."

As for why Phillips believes advocacy is important, she said: "Neal Lane, President Clinton's science advisor, spoke frequently and eloquently about the need for all of us to be 'citizen scientists.' By that, he meant that we all need to engage with the public and policymakers in constructive ways – both talking about our work and its importance, and really listening to hear the questions and concerns of those who come from different backgrounds. Neal's call to action really resonated with me, and I have long tried to engage with policymakers and the public to explain what my colleagues and I do, and why they should care about it. Engaging with non-scientists is a great opportunity to think about what we all do in a new way and to share the beauty, excitement and impact of our work."

Eliot Kapit, associate professor at the Colorado School of Mines, met with the science staffer from the office of Senator Cory Gardner (R-CO) to ensure that key language was included in the National Quantum Initiative Act (NQI), which was signed into law by President Trump last year.

"I'm very honored to receive the award! I was happy to help the APS work with Senator Gardner's office (which was very receptive and helpful) to ensure that the National Quantum Initiative Act was properly structured to best fund quantum technology research without cutting support for other areas," said Kapit.

He added, "I think science policy advocacy is vital, because, almost definitionally, new research is strange and complex, and its purpose and importance are generally not at all obvious to people without advanced degrees or training. So, if we as physicists don't make the effort to explain in plain English what we're doing and why it's interesting and valuable, then we can't expect anyone to care, much less want to support our work."

Ivan Deutsch, a physics and astronomy professor at the University of New Mexico, also played a role in ensuring that the language in the NQI was appropriate by meeting with staffers in the office of Senator Tom Udall (D-NM).

"Honestly, it was an amazing surprise. I never expected that the small part I played in working with the American Physical Society to get the National Quantum Initiative 'right' would be directly recognized. I was doing what I thought was necessary to ensure that the NQI would best benefit all of the physics community. I know that there are many others who have been tireless in their efforts and to whom we owe a debt of gratitude."

Science policy is important, he added, because "as we all see, science is becoming increasingly politicized. Only scientists can provide the necessary perspective to policymakers to ensure that key goals of discovery and innovation are carried out in a way that benefits all of society."

Francis Slakey, APS chief government affairs officer, said the award recipients were excellent partners with APS OGA in advocating for key science policy issues.

"The 5 Sigma Physicist awardees are representative of the best in science, and we are thankful that they volunteered their time and expertise to advance science policy goals. We congratulate them on a job well done and look forward to working with them and many other APS members in the future," said Slakey.

The author is APS Senior Press Secretary.

S&T CONTINUED FROM PAGE 4

$22 million when it was defunded in 1995 as part of the new Republican majority's broad spending cuts. At its height, OTA released around 50 reports annually on a variety of topics, such as the effectiveness of energy research programs, the feasibility of President Reagan's missile defense initiative, and policy options for addressing climate change.

The latest efforts in the House to revive OTA build on two decades of attempts. In the 2000s, Rep. Rush Holt (D-NJ), a physicist who now heads the American Association for the Advancement of Science, was a leading advocate for restoring the office. Since then, Rep. Bill Foster (D-IL), another physicist, has picked up the mantle and recently partnered with Rep. Mark Takano (D-CA) to build support.

In an op-ed on May 1, Takano and freshman Rep. Sean Casten (D-IL) laid out a new case for OTA, arguing that neither GAO nor CRS could fill OTA's shoes. "In the ecosystem of congressional support agencies CRS summarizes, GAO evaluates, and the OTA anticipates," they wrote.

Budget documentation released by the House Appropriations Committee echoes the sentiment that OTA would play a unique role. It states, "Congress does not have adequate resources available for the in-depth, high level analysis of fast-breaking technology developments and their public policy implications that was formerly provided by OTA. While the GAO has increased its technology assessment activities attempting to fill that gap, the structure and culture of GAO somewhat constrain its ability to replicate OTA."

The author is a Science Policy Analyst with FYI.

FYI has been a trusted source of science policy and funding news since 1989, and is read by members of Congress and their staff, federal agency heads, journalists, and US scientific leaders. Sign up for free FYI emails at aip.org/fyi.

FELLOWS CONTINUED FROM PAGE 1

BSU has a legacy of being a teacher's college, which has helped them to become the largest producer of teachers in Massachusetts, graduating over 400 students that enter the teaching profession each year. Most recently, the undergraduate science programs were revised due to receiving the NSF STEP grant, which seeks to increase the number of students receiving degrees in STEM fields. PhysTEC Fellows Jeff Williams, Allison Daubert, Tom King, and Steve Krajeski want to couple this initiative with PhysTEC to increase interest in STEM education and in physics teaching education at BSU by exploring new avenues of collaboration between departments and the use of learning assistants as peer tutors for their introductory physics courses.

A key mission of Clemson University is to engage its students in teaching and public service. PhysTEC Fellows Sean Brittain and Chad Sosolik look to use this commitment and the strength of Clemson being a flagship institution in the state with a stable, growing number of physics majors to further align the Department of Physics and Astronomy with teacher education. They will do this by implementing a learning assistant program. These learning assistants will be used to facilitate small group discussion, guide work in lab sections and facilitate group discussion during lectures. In addition, Brittain and Sosolik will continue to look for ways to utilize Clemson's existing connections with neighboring South Carolina school districts.

In recent years, the Department of Physics and Astronomy at Colgate University has experienced strong growth, nearly doubling the average number of graduates. PhysTEC Fellows Beth Parks and Meg Gardner look to use this growth to produce physics teachers in the state of New York, where it is projected that by 2022 there will be an overall shortage of 10,000 teachers. With support from their university, Parks and Gardner will create materials to publicize certification opportunities to students in physics and astronomy and work closely with NYS Department of Education to streamline course requirements for these certifications.

UTRGV is a PhysTEC member and a Hispanic-serving institution whose mission statement expresses the goal of creating an environment of student success and community engagement by creating an innovative and accessible educational environment. PhysTEC Fellows Liang Zeng and Nicolas Pereyra will look to harness the ideals of this mission by enhancing the advertisement of physics teaching as a career among physics majors and by collaborating with the University Learning Center Director to implement a learning assistant program.

The University of Washington Bothell is known for its student experience grounded in hands-on learning, close relationships with faculty as teachers and mentors, and personalized support from staff who are dedicated to student success. PhysTEC Fellows Rachel Scherr, Carrie Tzou, Paola Rodriguez Hidalgo, and Joy Shapiro Key hope to leverage these ideals into creating an atmosphere of sustainability for physics teacher education. To accomplish this, they will collaborate with the university in designing a course on teaching physics to meet discipline-specific pedagogy requirements; assist it in obtaining state approval of a teacher certification program; and work with other departments to ensure that state competency requirements are being met.

More about PhysTEC and its special initiatives, including the PhysTEC Fellows program, is available online at phystec.org.

The author is Senior Program Coordinator in the APS Department of Education and Diversity.

LIGO CONTINUED FROM PAGE 3

and one neutron star merging with a black hole. The researchers have moved away from their previous mode of secrecy. They now immediately release public alerts when they pick up interesting signals, which guides their collaborators at conventional telescopes to look for potential accompanying electromagnetic signals. The community has split in two directions: those who work on detection, and those who sift through the data for new astrophysics, says Fishbach.

Working in the second camp, Fishbach uses gravitational wave data to study cosmology. Among the biggest mysteries is the value of the Hubble constant, a number that describes the rate at which the universe is expanding. Cosmologists have calculated the Hubble constant using two independent methods, but the answers disagree by about four standard deviations. One method, using localized measurements of supernovae, has delivered Hubble constant values around 74.03±1.42 kilometers per second per megaparsec, while the other method, based on cosmic microwave background observations, delivers values of around 67.4±0.5.

The LIGO collaboration re-calculated the Hubble constant from the binary neutron star merger data [*Nature* 551, 85 (2017)]. Using data from just that one event, they were able to calculate the Hubble constant to about 15 percent precision. In 2018, Fishbach and two colleagues estimated they can calculate the Hubble constant to a precision of approximately two percent within five years and approximately one percent within a decade [*Nature* 562, 545 (2018)]. At that precision, gravitational waves could offer a third independent method for resolving the conflicting values.

LIGO needed an optical counterpart to the gravitational wave signal to calculate the Hubble constant. However, optical events do not accompany black hole mergers, which are the most commonly detected gravitational wave signals. At the April meeting, Fishbach presented a method to calculate the Hubble constant without optical data, with the intent of applying this method to black hole mergers. In this method, they identify a volume of space where the signal came from and calculate the Hubble constant from all the galaxies in that volume of space. This method isn't as precise as using an optical counterpart, but could be used as a backup plan for calculating the Hubble constant, says Fishbach.

Researchers are also using gravitational waves to better understand black holes. LIGO's detectors are sensitive to stellar mass black holes up to 100 times the mass of the sun—and quite efficient at finding them, too, compared to X-ray telescope efforts since the 1970s. If you count both black holes in each merger, "we're now at the point where we've discovered as many [stellar mass black holes] with gravitational waves as we have with X-rays," says Christopher Berry of Northwestern University.

Studying stellar-mass black holes could help them understand larger black holes, including the behemoth recently imaged by the Event Horizon Telescope, M87, which is 6.5 billion times the mass of the sun (see box below). "One of the biggest questions in astrophysics right now is, where do supermassive black holes come from?" says Berry.

One hypothesis is that they form from small black holes merging together. But astronomers have only observed either black holes five to fifty times the mass of the sun, or supermassive black holes, which are hundreds of thousands to billions of times more massive than the sun. "We've not seen anything in between," says Berry. It's unclear why these intermediate-scale black holes are so rare, or if they even exist. Consequently, it is unclear how a stellar black hole might become supermassive.

The data can also reveal more about the life and death of stars. "I have a colleague who likes to refer to this as black hole paleontology," says Berry. "Just how paleontologists try to figure out how dinosaurs lived by looking at their bones, we're trying to figure out how massive stars lived by looking at their remnants, black holes and neutron stars."

Gravitational waves from black hole mergers can reveal a lot about the objects involved. Theoretically, all you need to know to fully characterize a black hole are its mass, angular momentum, and electric charge. And because physical black holes are all neutrally charged, really all researchers need to find out are its mass and angular momentum.

The gravitational wave signal is particularly helpful in elucidating the black holes' mass, as well as its angular momentum (although with less certainty). Researchers determine the black holes' mass and angular momentum by fitting the gravitational wave to model waveforms.

LIGO and Virgo are hoping for a Japan-based detector, called KAGRA, to join the network before the third observing run ends. LIGO is also planning to build another observatory in India, to turn online in the mid-2020s. Further ahead, the European Space Agency plans to launch the Laser Interferometer Space Antenna (LISA) in 2034, which should detect gravitational waves of low frequencies that are undetectable on Earth due to noise. "I'm definitely excited for the era where we have hundreds of [detections]," says Fishbach. "We'll be able to do so much science."

The author is a freelance science writer based in Tucson, Arizona.

First Black Hole Image: In A Nutshell

BY SOPHIA CHEN

On April 10, 2019, the Event Horizon Telescope collaboration (eventhorizontelescope.org) released the first direct image of a black hole. The picture spread across online and print media, even making it to the front page of *The New York Times*. At the APS April Meeting in Denver, two members of the collaboration, Shep Doeleman (Harvard University) and Avery Broderick (University of Waterloo), sat down with *APS News* to explain their iconic photograph. The following is a summary of the key facts and figures.

Date Recorded: April 2017

Location: The center of the galaxy Messier 87 in the constellation Virgo

Distance: 55 million light years from Earth

Mass: 6.5 billion solar masses

Number of Observing Facilities: Eight observatories on four continents

Number of People Involved: 200+

Wavelength: 1.3 millimeters (230 GHz)

Orientation: The image shows the black hole almost directly face-on: its angular momentum vector points into the page at an angle of 17 degrees, counterclockwise. That is, the black hole rotates in the clockwise direction. The researchers infer its orientation from the position of a jet that appears in X-ray images of the area and from models they have built and tested.

Notable features: The light comes from gas, predominantly hydrogen, which orbits the black hole and emits radio waves. The bright ring of light is the so-called photon orbit, where gravity is so strong that it bends light in closed paths around the black hole. Researchers refer to the boundary between the ring of light and the interior darkness the black hole's shadow. "It's the telltale signature of the event horizon," says Doeleman.

Image Processing: The raw telescope data is missing parts of the image and requires image reconstruction to fill in the gaps. The researchers reconstructed the image in three parallel efforts, says Broderick. One team filled in the missing parts with mathematical algorithms, for example, that assume the image comes from point sources. The two other teams

Portrait of a black hole. IMAGE: EHT

used two different astrophysical models to fill in the missing pixels. They compared the three different images and found that they agreed to a high statistical threshold. Ultimately, this image is a composite of the three efforts.

Why does it look like a donut?

The gas is actually evenly distributed around the black hole. But its emitted light is distorted from gravitational lensing effects. One predominant effect is so-called relativistic beaming, or Doppler boosting, which causes light moving toward Earth to appear brighter and makes the donut brighter on one side.

The author is a freelance writer in Tucson, Arizona.

THE BACK PAGE

The Workshop and the World

BY ROBERT P. CREASE

But it's real for us!
It's real for us!
Doesn't matter what the muggles say,
It's real for us!
—Lauren Fairweather

Four hundred years ago, Francis Bacon had a terrific idea. Let's stop learning about nature accidentally. Each country needs to establish laboratories for people to investigate nature systematically. The labs can collaborate, and countries can use the findings to govern better. This will make human life, and the fortunes of the countries, flourish. Inspired by this vision, various nations began to train and support science, and have now built up what is in effect a global scientific workshop.

What went wrong? In the past few years in particular, more blatantly than ever, politicians and others are confident they can ignore the findings of the workshop.

Lauren Fairweather's song "It's Real for Us" is about how a young person's love for the magical world of Harry Potter helps her cope with a world she finds difficult and alien. Substituting magic for what's real sometimes helps individuals pursue their desires and dreams. Turn this upside down, however, and you get the current science denial worldview of many politicians, though without Fairweather's self-conscious irony. Whether they actually believe in the magical world or are spinning things to get votes does not matter; what matters is that their substitution of myths and cherry-picked or fake facts works for them and their voters.

Denouncing, conducting exposés, and doing epistemology have little effect. *Denouncing* science denial leaves intact the social and political atmosphere that fosters it. *Exposés* are ignorable and can be portrayed as tainted. Conducting *epistemology*, proclaiming something like "Science works!" and showering people with facts and data about how great science is, preaches to the converted and comes off as aloof and abstract. One has to start by understanding what makes the social and political atmosphere in which science denial takes place flourish, and what can be done about it.

"Most people learn more easily through stories than data. *Jaws* and *Enemy of the People*, which expose the all-too-rational calculus of science denial, are good examples. We need twenty-first-century Aesops to tell more dramatic stories of what happens when we wish away sharks."

Some of the features that make science work are that it is a collective enterprise, technical and abstract, fallible, affects nature, can be passed on without reflection, and has social consequences. But these features can also provide a veneer of legitimacy to those who want to deny scientific findings. That it's a collective means it can potentially promote disguised interests and amount to a "hoax." That it's technical and abstract can invite reactions like "I am not a scientist." That it's fallible can appear to make it reasonable to say "The jury is still out." That it affects nature can prompt fears of producing Frankensteins. That its tools can be easily passed on invites taking them for granted. That it has social consequences, sometimes threatening deeply held beliefs, can make it seem to threaten human values.

Fighting science denial is a bit like reducing crime, in that it requires both short-term tactics and long-term strategies, the former inhibiting it without significantly changing the world in which it happens, the latter trying to remove the conditions that foster it.

One short-term tactic might be demanding that politicians make pro-science pledges, or explain why they will not. Consider this: "I pledge to defend and maintain the scientific infrastructure of the country, and to let my decision-making be guided by facts rather than ideology or financial interest." That's reasonable and open-ended, because those who let gut instinct, ideology, class, or personal interest determine how the world works do not act in the public and national interest.

"Why is this person comfortable?" IMAGE: DELICIA KAMINS

Another tactic is to show how science deniers betray the very values they profess. Galileo was a master at this, citing church authorities and doctrine in defense of his work. The point of the Bible, he said, is "to teach us how one goes to heaven, not how heaven goes!"

A modern-day Galileo on Fox News might say something like, "The Founding Fathers taught us how to create legislation, not to legislate Creation!"

Here's an even more incendiary comparison: Science-denying politicians are like the Islamic State militants who bulldoze archaeological treasures and smash statues. Both believe that they are motivated by higher authority and that mainstream culture threatens their beliefs, and want to damage the means by which that mainstream culture survives and flourishes. If anything, the ISIS militants are more honest, for they openly admit that their motive is faith and ideology while Washington's cultural vandals do not. It's disingenuous, prevents honest discussion of the issues, and falsely discredits and damages American institutions. Is comparing science-denying politicians to ISIS militants really over-the-top? When the North Carolina state legislators forbade incorporating scientific findings into state policies by state law, it damaged the ability of the state's officials to protect its coastline, its resources, and its citizens; it prevented other officials from fulfilling their duty to advise and protect innocent citizens against threats to life and property. At debates and press conferences, such politicians should be asked: "Explain the moral difference between ISIS militants who attack cultural treasures and politicians who attack the scientific process." How they respond will reveal much about their values and integrity.

Another tactic is to use comedy and ridicule. Comedians have an ability to cut to the chase in a way that speaks truth to power, having a license to be inappropriate. A Doonesbury cartoon strip once featured an "honest" science denier interviewed on a radio talk show. "I don't oppose sound climate policy because it's flawed," he says. "I oppose it because I care *much* more about my short-term economic interests than the future of the damn planet. *Hello*?" Humor contributes to what the American philosopher C. S. Peirce called "the social impulse" that disrupts "tenacity," or the urge to cling to select beliefs, by drawing listeners into a wider and wilder space in which the presence of more factors comes into play. In Max Weber's terms, such humor illustrates in detail that science deniers are adopting the "ethics of conviction" as opposed to the "ethics of responsibility."

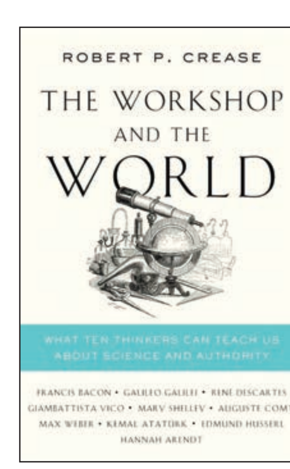
Another strategy is to tell parables. A parable, like an Aesop's fable, is a real or fictional story with a built-in, easily graspable lesson. Most people learn more easily through stories than data. *Jaws* and *Enemy of the People*, which expose the all-too-rational calculus of science denial, are good examples. We need twenty-first-century Aesops to tell more dramatic stories of what happens when we wish away sharks.

Did you hear the one about the person who was convinced, not altogether wrongly, that the medical establishment was corrupt, and decided he was the only person who could fix it? "Make America Healthy Again!" was his slogan. His campaign to be the next person in charge succeeded. His solution was to get rid of medical and lab tests, destroy thermometers for taking temperature and stethoscopes for detecting heartbeat. The people ended up worse off but happier, convinced they were in good hands.

Yet another strategy is to prosecute science deniers. In 2015, US Senator Sheldon Whitehouse of Rhode Island proposed that organizations bankrolling campaigns of climate science disinformation should be investigated for racketeering, a fraudulent activity that includes conspiracy to deceive the public about such things as risk. Such laws have been successfully used to prosecute tobacco companies for misleading the public about hazards. What's the difference between endangering the public by hiding evidence that smoking is hazardous, and endangering the public by concealing evidence of climate change? The crime is like shouting "Stay put! Everything's OK!" in a burning store so that people carry on shopping. Is this a dampening of free speech? Or is being misleading and deceptive about serious hazards a crime?

Such short-term tactics can discourage lazy and ideological thinking, curb the human appetite for fake assertions, and entice citizens to look past private interests and to regain an appreciation for the natural world. They increase damaging consequences for magical thinking in an environment that encourages it. These tactics will not eradicate science denial, but doing all of them all the time may help discourage politicians who practice it from getting elected.

More long-term strategies are also needed to fight science denial. By far the most important one is to tell the story of how we got into this situation. The early promoters of science, including Bacon, Galileo, Descartes and others, also encountered science denial, and had to forge ways of countering it. Most instances of science denial are simply recycled versions of what they encountered, and we can learn much from how they responded. Furthermore, science denial arose because of the way our traditions developed. We didn't get in this position from out of nowhere, but only thanks to how our traditions developed. Only by reviewing how the authority of the scientific workshop was promoted, defended, came under attack, and responded can we have an idea of how to go forward today.



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