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APS physics

ICARUS Arrives Intact
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2017 APS Division of Particles and Fields Meeting

By Eran Moore Rea

Three particle physics collaborations announced significant new experimental results at the 2017 APS Division of Particles and Fields meeting from July 31 – August 4 at Fermilab.

CP violation with neutrinos: 2 sigma

The Tokai to Kamioka (T2K) collaboration shoots a beam of neutrinos across Japan to measure the ways neutrinos can change from one type to another during the journey. On Friday, August 4 2017, Chang Kee Jung, former International Co-spokesperson for the T2K collaboration, presented the first experimental indication of charge-parity violation in neutrinos.

Charge-parity (CP) symmetry is the theory that elementary particles will act in the same way even when the spatial coordinates are inverted and the sign of the charge they carry is flipped. CP-symmetry has previously been proven to be violated, but only for quarks. It is possible that CP-violation is the reason behind the matter-antimatter asymmetry of the universe (that is, that despite current big bang predictions, the universe is dominated by matter—humans, trees, stuff—and very little antimatter), but only if it is present for leptons as well as quarks.

Particle physicists call a 2-sigma result like T2K's an observation—that is, not yet a definitive discovery. 2-sigma means 95.5% confidence, which might seem like enough, but with so much data in large physics experiments, scientists have mostly agreed that 5 sigma, or 99.99994% is the "gold standard" to claim an actual discovery.

"Today's result … gives us a reachable target," Jung said. He expects in the next several years that T2K as well as the NOvA experiment at Fermilab will be able to reach 3 sigma, and once DUNE

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International News

2017 Canadian-American-Mexican Conference

By Midhat Farooq

Graduate students from Canada, the U.S., Mexico, and Cuba in Washington D.C.

On the morning of August 17th, almost 100 physics graduate students from Mexico, the United States, Canada, and Cuba sat in a room together at the first session of the 2017 APS Canadian-American-Mexican Graduate Student Physics Conference (CAM), held in Washington D.C. Quiet anticipation filled the air as the students waited for the conference to begin, looking around at their international peers with friendly smiles, excited to meet each other and share their research and experiences in the following days. One might wonder what brought such a diverse group of students together.

Back in 1994, the Canadian Association of Physicists (CAP), APS, and Sociedad Mexicana de Física (SMF) jointly hosted the first international North American physics conference, in Cancun, Mexico, which provided a platform for physicists from all over the continent to come together for intellectual discussion, professional development, and the opportunity to form collaborations. In subsequent years, CAM was redesigned to serve graduate students exclusively. Since then, it has taken place biennially, with the previous two held in Waterloo, Canada (2013) and Oaxaca, Mexico (2015). This past August, CAM2017 embraced the theme "Transcending Boundaries."

As the conference is largely

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Forging New Connections

By Abhishek Agarwal and Samindranath Mitra

The editors of *Physical Review Letters,* who have a ringside view of emerging research directions, are seeing more papers that address condensed matter physics with techniques and ideas from quantum field and string theories, often with authors from both communities. So, when then Editor in Chief Pierre Meystre launched the "Physics Next" series of workshops on topics that are "beginning to emerge from the noise," the overlap of quantum field theory and condensed matter physics was a logical choice.

The workshop took place in Riverhead, Long Island in August. The scientific program was designed by Subir Sachdev, a condensed matter physicist at Harvard who often collaborates with high energy physicists, and John McGreevy, a string theorist at the University of California at San Diego who now focuses mainly on condensed matter physics. Around thirty early, midcareer, and senior theorists and experimentalists gathered over three days to discuss four broad topics—topological phases, many-body localization and quantum chaos, anomalous trans-

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Researchers and editors of the Physical Review journals at the second Physics Next workshop

Virgo & LIGO: Joint Detection of Gravitational Waves

By David Voss

On September 27, researchers from the Advanced Laser Interferometer Gravitational Wave Observatory (LIGO) and the Advanced Virgo Detector announced their joint detection of a gravitational wave signal from the coalescence of two black holes. The observation by three detectors (two from LIGO and the Virgo detector) allows the teams to improve their ability to identify where in the sky the waves are coming from. The announcement was made at a meeting of the G7 science ministers in Turin, Italy, and a paper describing the detection has been accepted for publication by *Physical Review Letters*.

The signal, which was observed on August 14, 2017, comes from a merger of a black hole 30.5 times the mass of the sun with another black hole 25.3 times the mass of the sun. The event occurred 540 megaparsecs from Earth, or about 1.8 billion light years away. Because the gravitational wave detection network involves three detectors, the researchers have been able to narrow down the location of the signal source by a factor of around 20 compared with LIGO's previous detections.

Each of these three detectors, LIGO's two in Hanford, Washington and Livingston, Louisiana, and Virgo's in Pisa, Italy, recorded the characteristic "chirp" signal of the black holes circling each other, then speeding up and merging. By comparing the waves' arrival time at each detector, the researchers were able to improve the determination of the source direction. Previous detections by LIGO involved two detectors,

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Research News: Editors' Choice

physics.aps.org

A Monthly Recap of Papers Selected by the Physics Editors

Spinning a tale of graphene and spiders

Spider silk is known for its high tensile strength and toughness, but researchers have now found they can improve on nature by feeding graphene and carbon nanotubes to these tiny weavers. Lepore et al. report in *2D Materials* (DOI: 10.1088/2053-1583/aa7cd3) that after spraying water containing graphene flakes or carbon nanotubes into a corner of a box of spiders, and waiting until the animals had ingested the mixture, the resulting silk was markedly stronger and tougher. The team tested the carbon diet on 21 spiders of three different species (alas, 6 died before their silk could be obtained). Using a nanotensile tester, the researchers measured the silk that was successfully obtained, and they used Raman spectroscopy to characterize the molecular structure of the unmodified and modified silk samples. On average, the team notes, the strength and toughness of the silk from nanotube-fed spiders surpassed natural silk and approached that of the strongest artificial carbon fibers and natural materials (limpet teeth). These new results show that a possible way toward improved silk fibers for a variety of applications may indeed lie through the spiders' stomachs.

Carbon diet for better silk

Nuclear Fluid Swirls at Record-Breaking Speed

Observations of gold ion collisions reveal that the post-crash nuclear matter rotates faster than any other recorded fluid. This strong swirling occurs in a hot mixture of quarks and gluons, called the quark-gluon plasma. Created in heavy ion collisions, this plasma was presumably the dominant form of matter during

RESEARCH continued on page 6

Spotlight on Development

Shining the Spotlight on You

Dear APS member,

As the end of 2017 fast approaches, we wish to thank you for your continued involvement and support. We know that at this time of the year you have many choices of worthy, charitable causes and related year-end campaigns, and we are most grateful for your willingness to keep APS in mind.

Thanks in part to your financial generosity, APS has built an impressive track record of programmatic endeavors that strengthen the Society's mission and make it a powerful advocate for physics and our community:

- Increasing minority representation in graduate physics programs: Bridge Program (Education & Diversity)
- Reversing the severe shortage of qualified high school physics teachers: PhysTEC (Education & Diversity)
- Engaging with and educating our public officials: Congressional Visits Day (Office of Public Affairs)
- Promoting diplomacy by collaborating with physicists and physics societies around the globe (International Affairs)
- Motivating and empowering the next generation of physicists through the distribution of free materials and lab experiments in middle school: PhysicsQuest (Outreach)
- Supporting, informing and retaining undergraduate women in physics: Conferences for Undergraduate Women in Physics (Education & Diversity)

These above programs have been recognized both nationally and internationally for their value to the physics community in helping inspire and prepare the next generation of physicists.

Here is what some of you have said about the reasons for giving to APS.

"APS programs make a big difference to students and researchers; I know my donation is effectively used for important purposes."
— Uwe C. Tauber

"APS has been a significant part of my life. I have attended 51 March meetings, and look forward not just to learning new physics, but to reuniting with many friends I have made through APS."
— Philip Taylor

"APS programs foster a more diverse community of scientists, which is paramount to generating different perspectives and innovative thinking, both critical elements in the successful development of high-quality science."
— Anonymous

"… I also believe in international dialog and cooperation for the betterment of the planet and its inhabitants, and view scientific enterprises as being critical in fostering communication and understanding. That's why I give to APS."
— Stephen Schiff

Thank you again for your valued philanthropic partnership with APS.

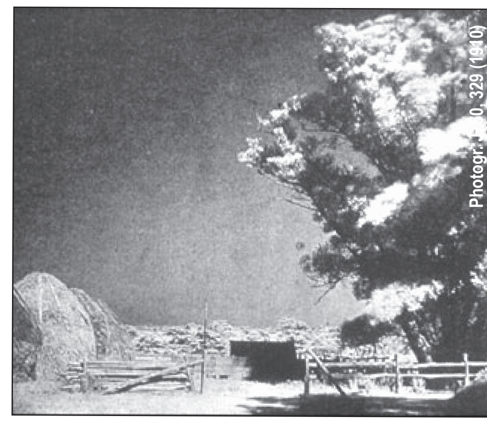
Irene I. Lukoff (On behalf of the APS Development Team)

This Month in Physics History

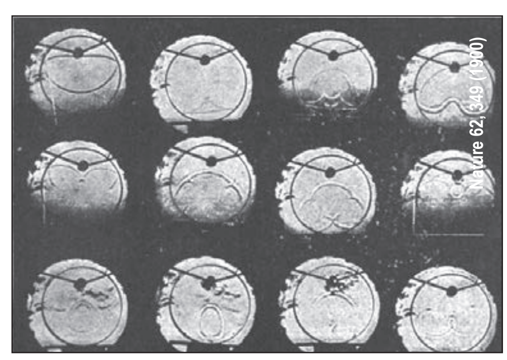
October 1910: First infrared photographs published

Infrared photography is an invaluable workhorse tool across many different scientific fields and practical applications, as well as a popular hobby among professional and amateur photographers. And we owe its existence—as well as that of ultraviolet photography—to an enterprising American physicist and inventor named Robert Williams Wood, best known in scientific circles for his research on optics and spectroscopy.

Infrared radiation was discovered in 1800 by Sir Frederick William Herschel, best known for building telescopes and discovering the planet Uranus. Herschel painted the bulbs of three thermometers black, and then arranged them with one tip in the solar spectrum made by a prism, and the other two outside the spectrum to serve as controls. His first finding was that as he moved the thermometer across the spectrum from violet to red, the thermometer temperature steadily increased. His second was that moving the blackened thermometer just beyond the red end of the spectrum produced the highest temperature of all. This experiment was the first observation of light beyond the visible spectrum.



Infrared landscape image taken by Robert Wood



Wood's photographs of sound waves

Photography came into its own in the 19th century, but it was not possible to make pictures of anything in the infrared, because the chemicals used for early photography were not sensitive to longer wavelengths of light. Wood resolved that issue and thereby launched an industry.

Born in Concord, Massachusetts in 1868, Wood initially planned to become a priest. But one night he observed an aurora and became fascinated by what might cause such a phenomenon. He thought the culprit might be "invisible rays," leading him to study optics instead. After earning degrees from Harvard, MIT, and the University of Chicago, he joined the faculty of Johns Hopkins University in 1901, where he remained until his death in 1955.

Wood made waves early in his career with his infamous debunking of French physicist René Blondlot's claim to have discovered a new type of radiation called "N-rays." Unable to replicate Blondlot's results, Wood traveled to France in 1904 to observe the experiment firsthand. He removed a crucial prism from the apparatus between runs when the Frenchman wasn't looking, and when Blondlot still claimed to observe N-rays on the second run, Wood concluded he was deluding himself, and wrote a letter to *Nature* debunking the claim.

The year before, in 1903, Wood invented an ultraviolet filter for photography, which he made from nitroso-dimethyl-aniline, combined with a small amount of a dye called uranine. This made the filter block visible light but transmit ultraviolet, and he used it to take the first photographs of ultraviolet fluorescence. The filter became known as "Wood's glass," and was the technology behind blacklight lamps. It also transmitted some infrared light, although very long exposures were required.

Several of his photos appeared in the October 1910 issue of the *Royal Photographic Society Journal*, as illustrations for Wood's papers on the optical effects involved—including the so-called "Wood effect," which is the dreamlike appearance of photographs in the infrared. Infrared photographs feature a milky appearance to skin in portraits, and also dark skies—the Rayleigh scattering that makes the sky blue doesn't scatter much infrared. Also, the infrared wavelengths penetrate a few millimeters beneath the dermis, and then reflect back out of the skin, so they can image blood vessels within this thin layer.

Wood didn't show much interest in profiting from his filters, even though during World War I, infrared-sensitive photographic plates were used for spectroscopic analysis. It wasn't until the 1930s that infrared film hit the commercial sector, when Kodak introduced the first emulsions designed for infrared photography. By the 1960s, the company offered 35mm false-color infrared film, and the popularity of infrared photography boomed—driven in part by its use in pop music album covers by rock stars such as Jimi Hendrix and Frank Zappa. The advent of digital cameras made physical films obsolete, and Kodak responded to the sharp decline in demand by discontinuing its 35mm infrared film products in 2007.

While Wood's specialty was optics, he also

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News from the APS Office of Public Affairs

Hundreds of Students Contact Senators and Urge Support of Science Research Programs

By Tawanda W. Johnson

Recently, nearly 200 physics undergraduate students from across the country contacted 80 U.S. senators and requested support for science research opportunities for undergraduates, including those funded by the National Science Foundation. The students made the calls as part of an advocacy campaign supported by the APS Office of Public Affairs (OPA) and the American Institute of Physics' Society of Physics Students (SPS).

"This campaign was a surprise success. More students participated than we expected, and they contacted key senators who hold positions on important committees that oversee federal funding for science programs," said Francis Slakey, APS OPA interim director.

Brad Conrad, director of SPS, said it was "fantastic" having SPS and APS OPA work together on such an important campaign, for which SPS reached out to its numerous student chapters. "It was a great initiative … It's important for students to understand that they are not passive; they have a voice; they vote and can impact the world around them."

To measure the campaign's success, Allen Hu, OPA policy analyst, developed a metric for assessing which senators to approach.

"We were looking for a way to measure the effectiveness of our advocacy campaigns," said Hu. "We developed a metric that assigns a number value to each senator ... based on a few key categories, including if they were in a party leadership position or if they were on the Appropriations Committee," he explained. The resulting evaluation showed that this was one of the most successful grassroots campaigns OPA has run.

In addition to SPS, OPA also relied on the expertise of Max Magid, a Georgetown student who interned in the Washington, D.C. office during the summer. "I helped connect OPA with members and students who were willing to write their senators in support of our campaign. I also tailored the communications to match the way students think," said Magid.

Additionally, he helped find contact information for directors of NSF-funded Research Experiences for Undergraduates programs who then asked their students to participate in the campaign. "I am pleased it went so well, and I hope APS can use lessons from this campaign to run even more successful ones in the future," he said.

Conrad echoed that sentiment: "SPS would be glad to work with APS again so that students can work to impact the world around them."

Similar campaigns will be underway soon, said Greg Mack, APS government relations specialist. He added, "Our goal was to give undergraduates an opportunity to speak up in support of physics. We are elated that this campaign was successful, and we look forward to including SPS in many more campaigns in the future."

The author is Press Secretary in the APS Office of Public Affairs.

Helping Hand or Hubris?

By Sophia Chen

Over the last decade, Harvard climate scientist David Keith has pushed a controversial idea for fighting global warming: spraying molecules such as sulfur dioxide or calcium carbonate into the upper atmosphere. The scientific premise is simple enough. The particles reflect solar radiation back into space and increase cloud formation. If you inject enough of it up there, global warming could be stopped or reversed.

As 2016 and 2017 look to become the two hottest years on record, Keith argues that this tactic, known as solar geoengineering or solar radiation management, could be an important tool for reversing rising temperatures. But at the moment, Keith says, the proposed technology is unvetted, poorly understood, and insufficiently funded. Keith thinks that the research on it needs to ramp up now. "There should be a serious, international, open-access research effort on the efficacy of solar geoengineering," he says.

That's why Keith and his collaboration—named the Stratospheric Controlled Perturbation Experiment, or SCoPEx—plan to launch a balloon in Tucson, Arizona, to run some small geoengineering tests sometime next year. The balloon, hovering in the stratosphere at 20 kilometers altitude and cruising at a couple of meters per second, will release up to a kilogram of aerosol particles into the air while the collaboration monitors it from the ground.

Keith and Harvard chemist Frank Keutsch will lead several experimental runs during which the balloon takes measurements for a few hours at a time. According to the SCoPEx website, they will first release ice to test whether their hardware works. On subsequent flights, they will release less than a kilogram of calcium carbonate, possibly followed by sulfate compounds.

David Keith

Their funding will come from Harvard internal funds and likely Harvard's Solar Geoengineering Program, which has raised money from Microsoft co-founder Bill Gates, the Hewlett Foundation, the Alfred P. Sloan Foundation, and other philanthropists. SCoPEx follows in the wake of several other solar geoengineering collaborations that have failed to pick up momentum, such as at the 2011 E-PEACE experiment out of the University of California, San Diego, and the SPICE collaboration in the U.K., which stalled in 2012.

Keith's group wants to take basic measurements to understand what happens when the balloon releases the aerosols. "We do have laboratory experiments going on, but there's lots of things that you can't replicate in the lab," Keith says. For example, it's difficult to make a lab-scale model of the stratosphere's high levels of ultraviolet radiation or the fluid dynamics of an open space as vast as Earth's atmosphere. The balloon will measure the dynamics of particles mixing and reacting with the surrounding molecules. These new measurements could help refine solar geoengineering climate models.

Keith stresses that this experiment is not a test of full-scale solar geoengineering. Its emissions would be negligible: commercial airplanes release more sulfates per minute of flight than would be released in this experiment. In his 2013 book, *A Case For Climate Engineering*, Keith points out that volcanic eruptions, which cool the planet via the same principle, release millions of tons of particles per eruption. The point of the experiment is to gather evidence to begin to intelligently evaluate the technology. In the event that global temperatures rise so much that solar geoengineering deployment ends up looking like the best solution, he wants policymakers to be as informed as possible. "I'm in favor of people knowing more," Keith says.

However, critics argue that even small-scale experiments are a slippery slope. If early test results are promising, policymakers may be biased to sink more money into solar geoengineering at the

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Profiles in Versatility

Medical Physicist Studies Transgender Athletes

By Alaina G. Levine

By day, Joanna Harper is a mild-mannered medical physicist working in a major medical center in Portland, Oregon. She spends most of her time in radiation oncology, working out how to detect cancer with CTs and MRIs. She does computer simulations of the patient treatment plan and then consults with the oncologists to help them determine the best course of action. "The goal … is to maximize the radiation to the tumor and minimize radiation to the surrounding tissue," she explains. "There are a number of strategies that can be used to do that." She also engages in quality assurance of the radiation devices. With a master's degree in medical physics from the University of Western Ontario, Harper is well-positioned to take on these challenges.

Harper loves her job and she has been at it for more than three decades. "I think I chose a great career, because treating people correctly with radiation is an important thing," she says. She especially enjoys the constant collaboration with her colleagues in the medical center. "For a physicist I have pretty good people skills," she says with a laugh. "A lot of what we do is interact with the physicians and radiation therapists. This work is more than making measurements. Being part of the team is one of the things that has kept me in the field for 30 years."

Joanna Harper

And this would be a fabulous story in and of itself, of a superstar who chased a traditional career in medical physics. But there is more to this story. On her own time, Harper has dedicated herself to another pursuit: Harper is a competitive runner and for over 40 years she has been competing in races that range from 1500 meters on the track to road marathons. "I am a good amateur runner but by no means a professional," she says. "If I made my living off of running I would have starved years ago."

Thirteen years ago she started thinking about fitness levels of male and female athletes and wondered if anyone had studied how a person's fitness changes when they change genders. The catalyst for this musing was her own gender transition from male to female in 2004. Part of the process involved hormone replacement therapy, which blocked the production of testosterone and added estrogen in her body. The less testosterone her body produced, the more she lost the physical advantages of being male in her distance running. "I understood before I started my transition that with lower testosterone levels I would run slower, but I had no idea how quickly that would happen and how much slower it would be," she notes. Within three weeks of starting the hormone therapy, her running pace and energy decreased, and by nine months, she was running about 12% slower than she had as a man.

As a physicist, she was curious about the mechanism behind this change in her fitness ability. Harper pored over statistics about fitness levels of male and female runners

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made important contributions to the field of ultrasound. It started with a demonstration for his students to elucidate the wave nature of light by photographing the sound waves given off by an electric spark (a method invented by August Toepler). During World War I, Woods shifted to ultrasonics, and he worked in Paul Langevin's lab developing ultrasound for detecting submarines. By 1926, he wound up working with Alfred Lee Loomis to develop high-power ultrasonic sources. Their experiments revealed that ultrasound could melt the interior of an ice cube before the exterior, tear apart living cells, and kill frogs, mice, and small fish with just one or two minutes of exposure.

Over his long and varied career, Wood also assisted in the investigation of the infamous Wall Street bombing of 1920, among other cases, and is often credited with the invention of tear gas. He spun the surface of mercury into a parabolic mirror and with it built a working reflecting telescope. In addition to scientific treatises, he co-authored two science fiction novels (*The Man Who Rocked the Earth* and *The Moon Maker*), as well as two children's books of nonsense verse. He died in 1955 in Amityville, New York.

Today, infrared photography is used in the study of plant diseases, revealing changes in pigment or cellular material; in paleobotany; to enhance details of deeply pigmented tissues in photomicrography in the biological sciences; and by the textile industry to detect irregularities in fibers. It is also used in criminal investigations to examine and identify cloth, fibers and hair, and it's become a standard laboratory tool for imaging faded, damaged or altered documents. One hopes Wood would be gratified to see how ubiquitous his technique has become.

Further Reading:

Klotz, I.M. (May 1980) The N-Ray Affair, *Sci. Am.*, May 1980.

Seabrook, W. (1941) *Doctor Wood, Modern Wizard of the Laboratory*, New York: Harcourt Brace.

Wood, R. (1903) On screens transparent only to ultraviolet light and their use in spectrum photography, *Phil. Mag.* 5, 257-263.

Wood, R. (1910) Photography by invisible rays, *Photogr. J.* 50, 329.

ICARUS Arrives at Fermilab

By Eran Moore Rea

Across the Atlantic, through the St. Lawrence and four Great Lakes, over the highway from a port in Indiana, finally settling at Fermilab outside of Chicago—ICARUS has finished its journey.

The detector, which holds 600 tons of liquid argon, was transported from outside Gran Sasso in Italy to Fermilab in Batavia, IL. In 2018, ICARUS will begin taking data, ramping up to become one of three detectors for Fermilab's Short Baseline Neutrino (SBN) program. SBN will be the first of its kind to use two liquid argon detectors to study neutrino oscillations—one at the source and one at a distance.

The hardware and setup of SBN are very similar to Fermilab's planned Deep Underground Neutrino Experiment (DUNE). Now in the planning stages, the DUNE experiment will shoot neutrinos through Earth from Fermilab to a detector in Lead, South Dakota.

DUNE will also use two liquid argon detectors. For a large enough volume of liquid argon, it becomes statistically likely that even for a beam of famously nonreactive neutrinos, some of them will directly collide with individual argon nuclei. When this collision occurs, physicists can study the particles that are produced from the collision to determine which type of neutrino was involved.

There are already neutrino experiments using liquid argon detectors—MicroBooNE at Fermilab is one—but until now, no experiment has used such detectors in both "near" and "far" locations. These experiments look at the details of neutrino oscillations, in which a neutrino of one type transforms into another type as it travels. Comparing the differences in the neutrino signature between the two detectors allows scientists to study how the particles change.

Specifically, scientists hope they can address an anomaly that's been debated since it was first seen in the early 2000s. When an earlier experiment called MiniBooNE saw an anomaly in its electron neutrino results that might signal the exis-

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LeRoy Apker Awards: Honoring Exceptional Undergraduate Research

By Rachel Gaal

As physics students were ramping up for another academic school year, a few select seniors were enjoying one of the high points of their undergraduate careers: the APS LeRoy Apker Award Selection Meeting on August 23, 2017. Out of the seven finalists selected from the applicant pool, only two are chosen as recipients for the prestigious APS undergraduate award, which recognizes outstanding achievements in physics and demonstrated potential for future scientific accomplishment. On October 23, the selection committee will announce the winners—one to a student from a Ph.D.-granting institution, and one to a student from a non-Ph.D.-granting institution.

The judges praised all the finalists. "The talks were at a level far beyond what one might expect from an undergraduate," said committee member Amy Graves of Swarthmore College. "These students spoke to us like peers, and exhibited a mastery of both the details and broad implications of their work. Several students introduced me to work that will impact my own research and teaching. Particularly impressive was the back and forth we were able to have with the speakers …"

Graves also emphasized that although these finalists are all jockeying for one of the two awards, they should recognize they are "already winners." In addition to the honor of being invited to present their work in Washington D.C., each of the finalists received an honorarium of $1,000, and their institution's physics department received the same amount to support undergraduate research.

From numerical modeling to astrophysics, the Apker finalists gave enthusiastic presentations. Gregory Ridgway of University of Maryland, College Park, created an algorithm to facilitate difficult field theory computations. Amar Sehic of Colby College broke down the complicated mathematics behind conservation laws and symmetry transformations. Both Ridgway and Sehic emphasized the painstaking derivations that went into their research.

Another finalist, Calvin Leung of Harvey Mudd College, used fluctuating light sources from the Milky Way to create a "cosmic random number generator" that he used to test the famous quantum inequality known as Bell's Theorem. He was a main

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run by and for graduate students, CAM's unique design allows these students to give research presentations to an audience of their peers, providing a less intimidating environment than other conferences, while simultaneously challenging them to explain technical work in terms accessible by any physics graduate student. Additionally, the conference offers attendees the chance to meet people from around the continent and to learn about each other's experiences. Hence the young scientists are able to share not only stories about life in graduate school, but also their distinct perspectives developed in different cultures. This year, in addition to attendees from Canada, U.S. and Mexico, a delegation of 15 Cuban students was invited to CAM for the first time, marking a historic moment and giving additional meaning to the theme of the conference by transcending a political boundary.

The conference kicked off with opening remarks from Matiás Moreno from SMF, Christopher Pugh of CAP, and APS CEO Kate Kirby. A plenary session featuring Eduardo Gómez García from Universidad Autónoma de San Luis Potosí, México and Melissa Franklin from Harvard University, USA, followed. The room was packed with the kind of energy one experiences at the beginning of a big journey. This energy was reciprocated by the speakers. García gave an outstanding talk explaining the importance of precision measurements and how his research group studies the weak force using laser cooled francium atoms. The talk transcended a disciplinary boundary by engaging students with backgrounds in both particle physics and quantum optics. Franklin gave a broad overview of particle physics and its future, interactively challenging the audience by asking questions like "What do you guys think about at night [if not particle physics and the universe]?" Her energy, humor, and thought-provoking questions captured the attendees' attention that morning and set a positive tone that carried throughout the conference.

CAM's agenda included four more plenary sessions, several graduate student poster and oral presentations, and two panels. The first panel featured professionals in physics, and the second had student panelists. While the talks and presentations promoted research discussions, the panels provided an avenue for comparing and contrasting the four countries' academia, politics, and cultures. The first panel emphasized the value and various benefits of scientific collaborations, and all four panelists recognized that international collaboration is necessary for the success of science. Specifically, García pointed out that collaborations provide indispensable resources that enable more competitive research to take place in Mexico. María Sánchez Colina, president of the Cuban Physical Society, explained that science and collaborations in Cuba tend to be more heavily focused on biological and medical fields, and that future collaboration with the U.S.—both scientific collaborations and conferences such as CAM—could help in the development of physics research and technology in Cuba. In contrast to the serious discussions during the day, the evenings were full of lighthearted conversations at both the welcome reception and the conference banquet in the foyer of the Rayburn House Office Building on Capitol Hill. This gorgeous high-ceilinged room where legislators often meet made for a memorable experience for both the local and international attendees.

It is impossible to do the entire conference justice as CAM consisted of many great moments. Most notable, however, were those showing that the physics community is becoming more aware of societal issues. This was exemplified when Pauline Barmby, from University of Western Ontario, started her plenary talk on astrophysics by acknowledging that we were gathered on the former lands of the Native American people, setting an example for all to follow. Another interesting moment came when the graduate student panel discussed how in the United States, the topic of diversity is often focused on people of color, but that this might not necessarily be the case elsewhere. Panelist Ana Avilez-Lopez told us that indigenous people for whom Spanish is not their native language are an underrepresented group in Mexico, and they are often left behind by science. Such discussions taking place at CAM demonstrates that physicists around the continent are actively working towards the goal of a diverse and inclusive scientific community.

Another area in which academics are gaining awareness is the number of available academic jobs, or rather lack thereof. APS Careers Program Manager Crystal Bailey served on the first panel and presented statistics showing the high percentage of graduate students that are currently transcending a career boundary by working outside of academia.

Whether graduate students choose to carry on with research in academia, work in industry, or pursue careers in policy or advocacy work, the field of physics continues to thrive, and APS conferences like CAM enhance it by providing a place where young scientists can come together to learn and share their research and experiences, as well as develop personal and professional connections.

CAM 2017 was jointly funded by CAP, CAP Foundation, SNOLAB (the expansion of the Sudbury Neutrino Observatory), SMF, The National Council For Science and Technology in Mexico (CONACYT), APS, the APS Forum on Graduate Student Affairs (FGSA), the National Science Foundation, the APS Office of International Affairs, and the U.S. Liaison Committee for the International Union of Pure and Applied Physics. The international organizing committee was led by Krista Freeman, Past Chair of APS FGSA.

Midhat Farooq is a graduate student at the University of Michigan and does research in particle physics at Argonne National Laboratory. She served on the university's physics graduate council and on the executive board of its Society for Women in Physics, and has organized outreach and professional development events. Midhat has joined the graduate student government at Michigan and has advocated for graduate student issues on Capitol Hill. She is also participating in two APS committees and working with the APS FGSA. Her goal is to pursue a career in advocacy and science policy.

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port, and gauge and gravitational dualities.

Relativistic quantum field theories are a suitable framework for the study of several intriguing properties of recently discovered materials, such as the Dirac and Weyl semimetals. These condensed matter systems are fundamentally nonrelativistic, but some of their physical properties are described by equations that assume a relativistic form with an emergent velocity (e.g., the Fermi velocity) playing the role of the speed of light. For example, negative magnetoresistance in certain semimetals can be understood as a manifestation of chiral anomaly—the same phenomenon that accounts for the decay of neutral pions in particle physics. Physicists typically study such physical phenomena with large colliders, so being able to do so in living-room-sized laboratories is an exciting prospect. With this goal in mind, theorists and experimentalists at the workshop discussed several new points of contact between relativistic field theory and condensed matter physics.

Another agenda topic was the propagation and dissipation of quantum information—lying at the heart of some of the hardest issues in physics, such as the black hole information paradox. Several theorists presented ideas for probing fundamental issues in quantum mechanics within the context of many-body physics as well as progress in understanding the growth, diffusion, and scrambling of quantum information. Experimentalists at the meeting surveyed schemes for testing related ideas, many of which would have been considered theoretical speculation only a few years ago.

Several presentations were on a particular theoretical nonrelativistic many-body system—the Sachdev-Ye-Kitaev (SYK) model. In its conventional formulation the SYK model describes interacting Majorana fermions, but certain limits of this model are believed to encode the dynamics of black holes embedded in a curved two-dimensional space (known as the 2D anti-de Sitter space). Such black holes arise within string theory with enticing connections. Theorists from the condensed matter, high energy, and nuclear physics communities were among those who discussed the scope of the SYK model. It seems that experimental implications of the SYK model may yet open a door to studying black hole phenomena in condensed matter physics labs.

Our hope in organizing these workshops is to foster increased collaboration across traditional subject boundaries. The topics discussed at the August workshop, of which the ones cited above are but a sampling, should assuage our concerns regarding increasing specialization. As one of the experimentalists noted at the end of the three days, the workshop was successful in living up to its name—helping the editors of the Physical Review journals to keep up with what is next in physics.

Abhishek Agarwal is an associate editor of Physical Review Letters. *He received his Ph.D. from the University of Rochester in 2005. Abhishek's research interests lie in the study of gauge and string theories.*

Samindranath Mitra is an editor of Physical Review Letters. *He received his Ph.D. at Indiana University (Bloomington) in 1994, where he worked on the theory of the quantum Hall effect.*

Education & Diversity Update

The 5+ Club Applications

Now accepting applications for The 5+ Club—institutions that have graduated five or more physics teachers in the past academic year. For more information and how to apply please visit phystec.org/the5plus/index.cfm

APS Releases updated statistics to compare institutions

Want to see how your institution compares nationally in terms of producing physics degrees and encouraging diversity among these degrees? The latest numbers from national databases are now available at aps.org/programs/education/statistics/compare.cfm Updated tables showing top educators by degrees can be found at aps.org/programs/education/statistics/topproducers.cfm Thanks again to Sam Montgomery from the New Mexico Institute of Mining and Technology for his help in assembling the data.

Deadline to Apply to Host a 2019 APS CUWiP: November 1

APS Conferences for Undergraduate Women in Physics (CUWiPs) are three-day regional conferences at multiple sites across the U.S. and Canada, and are designed to increase the recruitment and retention of undergraduate women in physics. If you are interested in applying to be a host site for our 2019 conferences, please visit **go.aps.org/cuwiphost** and submit an application by November 1. Email women@aps.org for more information.

Professional Skills Workshop at Division of Nuclear Physics Meeting in Pittsburgh

The APS Division of Nuclear Physics will host a Professional Skills Development Workshop on October 24, 1:00 pm - 8:00 pm at the Marriott City Center in Pittsburgh. These workshops are designed to provide women physicists with professional training in effective negotiation and communication skills, as well as a special opportunity for networking. If you are interested in attending, please email women@aps.org

APS Bridge Program Graduate Student Induction Manual Now Available

The APS Bridge Program (APS-BP) would like to announce a new guide for graduate student induction. The APS-BP Student Induction Manual documents effective practices for inducting new students into graduate programs, as identified and described by APS Bridge Sites. It also includes specific strategies for developing a solid foundation for students before and well after their arrival on campus. To download the manual, go to www.apsbridgeprogram.org/resources/manual Special thanks to Dr. Geraldine Cochran of Rutgers University, the primary editor of this manual.

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contributor to the research, which was featured in *Physics* Editor's Choice in February 2017. And Ephriam Bililign of North Carolina State University took a hands-on approach, investigating the properties of granular systems by varying the position and amount of force applied to homemade granular packings.

Each student traveled different paths, and many of them are using their research presented at the Apker Selection Meeting as springboards: Angela Harper of Wake Forest University was recently named a Churchill Scholar, and she will continue her research on organic electronics at Cambridge University while earning a M.Phil in physics; Sylvia Biscoveanu of Penn State University won a Fulbright Scholarship and is headed to Monash University to continue her astrophysical data analysis for the Laser Interferometer Gravitational Wave Observatory (LIGO); and Arvind Srinivasan of St. Mary's College is now a full-time physicist for the Naval Air Systems Command (NAVAIR), working on data sensing, holography, and infrared imaging. The remaining students are either pursuing their advanced degrees this coming fall or already have their first technical job.

The Apker award finalists all embodied the legacy of LeRoy Apker, who was an experimental physicist and an APS Oliver E. Buckley prizewinner in 1955. The award was endowed by his wife, Jean Dickey Apker, to recognize students who will likely leave behind a record of exceptional research and scientific curiosity.

Visit the APS Awards page to learn more about the LeRoy Apker Awards.


Adam Negussie

The 2017 Apker Award finalists (L-R): Ephraim Bililign, Calvin Leung, Amar Sehic, Andrea Biscoveanu, Angela Harper, Arvind Srinivasan (Not shown: Greg Ridgway).

VIRGO continued from page 1

which meant that the mergers could be identified only as lying somewhere in large portions of the sky.

"This signal has been traveling for almost 2 billion years towards Earth," said Jo van den Brand of Vrije Universiteit Amsterdam, spokesperson for the Virgo collaboration. "The signal was first detected by the LIGO detector in Louisiana, then 8 milliseconds later by the LIGO detector in Hanford, then 6 milliseconds after that, by the Virgo detector."

Brand said that this heralds a new era of "multi-messenger" gravitational wave astronomy. "With this triangulation, we can locate the source that is emitting these gravitational waves, and this is important because we expect that many such merger events emit other messengers, such as light, x-rays, radio waves, neutrinos, or other sub-atomic particles. These can be studied by both astronomers and astroparticle scientists."

In addition to better localizing the gravitational wave source, the participation of Virgo means that the polarization of the waves can be studied. Like other kinds of waves, gravitational waves oscillate in specific directions. Both of LIGO's detectors are oriented in similar ways, so they were unable to sense the oscillation direction.


Virgo/European Gravitational Observatory

Aerial view of the Virgo interferometer in Cascina, Italy

Virgo is oriented in a way complementary to LIGO, so analysis of signals from the three detectors can reveal information about the polarization. With this information, even more stringent tests of general relativity should become possible.

"We were really eager that Virgo join us in this endeavor," said LIGO spokesperson David Shoemaker of MIT. "This information that comes from position is an amazing addition. We can use this information from pointing to give to our traditional astronomy colleagues [who use] telescopes on the ground and satellites, so that we can do this next step of multi-messenger astrophysics." He added, "The future is incredibly bright for the Virgo-LIGO network."

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of different ages and found that as a 48-year-old woman (the age she was when she completed her transition), her running ability compared to other women her age was exactly in line with her previous running ability as a male athlete. While she was happy to better understand why her running economy had changed, she was curious about the fitness experiences of other people who transition.

"In 2007 I met another trans woman who was a distance runner and the exact thing happened to her," says Harper. "And at that point I said 'ah ha!'" She started collecting data on trans people who are runners and was able to gather 200 race times from eight transgender women including herself, with a goal of determining if transgender runners who transition from male to female have a competitive advantage. When she examined the runners in her study, she saw that they all had the same pace they should be running for their age as women. Therefore, they did not have a competitive advantage in running even though they had been male before. Her data collection began to blossom and soon she wrote a paper on the subject in the *Journal of Sporting Cultures and Identities*. She then parlayed this knowledge into pro-bono consulting for organizations like the International Olympics Committee and the International Association of Athletics Federations about how to appropriately regulate the participation of transgender athletes in sports.

Harper's goals in bringing these issues to light are concretely related to her insights concerning misconceptions about transgender athletes. First of all, there is an erroneous notion that "transgender women will dominate sports because of unfair advantages they gain from their previous lives," she says. But her own research has shown "that's simply not going to happen." As she wrote in an op-ed in the *Washington Post* in 2015, some people "can't get past the idea that I'm a man trying to profit in a woman's sport." Additionally, people mistakenly think that transgender men, because of their previous lives as women, will be unable to compete. "This is not true," she says. "There are trans men who are doing quite well athletically."

"I hope to change public perception on transgender athletes," she says. "There is a question of how do we decide who gets into women's and men's sports, and I feel strongly at this point that testosterone should be the tool we use to separate male athletes from female athletes. But there is a great percentage of the populace that is skeptical of that idea, and I hope that more research will support the testosterone separation of male and female athletes."

Harper's "hobby," as she calls it, continues to expand, and most recently she has been involved in a court case concerning an intersex athlete who competed in the 2016 Olympic Games in Rio. She notes that this is a pivotal case regarding whether or not we use testosterone as the means to separate male and female athletes. She is writing a book about the science and history of gender variance in sports as seen through her personal lens. She is also collaborating with an athlete who is currently transitioning, and has been collecting as much data as possible about her athletic abilities as she makes the transition.

With a medical physics background, she has a distinct edge in this research endeavor. "Obviously physicists excel in pattern recognition and analyzing data," she says. "There is probably no other profession better at logical thinking than being a physicist."

Ultimately, Harper hopes her side gig will lead to a fairer system for transgender athletes to compete on the world athletic stage. As she wrote in *The Washington Post*, "I hope the mounting evidence, coupled with exposure to trans women athletes, will go some way toward changing hearts and minds. The rules established by different leagues are unnecessarily inconsistent, and prejudice persists at all levels of sport—from elite leagues down to high school teams." Finally, "I would like to assert that those of us who don't fit easily into the standard notion of male and female are just one more variety of human, and there is nothing to be feared or hated," she says. "We just want to live and breathe and play sports like any other human being."

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and Hyper-Kamiokande begin taking data, 5 sigma.

Neutrinos scattering off nuclei: 6.7 sigma

A hand-held neutrino detector weighing about 32 pounds used by the COHERENT collaboration at Oak Ridge National Laboratory reported a 6.7 sigma discovery of coherent neutrino-nucleus scattering. As physicists work to understand the way neutrinos oscillate from one type to another, it is important to also understand what happens when those neutrinos interact with different types of particles. "There are a lot of neutrino cross-sections predicted in the Standard Model, but many have *theoretical* uncertainties with of 20% or 30% or even 100% … for this one, the theoretical uncertainty is less than half a percent," Philip Barbeau of Duke University said. According to Barbeau, that means that analyzing the data from this process will open the door for new types of searches for physics beyond the Standard Model. Barbeau is an Analysis Coordinator on COHERENT; he presented the results on August 4.

Right now, COHERENT's result is within 1 sigma of the Standard Model prediction. "We were a disparate group of researchers who for over 43 years had been trying to individually observe this on our own," Barbeau said. In 2012, several different collaborations joined to create COHERENT. "Really, it's now an era of neutrino miniaturization, with this hand-held detector … when you miniaturize technology, new questions and new capabilities pop up as a result."

Dark Energy Survey: agrees with current theory to 1 sigma

Using gravitational lensing data, the Dark Energy Survey (DES) collaboration has analyzed what is to date the largest and deepest segment of the night sky. Using the Dark Energy Camera mounted on the Victor M. Blanco 4-meter Telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile, DES found values for the cosmological constant, a "leftover" value in the equations of general relativity that describe the universe. Theorists believe this constant may describe the effects of dark energy that is responsible for the accelerating expansion of the universe. On August 3, DES released data that agrees to one sigma with standard theories. This means that, despite other studies that found values slightly further away from PLANCK/standard theories, the new DES data provide more evidence that the current standard theories of the universe hold.

Describing DES's data, presenter Daniel Gruen from SLAC said, "The best comparison of structure when the universe was 400,000 years old at 10 billion years old says the simplest model describes the universe well." The current result covers one year of DES data; there will be three years of data total, with more results to come.

The author is a freelance writer based in Minneapolis, Minnesota.

Telescopes at Cerro Tololo Inter-American Observatory in Chile used to conduct the Dark Energy Survey

ICARUS continued from page 4

tence of a fourth type of neutrino, the scientific community responded by setting up new experiments; SBN is one of them. SBN's detector separation is less than a kilometer, while DUNE's baseline is nearly 1300 kilometers.

There are already experiments with a near and far detector studying neutrino oscillations; the NOvA experiment based at Fermilab and the T2K experiment in Japan are examples. The advantage of the new experiments, said Sam Zeller, co-spokesperson of MicroBooNE and Fermilab's Deputy Neutrino Division Head, is that "You can see a lot more of what's going on in the neutrino interactions" using a liquid argon detector.

"Another technology we might compare this to are Cherenkov detectors, but those detectors operate best at low energy. In order to do the type of physics we want to do, we need to study neutrino oscillation patterns over a much larger range of energies, so you can see the oscillatory structure in the neutrino data," Zeller said.

ICARUS is the largest particle detector to ever be transported in its complete form. And size matters for neutrinos; as the neutrino beam naturally spreads out over longer and longer distances, researchers need a larger and larger volume of liquid argon to detect them.

During the 2017 APS Division of Particles and Fields meeting, I toured the new home of ICARUS, where personnel from a Spanish shipping company were finishing the installation. Inside the new facility there was what looked like a huge tub waiting for the two truck-sized aluminum-encased ICARUS argon chambers parked outside of the facility.

Currently there are over 200 scientists participating in the SBN program that will include three detectors which are currently at different stages: MicroBooNE is already operating, ICARUS is being installed, and the SBN near detector is in the design stages.

The story of ICARUS is a human story as well as a scientific one, as Peter Wilson, SBN program coordinator, and Cat James, deputy SBN program coordinator, explained to me as we wander around the ICARUS building.

The installation of ICARUS at Fermilab marks the first time that CERN has sent its own personnel—that is, physicists, engineers and technicians that work for CERN, not users employed at other academic institutions—to work on a research collaboration at Fermilab. It's only in the past few years that CERN has started contributing as a member institution to collaborations centered on instruments not located at CERN. So, while Fermilab has been a member institution of a scientific collaboration at CERN for many years, CERN has only just joined as a member institution of the SBN program at Fermilab.

"Originally there was a proposal to move ICARUS to CERN," Wilson said, "on a new neutrino beam there. CERN made a strategic decision not to build a new neutrino beam, but to do neutrino physics elsewhere. So what's happening now is that the neutrino physics community is coming together here at Fermilab."

The author is a freelance writer based in Minneapolis, Minnesota.

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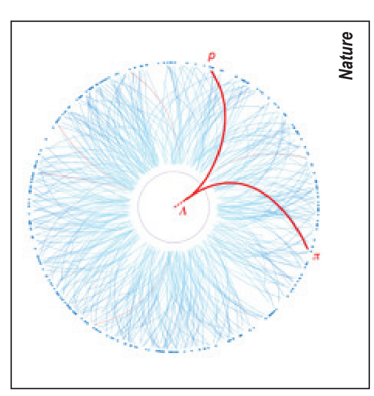
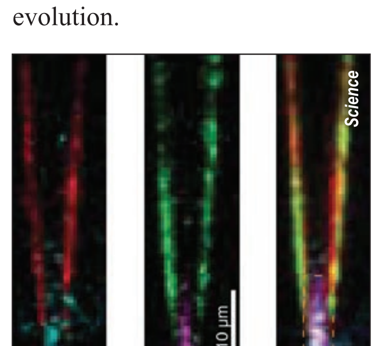
the first microseconds after the big bang. Recent observations showed that the quark-gluon plasma has an extremely low viscosity, which led to predictions that this fluid could rotate very quickly. The STAR collaboration looked for evidence of this swirling motion in off-center collisions at the Relativistic Heavy Ion Collider. As reported in *Nature* (DOI: 10.1038/nature23004) they found that the

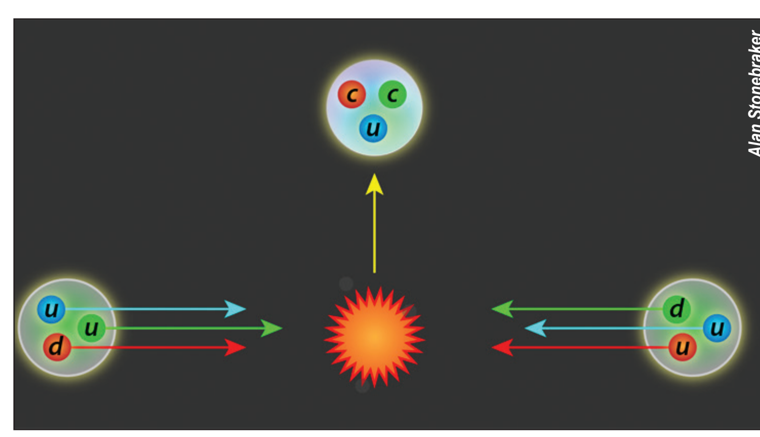


Colliding protons produce double the charm.

Λ hyperon particles produced in the collisions had spins that, on average, lined up with the inferred angular momentum of the system. This spin polarization implied that the quark-gluon plasma at the collision center rotates about 10^{22} times per second, which is a quadrillion times faster than any other known fluid. The results could help refine theories on quark-gluon plasma evolution.



New technique for looking at surface chemistry.



Particle tracks reveal quark-gluon plasma rotation.

Snapshots of surface chemistry

Much of surface chemistry depends on the local properties that atoms and molecules encounter on a substrate, and researchers have now found a way to look at the orientation of interfacial water thanks to second-harmonic generation (SHG) microscopy. In SHG, a laser beam (say, red) entering a material produces another beam at twice the frequency (say, green). However, this only occurs in materials whose structure breaks symmetry, such as certain crystals and interfaces. In *Science* (DOI: 10.1126/science.aal4346), Macias-Romero et al. report that they can take advantage of the surface selectivity of SHG to image the structure and dynamics of water molecules on a glass capillary. With their setup, the researchers mapped in 3D the orientation of water molecules at the glass surface for different pH values of water. Each molecule's orientation depends on the local surface charge, so these maps revealed the extent of deprotonation as SiOH was converted to SiO^-. This capability should benefit researchers in many fields where interfacial inhomogeneities influence the surface chemistry.

New Particle Is Doubly Charming

High-precision experiments at CERN have provided unambiguous evidence for a new baryon containing two charm quarks. In principle, baryons can be composed of any combination of three quarks. However, common baryons like protons and neutrons only contain light quarks, and all known baryons contain at most one of the three heavy quark types (charm, top, and bottom). As reported in *Physical Review Letters* (DOI: 10.1103/PhysRevLett.119.112001), CERN's Large Hadron Collider beauty (LHCb) Collaboration has now discovered a baryon known as the Ξ^{++}_{cc}, which is made of one light (up) quark and two heavy (charm) quarks. Previous experiments had hinted at the existence of a related doubly charmed particle called the Ξ^{+}_{cc}, but LHCb has now sifted through data from LHC's latest run to provide better-than-5-σ evidence for the Ξ^{++}_{cc}. The collaboration also determined with high precision its mass: 3621 MeV/c^2—a value in good agreement with theoretical expectations. While the existence of this particle was expected, the Ξ^{++}_{cc} will provide researchers with a unique system for testing quantum chromodynamics, the theory for the strong interaction that binds subatomic particles together. (For more, see the Viewpoint by Raúl Briceño in *Physics* "A Doubly Charming Particle.")

HUBRIS continued from page 3

expense of exploring better options. "Even basic research has political implications," says David Dana, a legal scholar at Northwestern University whose specialties include environmental law.

Furthermore, you would still have to do a much larger experiment—inject orders of magnitude more aerosol—to accurately model the climate effects of solar geoengineering, says climate scientist Gabriele Hegerl of the University of Edinburgh, who co-authored a 2009 article in *Science* titled "Risks of Climate Engineering." Hegerl says that to determine how much volcanic eruptions cooled Earth, climate models aggregated data over multiple eruptions.

In the *Science* article, Hegerl and her co-author, MIT atmospheric chemist Susan Solomon, write that it's irresponsible to promote solar geoengineering simply because it lowers temperatures. Temperature is only a symptom of a larger environmental problem. "Solar radiation management doesn't attack the global warming problem at its root, which are emissions," Hegerl says.

Consequently, the technology won't be an environmental panacea. For example, solar geoengineering won't address ocean acidification at all, where rising carbon dioxide levels have resulted in a more acidic ocean because of increased carbonic acid in the water. It could also reduce rainfall in monsoon regions in East Asia, Africa, and North America, as found in a 2013 study. "I'm quite nervous about it," Hegerl says.

If side effects like drought do indeed occur, it will be statistically challenging to prove solar geoengineering caused them, Hegerl says. For example, it may be impossible to quantify the exact decrease in rainfall caused by injected aerosols. That's because precipitation, temperature, and other weather phenomena depend on so many coupled variables. "We could cause potentially harmful changes that would be really tricky to prove were from solar radiation management," she says. Once deployed, it could be difficult to hold solar geoengineering accountable for its side effects.

Keith acknowledges potential side effects could occur, but he thinks that the path forward is to do more research. They have begun to investigate side effects for their balloon experiment. For example, some types of proposed aerosols could destroy ozone in the stratosphere. Keith's group has chosen to release calcium carbonate because their model predicts that it could actually help restore ozone.

Technical considerations are merely the tip of the iceberg, though. "The real disagreements are about the bigger questions," Keith says. "The ethics, the broader climate policy."

From the policy perspective, critics argue that should the technology come to fruition, governments could be less motivated to cut emissions—an example of a so-called "moral hazard." Dana, who considers himself neither for nor against solar geoengineering, has conducted surveys designed to answer this question. "It's pretty early research, but the results do suggest that if people hear that solar geoengineering might work, they might be less supportive of things like carbon taxes," he says.

The current political climate isn't promising, either. Solar geoengineering requires global cooperation, something that looks uncertain in the wake of President Trump's pledged exit from the Paris Climate Accord. "If we can't pull [the Paris Accord] off, it seems even less likely we can cooperate on geoengineering," Dana says.

And what if geoengineering is just technological hubris? Top-down approaches for "fixing" the environment often have unintended consequences. For example, in the mid-twentieth century, the U.S. Army Corps of Engineers straightened Florida's Kissimmee River to prevent flooding, only to damage the local ecosystem of birds and fish. Beginning in the 1990's, the government restored the river's previous path. "Humankind doesn't have a great track record of implementing amazing technological solutions," Hegerl says.

Because solar geoengineering proposals have largely been theoretical, government regulations for it don't exist yet. Keith's group plans to name an independent advisory panel to guide the experiment. "It's really important to have a high level of transparency and to have some sort of independent regulatory oversight," he says.

Although no government is anywhere near ready to deploy solar geoengineering, the likelihood of using the technology in coming decades is increasing. "If you look at the projections for cutting emissions and how slow it is for emissions reductions to affect climate, there's a pretty good argument we'll have to do something," Dana says. Debates over solar geoengineering—and its risks—are moving toward the mainstream.

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

The Back Page

The Federal Budget Part Two: A Tutorial and Update on the Fiscal Year 2018 Physical Science Research and Development Budget

By Cherry Murray

Note: This article is based on a presentation given to the 2017 APS April Meeting in Washington DC in January 2017, with an added early September update. Part One was published in the August/September issue.

When I gave a presentation at the APS "April" Meeting last January I had just completed my appointment as the Director of Science at the U.S. Department of Energy (DOE), which as the *APS News* readership knows is the largest funder of physical science research in the federal government.

I hadn't actually paid a lot of attention to the entire federal budget until I became a federal employee, and then I found it to be quite sobering.

This Back Page article is spread in two parts across two issues of *APS News*. First, in Part One in the September issue, I covered some historical trends in U.S. research and development (R&D) funding, contrasted with that of some other nations, and then provided an early June update on the administration's proposed budget for next fiscal year (FY18) and a call to the physics community to respond.

In this Part Two, I will give a short tutorial on the federal budget as a whole and where R&D fits into it, and a mid-September update on the congressional budget marks for FY18.

The Federal Budget—a Tutorial

As a reminder from Part One, the U.S. federal government is normally working on three annual budgets simultaneously. The budget for fiscal year (FY) 2017, from October 1, 2016 to September 30, 2017, is being executed by agencies now. Let's call that budget the FY budget.

At the same time, the FY+1 budget is under consideration by Congress; that budget is (normally) submitted to Congress by the president during the first week in February of FY, i.e., four months after the start of FY and eight months prior to the start of FY+1. Congress must assess this budget, usually through hearings and testimony, and enact 12 separate appropriations for the FY+1 budget.

Because of the turnover in the presidential administration last January, submission to Congress of the president's FY18 proposed budget was delayed until late May, and congressional budget hearings were held for FY18 in June and July. The House has just, in mid-September, passed a package of twelve appropriations bills, and the Senate Appropriations Committee is in the process of passing appropriations bills out of its various subcommittees.

Concurrent with congressional consideration of the FY+1 budget, the administration is formulating the FY+2 budget, a process led by the Office of Management and Budget (OMB) and negotiated separately with each agency; the formulation process can take as long as one year prior to the submission to Congress.

Figure 1 shows a pie chart of the U.S. federal budget enacted in 2015 (FY15)

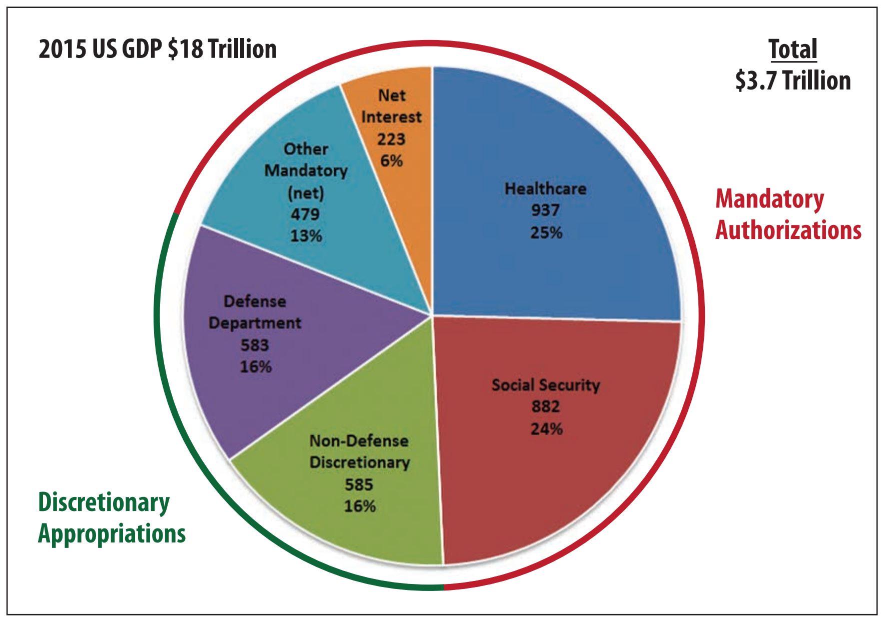


Fig. 1. Pie chart of the U.S. 2015 fiscal year enacted budget showing mandatory and discretionary parts. Source: Congressional Budget Office (CBO)

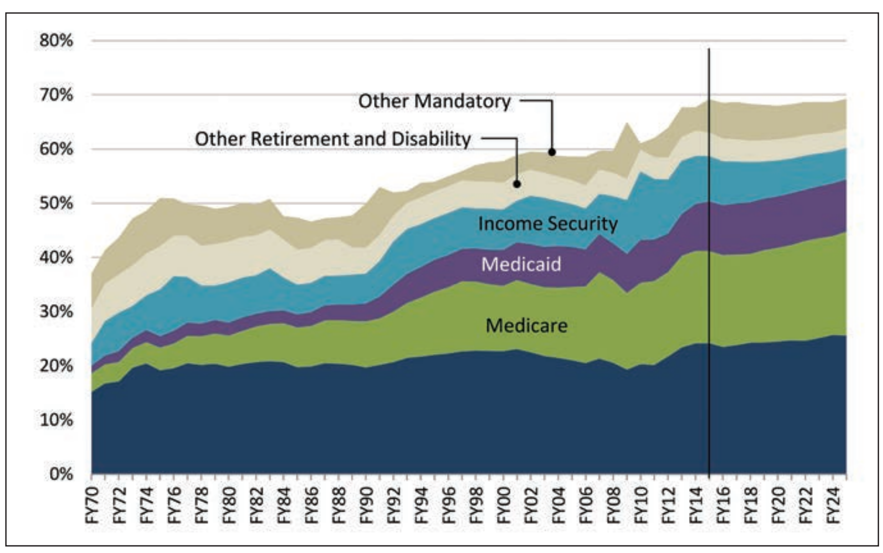


Fig. 2. Historical growth and projections of the mandatory programs. Source: Congressional Research Service

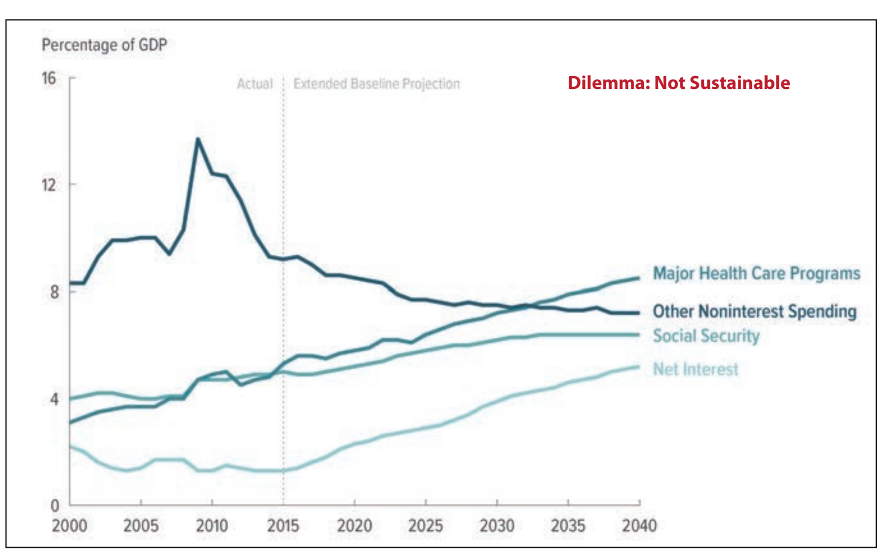


Fig. 3. CBO projections for a "spending in a business-as-usual" scenario

The FY15 enacted federal budget was $3.7 trillion. Two thirds of it was "mandatory." This includes what are called entitlement programs: Social Security, and the major healthcare programs for retirees and low-income earners, Medicare and Medicaid, along with other programs like unemployment, food stamps, federal housing loan programs, veterans' retirement, and the net interest on the U.S. national debt.

The mandatory parts of the budget are mostly not appropriated (Social Security is appropriated, but it's still considered a mandatory entitlement program) and they are authorized by bills in Congress through various authorizing committees. Some are authorized for many years, but many are authorized for only a single year.

Relevant to physical science research is the "discretionary" spending, a yearly budget process through the appropriations committees of Congress. This comprises about half defense and half nondefense spending. And the research and development (R&D) part of each of those is about 10%; together a very small slice of the total federal budget—roughly 3%.

Here is an issue: For the past 50 years, the U.S. has been running an annual budget deficit, and it's getting worse. The differences between federal outlays and revenues have averaged about 3% of the U.S. gross domestic product (GDP), currently around $18 trillion. We must borrow money to pay for these ~3% per year deficits, with the net interest on the federal debt part of the mandatory part of the budget.

In its proportion of the federal budget and in real dollars, mandatory spending has been climbing dramatically, and discretionary spending, which includes R&D budgets, has been going down. The federal budget is now two-thirds mandatory versus one-third discretionary, rather than the other way around as in the 1970's.

Within mandatory spending Medicare and Medicaid are growing the most rapidly. Social Security is growing as well but not as rapidly. The Congressional Budget Office (CBO) projections for the mandatory programs are shown in Figure 2.

In fiscal year 1970, about 16 people were paying into the system for each worker getting Social Security and Medicare entitlement program retirement and disability benefits. Today, there are about 3 people paying into the system for every one recipient. The baby boomers are now beginning to retire. In 2024 there will be 2 people paying in for each recipient.

If we continue with our current policies then our deficit is only going to get worse, with a ballooning net interest payment. In Figure 3 you can see this in the CBO projections assuming business as usual out to 2040.

The peak in 2009-2010 is the stimulus spending of the 2009 American Recovery and Reinvestment Act. Other noninterest includes all discretionary spending.

Our national debt is now larger than GDP and comparable in current dollars to what it was in World War II—and if you just extend what we're doing today, then our interest payments become three times larger by 2040. This is not sustainable.

About 20% of the nearly $20 trillion current national debt is held by foreign countries, the largest holders being China and Japan. This is a strategic risk and not internationally sustainable.

What this means is that in the next few years spending caps such as the 2011 "sequester" on the discretionary spending levels can go only so far: we will need to begin to address the biggest cause of the problem: net future spending on the major entitlement programs Medicare, Medicaid and Social Security.

If we cannot contain the spending on the major entitlement programs, federal spending on the discretionary part of the budget, including R&D—our investment in the future—will continue to decrease.

As of mid-September, there has been no agreement on healthcare spending reform, the administration, the House and the Senate are all in negotiations about raising the debt ceiling for temporary hurricane relief, a short continuing resolution keeps the government operating until early December, and Congress is working hard on passing all of the appropriations bills. The Senate subcommittee marks and the House marks for the appropriations restore much of the president's proposed drastic cuts to research spending for FY18 to close to FY17 levels, with some strong differences between the House and Senate marks in some of the applied research programs such as energy, space, and manufacturing. Both major funders of basic physics research, National Science Foundation and the DOE Office of Science, can expect that "level is the new up." It behooves you to continue to tell stories of the impact that your research has had, and make the argument that although federal R&D funding in a broad mix of fields is only 3% of the annual budget, it is a critically important investment in the future of our nation.

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