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APS physics

More from the 2017 APS April Meeting
(which was held in January)
Pages 3-5

Gravitational Waves: Hints, Allegations, and Things Left Unsaid

By Gabriel Popkin

Data from the Green Bank Telescope in West Virginia (shown) and Arecibo Telescope in Puerto Rico help researchers use pulsars to study gravitational waves.

2017 APS April Meeting — If the 2016 APS April Meeting was a champagne-soaked celebration for gravitational wave scientists, the 2017 meeting was more like spring training—there was lots of potential, but the real action is yet to come.

The Laser Interferometer Gravitational-Wave Observatory, or LIGO, launched the era of gravitational wave astronomy in February 2016 with the announcement of a collision between two black holes observed in September 2015. "I'm contractually obligated to show the slide [of the original detection] at any LIGO talk for at least another year," joked Jocelyn Read, a physicist at California State University, Fullerton, during her presentation at this year's meeting.

The scientific collaboration that operates the two LIGO detectors netted a second merger between slightly smaller black holes on December 26, 2015. (A third "trigger" showed up in LIGO data on October 12, 2015, but ultimately did not meet the stringent "five-sigma" statistical significance standard that physicists generally insist on.)

The detectors then went offline in January 2016 for repairs and upgrades. The second observing run began on November 30, but due to weather-related shutdowns and other logistical hurdles, the two detectors had operated simultaneously on only 12 days as of this year's meeting, which limited the experiment's statistical power. Collaboration members said they had no new detections to announce.

Instead, scientists focused on sharpening theoretical estimates of how often various events occur. In particular, they are eager to see collisions involving neutron stars, which lack sufficient mass to collapse all the way to a black hole. Neutron star collisions are thought to be plentiful, but would emit weaker gravitational waves than do mergers of more massive black holes, so the volume of space the

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Physical Review Materials

APS has launched *Physical Review Materials*, a broad-scope international journal for high-quality papers from physicists, materials scientists, chemists, engineers, and researchers in related disciplines. The initial call for papers is scheduled for mid-March 2017, and APS expects to publish the first issue in mid-2017.

In a message to the leadership of member units, APS Editor in Chief Pierre Meystre and APS Publisher Matthew Salter noted that "The decision to launch *PRMaterials* was made following intensive consultation with a wide variety of stakeholder groups within APS and the broader materials research community."

"Behind every giant technological development we can find a number of new materials," said Mu Wang, an editor of the new journal. "Materials physics, in fact, is strongly associated with condensed matter physics, chemistry, metallurgy, crystallography, and so forth. It is interdisciplinary."

"I believe there is a unique value to a materials research journal with the same high standards for peer review as the other *Physical Review* journals," said Managing Editor Athanasios Chantis. "*Physical Review Materials* will give APS a chance to play a leading role in this area."

"I'm delighted to welcome *PRMaterials* to our family of APS journals," said 2017 APS President Laura Greene. "As a materials physicist myself, I have felt the need for this journal. Pierre and Matthew worked closely with the APS Division of Materials Physics, the Division of Condensed Matter Physics, and many other relevant units to determine a well-defined scope and business model that will serve our community very well."

Watch for updates at journals.aps.org/prmaterials

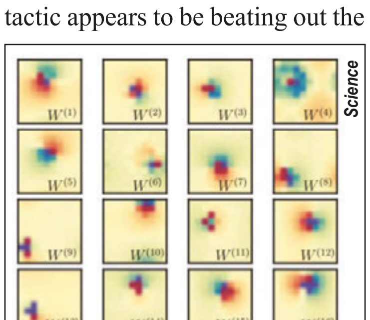
Research News: Editors' Choice

physics.aps.org

A Monthly Recap of Papers Selected by the Physics Editors

Computers Learn Quantum Physics

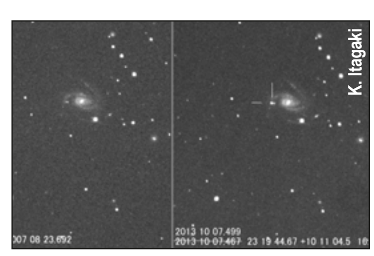
Finding the ground state of a system of many quantum particles is a challenge for even the best numerical simulation methods. But what if scientists used the idea behind machine learning and unleashed "computer players" to learn and solve the ground state of quantum many-body systems, much like computer programs that play chess or Go? Writing in *Science* (doi: 10.1126/science.aag2302), Giuseppe Carleo and Matthias Troyer describe an artificial neural network that acts as a computer player. So far, this tactic appears to be beating out the competitors—solving the ground states of quantum many-body systems faster than most numerical methods used in quantum calculations. Using a reinforcement-learning scheme, the team demonstrated that their method was capable of both finding the ground state and describing the evolution of complex interacting quantum systems over time. Although Carleo and Troyer only examined a few problems with known solutions, their program's ability to outperform state-of-the-art numerical methods in accuracy might give other scientists reason to expand upon their work in the future.



Neural nets in physics

Infant Supernova Spotted

In a serendipitous discovery, researchers at the Intermediate Palomar Transient Factory (iPTF) snagged the first optical spectra of a supernova right after its explosion. Most stars that are much more massive than the Sun explode as supernovae at the end of their lives, but researchers do not yet fully understand why and how they explode. Finding and observing a supernova explosion in its first stages is challenging: In our galaxy, these are rare events, and young supernovae even rarer. As reported in *Nature Physics* (doi:10.1038/nphys4025), scientists at the iPTF observed supernova SN 2013fs a mere three hours after explosion, and they were able to record its optical spectra as early as six hours after explosion. By characterizing the spectral lines corresponding to emissions of ionized oxygen, nitrogen, iron, helium, and hydrogen, the team shed light on both the matter ejected by the explosion and the environment surrounding the star prior to explosion. Their analysis indicates that SN 2013fs is a type II supernova originating from a red supergiant star, and that it was surrounded by a dense shell of gas, which could have been produced by instabilities during the supergiant's terminal years.



A supernova is born.

Hairdressing with Physics

Hairdressers are quick to give their tips for applying shampoo and other treatments. Now physicists have chimed in with their own

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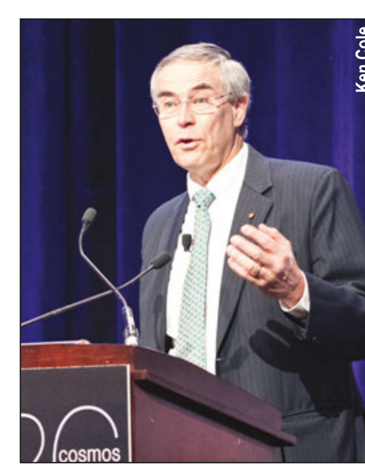
"Science is Not Just For Scientists"

By Rachel Gaal



Rush Holt

2017 APS April Meeting — Amid the political turmoil after U.S. President Donald J. Trump's election, scientists have started debating the future of science. As part of that discussion, three physicists spoke to a nearly full house at a plenary session titled *Science Policy in the 21st Century* at the 2017 APS April Meeting in Washington DC.

Rush Holt, CEO of the American Association for the Advancement of Science, a physicist and former member of Congress, captured the worries of many. "I have never seen the scientific community so uncertain, concerned, or so anxious ... We [scientists] have a reverence for evidence, but now [people] see evidence as willfully denounced and banished in principle," said Holt.

Yet the problem, he emphasized, does not lie in people's capability to understand scientific evidence.

"[Scientists] should switch from communicating the right answer to communicating the right process," Holt proposed. "[A change] will not be done by asserting the facts, it will be done by empowering people to handle evidence for themselves, no matter their level of expertise. They can demand evidence and make judgments about its value … It's their job to do it for themselves … Science is not just for scientists".

Cherry Murray, former Director of the Department of Energy's Office of Science in the Obama administration and former APS President, showed the numbers behind science research funding in past years and discussed the division of discretionary and non-discretionary spending in the U.S. budget. Her personal take on the data: expect across-the-board cuts.

"I predict that the federal funding for [science] research will be going down. … And it's not because the government believes that research is not a good investment," assured Murray. "It's because discretionary research and budgets are being highly strained … it's better to come together as all of science, rather than pointing fingers at other disciplines and saying 'we should be funding this and not that'...".

To successfully change things on any political level, the speakers agreed that getting involved in public policy is the way to make a difference. That message was driven home by Congressman Bill Foster, 11th congressional district representative from Illinois. Foster is the

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Spotlight on Development

APS Supports Industrial Physics—You can too!

By Irene Lukoff, APS Director of Development

From laser technology to microelectronics to advanced materials, physicists working in the private sector have utilized fundamental physics research to create new major industries and ensure our country's position as the world's leading economy.

APS is committed to working with industrial leaders, government agencies, and university physics departments to ensure that the American industrial physics community remains competitive and pre-eminent in the 21st century and beyond. Toward that end, APS has launched a series of initiatives in concert with the APS Industrial Physics Advisory Board, including:

- An upcoming *Report on the Economic Impact of Industrial Physics in the United States*
- Technical meetings focused on increasing the synergy between industrial physicists and new industry drivers. (The first of these, in April 2017, will be Actualization of the Internet of Things.)
- Innovative programs to provide support for entrepreneurship in physics
- Multi-dimensional efforts to better prepare physics students for industrial or entrepreneurial careers

Such programs require financial support (from both individuals and institutions) that will help APS continue its leadership in serving the entire physics community—of which more than 50% works in industry. We are grateful to the American Institute of Physics for its generous lead grant in support of the *Economic Impact* study.

Our immediate need is additional financial support for the production of this report. We will analyze the essential role of physics as a source of technology for economic growth, similar to a study of industrial physics in the UK. Our goals, however, are much greater, and we intend to use this report to catalyze a broader range of APS activities in partnership with industry leaders, government agencies, and universities. We want to ensure U.S. leadership in industrial physics in the coming decades in order to support the vital technology base essential to a strong economy.

To do this, we will nurture APS programs focused on three factors critical to that success: preparation of a talented industrial physics workforce; a culture of innovation in physics-based industries; and a sustained investment by industry in the support of industrial physics.

If you would like to join us in this effort, either through your own or your company's financial contribution and/or by directing us to other potential donors, please contact Irene I. Lukoff, Director of Development at 301-209-3224 or lukoff@aps.org. Your support will go a long way toward ensuring that APS can continue to help industrial physics flourish. Thank you!

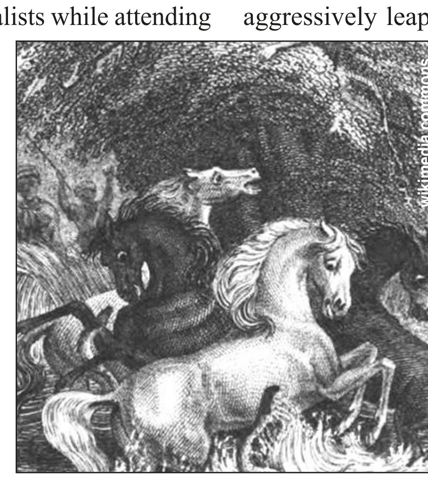
This Month in Physics History

March 19, 1800: von Humboldt Hunts Electric Eels

Friedrich Wilhelm Heinrich Alexander von Humboldt is justly lauded as one of the most influential naturalists in history, a polymath who traveled around the world and carefully recorded his observations in many published books. Among his lesser-known achievements was an account of the unusual behavior of electric eels.

Humboldt was born in 1769 to Alexander Georg von Humboldt, a former major in the Prussian Army. His mother—his father's second wife—was a former baroness by marriage who had inherited a considerable fortune upon her first husband's death. The youngster's love of nature was evident from the start. He even earned the nickname "the little apothecary" as a child, given his penchant for collecting plants and insects, all carefully labeled and preserved.

His father died when young Alexander was just 10 years old. He was never close to his mother, but she made sure he received a proper education. Initially meant for a political career, Humboldt got to know several leading naturalists while attending the University of Göttingen, and dreamt of becoming a scientific explorer himself. But his first position was as a mine inspector for the Department of Mines in Bayreuth; his scientific endeavors were more of a hobby.



While exploring Venezuela in 1799, Alexander von Humboldt observed wild horses being shocked by electric eels.

Then his older brother, Wilhelm, introduced him to Johann Wolfgang von Goethe during a trip to Jena. The naturalist returned for a three-month visit in 1797. Thanks to Goethe's influence, Humboldt became fascinated by the emerging field of galvinism, after the two men experimented with a frog leg connected to metal and found that moisture from their breath could trigger an involuntary reaction in the detached limb. When a lightning bolt killed a local farmer and his wife, Humboldt analyzed their corpses, and he reproduced Luigi Galvani's work on stimulating muscles and nerve fibers with electric shocks, using himself as a subject.

The death of Humboldt's mother in November 1796 meant that he now had the financial resources to travel the world on scientific expeditions. He partnered with botanist and physician Aimé Bonpland and received permission from the royal Bourbon court in Spain to travel to the Spanish holdings in Central and South America. Their ship landed in Cumana, Venezuela, on July 16, 1799.

On March 19, 1800, during a four-month excursion to explore the course of the Orinoco River, Humboldt and Bonpland recruited natives in the South American village of Rastro de Abaso to help them capture live specimens of electric eels, which fascinated Humboldt. The creatures were difficult to catch because they burrow into the muck of shallow waters.

The natives suggested "horse fishing"—corralling several wild horses and forcing them into the shallow water. According to Humboldt's account, the alarmed animals stamped and snorted, riling up the eels and compelling them to attack by pressing their long bodies to the horses' bellies, releasing a series of electric shocks. Surprisingly, this worked, although some of the horses drowned in the process. The eels quickly exhausted themselves and were much easier to catch with small harpoons on ropes.

Many scientists thought this was just a tall tale—one naturalist memorably called it "tommyrot"—because nobody had observed such behavior since. But in 2016, a biologist and neuroscientist at Vanderbilt University named Kenneth Catania published a paper reporting on a series of lab experiments with electric eels. His findings lent credence to Humboldt's account of eels aggressively leaping up and stunning the horses with a series of high-voltage discharges.

Catania argued that, under certain conditions, this mode of attack might be more effective than simply discharging electric shocks in the surrounding water. In 1838, Michael Faraday conducted his own experiments with electric eels and experienced only mild shocks, presumably because water in nature, with its copious dissolved salts, is a good conductor of electricity. Catania's work suggests that Humboldt's account would be especially plausible during the onset of the dry season, when eels are more likely to become stranded in shallow bodies of water.

Humboldt's first excursion was a smashing success, and he organized more expeditions, including one to Russia in 1829. Humboldt became one of the most famous men in Europe, in part because he published so much of his work, including several lavishly illustrated popular accounts. He certainly influenced other scientists, such as Charles Darwin, who told Humboldt how much the naturalist's writings had inspired him to want to travel to distant lands to study nature. Humboldt is cited frequently in *Voyage of the Beagle*. And in a letter to Joseph Dalton Hooker, Darwin declared Humboldt to be "the greatest scientific traveler who ever lived."

The cost of all those expeditions, as well as publishing more than thirty volumes about his work, gradually depleted Humboldt's fortune. In later years, he depended on a pension awarded him by

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Education & Diversity Update

Congratulations to Cal Poly San Luis Obispo for sending the highest number of undergraduate women to CUWiP!
Cal Poly San Luis Obispo sent 20 undergraduate women to the 2017 APS Conference for Undergraduate Women in Physics (CUWiP) at UCLA.

Phys21: Preparing Physics Students for 21st Century Careers
A new report provides information about the skills and knowledge that employers of physicists are seeking, and describes ways in which physics departments can help students acquire those skills and that knowledge. Learn more at compadre.org/JTUPP/.

Woman Physicist of the Month—January 2017


Laura Sinclair

Laura Sinclair is a physicist in the Applied Physics Division at the National Institute of Standards and Technology (NIST). She is recognized for pioneering new robust optical tools based on fiber frequency combs that operate outside well-controlled laboratory environments. Sinclair's internationally acclaimed comb research has been applied to time transfer across large distances and precision measurements of airborne contaminants in turbulent environments, dramatically increasing observation periods from hours to weeks. Recently, she was the technical lead of a team that was able to synchronize clocks over kilometers of turbulent air to within femtoseconds. When not wrangling optics equipment, Sinclair organizes a monthly "Awesome Women in Science" coffee hour to connect technical women across the NIST Boulder campus. Since 2008, she has served with the Rocky Mountain Rescue Group.

Woman Physicist of the Month—February 2017


Rae Robertson-Anderson

Rae Robertson-Anderson is Associate Professor and Chair of the Physics and Biophysics Department at the University of San Diego (USD), where she has been a faculty member since 2009. In 2012, she was awarded a Department of Defense Air Force Office of Scientific Research Young Investigator Program Award for her work with entangled DNA molecules. A few months later, she earned a National Science Foundation Career Award, and has developed a novel fluorescence force-measuring optical tweezers diagnostic with which she can track single molecules in complex actin networks. Anderson created an advanced biophysics laboratory course where undergraduate students learn to assemble optical tweezers and then pursue research projects. She has built a thriving undergraduate research program, and was invited to give a talk at the 2016 APS March Meeting about its successes. She has also sparked an increase in female students declaring majors in biophysics, bringing the overall percentage of female physics majors at USD up to 40%.

Nominate the next Woman Physicist of the Month at www.womeninphysics.org

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King Frederick William III, making him royal chamberlain. While initially this came with few obligations, the king insisted Humboldt return to Berlin in 1836, despite the naturalist's love of Paris.

After a lifetime of travel and adventure in pursuit of scientific knowledge, Humboldt died peacefully at age 89 in his Berlin home, reportedly exclaiming—poetic to the end—"How glorious these sunbeams are! They seem to call Earth to the Heavens!" He was given a stately funeral procession through the city streets and was buried beside his brother and sister-in-law. He never married, and left his entire estate to his valet, sparking speculation about his sexual preferences—still a strong source of contention among historians. Ultimately, it is his scientific passion that is remembered. As Robert Ingersoll wrote, "He was to science what Shakespeare was to the drama."

Further Reading

Catania, K. 2016. Leaping eels electrify threats, supporting Humboldt's account of a battle with horses. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 6979.

Wulf, A. 2015. *The Invention of Nature: Alexander von Humboldt's New World.* New York: Knopf.

Little Boy and Fat Man Cast Shadows Over April Meeting

By Gabriel Popkin

Fragments of bomb prototypes.

2017 APS April Meeting — The Manhattan Project culminated in August 1945 with the dropping of atomic bombs on Hiroshima and Nagasaki, bringing World War II to a sudden and dramatic close. More than 70 years later, historians, scientists, and the public continue to study and debate the project's genesis, impact, and legacy. That debate took the stage at the 2017 APS April Meeting, where a series of sessions highlighted how the singular and storied project laid the groundwork for massive public funding of U.S. science, and reminded attendees of the very real dangers nuclear weapons still pose.

Yale historian of science Daniel Kevles said the atomic bomb project dramatically enhanced physicists' role in society. "In the wake of Hiroshima and Nagasaki, the members of the Los Alamos generation were … a new power group in American society, thought to hold the future of civilization in their hands," he remarked. The wartime project's infrastructure—described by Kevles as a "nuclear-industrial complex"—quickly morphed into vast peacetime bureaucracies, particularly the Office of Naval Research and the Atomic Energy Commission, which continued to grow in scope and funding. (The AEC's functions were eventually subsumed into the Department of Energy in 1977.)

Physicists used their elevated status to both promote and try to dismantle the nuclear weapons complex. Most famously, Edward Teller argued for the development of the hydrogen bomb and led its development at the Lawrence Livermore National Laboratory. But others grew fearful of the threat posed by the proliferation of nuclear arms, and lobbied to reduce or eliminate them.

Physicists have also done critical arms-control work within the government, advising politicians who need to make nuclear policy decisions. Recently retired State Department physicist James Timbie received the 2017 APS Leo Szilard Lectureship Award for "demonstrating resolve, creativity, and skill in advising national security leadership on nuclear arms control and nonproliferation agreements."

In his lecture, Timbie described how he and colleagues developed the technical mechanisms necessary to enforce arms control accords such as the landmark Strategic Arms Reduction Treaty, signed in 1991. A photo of Timbie speaking with then-U.S. Secretary of State John Kerry in Lausanne, Switzerland in 2015, during a break in the negotiations with Iran over the nuclear deal that the two countries finalized later that year, showed that physics expertise was central to the agreement. Timbie noted the need for physicists working in policy to possess both technical expertise and an understanding of how politicians think. "The science has to be right," he said, "and political documents need to be acceptable to governments."

Allen Sessoms, a professor at Georgetown University and current APS Forum on Physics and Society chair, drew lessons from his tenure at the State Department in the 1970s and 80s. In a particularly dramatic episode in 1979 (known as the "Vela Incident"), a U.S. satellite detected a flash of light in the south Atlantic, and the White House disagreed with the CIA's assessment that it was a nuclear test, which would have violated the 1963 Nuclear Test Ban Treaty. Sessoms and his colleagues were asked for their opinions, and ultimately concluded that it was

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Fish Schools and Dolphin Tails

By Katherine Kornei

Winter (left), a dophin that lost her tail after being caught in a net, swims with poolmate Hope at the Clearwater Aquarium in Florida.

Several groups presented their research on swimming creatures at the APS Division of Fluid Dynamics annual meeting last November in Portland, Oregon. Two of these studies—one on how schooling fish save energy and the other on a dolphin learning to swim with a prosthetic tail—show that there is rich physics in how animals move through the water.

The benefits of schooling

Many fish such as sardines and snapper swim together in tight-knit groups. This schooling behavior may reduce drag and help the animals evade predators. Researchers from the Massachusetts Institute of Technology (MIT) shared new simulations of how schooling fish might be able to move more efficiently by sensing and using vortices shed by other fish.

The team of engineers ran computer simulations of two fish swimming one after the other in a line. The lead fish created a wake as it swam, and the researchers investigated how the rear fish, sensing that water movement, could theoretically undulate its body to optimize its forward momentum.

Biologists have shown that fish are able to sense local perturbations in the water. Most fish have a "lateral line" running along their sides, a unique sensory organ containing neuromasts, which are made up of mechanosensory hair cells similar to those in our ears. A pressure gradient across the body of the fish causes the neuromasts to bend very slightly, which the fish can perceive. "Using just this signal, fish can identify small vibrations from prey and even localize where their prey are," said Amy Gao, a graduate student involved in the research at the Tow Tank Laboratory at MIT. "You can't sneak up on a fish."

Using numerical simulations, Gao and her collaborators showed that this ability to sense the local flow allowed the rear fish to essentially slalom around the vortices shed by the lead fish. "The rear fish adjusts its motion to take advantage of vortices along its entire body," explained Gao. The researchers demonstrated that, at least in theory, schooling fish can use information from their lateral lines to expend less energy.

The team hopes that this work might lead to underwater vehicles having "smart skins" with sensors akin to a fish's neuromasts. In dark or murky waters, typical light-based sensors are not useful, and a vehicle that could perceive and respond to changes in water pressure would still be able to navigate. "This kind of information will make it possible for manmade vehicles to avoid obstacles and operate stably in areas that are currently very dangerous, such as in surf and shipwreck zones," said Gao. That's

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Solar Eclipse Offers Up a Scientific Bonanza

By Gabriel Popkin

2017 APS April Meeting—Some things stand out best when the lights are dimmed. On August 21, 2017 nature will turn down Earth's brightest light of all, when the shadow from a total solar eclipse passes coast-to-coast over the United States. From Newport, Oregon to McClellanville, South Carolina, this total eclipse will plunge parts of 12 states into darkness lasting up to nearly three minutes. "We are trying to persuade people how wonderful it will be to travel into the path of the eclipse," said Jay Pasachoff, a physicist at Williams College in Williamstown, Massachusetts, speaking at a press conference at the 2017 APS April Meeting in Washington, D.C. "This goes for the general public, for physicists, and for teachers and their students."

Solar eclipses have played important roles in physics history, from Pierre Janssen's discovery of helium in 1868 to Arthur Eddington's experimental confirmation of Albert Einstein's general relativity theory in 1919. The 2017 eclipse will add to that legacy, says Edward DeLuca, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics. "This eclipse is going to be very productive scientifically, because the path covers a large area of a very populous, high-technology country."

Many of the planned observations will focus on the sun's corona—massive wisps of plasma that jut from the solar surface up to millions of kilometers into space. The corona is usually outshone by the sun by around a million times, making its light difficult to isolate. Instruments called coronagraphs can block much of the sun's direct glare, but because the moon's angular size from Earth is so close to that of the sun, solar eclipses still provide the best view, especially of the inner corona near the solar surface. "It's a unique perspective to focus our instruments onto just the corona," says Steve Clarke, director of NASA's Heliophysics Division, which is funding 11 eclipse studies.

What goes on in the corona can shed light on the inner workings of the sun. The sun is now approaching a solar minimum, the low point in the sun's 11-year activity cycle. Though the number of sunspots on the sun's surface is the cycle's best-known feature, the sizes of coronal plumes are also affected by it. From an outpost on the campus of Willamette University in Salem, Oregon, Pasachoff will add photographic and spectroscopic data to his decades-long series of eclipse observations, to track how the corona changes through the cycle's peaks and valleys. He will then look for clues as to whether the sun has recently gone through a minimum, or whether the next cycle may be delayed, as some suspect.

Pasachoff will also gather data to try to understand how the corona gets so hot—up to a million kelvin, compared to only around 5,800 kelvin at the sun's surface. "There are 12 different models" to explain coronal heating, Pasachoff says. "There are a bunch of people who say they know, but they disagree. We're trying to provide some observational backing."

As society has become increasingly technology-dependent, understanding the corona has become important for a broader group of stakeholders than just scientists. Solar storms—blasts of powerful charged particles that stream out from the corona—can bring down power grids and disrupt GPS and communication satellites. But prediction of solar storms is poor, with scientists sometimes able to provide only around an hour's warning before a major solar storm arrives at Earth, says Clarke.

To improve such predictions, Shadia Habbal of the University of Hawaii will deploy teams of "solar Sherpas" with portable spectrographs to several sites in the western U.S., where skies are most likely to be clear, to look for visible emission lines from iron and other elements that have been highly ionized by the corona's extreme temperatures. These data will help her produce what she calls "a temperature map of the corona." Such a map could help scientists better understand the formation of coronal mass ejections—massive blobs of fast-moving particles that cause some of the biggest challenges to Earth-based infrastructure.

The August 21, 2017 solar eclipse can be seen across the continental United States.

DeLuca, meanwhile, will fly a National Science Foundation-funded airplane from southeastern Missouri to Tennessee, over the region where the eclipse will last the longest. His team will test a spectrograph designed to observe infrared emission lines, most of which are blocked from reaching the ground by water vapor in Earth's atmosphere. These data could serve as a proxy for the sun's internal magnetic field, which is believed to be largely responsible for space weather, but whose behavior remains poorly understood.

By the time August 21 rolls around, solar physicists like DeLuca, Habbal and Pasachoff will have spent more than a year preparing for less than three minutes of data collection. It's worth it, they say. "People ask me all the time, haven't you seen enough eclipses?" said Pasachoff, who holds the world record of most eclipses viewed, at 66. "I say, if you were a heart surgeon and somebody told you this is your only opportunity to look inside a human heart, but it's only for two minutes and you have to go to Africa, nobody would say 'Didn't you do that four years ago?'"

"Until we can make artificial eclipses in space as good as what we get here on Earth," he added, "It's very worthwhile to study solar eclipses."

The author is a freelance science writer in Mount Rainier, Maryland.

Nobel Laureate Dan Schechtman: Advice for Young Scientists

Physicists long believed that the structures of all crystals consisted of patterns that repeated over and over again. But that all changed in 1982, when Dan Shechtman of the Technion Institute in Israel was on sabbatical at the National Bureau of Standards (NBS, which later became NIST). He looked through his microscope and saw something he thought could not exist—crystal structures that are mathematically regular but do not repeat themselves.

Shechtman had discovered quasicrystals. Today, they are in a variety of applications including steel armor and non-stick frying pans. But back in the 1980s, his work shook up the world of chemistry. Although his discovery was first shunned by certain scientists, including his team leader at NBS and Linus Pauling, it started a new era of crystallography and garnered him the Nobel Prize in 2011.

Alaina G. Levine had the chance to sit down with Shechtman while at last year's Lindau Nobel Laureates Meeting to discuss his advice for success in science and how to deal with rejection. This interview has been edited for space and clarity.

AGL: How did you get interested in science?

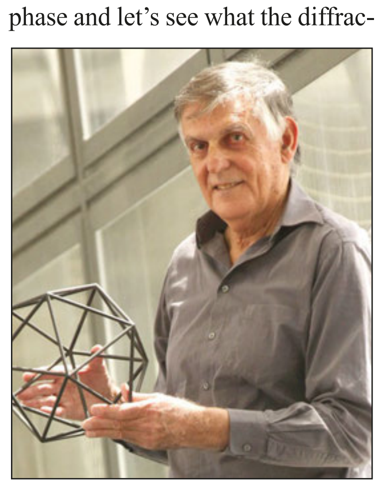
DS: My grandfather brought to me the first facts of science and he explained to me how things work. He also bought me a very important present that later shaped my life—a magnifying glass. I was 7 years old, just starting school. I was walking with this magnifying glass looking at insects and flowers and everything small, and I fell in love with the world of small things. This was the start.

When I was 10 years old, [one of my teachers] said to the class "We have a microscope in school," and I jumped and asked "Can you bring it to class?" and I kept asking him. Finally after several weeks of asking, he brought it to class and he said "Dan, You're the most interested here, why don't you come to the microscope and look at it." I came to the bench and looked at the microscope and I could not leave the microscope. It was amazing, amazing! So the teacher said "Sit down and let others try" and I said "Wait, wait! noooo!!"

In 1966 or 67, while I was doing my master's degree at the Technion, they bought the first transmission electron microscope. I sat by the technician who assembled the microscope, day and night. He was Japanese. He spoke [no] English. So I learned the mechanics of the machine, how to use the machine properly. I studied the theory and practice. I became an expert in transmission electron microscopy. What is an expert? Somebody who can teach. I taught many classes in this.

AGL: You were 41 when you made your discovery. Tell me about what led up to that moment.

DS: On April 8, 1982, I looked in the microscope, about half a year after I arrived at NBS for my sabbatical and I said, "Hmm, that's interesting". You know how Archimedes shouted Eureka? You don't do that anymore. Today when you make a discovery, usually the first mention is, "Hmm, that's interesting" or "Hey! What's going on here? This may be a discovery." At that moment, I said here is the phase and let's see what the diffraction pattern is, and I said "ein chaia kazo", which is Hebrew for "There ain't no such animal!". So I looked again and said I must show this to someone. I walked out of the room and I looked left and right. There was nobody. So I went back to the microscope. I continued until the evening to try to find out what I had. Immediately my thought was that this is a twin structure. I spent all afternoon looking for the twins with every method that was available, but couldn't find it. So I knew it was something. But what was it? I knew what it was not a twinned structure.



Dan Shechtman and the Blech model

The first person who was willing to work with me brought up the notion of a new structure. He was Ilan Blech who was a professor at the Technion. He proposed a model to show how such materials could have been created. It's called the Blech Model. It's a physical model of icosahedra joining in space. Together with him we sent a paper for publication to the *Journal of Applied Physics*. It was rejected right away. The editor didn't even send it for review.

So I sent the paper to the *Journal of Metallurgical Transactions*, which published it eight months later, in June 1985. In the meantime, I showed the rejected paper to John Cahn, who was my host at NBS. I asked him why was it rejected. He read it, and said "Danny we have something fantastic here. Let's do something completely different. Let's write another paper, a short one and send it to PRL." We did and it was accepted and published in November 1984. So the second paper was published first. Ilan Blech and Denis Gratias, a mathematical crystallographer from France were also with us on the paper.

When this was published in 1984, hell broke loose all over the world. I was getting emails, telephone calls, letters. In the paper I explained how to make the material. This was a fast growing community of brilliant young scientists who took my discovery and turned it into a thriving science. They found many, many new alloys, including stable ones. They studied their properties. Uh! We had such fun in those days. We were a close community. Everybody knew everybody.

AGL: So basically there was the moment in 1982 and the moment when the paper came out. What happened in between?

DS: In the end of 1983, I left NBS to go back to Israel, and I started to talk about my 10-fold diffraction patterns and something new in crystallography. And people said this is nonsense. So the reaction varied, between the reaction of my host, John Cahn, who was positive, and said "Danny this material is telling us something and I challenge you to find out what it is." He encouraged me to continue studying it. The other side, the worst reaction, was from my group leader who came to my office one day, smiling sheepishly and put a book on my desk on x-ray crystallography. He told me to "read this book and you'll understand what you're talking about." I said "I don't need to read the book. I'm a professor at the Technion. My material is not in the book." A few days later, the group leader said to me "You are a disgrace. I want you to leave. I cannot have my name associated with you." So I had to leave my group but I found another researcher there who was willing to adopt a scientific orphan—me.

AGL: What motivated this behavior?

DS: This was a shocking discovery. We had 70 years of established crystallography without any exception to periodicity. Hundreds of thousands of phases were studied. The science of crystallography was considered a mature science.

AGL: What advice do you

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News from the APS Office of Public Affairs

APS Leads in Capitol Hill Meetings with New Congress

By Tawanda W. Johnson, APS Press Secretary

APS was the first scientific organization to coordinate a "congressional visits day" on Capitol Hill with the 115th Congress, and according to the APS members who participated, congressional staffers responded positively to the Society's messages.

The meetings, held in late January, were part of the APS Leadership Convocation, an annual gathering of unit officers that provides an opportunity to meet and interact with APS elected leadership and staff. Attendees learn about APS programs and services, as well as network with and learn from each other.

The APS Office of Public Affairs, working with the Physics Policy Committee and the Board Executive Committee, identified five key issues for the Hill meetings. All participants were asked to discuss the federal research budget and scientific infrastructure; they were also provided optional information on science education, clean energy jobs, and managing the cost of helium.

"I was surprised and pleased at the response we received from about eight offices we visited, especially on the issues of education and science infrastructure," said E. J. Zita, a physicist at The Evergreen State College and a port commissioner in Port of Olympia, Washington.

Added Maria Spiropulu, physics professor at the California Institute of Technology and chair of the Forum on International Physics for APS, "The visit was very successful; the follow-up is important after such a visit to create persistent links with people on Capitol Hill."

Zita and Spiropulu were among 53 APS members from 23 states who participated in 82 congressional meetings. Staffers in the APS Office of Public Affairs (OPA) prepared the members for the meetings via a video presentation, web conferences, in-person training, and one-page issue briefs.

"APS set up these meetings in an organized way and prepared us with coherent messages that were really useful and helped us to be more effective," said Zita.

Spiropulu said it's imperative for scientists to meet with their congressional representatives.

"We live in times of exponential progress in science and technology. Scientists need to take the time to explain their work and the impact of their work," she said.

Helping members maintain contact with their congressional representatives is crucial to becoming effective science policy advocates, said Greg Mack, APS government relations specialist who oversees the Society's grassroots program.

"We want them to continue having those conversations about science policy. Sending emails, making phone calls, and holding meetings are all ways they can continue to keep the connection strong," said Mack.

He added he plans to follow up with APS members in key congressional districts to develop advocates to focus on state-based meetings.

Francis Slakey, interim director of OPA, said the APS members' comments from the January meetings would be put to good use.

"We are assembling feedback from members, and the information will be used to fine-tune our messages and asks," he said. "We'll also be sharing this information with other scientific societies to help inform their congressional visits."

To learn more about getting involved with grassroots advocacy, contact Greg Mack at mack@aps.org.

APS members spoke with their representatives on Congressional Visits Day (L-R): George Leonardo, staffer in the office of Sen. John Cornyn (R-TX); Jodi Cooley, Vernita Gordon and Carlos Bertulani.

Kavli Foundation Keynote Plenary: From Quarks to the Cosmos

The 2017 APS April Meeting featured a keynote plenary session sponsored by the Kavli Foundation with three speakers on topics ranging from the smallest particles to the entire universe. (L to R): Barbara Jacak of the University of California Berkeley spoke on the properties of quark-gluon plasma created by heavy ion collisions; Cora Dvorkin of Harvard University covered the latest results in cosmology; and S. James Gates of the University of Maryland presented his results on supersymmetry and its mathematical connections to error-correction codes, card games, and music. This and the other plenary sessions can be viewed at aps.org/meetings/april/

International Firsts in Physics

By Rachel Gaal

2017 APS April Meeting—After 14 years of slingshotting electrons around its ring of magnets, the BESSY-1 accelerator was due for an upgrade. The synchrotron radiation source, once housed at the Helmholtz-Zentrum Berlin (HZB), was set to be decommissioned at the end of 1999, in favor of its successor, BESSY-2. While it seemed that BESSY-1 was headed for the junkyard, Germany had other plans—to donate it to a growing effort outside of Europe, a joint synchrotron radiation facility that would be built somewhere in the Middle East. Worth $60 million at the time, this donation was a key step forward to foster a radical type of scientific collaboration in the Middle East.

Now known as SESAME, the Synchrotron-light for Experimental Science and Applications in the Middle East, the third-generation light source is housed in Allan, Jordan, with the new and improved BESSY-1 serving as the injector for the main ring. SESAME recently reached another milestone in mid-January 2017, successfully circulating its first beam.

"SESAME started in 1997, and the facility is finally completed," Herman Winick of SLAC and member of SESAME's Scientific Advisory Committee announced at the 2017 APS April Meeting. "The first beams are finally going around the 2.5 GeV storage ring, which is the first in the Middle East."

Modeled after the cooperative framework of the European Organization for Nuclear Research (CERN), the SESAME synchrotron is supported by nine members: Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and Turkey. Before becoming its own independent intergovernmental organization in 2004, it was established under the auspices of UNESCO.

"The 2.5 GeV machine is small, at 133 meters in circumference," Winick continued. "But it can support 28 simultaneously operating beamlines, and it's been gratifying to see Middle East engineers working on this … countries that might not normally recognize each other want to train their students here and do research. [They are] discovering they can do world-class research at home."

This type of scientific collaboration is designed to combat the notorious "brain drain" in developing countries, where many talented scientists are recruited outside of their home country to conduct research—rarely returning due to lack of state-of-the-art facilities and research opportunities.

Young students at the African Institute for Mathematical Sciences

Many African countries, including more developed areas such as South Africa, fall victim to the drain. Neil Turok, director of the Perimeter Institute for Theoretical Physics and founder of the African Institute for Mathematical Sciences (AIMS South Africa), described his experience with this quandary at the 2017 APS April Meeting:

"Tens of thousands of undergrads graduate from African countries, but they don't have the quality of education to allow them to do everything … and there is always encouragement for [graduates] to come to the U.S. or the U.K., but they never come back. We want to change that."

Focused on training postgraduate students across Africa, AIMS South Africa has been in operation since 2003, and has expanded its original center in South Africa to operate in Senegal, Ghana, Cameroon, Tanzania, and Rwanda. The centers feature 24/7 learning environments for the students, with resident tutors, libraries, and computer facilities at their fingertips. Turok called it the "epitome of a university."

"No matter the scientific areas our students go into, we designed a center that would allow them to go into any area of science and technology," Turok said. "The students way exceeded our expectations [when we started]. We had students that came out of the Congo—these sophisticated, young intellectuals—that took full advantage of our system."

In 2008, Turok was awarded the TED prize for his Next Einstein Initiative: a push to harness the creativity and knowledge that African students needed, who were "starved of opportunity" and in need of a better future.

"We ran for five years ... and then I gave a TED talk that made me publicly commit to finding the next 'African Einstein.' And to do so, I want[ed] to establish 15 AIMS centers in Africa," explained Turok. "We are slowly getting there ... each [center] has between 50-100 students, with postgraduate and Ph.D. students. We get over 4,000 applications per year … our progress is truly exciting."

So far, 70 percent of graduated students have stayed local—working, teaching, or pursuing advanced degrees in African countries. New science initiatives in Africa, such as the Square Kilometer Array and the Quantum Leap Africa Research Centre, will keep well-trained students and graduates in their native countries for research and collaborative opportunities.

Another international pursuit was announced at the 2017 APS April Meeting—two efforts to detect dark matter, at new underground labs in Africa and South Korea. Zeblon Z. Vilakazi of the University of the Witwatersrand is looking to establish a Southern African Underground Laboratory, one of few in the southern hemisphere.

"We propose to extend Mponeng Gold Mine, a sister gold mine to TauTona, down to 4500 meters, which would be the deepest mine in the world," Vilakazi announced. "The deeper underground … provides [more] natural shielding that attenuates all the cosmogenic background.

Partners in Germany and France have already voiced their support, including South African institutions of Stellenbosch University, University of Western Cape, University of Cape Town, Saldanha

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only Ph.D. scientist that remains in Congress. Rush Holt, who also served as New Jersey's 12th district representative, served alongside Foster until his resignation in 2015.

"People ask me, 'why does anyone want to take this job [as a congressman]?'," explained Foster. "Well, there's this thing they give you … a voting card ... and you take this card, you take it across Independence Avenue, onto the floor of the U.S. House of Representatives, and you take the card, put it in a slot, and you press the red ['no'] button or the green ['yes'] button, and the world changes a little bit—and that's why you take the job. The rest is just noise."

Although the three speakers do not expect every physicist to run for office, as that task itself is a full-time job, their advice was to contact local representatives to convey the importance of science-based evidence and the value of science in everyday life.

Cherry Murray

"Some of these stories need to be about science and education as an investment for the future," added Murray during her response to tips for talking to political officials. "... like your work with accelerators, [which] might be used for cancer therapy … or [that] they have these effects for other things [beyond] high energy physics that helps society … that would be a really good story to tell."

Bill Foster

During a time of international tension, Sergey Kislyak, Russia's ambassador to the United States, offered his views at a scientific session, *Physics Improving International Diplomacy.* As the history of U.S. and Russia relations shows, he said, scientific collaboration played a crucial role in achieving scientific discoveries and achievements, even throughout the Cold War.

"I think a lot of things can still be done at this point," commented Kislyak. "... It's very important that ties between people and understanding between people is remembered … Science and technolog[ical] collaboration is one of the best vehicles to build that type of trust, because they [scientists] are interested in the success of the collaboration, [and] they understand what the other side needs [or] what it doesn't."

"Think [of the] Russians and Americans on the space station," Kislyak continued. "They risked their lives together to be able to continue the exploration of space … That's the model we need to strive for."

To obtain resources for contacting your local state representative, contact the APS Office of Public Affairs.

To watch the Plenary Sessions and other featured scientific sessions from the APS April Meeting, visit the APS April Meeting Homepage.

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Military Academy, EARTH Foundation, iThemba LABS, and the University of Witwatersrand.

Yeongduk Kim of the Institute for Basic Science (IBS) in South Korea is in charge of the new underground lab under construction in an active iron mine there. "The Center for Underground Physics (CUP), which was approved by IBS in 2013, [will be] a new world-class underground in terms of quality ... we wanted to make final detectors from the very raw materials in the center, by growing the crystals underground. We are [also] fabricating the sensors to work at a temperature lower than 1 kelvin."

A smaller laboratory, currently located in an underground power plant, will be replaced in 2019. There, CUP hopes to confirm the annual modulation signal from dark matter particles that the DAMA collaboration detected over 20 years ago. Kim said that the COSINE-100 project is the first serious experiment to use the same kind of sodium iodide crystals as the DAMA collaboration to compare and "double check" their results in 2017.

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LIGO detectors can scan for such events is smaller.

Even with recent upgrades, failure to detect a neutron star merger during the current observing run would not rule out existing models, said Read. But she added that with future improvements and the long-anticipated addition of Virgo, a LIGO-like detector based in Cascina, Italy, neutron stars should soon come out of hiding. "We're expecting that with a little more volume and a little more time, we're going to be starting to make some astrophysically interesting statements."

LIGO scientists are also looking for signals from individual pulsars—rapidly rotating neutron stars that are observed on earth as pulses of radio waves. A bump on a pulsar's surface should produce gravitational waves, but so far, no waves with the right shape have been picked up. This absence puts a limit on the size of any irregularities and on the emission power of gravitational waves from nearby pulsars such as the Crab and Vela pulsars, said Michael Landry, head of the Hanford LIGO observatory, and could soon start putting limits on more distant ones.

Presenters dropped a few hints of possible excitement to come. LIGO data taken through the end of January produced two short signals that were unusual enough to exceed the experiment's "false alarm" threshold—signals with shapes and strengths expected to show up once a month or less by chance alone. Both LIGO collaboration members and astronomers at conventional telescopes are investigating the data to determine whether they represent real events.

For now, potential events will continue to be scrutinized by collaboration members, and released to the public via announcements coming months after initial detection. But LIGO leaders expect to shorten the lag time as detections become more frequent, perhaps eventually putting out monthly updates. "We hope to make it quicker," said LIGO collaboration spokesperson Gabriela González, a physicist at Louisiana State University in Baton Rouge.

LIGO is not the only means by which scientists are searching for gravitational waves. Some scientists are using powerful radio telescopes to track signals emanating from dozens of extremely fast-rotating pulsars. A specific pattern of correlations between tiny hiccups in the arrival times of these pulses would be a signature of long-wavelength gravitational waves expected from mergers of distant supermassive black holes.

Teams in the U.S., Europe, and Australia have monitored pulsars for more than a decade, so far without positive results. But in an invited talk, Laura Sampson of Northwestern University in Evanston, Illinois, coyly announced "hints of some interesting signals." With 11 years of timing data from 18 pulsars tracked by the Green Bank Telescope in West Virginia and the Arecibo Telescope in Puerto Rico, Sampson and other scientists affiliated with a collaboration called NANOGrav have eked out a result with a statistical significance of around 1.5 to 2 sigma. "It's the first hint we've ever had that there might be a signal in the data," Sampson said. "Everything we've done before was straight-up limits."

As NANOGrav continues to gather data, their signal could grow toward the 5-sigma gold standard, or it could vanish. Sampson and her colleagues hope to have an answer in the next year or two. "This is of course very exciting news," said Gonzalez.

The author is a freelance science writer based in Mount Rainier, Maryland.

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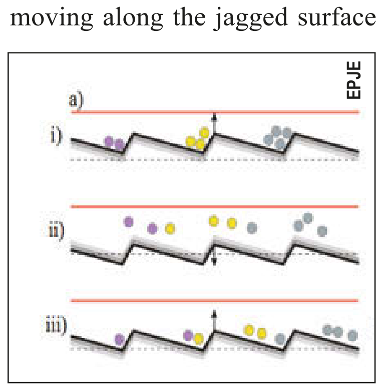
grooming advice. A new theoretical study published in the *European Physical Journal E* (doi: 10.1140/epje/i2016-16116-4) concludes that massaging perpendicular to the hair strands can help transport the nanoparticles in shampoo-like drug treatments toward the hair follicle. The secret is in the structure of hair cuticles, which have a rigid saw-tooth structure. By using standard models of random motion, Matthias Radtke and Roland Netz were able to simulate the motion of particles moving along the jagged surface



Particles ratchet along hair

of the hairs as a result of the oscillatory motion of massaging. They found that the sawtooth-like surface helped guide the nanoparticles toward the bottom shaft near the follicle when massaged perpendicular to the strand. When massaged relative to the strand in a parallel motion, the particles were found to move up the strand, away from the narrow shaft of the cuticle. Radtke and Netz also adjusted the size and shape of the particles and found the smaller the particle size, the faster they moved down the shaft to the cuticle of hair.

Starlight Puts Quantum Mechanics to the Test

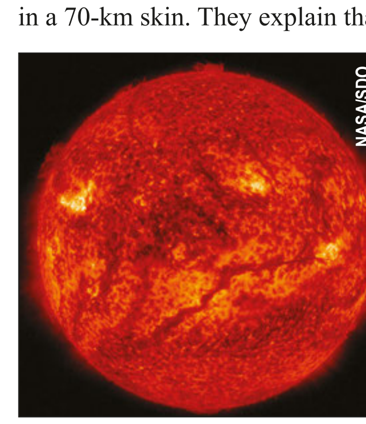
Researchers have used light from two stars in the Milky Way to close a loophole in experiments that support nonlocality—the notion that very distant phenomena can

Cosmic test of quantum mechanics

be correlated by quantum entanglement. Nonlocality can be verified through so-called Bell tests, experiments whose outcomes cannot be explained by any local theory. But the experiments can have loopholes that allow a purely classical interpretation. In 2015, scientists closed two major loopholes in the same experiment (see Viewpoint: physics.aps.org/articles/v8/123), but a third back door remained ajar: Bell tests could be invalid if some of the experimental parameters were correlated through an unknown mechanism instead of being randomly chosen. Handsteiner et al. have now closed this "freedom of choice" loophole by exploiting the random nature of starlight. Using two telescopes, the authors collected photons from two stars and used the photons' fluctuations to create randomized settings for Bell tests. The results, described in *Physical Review Letters* (doi: 10.1103/PhysRevLett.118.060401) close the loophole over a time-scale corresponding to the time taken by light to travel to Earth, 600 years—a 16 order-of-magnitude improvement over previous tests. (For more, see the Synopsis "Cosmic Test of Quantum Mechanics" in *Physics* at physics.aps.org/synopsis-for/10.1103/PhysRevLett.118.060401)

Light Slows Sun's Surface

Using a new imaging technique that tracks seismic waves moving through the Sun, researchers have confirmed that the star's surface rotates slower than its interior and they may have figured out why. In a paper in *Physical Review Letters* (doi.org/10.1103/PhysRevLett.118.051102), Cunnyngham et al. propose that photons radiated from the surface extract angular momentum, slowing down the surface rotation. Past observations have had limited resolution (about 2000 km), but the team's new measurements probed the Sun's outer layers with 10-km resolution, finding that most of the rotation slowdown happens in a 70-km skin. They explain that



Photons put a brake on the sun

as photons diffuse outward from the core, their exchange of angular momentum with turbulent plasma produces a mild braking force. This braking is most effective at the outer layer of the Sun, where the plasma density is lowest. The researchers calculated the rotation speed implied by their photon-braking effect and found good agreement with their solar observations. This braking mechanism would not be sufficiently strong to affect the rotation speed of the Sun's core, but it could be relevant for brighter stars, which radiate more photons. (See the Focus story "Photons Brake the Sun" in *Physics* at physics.aps.org/articles/v10/13.)

ANNOUNCEMENTS

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indeed a nuclear test. "Science is an add-on to the political discussion," he said, "but it allows an honest broker to give advice."

Though most talks centered on the original bombs' development and legacy, one presentation zeroed in on the devices themselves. John Coster-Mullen, a retired photographer and truck driver from Waukesha, Wisconsin, pieced together over two decades a replica of the Little Boy uranium bomb that was dropped on Hiroshima, and self-published a book on the bomb's design that has been lauded by experts for its accuracy.

Recently he discovered that an area where early bomb prototypes were tested has become publicly accessible, and he displayed at a press conference pieces of bomb casings that he and a colleague collected during a 2013 visit to the site. He did it all without official assistance from Department of Energy personnel, he noted, who to this day have kept Little Boy's design classified. "There are some people who like what I've done and some people who don't," Coster-Mullen said. "I have a fan base at Los Alamos because I've preserved a lot of their history."

Planning for the nuclear weapon-themed sessions got underway well before the 2016 U.S. presidential election. Nevertheless, Donald Trump's nascent presidency added a note of urgency to the proceedings. Speakers noted the decision by the board of the *Bulletin of the Atomic Scientists* to advance the hands of its "doomsday clock" to 2.5 minutes before midnight. They also cited President Trump's statements and tweets suggesting an ambition to rebuild the U.S. nuclear arsenal, and the lack of technical expertise held by Rick Perry, the nominee to head of the Department of Energy, in contrast to his predecessor, physicist Ernest Moniz.

As the threat of nuclear weapons regains currency after a post-Cold War lull, and while many of the experts who have long advised the government approach retirement, a new generation of physicists must get involved, speakers urged. Technical expertise will continue to be needed to steward existing weapons stockpiles, establish and enforce monitoring regimes to prevent additional countries from acquiring weapons, and advise governments on the severity of threats from newly nuclear-armed countries such as North Korea.

That expertise should be provided no matter which party is in charge in Washington, Sessoms added. "Nuclear weapons are not an ideological issue."

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good news considering that the deep ocean is one of our planet's most unexplored ecosystems.

Swimming like a dolphin

Hundreds of thousands of whales, dolphins, and porpoises die each year after becoming snared in fishing traps and lines, but Winter was one of the lucky ones. The female Atlantic bottlenose dolphin was entangled in a crab trap line near Cape Canaveral, and a fisherman spotted her and called an animal rescue team.

Winter survived, but the accident had cut off circulation to the two-month-old's tail, and it could not be saved. The dolphin amputee now lives at an aquarium in Florida, and marine veterinarians have outfitted her with a prosthetic tail. At the APS meeting, physicists shared new results of a hydrodynamic study of Winter swimming with her prosthesis.

Without her prosthetic tail, Winter tends to move her body side to side to propel herself forward, unlike able-bodied dolphins that move up and down. "When Winter lost her tail, she lost her ability to undulate from top to bottom and adopted a side-to-side undulation," explained Ayodeji Toluwanimi Bode-Oke, a graduate student in the Mechanical and Aerospace Engineering department at the University of Virginia, who was involved in the research. This unnatural movement stresses Winter's spine, and she has begun to show early signs of scoliosis.

The research team analyzed videos of Winter wearing her prosthesis and modeled her movements in three dimensions. By outfitting Winter with a prosthetic tail, her trainers at Clearwater Marine Aquarium are slowly retraining her to swim like a dolphin.

Bode-Oke and his collaborators studied Winter's wake patterns as she flapped her prosthetic tail up and down. The researchers showed that only the downstroke of Winter's tail propelled her forward. Able-bodied dolphins—like Winter's pool-mate Hope—propel themselves on both the downstroke and upstroke of their tails. But in Winter's case, the upward movement of her tail was actually holding her back. "The upstroke causes drag that almost cancels out the thrust production in the downstroke," explained Bode-Oke. "Winter consumes twice the power and produces one quarter the thrust of a normal dolphin over the course of each flapping stroke."

In order to test how Winter's increased drag affected her movement, the scientists calculated Winter's stride length—her forward movement in one flapping motion of her tail, relative to her body length. They determined a value of about 0.35, far less than that of healthy dolphins, which have stride lengths of 0.80–0.90. Bode-Oke and his colleagues hypothesize that Winter's curved body shape, caused by her scoliosis, might be preventing the dolphin from swimming as efficiently as Hope.

These hydrodynamic analyses will be useful for designing new versions of Winter's prosthesis, Bode-Oke says. For now, the dolphin is happy to consume handfuls of capelin and silversides, her two favorite kinds of fish, as the scientists do their work.

The author is a freelance science writer based in Portland, Oregon.

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offer young scientists about dealing with rejection?

DS: I have several [pieces of advice]. Number one, become an expert in something you like. Try to be the best in something you like. Once you are an expert and someone criticizes you, then you can say "You may be the greatest scientist in the world but I am an expert in this." Number two, pay attention to details, especially surprising details that you don't expect. And if you find something strange, don't let it disappear. Study and find out what it is. Sometimes it will be an artifact, but in some cases, you've made a great discovery that will determine your success in science and your career. So be like a Rottweiler: bite and don't let go! And if somebody says this is rubbish, say "Don't tell me it's not in the book. Show me what's wrong". Check yourself ten times before you start talking. Make sure you don't make a mistake. But as an expert, trust yourself.

AGL: Can you tell me about your experience with the late Linus Pauling?

DS: Pauling was arguably the greatest chemist of the 20th century. He was a brilliant scientist. But he lacked one thing—he was not modest. He thought he understood everything. When he started to argue with me and also my followers, he entered my territory without being an expert in electron microscopy. He tried to find faults in our models.

AGL: What advice would you offer a young scientist coming to a conference, to go up to a leader in the field?

DS: One piece of advice: Develop your social skills. Social skills are as important as intellectual skills for succeeding in life.

The Back Page

Physics for the Masses

By Ivan K. Schuller

"You must be very intelligent" is one of the better reactions we physicists evoke when interacting with the general public. In fact, probably what members of the public mean is that physicists "are very boring." Try it at a family gathering, in an airplane, at the grocery store, in a bus, or any occasion when you are with nonscientists. Keep in mind that these very same people are the voters that decide who will make future major decisions regarding scientific funding and the direction of science.

The public can be divided into three groups: a small minority that is in constant contact with scientists and thus may understand somewhat what we do, a minority (probably less than 1 percent of the population) that has a positive appreciation of science, and a large majority that neither understands science, the connection to technology, nor the funding process for science. This large majority, in the best case, believes that we are dedicated to solving short-term practical problems such as curing cancer, developing green energy, reducing global warming or developing bigger bombs. Alternatively, they may believe that we work in purely philosophical, esoteric areas, unconnected to their daily lives.

Unfortunately, as a result of whom they vote for, this large majority ultimately makes important decisions regarding funding, the validity of certain theories such as evolution, and even the importance of science for decision making in the government. Simply put, a large uninformed public makes collective decisions about science, which not only impact the well-being of science but also the future of the world. I believe the current situation is bad and seems to be getting worse.

I have presented the issues outlined above to many different audiences of scientists and heard many criticisms, including:

- The public already understands what we do.
- Educate them and they will understand the importance of science.
- Don't dumb down the physics in order to make it understandable.
- Trying to change things is a waste of time

Sorry. None of the above statements are valid. Not only is our (scientists') well-being at stake, but also the well-being of the world. Perhaps most importantly it is our obligation to inform the public!

In order to propose specific solutions to this problem it is important to understand that there are three areas which must be explained to the public in a *steady*, *continuous* and *relentless* fashion: the funding process, the effect of physics on technology, and the scientific method. These are also in the order in which they are easier to explain and probably receive a more positive reception from the public.

The public perceives that the funding process for university research is as follows: Highly paid professors get a cohort of students, are well funded by the university, dedicated to traveling to exotic places for so called "scientific meetings," working short hours, and having free summers for vacations. They don't know that generally we are paid for only nine months (mostly for teaching), that we have to get grants to fund salaries and tuition for graduate students, pay for all scientific costs, and that in our travels we are mostly inside a meeting room discussing highly technical matters. They don't really know that all the funding comes from sources outside our universities and that on top of it we pay a whopping "overhead," often more than 50 percent, that doesn't go to research. When explained the reaction from the public is either incredulity or astonishment that anybody would do this. This is easy to explain.

The relationship of physics to technology is harder to explain. The public believes that single personalities such as Steve Jobs come up with an idea such as the iPhone from scratch. They don't understand that many of these developments are based on work of many individuals and that without detailed scientific knowledge they would not be possible. There are many examples of technological developments that the public encounters on a daily basis, and these of course have their origins in basic science. Since the public can relate to technology, this is a good avenue to explain that the quality of life has enormously increased because of the discovery of X-rays, invention of the laser, development of ultrasound or MRI, wireless communication, computers, etc. All are a consequence of science.

The importance of fundamental science is the hardest to convey. The public doesn't realize that marvelous technology arises, often *unexpectedly,* from scientific discoveries such as the basic physics of semiconductors, the discovery of giant magnetoresistance, and the invention of the World Wide Web. This has to be communicated in many different ways and it is not clear to me if there is a single approach to explaining fundamental science to the general public.

(Left) Public lectures are an important part of connecting with voters who elect representatives who make decisions about science funding. Here, James Kakalios of the University of Minnesota talks about the physics of superheroes. (Right) The author with his Emmy award.

Probably most of you have encountered these issues in some form or another. Perhaps you don't agree with some of the details I raise, but I hope that we all agree on the general spirit. *Science is not appreciated and something must be done*. From the practical point of view, the most important point to realize is that the large majority of the public does not want to take a science class or have complicated facts explained to them. When somebody asks you the time, there is no need to explain how the watch works! The best we can hope is to convince the public that science is good and that it eventually improves the quality of life more than any other human activity.

It is very important to realize that not everybody can do this. The most important and perhaps difficult thing to convey is the passion many of us feel for physics. While delivery techniques can be improved and learned, passion is hard to learn and convey. So forcing everybody to contribute is not the right approach. This should be left to the few that have interest, are willing to spend time, and are passionate about it. It is especially important not to force young people who are starting a research career to spend time proselytizing to the public. Those that can do a good job will surface on their own. They can't be forced!

At the personal level many of us can help out the situation if we recognize that there is a need and are willing to sacrifice some time. There are many activities that one can perform individually without much bureaucracy:

- Many of us teach large undergraduate courses. At the end of each course one can in one hour describe how research is done at universities and explain one's own research. I have been doing this for many years and even managed to convert a few to become physicists.
- Participate in science-based artistic activities such as plays, movie productions, and exhibits, in different capacities as producer, writer, painter, or curator. This was done by a few and has been extremely successful.
- Interact with local museums and commercial enterprises to develop science-based activities such as science based social gatherings and public lectures.

What is attractive about these personal activities is that they are not regimented, can be done when one has time, and in the area in which one feels most comfortable. If you feel this is important and that not enough is done, at least you can have a personal satisfaction of having done something.

I propose here several possible practical solutions that APS can do, to perhaps modify the status quo:

1. Organize other similar organizations (AIP, ACS, IEEE, SPIE, MRS …) to carry out a concerted effort to explain the importance of science
2. Prepare and distribute a series of well-crafted PowerPoint presentations, which can briefly and easily convey the ideas mentioned above. These have to be properly vetted, at the right level, made appealing, and tested with the proper audience.
3. Develop a website where these types of resources are available for free. This has to be vetted and well developed, not just an overwhelming list of resources, which produces a large barrier for their use.
4. Develop a well-designed social media (Twitter, Facebook, etc.) plan to emphasize the message: science is good and leads to important societal changes, which are beneficial.
5. Encourage the APS membership on a regular, steady, and persistent basis (three to four times a year) to make it easy to find relevant material that is continuously updated.
6. Charge one of the APS units (for instance the Forum on Outreach and Engaging the Public) to monitor and report on a regular basis to the APS leadership the activities underway.
7. Encourage financially, with prizes, recognition, support, and so forth, any efforts in this direction as long as it doesn't violate the Hippocratic oath "Do no harm!"

Perhaps an effective way to implement these and many other possible ideas is to hire a marketing company to develop a well-designed advertisement campaign.

The most difficult part, not surprisingly, is to measure the effect of these types of activities. I am hoping that perhaps this article will stimulate not only a concerted effort in this direction but also will motivate somebody to invent a good method for measuring the effect of these activities.

In any case, I am sure that independent of anything that is done by others, I will continue contributing to this effort as much as I can. Please, join me!

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