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July 2016 • Vol. 25, No. 7

APS physics

U.S. Physics Olympiad Team Chosen
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Don't Forget to Vote in the APS General Election
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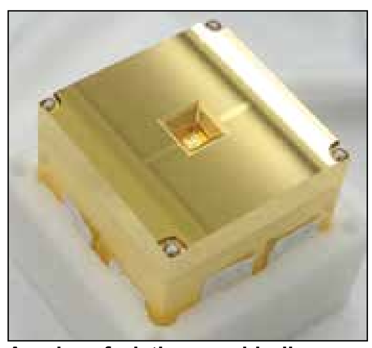
NASA and ESA May Team Up to Measure Gravitational Waves

By Katherine Kornei

After parting ways five years ago, the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) may yet collaborate on an orbiting observatory to detect gravitational waves. Public and professional support for this observatory, which would launch in 2034, has been buoyed by two major milestones that occurred this year: the first direct, ground-based detection of gravitational waves, and the successful demonstration by an ESA spacecraft of technologies necessary to detect gravitational waves in space.

In 1975 the concept of a ground-based gravitational wave detector "was literally sketched on a napkin at a NASA review panel meeting," says Ira Thorpe, an astrophysicist at NASA's Goddard Space Flight Center. It was at this meeting that Rainer Weiss, then an associate professor of physics teaching a course on general relativity at the Massachusetts Institute of Technology, met Kip Thorne, a physicist at Caltech. The two men talked late into the evening about ideas for a gravitational wave detector.

What emerged from those initial conversations and many others paved the way for the Laser Interferometer Gravitational-Wave Observatory (LIGO), a National Science Foundation-funded facility



ESA

A cube of platinum-gold alloy was the centerpiece of the LISA Pathfinder test

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APS Selects Editor in Chief

By David Voss

Pierre Meystre of the University of Arizona has been appointed Editor in Chief of the *Physical Review* research journals published by APS. Starting in mid-August 2016, he will take responsibility for APS journal content and will partner with senior leadership in setting the agenda and strategic vision for the journals. The APS Board of Directors unanimously approved the appointment, which was put forward by APS CEO Kate Kirby on June 16.

"I am honored and humbled to have been chosen to take the helm of the world's most respected physics journals," said Meystre in a statement released by APS, "and am looking forward to working with the terrific editorial and publishing teams at APS in continuing to serve the physics community by further expanding the quality and breadth of our publications." Meystre will be the 11th physicist to hold the position of Editor in Chief. His predecessor, Gene Sprouse, stepped down in May 2015.

U. Arizona

Pierre Meystre

Meystre is currently Regents Professor of Physics and Optical Sciences at The University of

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Physicist Makes Thin Films for Tough Conditions

By Gabriel Popkin

Next time you fly, think about the demanding conditions an airplane's windows have to handle: temperatures that can dip far below freezing, and bombardment by dust particles at more than 500 miles per hour. One of the people who help keep airplane windows ice-free and transparent in all conditions is Amethyst Radcliffe, a materials engineer at PPG Aerospace who graduated in 2014 from California State University, Long Beach with a bachelor's degree in physics.

Radcliffe isn't someone who knew she was going to be a physicist since age three. In fact, a high school teacher who recognized her talent in the subject had to plead with her to try harder in his class. During her undergraduate years, however, Radcliffe realized she was unsatisfied with the job prospects in art (her initial choice of major), and an advisor convinced her to make the switch. "Physics sort of stalked me until I decided I wasn't going to fight destiny anymore," she says.

Radcliffe gravitated toward the borderlands of physics and chemistry — how the arrangements of atoms and electrons in solids give materials the bulk properties that we're familiar with — electrical conductivity, heat capacity, interactions with light, and so on. She studied enzymes in a biochemistry lab on campus, and did summer research internships at NASA's Jet Propulsion Laboratory in Pasadena, California and at the Department of Energy's Los Alamos National Laboratory. She took courses to learn lab techniques such as X-ray diffraction, vacuum sputtering, and atomic force microscopy.

As Radcliffe neared graduation, she realized she was not tempted to follow her professors' career track into academia. She wanted to work in a faster-paced environment and to tackle problems that would have more immediate real-world impacts or could lead to new products. Though she wasn't aiming specifically for an engineering career, an opportunity opened up for a materials engineer at the paint and coatings manufacturer PPG Aerospace in Sylmar, California, north of Los Angeles. Radcliffe applied and got the job.

"It wasn't so much the title I cared about as much as the job description," she says.

Radcliffe graduated on a Friday in the spring of 2014 and started at PPG the following Monday. For the past two years, she has developed thin metal films that coat the windows, windshields, and canopies of airplanes. Thin films are ubiquitous in modern technology, used in everything from solar panels and laptops to eyeglasses and pharmaceuticals. Often the properties of the film material — for example, how it absorbs or emits light — must be tailored to meet the specifications for a particular device or application. The films Radcliffe

PPG Aerospace

Amethyst Radcliffe

develops are critical for keeping airplane surfaces ice-free — crucial for safe takeoff and flying in cold air — as well as shielding planes from electromagnetic interference and maintaining transparency in demanding conditions.

Much of what Radcliffe does is condensed matter physics — conducting theoretical studies to predict the properties of a particular material, and experiments to test predictions. But an academic physicist would typically stop there, publishing and presenting results for colleagues in industry to pick up and take the rest of the way to a commercial product. Radcliffe, by contrast, will continue working with a material until it's rolling off the assembly line.

She also reads the scientific literature to get ideas for new projects, keeps management informed about project progress through presentations and reports, and interacts with vendors. "Every day is differ-

RADCLIFFE continued on page 6

What Do You Do When a Senator Calls Your Research a Waste of Money?

By Sophia Chen

At a biology workshop in Washington, DC, this past May, David Hu clicked on an email from his university's media relations team. They'd written to tell him that a U.S. senator had just published a report calling his research a waste of taxpayers' funds. Out of 20 studies highlighted in Senator Jeff Flake's (R-AZ) 83-page report, titled "Twenty Questions: Government Studies That Will Leave You Scratching Your Head," Hu had co-authored three.

Hu was shocked. The Georgia Tech mechanical engineering professor had heard of members of Congress directly ridiculing scientific research, but he never imagined he'd be on the receiving end. "Everyone thinks it's not going to happen to them, that it'll happen to somebody else," he told *APS News*.

senate.gov

Senator Jeff Flake

Flake even appeared on Fox News' daytime talk show, *Fox & Friends*, to publicize the report. The show's host spun a game-show-style wheel divided into wedges, each wedge labeled with one of the twenty studies. After each spin, Flake briefly described

WASTE continued on page 6

Georgia Tech

David Hu

Revised 03/04/19

Members in the Media

"The way transitions happen is like a flock of birds, a school of fish … There's no one fish saying, 'Hey, I want everyone to be about five inches away from someone else, and we're going to have this shape.'"

***Neil Johnson**, University of Miami,* New York Times, *June 17, 2016, on the tracking of terrorists on social media.*

"Today even consumer detergent bottles are designed with supercomputers … the Chinese are getting good at building these computers, and it's a competitive issue now for U.S. industry and national security."

***Eric D. Isaacs**, University of Chicago,* New York Times, *June 21, 2016, on the closing technology gap between the United States and China.*

"I love chocolate and eat it quite frequently," he said. "I will eat more chocolate once it has less fat."

***Rongjia Tao**, Temple University,* Los Angeles Times, *June 20, 2016, explaining his motivations for running chocolate through an electric field.*

"We were convinced it was real, but if it was the only one, we thought that other people might have some doubts … Now we know that there are no doubts."

***Gabriela González**, Louisiana State University,* Los Angeles Times, *June 13, 2016, on the second gravitational wave detected by LIGO.*

"STEM education must now play the role of preparing our country for this new innovation-based economy or we will lose the American Dream for future generations."

***S. James Gates**, University of Maryland,* Chicago Tribune, *June 16, 2016.*

"It's far too early to jump up and down … [and] say the universe is messing with us."

***Sean Carroll,** Caltech,* Christian Science Monitor, *June 3, 2016, on the new research declaring a faster expansion rate of the universe.*

"My goal is neither to be an alarmist, [n]or to sidetrack future human explorations in deep space. Instead, I hope to point out that prudence suggests that we better understand [solar superflares], their ramifications for future spaceflight, and what is needed to protect crews from them."

***Lawrence Townsend**, University of Tennessee, Knoxville,* CBS News, *May 24, 2016, on the risks associated with future Mars missions.*

"It certainly isn't the first thing I would have written down if I were allowed to augment the standard model at will … Perhaps we are seeing our first glimpse into physics beyond the visible Universe."

***Jesse Thaler**, MIT,* Tech Insider, *May 26, 2016, on the evidence of a mysterious fifth force of nature.*

"For the first time, we've been able to understand their language and understand what they're telling us."

***Vassiliki Kalogera**, Northwestern University,* Tech Insider, *June 15, 2016, on the new capabilities of gravitational wave detectors.*

"It's definitely not going to improve whether I get to meetings on time, [but] it could help change the way science itself works."

***Andrew Ludlow**, National Institute of Standards and Technology,* Washington Post, *June 23, 2016, in discussing the building of the ytterbium atomic clock.*

This Month in Physics History

July 1816: Fresnel's Evidence for the Wave Theory of Light

Until the early 20th century, the question of whether light is a particle or a wave had divided scientists for centuries. Isaac Newton held the former stance and advocated for his "corpuscular" theory. But by the early 19th century, the wave theory was making a comeback, thanks in part to the work of a French civil engineer named Augustin-Jean Fresnel.

Born in 1788 to an architect, the young Fresnel had a strict religious upbringing, since his parents were Jansenists — a radical sect of the Catholic Church that embraced predestination. Initially he was home-schooled, and did not show early academic promise; he could barely read by the time he was eight. Part of this may have been due to all the political upheaval in France at the time. Fresnel was just one year old when revolutionaries stormed the Bastille in 1789, and five when the Reign of Terror began.

Eventually the family settled in a small village north of Caen, and when Fresnel was 12, he was enrolled in a formal school. That is where he discovered science and mathematics. He excelled at both, so much so that he decided to study engineering, first at the École Polytechnique in Paris, and then at the École Nacionale des Ponts et Chaussées.


wikimedia commons

Augustin-Jean Fresnel


wikimedia commons/Frank Schulenberg

Fresnel lens at the Point Arena Lighthouse in California.

After completing his studies, Fresnel worked on various civic projects for the French government, primarily building roads. A major project was to construct a road connecting Spain with northern Italy through France. In 1815, Napoleon Bonaparte returned from his exile to Elba. But Fresnel supported the king against Napoleon, so when the latter converged on Paris with his troops, the engineer lost his post and was placed under police surveillance. He opted to return to his hometown and focus on his scientific interests instead — most notably in optics.

When Napoleon was once again defeated, just 100 days later at Waterloo, and King Louis XVIII took the throne, Fresnel's engineering work resumed, but he continued his optics research, too. In particular, he built on the experimental work of Thomas Young, whose famous double-slit experiment was seen by many as evidence for the wave nature of light. Fresnel's own theoretical and experimental work led him to embrace this theory as well, even though it was not favored in textbooks at the time.

Fresnel wasn't familiar with much of work on the nature of light, but he was fascinated by diffraction. When a diffracting object such as a thin wire is illuminated, it produces a characteristic set of colored bands in the shadow. A breakthrough occurred when he pasted a sheet of black paper to one edge of a diffractor and realized that when he did so, the bright bands from the light vanished. He then devised mathematical formulae to predict the position of those bright and dark bands based on the pathlengths of rays crossing behind the diffractor. Later he used those same equations to predict the interference patterns produced by two mirrors reflecting light.

That became the basis for his 1818 treatise, *Memoir on the Diffraction of Light*. But Fresnel had published his preliminary results in July 1816, with the goal of fleshing out the mathematics to develop a full theory for his findings. In 1819, the French Academy of Sciences announced that the Grand Prix for that year would be given for the best work on diffraction. Fresnel jumped at the chance to share his work and submitted his full theory just before the deadline.

The judges that year included François Arago, Siméon Poisson, and Pierre-Simon LaPlace — all supporters of the corpuscular theory of light. Yet Poisson was so impressed with Fresnel's work that he made his own prediction using the theory — namely, that if parallel light hit an opaque disk, there would be a bright spot in the center of the shadow. This was experimentally confirmed, and Fresnel was awarded the Grand Prix. It was a major victory for proponents of the wave theory of light.

In addition to his work on optics, Fresnel also worked for the Lighthouse Commission. At the time, lighthouses relied upon mirrors to reflect light, but the reflected light was difficult to see from afar, and in heavy fog or stormy weather, it could barely be seen by ships at all. Fresnel realized that since the image quality was not important, a better approach would be to use a lens, but without most of the glass inside. He designed a

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Education & Diversity Update

Apply to become an APS Bridge Program Partnership Institution

Masters- and doctoral-granting institutions with physics departments committed to the principles underlying the Bridge Program are encouraged to apply to become APS Bridge Partnership Institutions. Deadline: September 2, 2016.

Also, institutions granted Partnership status are eligible to apply for $10,000 grants to improve access for underrepresented minorities to physics graduate programs. Deadline: December 2, 2016.

More information: apsbridgeprogram.org/institutions/partnership/ or email bridgeprogram@aps.org

National Mentoring Community is looking for mentors

The National Mentoring Community (NMC) is an effort to increase the number of African American, Native American, and Hispanic American students obtaining bachelor's degrees in physics. Through this program, APS is supporting mentoring relationships between faculty members and students by providing resources and networking opportunities to both. To learn more and register as a NMC mentor or mentee, visit aps.org/nmc

Upcoming National Mentoring Community Conference in Houston, TX

The NMC Conference will be held October 21-23, 2016 at the University of Houston, and will provide mentor and mentee training, career workshops, talks on the impact of mentoring on student success, an undergraduate poster session, information on research experiences for undergraduates, and even a talk on gravitational waves. Attendees will also enjoy some fun, social activities. Visit go.aps.org/nmc-conference to register and learn more.

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Arizona, Director of the Biosphere 2 Institute in Oracle, Arizona, Director of the Arizona Center for STEM Teachers, and has served as lead editor of *Physical Review Letters* since 2013. He will step down from those duties to devote full time to his new position on the APS senior management team.

He received his Ph.D. from the École Polytechnique Fédérale in Lausanne, Switzerland in 1974. He joined the University of Arizona as a professor of physics in 1986 and was head of the department from 2005 through 2007. Meystre is an APS Fellow and an optical physicist who specializes in quantum optics, atomic physics, and the statistical properties of radiation.

Barry Barish, a professor at Caltech and 2011 APS president, chaired the search committee that recommended Meystre. "We conducted a wide-ranging search to find the best possible candidate," said Barish. "We sought someone who is a prominent member of the scientific community, as well as having a broad knowledge of physics, a commitment to the APS, and a forward-looking vision for our journals. Pierre has all those qualities, plus he will bring abundant energy and a very human approach to the job."

"Meystre's passion for physics and commitment to the journals made a strong impression on all of us," added APS CEO Kate Kirby. "I look forward to working with Pierre and having him involved in the leadership of the Society."

In an interview, Meystre cited a number of priorities as Editor in Chief. "I'll be an ambassador to the physics community in some sense," he says. In addition, he wants to maintain and improve the quality of the 30,000 referees who support the journals, as well as strengthen communication between editors and authors.

When he starts in his new position, Meystre will be based full-time at the APS editorial offices in Ridge, NY. Until then, Editorial Director Daniel Kulp will continue as interim Editor in Chief. APS expects to begin promptly the search for a new lead editor for *Physical Review Letters*.

2016 U.S. Physics Olympiad Team Gets Ready

Ashauni Lennox/AAPT

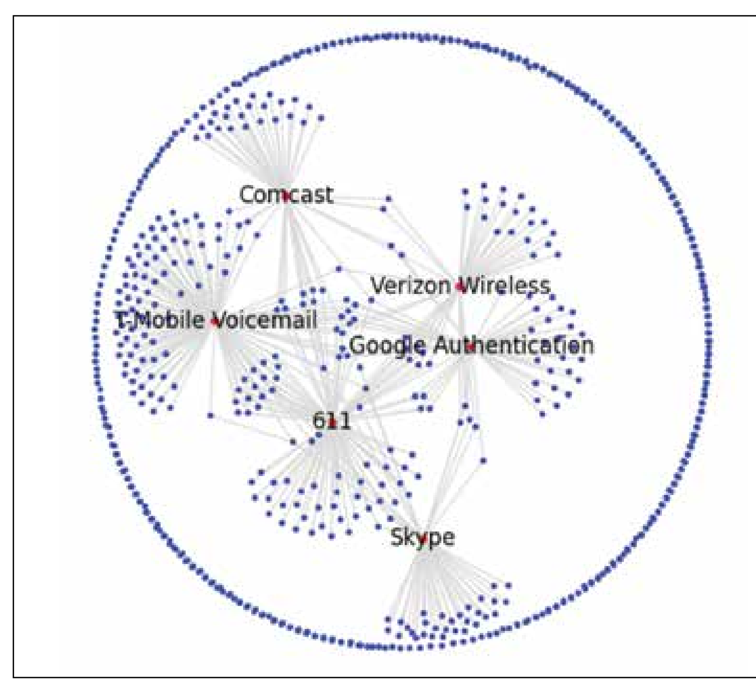
Five high-school physics students have been selected to represent the U.S. in the 47th International Physics Olympiad to be held July 11 - 17 in Switzerland and Liechtenstein. The team is organized by the American Association of Physics Teachers (AAPT), with sponsorship from several scientific societies, including APS. From left to right in the photo, the five are: Jason Lu, Adlai Stevenson High School, Lincolnshire, Illinois; Srijon Mukherjee, Amity International School, Noida, India; Vincent Liu, State College Area High School, State College, Pennsylvania; Abijith Krishnan, BASIS Scottsdale, Scottsdale, Arizona; Jimmy Qin, Seminole High School, Sanford, Florida. This year's team leaders are Paul Stanley, Academic Director; David Fallest, Senior Coach; Eugen Hruska and Mikhail Kagan, Coaches; and Chrisy Xiyu Du, Mark Eichenlaub and Kevin Zhou, Junior Coaches.

Research News: Editors' Choice

A Monthly Recap of Papers Selected by the Physics Editors

Metadata Monitoring More Invasive than Expected

In the wake of the U.S. National Security Agency's (NSA) collection of bulk telecommunications metadata, Mayer *et al*. report in *Proceedings of the National Academy of Sciences* (vol. 113, 5536) that they have revealed new privacy implications of metadata collection. Recruiting voluntary participants through an Android smartphone application, *MetaPhone*, the team retrieved historical phone-call and text metadata from over 800 users, accounting for more than 200,000 phone calls and 1.2 million text messages. When a participant contacts another number, the metadata of each can be accessed by the NSA through a connection called a "hop," (at present, rules limit the agency's surveillance to two hops of metadata retrieval). Despite anonymity of participants, researchers found that a two-hop path connected many users, caused in part by "hub" numbers (voicemails, telemarketers) that establish a bridge between certain participants when they call or text a hub. Many argue the retrieval of metadata has a lesser privacy impact compared to content disclosure, but the team showed it was trivial to re-identify dataset phone numbers — out of 30,000 randomly selected numbers, 32% of identities were matched using only free, public databases hosted by Yelp, Google Places, and Facebook. When these queries were used to look up more numbers within a two-hop path, the team could identify exchanges with health services or religious institutes, exposing the privacy impacts of surveillance access to metadata.

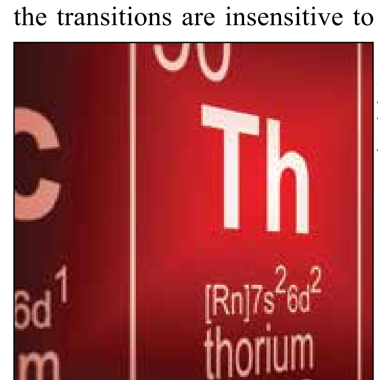


PNAS

Privacy and metadata

Potential Nuclear-Clock State Discovered in Thorium

A team of physicists has found the first direct evidence for a nuclear state in thorium-229 (Th-229) that has the right emission frequency and lifetime to be the basis for an ultraprecise nuclear clock. Today's best clocks are based on electronic transitions in atoms, with the second defined as 9,192,631,770 cycles of a cesium emission. Nuclear clocks could be much more accurate because the transitions are insensitive to



istockphoto.com

Thorium keeping time

stray electric fields and radiation. The Th-229 state has been sought for over a decade, but the telling evidence for its existence — an electron kicked out of the atomic shell — proved difficult to detect. As von der Wense *et al*. report in *Nature* (vol. 533, 17669), the team took numerous steps to purify their thorium source and to reduce spurious signals from background electrons. They found that the state's half-life is over a minute in doubly ionized Th-229 and were able to determine that its energy was between 6.3 and 18.3 eV — a range potentially accessible with lasers, a key requirement for a nuclear clock. Nuclear clocks could be up to 10 times more accurate than atomic clocks, allowing new ways to detect gravitational shifts on Earth or variations in fundamental constants.

Channeling Spin Waves

Two research groups have shown that they can control the propagation of spin waves, or magnons, in nanoscale waveguides. Magnons hold promise for logic devices that process information faster and with lower power consumption than electronics. However, until now research-

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Letters

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

Confirming Coulomb

"I enjoyed the "This Month in Physics History" article about Coulomb's experiments in the June 2016 issue. When I was a grad student at Columbia in the 1970s, Samuel Devons tried to reproduce the experiments using only technology available to Coulomb. Devons found it very difficult to reproduce the experiments.

John Farley
Las Vegas, Nevada

Basic Research Benefits

Lawrence Krauss makes many good points in his Back Page article (*APS News*, May 2016) comparing the LIGO discovery to the appreciation of aesthetic things of culture like art, music, and literature. I would add that, in addition to advancing understanding of our universe and ourselves within it, past evidence proves that even seemingly remote and "trivial" events such as this will always eventually lead to profound practical benefits to humankind; it's just a matter of time.

There are many examples in scientific history that prove this point. While the LIGO event is the province of general relativity, another such case is from special relativity concerning correcting the transformation equations between inertial reference frames from the Galilean group to the Lorentz group. The point seems trivial as it has no real practical, everyday consequences except at speeds close to light, so who cares? However, this "trivial" point ultimately led to our ability to unleash the energy of the atomic nucleus (for good or bad) through Einstein's mass-energy equivalence, which has had profound practical effects on humankind from bombs to nuclear energy.

Another example would be the revolution of quantum mechanics. The general public might have asked at the time, "Who cares if I put a free particle, which can have any energy, in a box and the box somehow tells the particle what energies it is now allowed and not allowed to have; while interesting, of what practical benefit is it to humankind?" However, the practical benefits to humankind have once again been profound, with all the applications to semiconductors, lasers, communications, medical imaging technologies, etc. There are many other examples that could be cited also.

It is my belief that the U.S. Congress should be made aware of this and continue to fund this kind of research, and all similar scientific research, even if any immediate practical benefits may not be evident at the time.

Frederick Weist
Clarksburg, Maryland

Biased Grades

I was pleased to see Emily Conover's article "Physics Grading Biased Against Women" in the April 2016 *APS News*. For many years I have used anonymous grading. Many of my colleagues thought it unnecessary, and teaching assistants needed persuading, yet a colleague adopted it for our Ph.D. comprehensive exams. It is a minor bother to set up identification numbers; I used the last 3 or 4 digits of the student ID numbers for all graded work; the numbers are also useful for sorting and returning graded work. When we called the identification numbers "magic numbers," the students liked the idea more. I found the idea liberating, and students could be more open in class discussion. There are other examples as well — anonymity in auditions, behind a curtain without shoes, has increased the number of women in orchestras [1].

Leonard Finegold
Media, Pennsylvania

[1] L. Finegold, *Journal of Science Education and Technology* 11, 255 (2002).

WAVES continued from page 1

managed by MIT and Caltech that started searching for gravitational waves in 2002. In February 2016 LIGO announced the momentous first direct detection of gravitational waves, which were produced by the merger of two black holes in a distant galaxy; a second such detection followed in June.

LIGO's exquisite sensitivity to gravitational waves means that its detectors record many spurious signals from vibrations caused by, for example, traffic and ocean waves. "Ground-based detectors have a hard lower limit on the frequencies they can detect at about 1 hertz because of seismic noise, which limits them to seeing very massive objects moving very fast," says Charles Dunn, Project Technologist at NASA's Jet Propulsion Laboratory. Furthermore, LIGO's ability to detect gravitational waves is limited by the relatively short lengths of its arms, because constructing extremely straight, long tubes on Earth's curved surface is both difficult and expensive.

The next literal jump in technology will be to take gravitational-wave detectors to space; an orbiting gravitational-wave observatory would overcome both the limitations of vibrations and the difficulty of achieving long laser pathlengths. "In space, we can get down to the 0.1 millihertz frequency range, which should allow observation of many more sources, including things that can be seen with more conventional telescopes," notes NASA's Dunn.

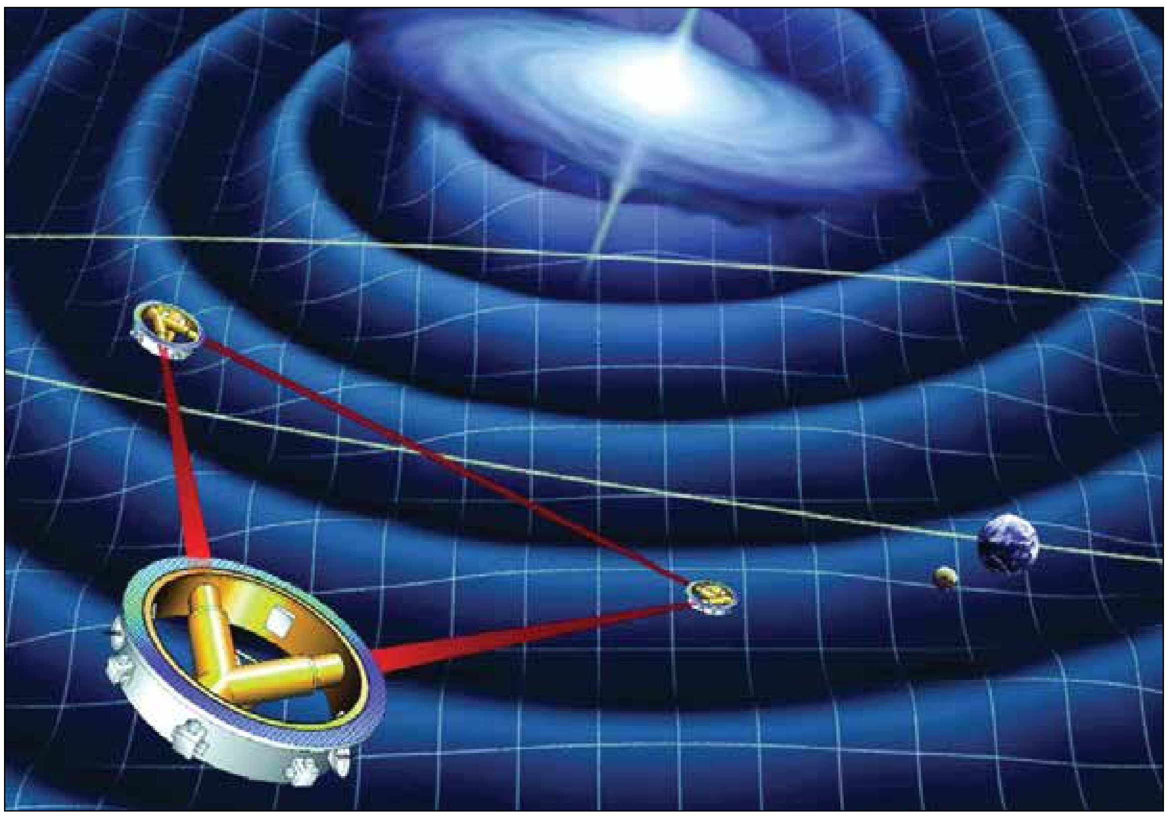
In the 2000s, NASA and ESA collaborated on developing a Laser Interferometer Space Antenna (LISA), a triangular interferometer with arms several million kilometers on a side that would be launched into orbit around the Sun. However, NASA withdrew from the collaboration in 2011 due to budget cuts, and ESA continued to develop the technologies necessary for LISA. "ESA took a gamble," says Paul McNamara, an astrophysicist at ESA and the deputy project scientist for LISA. "They wanted the science, and they spent a large chunk of money to demonstrate that it was possible." In 2013, ESA announced a science theme of "The Gravitational Universe" for the third large-class mission (L3) component of its Cosmic Vision 2015 - 2025 program, which solidified LISA's position in ESA's long-term planning.

Before NASA withdrew from the collaboration, the two agencies had decided to develop a small spacecraft to test the technologies necessary for a successful LISA mission. In December 2015, ESA launched that spacecraft, called LISA Pathfinder, to the L1 Lagrange point 1.5 million kilometers from Earth. One of the primary science goals of LISA Pathfinder was to demonstrate that two paperweight-sized cubes of gold and platinum onboard the spacecraft could be shielded from all forces save for gravity. "LISA Pathfinder shows that we can put a test mass in perfect free fall, which is what we'd need to do a full-scale gravitational-wave detector," says NASA's Thorpe, the U.S. lead for data analysis on the LISA Pathfinder mission.

An orbiting gravitational-wave observatory such as LISA would be complementary to ground-based facilities like LIGO. "The same sources that LIGO sees in their last couple of orbits before inspiral, LISA could see months to years before they merge," explains Thorpe. "LISA would see some of these sources first and could basically be an early warning system for LIGO and also, more importantly, for telescopes [that measure electromagnetic radiation]. That would be transformational science."

NASA is once again entertaining the idea of officially partnering with ESA on LISA. The U.S. agency has assembled an "L3 Study Team" to see how NASA might participate in LISA. Scientists and NASA leadership also have their eye on the 2020 Decadal Survey in Astronomy and Astrophysics, which will be conducted by the National Research Council to survey the priorities of the astronomy and astrophysics community. Most major missions require endorsement from the Decadal Survey before they can go forward, and previous Decadal Surveys have endorsed a LISA-like mission. "This science is so compelling, and we're making great strides with the technology," remarks Thorpe. "I'd be surprised if the U.S. community didn't want to be involved."

Katherine Kornei is a freelance science writer in Portland, Oregon.



ESA

LISA concept involves a triangular interferometer with several million kilometer long arms

FRESNEL continued from page 2

lens comprised of rings of glass prisms, resembling a giant beehive, with a lamp in the center. Those prisms serve to bend and concentrate light from the lamp (or other light source) into a bright beam that travels further and is easier to see, even in foggy conditions.

Fresnel's design was so effective that such lenses continued to be widely used in lighthouses until the mid-20th century. For a time, Fresnel lenses were used in the headlamps of cars, and they are still used in taillights and backup lights, and also in solar cookers. They are also common in lighting for film and theater — not only do they produce a brighter beam, but the light intensity is more uniform.

For all his successes, Fresnel never achieved fame as a scientist in his lifetime. Many of his papers were published posthumously. He did earn the respect of his peers, and his name is inscribed on the Eiffel Tower, along with the names of 71 other French luminaries. Yet Fresnel was never one to seek out the spotlight. As he wrote to Thomas Young in 1824, "All the compliments that I have received from Arago, Laplace, and Biot never gave me so much pleasure as the discovery of a theoretic truth, or the confirmation of a calculation by experiment." He died of consumption on July 14, 1827, at Ville-d'Avray in France.

Further Reading:

Fresnel, Augustin. (1818) "Memoir on the Diffraction of Light," *The Wave Theory of Light: Memoirs by Huygens, Young and Fresnel*. Woodstock, GA: American Book Company.

Fresnel, Augustin. (1819) "On the Action of Rays of Polarized Light Upon Each Other," *The Wave Theory of Light: Memoirs by Huygens, Young and Fresnel*. Woodstock, GA: American Book Company.

Washington Dispatch

POLICY UPDATE

ISSUE: APPROPRIATIONS AND AUTHORIZATION BILLS

Congressional committees continued the process of developing fiscal year 2017 spending bills for the Department of Energy (DOE), Department of Defense, National Aeronautics and Space Administration (NASA), National Institutes of Health, National Institute of Standards and Technology (NIST), and National Science Foundation (NSF). Consistent with the fiscal year 2016 - 2017 budget agreement the White House and Congress struck last fall, most science accounts were held to flat funding in committee "markups." Only one bill — appropriations for Energy and Water Development — reached the floor of either chamber, and it fell victim to an amendment on lesbian, gay, bisexual, and trans issues that peeled away Republican support for the measure.

With the legislative calendar shortened by the political conventions and the November election, it is likely that Congress will again resort to a short-term continuing resolution that would allow the federal government to function through the beginning of December. In a lame-duck session following the election, Congress will probably wrap almost all fiscal year 2017 spending legislations into an omnibus appropriations bill.

WASHINGTON OFFICE ACTIVITIES

ADVOCACY

At the 2016 APS April Meeting, the APS Office of Public Affairs (OPA) helped 335 meeting attendees make an impact by sending the APS Contact Congress letter to their Senators and Representatives. At the APS Division of Atomic, Molecular, and Optical Physics (DAMOP) meeting, an additional 317 attendees sent letters. This letter addressed science-funding issues, as well as the impact of child poverty on U.S. STEM Performance in International Student Assessments (known by the acronym PISA). The letter called for Congress to support sustained robust science funding and to request a National Academy of Science study of the child poverty issue. The DAMOP meeting letter focused on the appropriations bills that affect DOE, NSF, NASA, and NIST.

In late April, OPA's Government Relations Specialist Greg Mack accompanied Scott Franklin, professor of physics and astronomy at Rochester Institute of Technology and Director for its Center for Advancing Science/Math Teaching, Learning, & Evaluation, to meetings in House and Senate offices to discuss priorities for the physics community, including science funding, education, and issues faced by women in science.

In June, APS participated in a meeting at the Department of Education with other members of the Physical Sciences Education Policy Coalition, which has representatives from APS, the American Association of Physics Teachers, American Institute of Physics, American Astronomical Society, and The Optical Society. The meeting was intended to provide guidance to the Department of Education for the creation of a STEM Master Teacher Corps, called for in the Every Student Succeeds Act the president signed into law on December 2015 as a replacement for the 2002 "No Child Left Behind" Act.

MEDIA UPDATE

Sarit Dhar, associate professor of physics at Auburn University, published an op-ed on May 21 in the *Opelika-Auburn News*, urging the United States to step up its commitment to clean-energy research. Read the piece at go.aps.org/294ILst

PANEL ON PUBLIC AFFAIRS

At its June meeting, the APS Panel on Public Affairs (POPA) considered whether to archive the seven APS Statements up for review in 2016. Five of the seven statements will remain active. Of the two others, *Statement 96.2, Energy: The Forgotten Crisis*, will undergo a full review, rewrite, and membership evaluation, while *Statement 91.5, Reaffirmation of Statement on Scientific Review of Research Facilities Funding*, will be reexamined by the Physics & the Public subcommittee for further action.

POPA also approved a recently completed report on helium economics — *Responding to the U.S. Research Community's Liquid Helium Crisis: An Action Plan to Preserve U.S. Innovation*. Follow-on activities related to recommendations in the report are being developed. The Physics & the Public subcommittee presented preliminary data on how to overcome obstacles in recruiting teachers in the physical sciences; a full report is expected later this year. The National Security subcommittee proposed a statement on highly enriched uranium (HEU) reactor conversion and a potential study on the obstacles to elimination of HEU civilian reactors.

Following the recommendation of POPA, APS has begun a carbon inventory of the Society's operations.

A template for study proposals can be found online, along with a suggestion box for future POPA studies: go.aps.org/9XXVlv

Senate Introduces Science Research Legislation

By Sophia Chen

This June, the Senate introduced a bill regulating science research for several federal agencies. The bill, called the America Innovation and Competitiveness Act (S. 3084), will establish policy governing the National Science Foundation (NSF) and the National Institute of Standards and Technology and includes a 4 percent increase in authorized funding for both agencies between FY2017 and FY2018. (These funding levels do not reflect actual dollars appropriated to the agencies; they are aspirational guides for agencies' budgets.) Last month, Michael Lubell, the APS director of public affairs, spoke to *APS News* about the bill before its official release. While Lubell's comments apply to the June 15 working version of the bill, *APS News* has verified that his comments are applicable to the bill amended by the Senate Committee on Commerce, Science, and Transportation on June 28.

The Senate's bill marks a return to bipartisan collaboration in research policy after a polarized two-year battle over the bill's House counterpart, the America COMPETES Reauthorization Act (H.R. 1806). Since last summer, Senators Gary Peters (D-MI) and Cory Gardner (R-CO), two freshmen senators on the Senate committee, have worked together to gather input for the bill from researchers, academic officials, and industry leaders. In interviews with *ScienceInsider*, both senators said they support federal funding of science research.

Last fall, APS staff participated in a working group organized by the senators and provided feedback on a recent draft of the bill, Lubell says. "[The Senate committee] has been very thoughtful in this process," he says. "That doesn't mean that I necessarily agree with everything in the draft, but they've come up with a mostly reasonable bill."

Lubell says that APS has expressed its support of certain provisions in the bill. In particular, APS supports merit-based peer review and the need to minimize agencies' administrative burden. APS also supports a section of the bill that pivots attention to NSF's mid-scale projects that range from \$3 million to \$40 million. (Examples of current mid-scale projects include the construction of university radio telescope observatories and data management for dark energy observations.) Lubell says that NSF doesn't have a good strategy for managing these projects.

However, some parts of the draft are "problematic," says Lubell. The bill would create additional oversight of high energy physics research, beyond that currently provided by the High Energy Physics Advisory Panel in the Department of Energy. Although this committee "works quite well" according to Lubell, the bill creates another oversight subcommittee run by the National Science and Technology Council, a high-level interagency committee, whose members include the directors of NSF and the National Institutes of Health. "It's not at all clear what this panel would do because it's at too high a level," Lubell says.

Furthermore, the bill makes NSF responsible for a portion of the contingency funds of large-scale research projects, instead of leaving it to project managers. "It wouldn't damage the projects, but it creates more red tape," Lubell says. "If you're a project manager, you would have to justify to NSF the need for contingency funds." Lubell says that this provision is in response to NSF's reported mismanagement of the \$433 million National Ecological Observatory Network (NEON), a project for monitoring long-term ecological changes on a continental scale, which Congress approved for construction in 2011. After discovering that NEON was projected to overrun its budget by \$80 million, NSF fired its contractor in December last year.

LEGISLATION continued on page 6

International News

Why India Matters

By Sushanta K. Mitra and Vladimir Shiltsev

Vladimir Shiltsev

Sushanta Mitra

India has a rich tradition of physics, with such luminaries like J. C. Bose, S. K. Mitra, C. V. Raman, and S. N. Bose, to name a few. Now, under Prime Minister Narendra Modi, India is seeing a renewed investment in science and technology, particularly in big science projects. For instance, the budget for India's largest granting council for science, the Department of Science and Technology (DST), was increased by 17 percent from last year to \$660 million. This is coupled with the launch of some boutique programs like Make-in-India and Start-up India, which could boost further investments in particle physics, making sub-components for the Large Hardon Collider, among other opportunities. India's physics community is excited about all these new developments, and the global physics community should pay more attention to these new trends in investment in basic science in India.

There are several notable examples of large U.S.-India collaborations. Given the recent breakthrough observation of gravitational waves by the Laser Interferometer Gravitational-Wave Observatory (LIGO) collaboration, it is great to see that the LIGO-India project has recently received an in-principle approval from the Indian government. LIGO-India is a planned advanced gravitational-wave observatory to be located in India as part of the worldwide network.

The proposed LIGO-India project will be a collaboration between a consortium of Indian research institutions (Institute of Plasma Research Gandhinagar, Inter University Centre for Astronomy and Astrophysics, Pune and Raja Ramanna Centre for Advanced Technology, Indore), and the LIGO Laboratory in the U.S., along with its international partners in Australia, Germany and the U.K. LIGO in the U.S. will provide the LIGO interferometer hardware, along with training, support, and assistance with installation.

LIGO-India will provide research opportunities to hundreds of Indian students and scientists, and will definitely boost scientific ties between the American and Indian physicists. It will provide fertile ground for Indian scientists and engineers to work on a global-scale problem. It will also help local industries, particularly those engaged in ultra-high vacuum, to participate in this collaborative project with Indian and international scientists. This flagship project will further promote international collaboration, particularly with the U.S.; its bilateral relationship with India has been at an all-time high, as shown by the joint declaration of President Obama and Prime Minister Modi (see go.aps.org/2921BA6).

Another actively developing collaboration is taking place in the field of high energy physics. In 2014, the U.S. particle physics community came out with a decadal plan that calls for establishment of a world-leading neutrino physics research program in the U.S., which will be truly international from the very beginning and employ Fermilab's accelerator facilities. Fermilab and Indian institutions have been collaborating on high energy physics experiments since 1985.

INDIA continued on page 6

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the study that the wheel's indicator landed on. "I don't see the utility, frankly," Flake said on the show, when the wheel landed on one of Hu's studies. (Flake did not respond to a request to comment on this story.)

Hu's offending research consisted of a study on the mechanics of how animals dry themselves, a study on whether body size affects how fast mammals urinate (it doesn't), and one on the functionality of eyelashes in mammals — all supported by National Science Foundation funding. In Flake's report, embellished with brightly colored cartoons, the senator referred to each study respectively as "How Many Shakes Does It Take For A Wet Dog To Dry Off?"; "How Long Does It Take To Pee Like A Racehorse?" and "Which Has More Hairs, A Squirrel Or A Bumblebee?" Flake explained that he'd been motivated to expose these so-called wasteful studies after reading a 2014 *Huffington Post* interview with National Institutes of Health Director Francis Collins, in which Collins had said that they "would probably have had a vaccine in time" for ebola, had it not been for stagnant government spending. The funds from studies like these could be diverted to ebola instead, Flake suggested.

Since then, journalists and scientists have criticized the Flake report's inaccuracies, ranging from its incorrectly cited dollar amounts to its omission of essential context. But the report still poses a "serious problem" to the public image of science, says Michael Lubell, the director of APS Office of Public Affairs. "The reason it's serious is that most people are not in a position to evaluate what [Flake] says and whether [the report] is really valid," Lubell says. "The fact that some prominent senator is putting this out casts some doubt on whether federal agencies can function efficiently and effectively."

Flake's report is just the latest in a long line of accusations from politicians that scientists abuse the public's funds. In the 1980's, Senator William Proxmire would frequently award scientific studies his monthly Golden Fleece Award, which singled out federal projects he deemed wasteful. "There's really nothing new here. Congressmen have always found they can get attention by beating up on eggheads," says Spencer Weart, the historian emeritus for the American Institute of Physics. "The Congressman can show himself to be a champion of the common man by beating up on people who seem like they have their heads in the clouds." The media will often pick up reports like Flake's because they're looking for "something cute and humorous [that] … sounds ridiculous," Weart says. "It's the equivalent of a cat video."

Hu initially considered ignoring Flake's report, but Georgia Tech's media relations team "insisted" that he respond in writing, he says. Georgia Tech scientists usually post on a university blog, but Hu chose to publish his response as a *Scientific American* guest op-ed. In the piece, Hu explained the potential applications of the work and pointed out that scientists do not solely serve the public. But he also acknowledged scientists' failure to communicate the importance of their work to the public. He ended the op-ed diplomatically: "I sincerely thank Senator Flake for continuing this conversation. If it leads to better communication between the public and scientists, he will have done us a great service."

Flake, in turn, responded via a Facebook post that same day. "I appreciate Dr. Hu's thoughtful response to #20questions and I would welcome his input on how to better identify those projects that he believes are indeed wasteful," the senator wrote.

But Hu's case raises some questions about the effectiveness of public outreach. The conventional wisdom is that when scientists communicate their work to the public, the public will understand and support the work, and that support will trickle over to the politicians. But Hu is an exemplary science communicator: His research has been featured in publications such as *Discover* and the *New York Times*, and he even teaches science communication. Why did Flake still single him out?

The answer is unclear, but a soon-to-be-published survey conducted by nonprofit ScienceCounts may shed some light, says Lubell, a senior adviser for the group. (ScienceCounts has received funding from APS.) The survey found that some common science-outreach approaches are ineffective. From surveying 2000 people and conducting focus groups, they found that explaining the practical applications of research doesn't resonate with the public. In the absence of government funding, the public thinks that industry would have developed those products anyway. One focus group moderator pointed out that Google's first algorithms were NSF-sponsored research. "I had never seen such rapid-fire anger," Lubell says of the focus group. "What was the anger? It was, 'These guys became billionaires on my taxpayer dollar?'" Instead, the public supports government funding of discovery and breakthrough, such as the Higgs boson or new materials.

But the key to science communication, Lubell says, is to tell stories, not facts and figures. What kinds of stories? "That's a work in progress," he says. "We don't yet know how to tell the stories."

Hu now views the experience in a positive light. Many people wrote to him in support after reading his op-ed, and he even found a new collaborator who learned about his research from the article. "More people are going to read the *Scientific American* article than my journal articles," he says. He's pleased, too, with Flake's response. "I would love to go to a Republican convention and talk about science," he says. "But I haven't seen any invitations yet."

Sophia Chen is a freelance writer based in Tucson, Arizona.

LEGISLATION continued from page 5

The bill is a long-awaited renewal of the original COMPETES law, which was passed in 2007 to keep the U.S. a global leader in science. The law contained several provisions that expanded government-funded science research, such as one that set goals to double the NSF's budget within a few years (it did not come close to happening). The original COMPETES act received bipartisan support from both the Bush administration and Congressional Democrats and was renewed once, in 2010.

However, when the law expired in 2012, Congressional Republicans had begun to withdraw support for several of its provisions. (Programs authorized by the law could continue unchanged.) The debate in the House over the law's renewal grew increasingly vitriolic, with Rep. Lamar Smith (R-TX), the House committee chair, calling for stricter oversight of government agencies and instructing his staff to investigate review documents from NSF-funded studies.

Smith's detractors accused him of substituting peer review with political review, because he targeted climate and social science studies. Rep. Eddie Bernice Johnson (D-TX), the highest ranking Democrat on the committee, accused Smith in a letter of attacking these research fields "because the Chairman personally does not believe them to be of high value." The two parties disagreed so vehemently over the bill that the minority Democrats in the committee drafted their own legislation independently from the Republicans. This kind of partisanship was previously "unheard of," Lubell says, because the two parties have typically worked together on science bills.

The House finally passed its bill last May. The research community widely criticized the final version for being too restrictive. In particular, the bill included a contentious section that requires NSF-funded research to serve the "national interest," as defined by seven specific criteria, which include improving the economy, increasing partnerships with industry, and developing the scientific workforce.

Compared to the House, the Senate's bill looks much friendlier to researchers — but even if the Senate passes it, it will be difficult to predict how the two houses will reconcile their bills, especially in an election year. Lubell suspects that if both houses do get their acts together, the final version will be significantly watered down. "The House and Senate really don't see eye to eye on this bill," he says. "You're looking at something that will be very difficult to [send to] conference and come out with anything reasonable that the president would sign. Therefore, I don't consider the bill as a really signature piece of legislation this time around."

Sophia Chen is a freelance writer based in Tucson, Arizona.

INDIA continued from page 5

Indian scientists have made significant contributions to the Fermilab program. Several students have received their Ph.D. degrees under the Indian Institutions - Fermilab collaboration, so it is natural that India is already taking a very active role in this development. Culmination of the collaborative effort was an overarching goal of the Memorandum of Understanding between the U.S. and Indian Universities & the Accelerator Laboratories, signed on January 9, 2006 to extend the collaboration on accelerator development in both countries. The collaboration enables scientists in the U.S. and India to jointly develop and optimize the technologies for future high-power superconducting radio frequency accelerators, such as the Proton Improvement Plan-II accelerator for neutrino production at Fermilab and, as part of the India's 12th national plan, two accelerators in India for materials science, energy, and medical applications.

As mentioned by PricewaterhouseCoopers' *2015 Global Innovation 1000* report, there has been a 115 percent increase in India's R&D spending from 2007 to 2015, to $28 billion, which is coupled to a 116 percent increase in imports (primarily from the U.S.). This will provide a significant boost to India's innovation ecosystem. The increased funding from DST would be targeted towards building research centers and business incubators across academic campuses in India, and will facilitate the creation of campus-led start-up/spin-off activities. Also, additional funding will help India to take on more "risky" projects and allow Indian scientists to take part in "big science" initiatives. With India still being a low-cost country (the average engineering wage is less than $35,000 per year), this also brings a significant competitive advantage in developing technologies and hardware for various world-wide "big science" projects.

Also, APS is engaged with the Indian physics community through the Indo-U.S. Science and Technology Forum through a partnership to offer student, postdoc, and faculty exchanges. A call for proposals for these programs is issued each fall and more information is available at go.aps.org/1xicNwu. Now is an excellent time for U.S. physicists at all levels, from graduate students to senior professors, to capitalize on this growing momentum and engage in more long-term sustainable collaboration between the two countries.

S. K. Mitra is founder of the Micro and Nanoscale Transport Laboratory and Associate Vice President for research at York University in Toronto, Canada. V. Shiltsev is Director of the Accelerator Physics Center at Fermilab. Both are members of the APS Committee on International Scientific Affairs.

Related information

IndiGO consortium (gw-indigo.org)

LIGO-India (go.aps.org/29224C3)

India Institutions Fermilab Consortium (iifc.fnal.gov)

"More Money for India's Science," *Chemical & Engineering News*, March 9, p. 32 (2016).

RADCLIFFE continued from page 1

ent from the last," she says, "even if I am working on the same project."

She works on teams as small as three and as large as 15 people. Projects can last for as little as two years, but rarely longer than five years, since PPG, like any company, cannot invest indefinitely in an effort without some return.

Radcliffe says her physics background has given her a major leg up with the complex modeling she needs to optimize the properties of the metals and metal oxides that she works with. The chemistry she picked up along the way has also proven useful. "I work closely with chemists, and even though I don't have as much chemistry knowledge as they do, it greatly benefits our productivity [to be] speaking the same scientific language," she says.

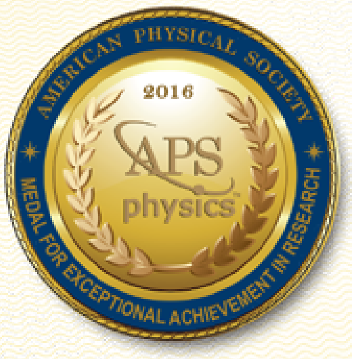
She has also had to learn certain skills on the job, including high-level statistical analysis and communications skills to present technical material to managers, who often do not have scientific backgrounds.

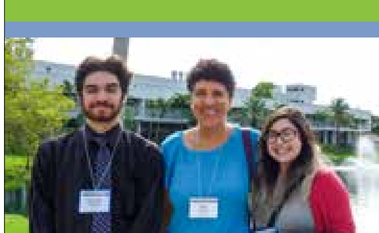
Engineering is an important career path, with around 11% of physics majors going directly into engineering jobs and earning starting salaries that often range between $49,000 and $65,000, according to statistics from the American Institute of Physics. The pathway provides endless opportunities to put physics into action, Radcliffe says. In the future she envisions pursuing a Ph.D. and directing a research and development laboratory.

"The most rewarding part of what I do is actually working with the material," she says. "Being surrounded by physics and chemistry as part of my job makes all those years studying for my degree worth it."

Gabriel Popkin is a freelance writer based in Mount Rainier, Maryland.

ANNOUNCEMENTS





RESEARCH continued from page 3

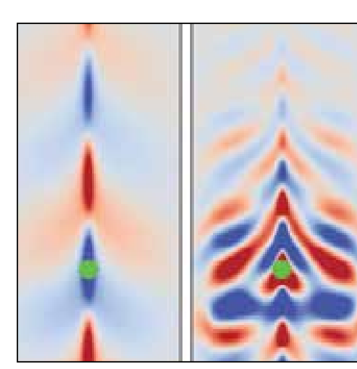
ers have not been able to make devices that guide magnons on sufficiently small scales for applications. As described in *Nature Nanotechnology*, Wagner *et al*. (vol. 11, 339) demonstrated a scheme in which magnons are launched by a microwave antenna and guided through a 40-nanometer-wide channel running along the wall between two magnetic domains on a ferromagnetic strip. Haldar *et al*. (vol. 11, 332) instead used nanolithography to fabricate a chain of 260-nanometer-wide nanoresonators, which can transport magnons generated by a nearby antenna along the chain. Importantly, both schemes are reconfigurable and could thus be used to realize programmable circuits. In the scheme of Wagner *et al*., a small applied magnetic field alters the position of the domain wall, shifting the waveguide. Haldar *et al*. use a magnetic field to control the magnetization state of individual resonators in the chain, thereby creating straight and curved spin-wave trajectories.

Black Holes Are Not Completely Bald

If you toss an encyclopedia into a black hole, is the information destroyed? John Wheeler famously said, "black holes have no hair," meaning that nothing would be visible from the outside. If this is the case, when a black hole evaporates it would destroy all the information it contains, as Stephen Hawking suggested 40 years ago. Since information loss violates quantum mechanics, this started what is known as the "black hole information paradox." In a paper in *Physical Review Letters* (vol. 116, 231301), Hawking *et al*. now suggest that black holes might have "soft hair," a kind of quantum peach fuzz of low-energy quantum excitations. Among other implications, soft hair would preserve at least a fraction of the information. So far the work relates only to electromagnetic forces, but the researchers are seeking to extend it to gravitation. Although the black hole information paradox remains unresolved, the new results point toward a fresh attack on the problem. (For more, see the Viewpoint "Black Holes Have Soft Hair" by Gary Horowitz.)

Watching Wound Healing Through Bandages

Some wounds, especially burns, must be carefully tended with constant monitoring of the dressing and healing process. This is typically done by visual inspection when the bandage is



Nature Nanotechnology

Programmable magnons

changed, but these manipulations can cause additional infection or tissue damage. Imaging with terahertz radiation might be one way to nondestructively inspect the wound area, since these frequencies penetrate many materials, especially textiles. In *Applied Physics Letters* (vol. 108, 233701), Suen and Padilla report their comparison of terahertz versus infrared and millimeter-wave imaging for noninvasive monitoring of wounds through clinical dressings and topical ointments. They found that while infrared radiation was strongly attenuated, the terahertz transmission was high for nonaqueous antimicrobial treatments and typical dressings. In addition to burn treatment, the authors suggest that terahertz imaging might also be suitable for monitoring and care of eye wounds and infections.

The Back Page

How can Physicists Help the Public Make Better Decisions about Science and Technology?

By Joel R. Primack

For more than 40 years APS has worked to improve governmental decision-making, mainly through the Congressional Science Fellowship program and through occasional studies of important science and technology issues. I helped to initiate these activities in the early 1970s, and they remain very valuable. But today's needs are far greater. How can APS and other professional societies more effectively combat anti-science propaganda and help the public develop better-informed views about science and technology? How can individual scientists communicate scientific concepts in a more understandable and engaging way? How can we encourage young scientists and students to participate in creating a scientifically responsible future?

The new science and public policy activities in the 1970s grew out of a "public interest science" movement [1,2], which assumed that better decisions would come from providing *improved knowledge* (for example, through science-based policy studies) and *expertise* (for example, Congressional Science Fellows). From participating in such activities, several thousand scientists have now become what former Presidential Science Advisor Neal Lane [3] called "civic scientists." Democratic decision-making on technological issues has certainly improved as a result.

But despite these efforts, the U.S. has continued to have difficulty addressing the crucial technological challenges of our time, including human-caused global climate change. Ever since about 1800, the doubling time for human production of carbon dioxide and other industrial waste products has been about 30 years. In the next 30 years or so, humanity must somehow stop this exponential trend and develop a sustainable relationship with Earth. Our collective impact on planetary systems is now so great that this growth in resource use must slow very quickly, despite global industrialization as an increasing fraction of the world's people improve their lives. Unfortunately, most people don't understand the dangers of exponential growth.

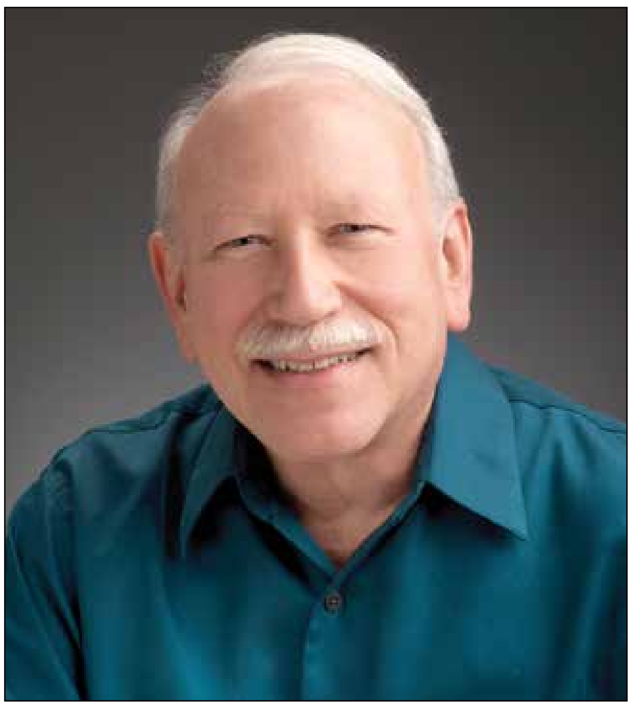
Frank von Hippel and I wrote *Advice and Dissent: Scientists in the Political Arena* [2] during the Nixon administration.

After President Nixon abolished the Presidential Science Advisory Committee, we thought things couldn't get worse — but we were wrong. For example, President Reagan committed many billions of dollars to the Strategic Defense Initiative without critical review — although the 1987 APS study on directed energy weapons subsequently showed that these "Star Wars" projects were extremely unlikely to succeed.

We did not foresee in the 1970s that the Republican Party would wage a war on science and other independent sources of truth [4]. Among the first things that Newt Gingrich's Republican Congressional majority did when they came to power in 1995 was to abolish the Congressional Office of Technology Assessment and the NSF Science for Citizens Program, and fire the only astronomer who ever headed the Smithsonian Air and Space Museum, Martin Harwit. President George W. Bush's administration appointed science advisory committees based on who had voted for him, and censored the public statements of government scientists on issues like climate change. The House Science Committee, chaired by Lamar Smith of Texas, has more recently been given sweeping investigative power by the House leadership and is using it to harass scientists. And Oklahoma Senator James Inhofe, chairman of the Senate Environment Committee, claims that global warming is a "hoax."

We also did not appreciate that prominent physicists like Frederick Seitz, National Academy president 1962-1969, would become what historians Naomi Oreskes and Erik Conway called "merchants of doubt" [5], attacking the scientific basis for regulating everything from cigarette smoking to carbon dioxide, claiming in every case that "The science is unsettled so action is premature." Such efforts unfortunately continue to work: Only about one in ten Americans understands that nearly all climate scientists are convinced that human-caused global warming is happening.

We also did not foresee that people's religious and political identities would increasingly determine their views on scientific issues like the existence of climate change — and that in the modern digital era people increasingly get information from sources, including social media, that often confirm their prejudices.



UC Santa Cruz

Joel R. Primack

So … What can we as individual scientists do to improve the situation?

First, individual scientists need to get better at explaining our research and also the scientific basis of public policy choices to the public. This is difficult for several reasons. One is because most non-scientists don't know enough about science, and also because scientific discourse is full of facts, theories, logical arguments, and jargon. We have to become better at presenting science in ways that people can grasp and act on.

Actor Alan Alda for 14 years hosted the *Scientific American Frontiers* TV show, constantly challenging scientists to explain things in a compelling way. In 2009 he founded the Alan Alda Center for Communicating Science at Stony Brook University. Alda and his team have been giving workshops for scientists about how to reach audiences by telling memorable stories. Most non-scientists quickly grasp ideas expressed as social situations and stories. The Alda team also leads improvisation exercises to help scientists learn to sense how the audience is responding and not overestimate how successfully they are communicating.

Several scientists have also been giving helpful workshops and writing books on communicating science effectively. Randy Olson, a former professor of marine biology turned film-maker, in his 2015 book [6] recommends a dialectical scheme for turning science into stories: background, problem, solution, which he summarizes as "And…But…Therefore".

The present era seems to be ripe for student involvement in hopeful causes. Scientists at colleges and universities can encourage and help our students to organize "Science Workshops on Political and Social Issues" to study important issues and help improve the world. When we were Stanford graduate students, physicist Robert Jaffe and I helped to organize a program of such courses that lasted 20 years and did much good — including helping to launch the Congressional Science Fellowship program.

When scientists become advocates, they may be perceived by their colleagues and the public as biased. But scientists have a right to express their convictions and work for social goals. These activities need not undercut rigorous commitment to objectivity in research.

What can professional scientific societies do?

Excellent science reporting can help, but scientists themselves — particularly diverse and articulate ones — are needed to explain the scientific background for important issues. We need human examples, demonstrating by their presence how a scientist thinks and acts. APS and other professional societies should encourage this by establishing new annual awards to recognize exemplary efforts of this sort by scientists at all stages of their careers.

I also suggest that leading professional societies collaborate to create online authoritative reviews of important science policy topics addressed to the public. A recent example of this is the report by the AAAS Climate Science Panel, *WHAT WE KNOW: The Reality, Risks, and Response to Climate Change*, on the web with an introductory video narrated by the president of the American Meteorological Society [7]. Creating videos and using social media to spread the messages is essential to reach a large audience in the modern world.

When serious disagreements remain about how to interpret the science underlying a policy decision, it is not advisable to paper over the differences. Nancy Ellen Abrams and Steve Berry suggested a better approach that they call Scientific Mediation [8]: Have experts who disagree write a joint report with the help of a mediator, in which they specify the topics on which they agree and disagree, and explain *why* they disagree on each of those points *to each others' satisfaction*, clarifying what additional assumptions they are making. These additional assumptions are often not scientific. Fracking and nuclear power might be good topics for Scientific Mediation.

Don't be discouraged by the tremendous challenges we face. Richard Feynman advised that in choosing projects, we should maximize the product of the (importance) x (probability of success). And don't underestimate the probability of success!

Sometimes one's public activities have unexpected benefits. When I was in Washington in 1976 to work with Senator Ted Kennedy to organize hearings and testify on the Science for Citizens bill, the Congressional Science Fellow in Kennedy's office got me invited to a meeting of President Ford's Science Advisory Committee that was discussing the proposed "Science Court". That's how I met the love of my life, my wife Nancy Ellen Abrams. Nancy was then working at the Ford Foundation, and she had been invited to the Science Advisory Committee meeting in the hopes that Ford would fund a trial of the Science Court. Nancy liked my critique of the Science Court at the meeting, one thing led to another … and we were married the following year. We have subsequently coauthored many articles and two books [9].

Side-benefits are not guaranteed, but scientists and science organizations can improve the way our society deals with issues of science and technology.

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