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Homer Neal 1942-2018
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PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH

Archiving Knowledge about Physics Teaching

By Charles Henderson and Paula Heron

Do laboratory experiments help students learn concepts? Why do so few women choose to major in physics? What is the most important skill for a high school physics teacher to develop?

Physics education researchers tackle these and many other questions about why students study physics, what they learn, and how their experiences affect their views about the discipline. Much of physics education research (PER) focuses on the concepts, principles, and habits of mind of physics, the traditional teaching methods and the culture of physics. As a result, PER has for many years found a home in the professional associations, conferences, and publication venues of physics. As the *Physical Review* journal family marks its 125th anniversary, we look back at the founding and development of *Physical Review Physics Education Research* in 2005, now a central and open-access home for this work.

The close connection between PER and physics as a discipline was acknowledged by the American Physical Society Council in its 1999 *Statement on Research in Physics Education* [1]. The Council recognized that implementation of PER ideas was best accomplished by having physicists within physics departments who specialized in PER. This statement came at a critical time for PER and helped usher in an era of rapid growth in the number of researchers, the number of Ph.D. programs, and a broadening of the field of inquiry.

At the same time, the development and adoption of many now-common teaching strategies and tools were spurred by advances in PER. These improvements could not have been possible without a strong research base that includes systematic empirical investigation and theoretical speculation. Observations and insights, including accounts of both successful and unsuccessful interventions, must be widely disseminated and subject to vigorous debate and replication. Room must be made for investiga-

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Update on the APS Strategic Plan

Throughout 2018, APS members, leadership, and staff have been preparing a new Strategic Plan to guide the Society in coming years (see *APS News*, February 2018). The process began in early 2018 at the APS Leadership Convocation when elected leaders of membership units (Divisions, Topical Groups, Forums, and Sections) provided input. Town hall meetings and invited focus groups convened at the APS March and April meetings to gather direct member comment. CEO Kate Kirby provided an update at the annual APS Business Meeting on April 13 and a member feedback form was made available on the aps.org website.

The APS Board of Directors is overseeing the work of preparing the new Strategic Plan and has delegated day-to-day efforts to a Steering Committee and subcommittees in four key areas: Ensuring a Meaningful Role in Scientific Research Dissemination; Serving Communities (Membership, Physics Community, and Society); Securing Financial Sustainability; and Increasing Organizational Excellence.

At its June retreat, the Board spent considerable time discussing progress on the Plan. In guiding the ongoing effort, the Steering Committee will combine reports from each of the subcommittees into a draft Strategic Plan for consideration by the Board at its September 2018 meeting and then by the APS Council shortly thereafter.

The final Strategic Plan will be submitted to the APS Board and Council for approval in November 2018. The approved Strategic Plan will be rolled out at the 2019 APS Leadership Convocation.

DON'T FORGET TO VOTE

Check your email for information about the 2018 APS General Election. Voting is open from July 2 to August 10. For a full list of candidates, candidate biographies, and candidate statements please visit **go.aps.org/aps-vote-2018**

Diversifying the Dark Matter Portfolio

By Leah Poffenberger

In 2012, CERN coaxed the long-sought Higgs boson into making an appearance, and in 2015, the Laser Interferometer Gravitational-Wave Observatory directly observed an elusive space-time wiggle. Both phenomena were theorized about for decades before their eventual discovery.

So perhaps it is high time for dark matter, the mysterious stuff that makes up around 27 percent of the universe, to finally reveal itself. But directly detecting particles that don't reflect, absorb, or emit light is no easy task, especially without knowing what kind of particles they are—or how they interact with regular matter.

One of the prevailing hypotheses for many years has been that dark matter consists of weakly interacting massive particles (WIMPs), which are possibly 100 times more massive than a proton. Over the past ten years, direct dark matter detection experiments searching for WIMPs have improved significantly, reaching better and better sensitivities, but, so far, the hypothesized particles continue to evade even the best detectors.

"I think this has been a little bit surprising—that no one has had any indication of detecting dark matter," says Jodi Cooley, a physics professor at Southern Methodist University and collaborator on SuperCDMS. "This is challenging theorists and experimentalists to start looking in new directions."

So does this absence of WIMPs—and a subsequent uptick

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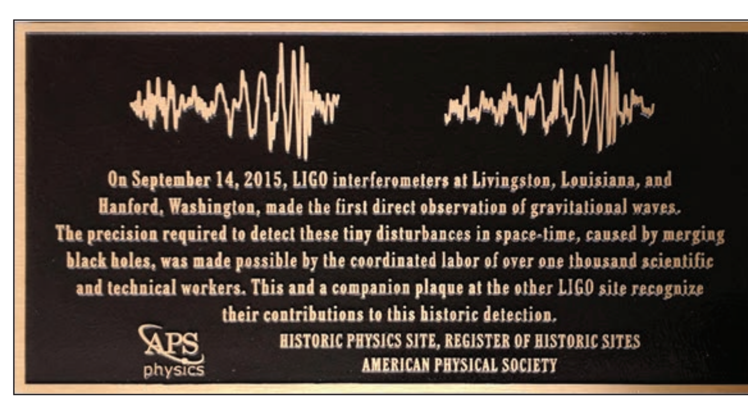
LIGO Labs Chosen as APS Historic Sites

By James Riordon



The LIGO facilities in Washington and Louisiana have been designated APS Historic Sites and will each receive a plaque honoring its contributions to direct detection of gravitational waves.

The LIGO (Laser Interferometer Gravitational-Wave Observatory) laboratories in Livingston, Louisiana and Hanford, Washington were declared APS Historic Sites in a ceremony on June 20 at the Livingston LIGO Science Education Center. APS President Roger Falcone and APS Historic Sites Committee Chair Paul Halpern presented the labs with identical plaques, each bearing the citation shown in the figure.

LIGO Executive Director David Reitze noted that the LIGO historic site designation is unusual, considering that most other APS Historic Sites recognize events that took place decades ago. "When I first received word … that we had won this award," said Reitze, "I was initially quite surprised because, I thought to myself, well we made these discoveries three years ago. ... But then I thought about it a little bit more. And I realized that, no, this was exactly the right thing to do because even though LIGO burst onto the scene … in 2015, this is something that's been going on for a long, long time."

Reitze pointed out that the National Science Foundation (NSF) began providing funding to Rainer Weiss to develop prototypes for LIGO over forty years ago. Weiss shared the 2017 Nobel Prize in Physics with Kip Thorne and Barry Barish. Construction of the LIGO sites began in 1995, and after running with the initial design parameters from 2002 to 2005, the observatories were upgraded to current sensitivities during the Advanced LIGO (ALIGO) construction phase that began in 2010.

The ALIGO upgrade was completed in 2015, and, said Reitze, "Literally, almost the day we turned on our detectors we detected the first gravitational waves from these colliding black holes."

The LIGO labs are the 41st entry into the APS Historic Site ledger, which was signed by Roger Falcone on behalf of APS and David Reitze on behalf of LIGO. It is the first entry to be accompanied by dual plaques, in recognition of the joint contribution of the LIGO labs, located over 3,000 kilometers apart. Each plaque includes inscribed depictions of the gravitational wave signals as detected at the respective laboratories.

Michael Landry, Observatory Head of the LIGO Hanford laboratory, noted with a laugh that the Livingston facility is listed first on the plaques, and Hanford is second, rather than conventional alphabetical order. "I think that order is a nod to the order in which the signals were received," said Landry. "I find it a little ironic that it took 1.3 billion years for that signal to get here, and yet when it was detected by the sites it was separated by 6.9 milliseconds." The difference in arrival time gives Livingston a one part in 10^{19} priority as the first site to detect gravitational waves.

In gratitude for the NSF's decades of support for gravitational wave research, Rainer Weiss presented NSF Director France Córdova with a photograph of Vannevar Bush at work cutting aluminum on a milling machine. Bush, explained Weiss, advised Franklin Roosevelt on scientific matters, and was crucial to founding the NSF. Weiss said that in the book *Science, the Endless Frontier*, Bush noted reasons that govern-

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Revised 07/16/18

Bend it like Bernoulli

By Sophia Chen

This summer, as World Cup fans cheer in front of TVs across the globe, take a look at the small grey-and-white sphere rolling at the players' feet. You may notice that even though the rules of the game haven't changed—the ball has.

Adidas calls its latest ball redesign the Telstar 18. Unlike the classic black-and-white leather ball with 12 pentagons and 20 hexagons stitched together, the Telstar 18 consists of 6 synthetic panels, glued together thermally, no thread required. Its surface is dotted with tiny raised stipples, pleasant to grip in your bare hands. It even contains a chip that your phone can read to unlock online soccer-related content.

But when it comes to playing the game, John Eric Goff knows that the ball's most important property isn't its matte finish or its phone-compatible features. It's aerodynamics.

The University of Lynchburg physicist and author of *Gold Medal Physics: The Science of Sports* has studied how different balls soar for over a decade. To measure aerodynamics, his team jam rods into the backs of soccer balls and blast them with 80 mile-per-hour winds in a wind tunnel. They used to use special launchers and high-speed cameras to analyze ball motion, too.

The irony is that they need to perform these tests at all: In professional soccer, game balls are standardized, so you might think that all balls will behave the same way. The International Football Association Board specifies the circumference, weight, pressure, and material. Before the design ever reaches the pitch, officials perform tests on a sample set of the balls to confirm they roll straight. They even soak them in tanks of water to figure out how much moisture the material absorbs so that the ball's weight doesn't increase too much during a rainy match.

But in spite of the standards, distinct designs still kick differently. Even when discrepancies seem subtle, the players feel it, and they don't appreciate having to adjust to a new ball. "If I kick a ball, I'm not good enough to be able to tell the difference," says Goff, who is unaffiliated with the World Cup and Adidas. "But at their level of ability, those players will notice if they kick a ball the same way year after year, and all of a sudden it doesn't fly the same way."

Famously, teams loathed the 2010 World Cup ball, the Jabulani, also made by Adidas—players complained the ball was too floaty. In a *New York Times* story that year, Spanish goalkeeper Iker Casillas compared it to a beach ball. "A disaster," France's Hugo Lloris added. The ball would wobble unpredictably like a beach ball during airborne kicks such as free kicks, penalties, and corner kicks.

In a 2014 paper, Goff and his collaborators at the University of Tsukuba in Japan pinpointed the physics of why players hated

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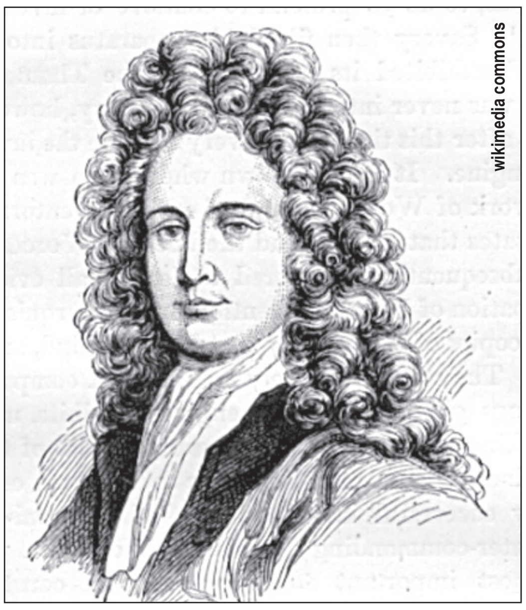
Physicist John Eric Goff studies the aerodynamics of soccer balls.

This Month in Physics History

July 2, 1698: Thomas Savery Patents an Early Steam Engine

As England hovered on the brink of the Industrial Revolution in the late 17th century, a major challenge was how to remove excess water from the mines. This was typically done by mounting a series of buckets on a pulley system driven by horses—a very slow and costly process. It fell to an English inventor and engineer named Thomas Savery to build the first working prototype of "an engine to raise water by fire."



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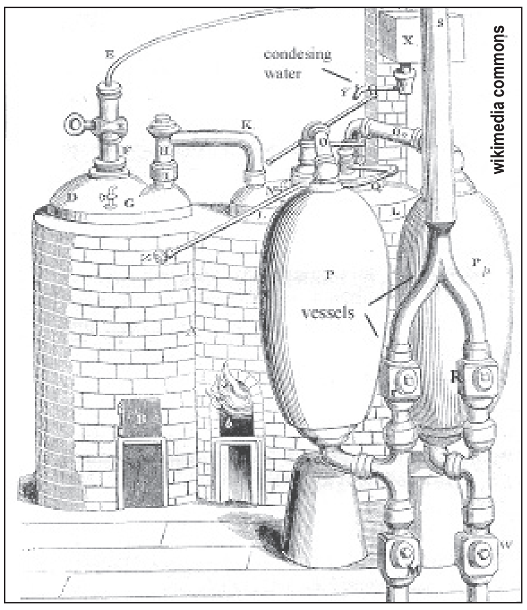
Thomas Savery

Born to relative privilege in 1650, Savery received an excellent education and grew up to be a military engineer. He was especially interested in math and mechanics, with a penchant for invention, including building a clock for the Savery family. Another of his early inventions was an array of paddlewheels to propel sea vessels. Despite a successful demonstration with a small paddleboat on the Thames River, the British Navy declined to adopt the invention for its own vessels. It was a haughty Navy surveyor named Edmund Dummer who sank the young inventor's hopes, asking why it is that "interloping people, that have no concern with us, pretend to contrive or invent things for us?"

Savery was also interested in steam engines. Earlier thinkers had speculated about such a contraption, most notably Edward Somerset, 2nd Marquess of Worcester, a nobleman with a keen interest in invention. His 1655 treatise, *The Century of Inventions*, included a description of a "water-commanding engine" constructed from the barrel of a cannon, intended for use in irrigation. Young Savery may have read Somerset's book on the subject. Legend has it that he bought up as many copies as he could find and burned them to solidify his own patent claims, but most historians do not find the story credible. Still, the designs were strikingly similar. He certainly believed such a contraption could be useful in keeping mines and pits from flooding, especially those in the Cornwall region.



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Savery's steam engine

Savery filed a patent for his first design for a "fire engine" on July 2, 1698, and soon after presented a working model to the Royal Society of London. After exhibiting his engine at Hampton Court for King William III, he was granted his patent for "a new invention for raising of water, and occasional motion to all sorts of mill works, by the important force of fire, which will be of great use for draining of mines … " That original 14-year patent received a 21-year extension by British Parliament in 1699 as part of the ""Fire Engine Act."

An elated Savery printed up a prospectus in 1702, entitled *The Miner's Friend*, and sent it to managers of mines across England, expecting an influx of new customers, but while his steam pump was useful for supplying water to estates and country houses, it was not immediately embraced by the mining industry.

The device required no heavy moving parts, relying on a vacuum to pull water into a separate container. Steam pressure would then force the water upwards with the help of a few simple valves to control the pumping. However, it was not the most efficient engine for lifting water, in part because the technology did not yet exist to machine tightly sealed joints. All the parts were made from brass, copper, and bronze, pieced together from casts or molded parts and then soldered or riveted together. The imperfect sealing meant the engines were prone to exploding. It also consumed too much fuel to make it economically viable for mining applications.

Still, Savery's design inspired later engineers to develop improved versions. One such person was a blacksmith named Thomas Newcomen, whom Savery had hired to forge his own engine. He let the blacksmith forge a copy of the machine for his own backyard research. Newcomen invented an atmospheric steam engine that used (as the

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name implies) atmospheric pressure to pump steam into a cylinder. Exposure to cold water then caused the steam to condense and created a vacuum inside the cylinder, and the resulting pressure drove a piston. He and John Calley built a working prototype in 1712 and used it to pump out a mineshaft flooded with water.

Savery held such a broad patent on the steam engine—namely the use of surface condensation—that he was listed as co-inventor on the atmospheric steam engine patent, even though Newcomen's engine showed vastly improved performance, significant mechanical differences, had no need for steam pressure, and used a vacuum differently. So Newcomen had little choice but to go into business with him, marketing his own superior design under Savery's patent. The patent expired in 1733, four years after Newcomen's death (Savery died in 1717). Today the Savery Company in the United Kingdom continues to manufacture an array of electro-hydraulic systems.

The design was good enough to dominate the mining industries for decades, as well as being used to drain wetlands, but it was still plagued by excessive use of steam, since the pumps had to be cooled after every stroke, then reheated. The full potential of the steam engine would not be realized for another 50 years. James Watt, an instrument maker for the University of Glasgow in Scotland, was tasked with solving the issues with the Newcomen steam engine.

Watt realized during a Sunday walk in 1765 that he could condense the steam without cooling the cylinder by using a separate condenser. He tested the concept the very next day in his laboratory, building a makeshift piston and condenser out of a brass syringe. It worked, although it would be another 11 years before Watt had a working prototype. His apparatus soon became the most popular design for steam engines in the 18th century—just in time to help usher in the Industrial Revolution. The watt unit of power is named in his honor.

Further Reading

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Marsden, B. 2002. *Watt's Perfect Engine*. New York: Columbia University Press.

Savery, T. 1827. *The Miner's Friend: Or, an Engine To Raise Water*. London: S. Crouch.

Corrections & Clarifications

In the June 2018 issue of *APS News*, an article on p. 3 about machine learning in physics misstated the use of AI in detecting gravitational lenses. Brian Nord's group did not use AI techniques to discover the eight gravitational lenses discussed; these were found conventionally, but the group is using AI for new searches.

In the same issue, the article "Spotlight on Development" (p. 2) showed a photo of muon detectors used in public outreach projects. The detectors were developed by the Cosmic Watch group at MIT (cosmicwatch.lns.mit.edu). A different group, which was funded by the APS mini-grants, used the detectors in an outreach program at Letchworth State Park in New York.

Homer Neal 1942-2018

By David Voss

Homer A. Neal, the Samuel A. Goudsmit Professor of Physics at the University of Michigan, died on May 23 at age 75. He was a Fellow of the APS and in 2016 became the Society's first African American president. In 2003, he was the recipient of the APS Edward A. Bouchet Award "for his significant contributions to experimental high energy physics, for his important role in formulating governmental science policy, for his service as a university administrator at several universities, and for his advocacy of diversity and educational opportunity at all levels."

"Homer was a very kind man who was passionate about physics," said 2018 APS President Roger Falcone. "He was tireless in expanding participation and connecting scientists globally, and extremely thoughtful about any activity he undertook, including his leadership of the American Physical Society. It was an honor and pleasure to work with him."

Neal received his Ph.D. at the University of Michigan in 1966. From 1976 to 1981 he was dean for research and graduate development at Indiana University, and provost at Stony Brook University from 1981 to 1986. From 1987 to 1993 he was chair of the physics department at the University of Michigan.

He was part of the D0 Collaboration at Fermilab that discovered the top quark in 1995. From 2000 to 2015 he was director of the University of Michigan team that collaborated at CERN on the ATLAS experiment and participated in the discovery of the Higgs boson in 2012.

"Homer Neal was a remarkable man," said APS CEO Kate Kirby. "His influence was felt well beyond the physics community, which was his home. APS is extremely fortunate to have benefited from his wise and steadfast leadership, and I feel privileged to have had the opportunity to work with him."

In addition to his scientific research, Neal was widely involved in science policy and served on numerous advisory boards. He was a member of the board of directors of the Ford Motor Company and was a Director of the Lounsbery Foundation. Neal was a member of both the Council for the Smithsonian Museum of African American History and the U.S. National Research Council Board on Physics and Astronomy. Before becoming APS President in 2016, he served as a member of the APS Panel on Public Affairs. Neal authored a textbook on science policy (*Beyond Sputnik*), which is used in courses at several institutions.

While on the U.S. National Science Board, he chaired the committee that produced the board's first comprehensive report on undergraduate science education. A result of that study was the Research Experience for Undergraduates Program (REU), and the Research Experience for Teachers Program (RET), both of which are flourishing today. He also served as Chair of the Physics Advisory Committee of the National Science Foundation. Neal offered testimony on numerous occasions to Congress, on matters ranging from the funding of national laboratories to the state of science education.

"I knew Homer for many years during his service to the community—first on the Board on Physics

Homer Neal

and Astronomy at the U.S. National Academies," said APS Past President Laura Greene. "More recently we worked quite closely in the APS presidential line—he preceded me as Past President. Homer was continually brilliant and compassionate—always giving a great deal of consideration for every issue; he never failed to provide an astounding jewel of insight and understanding. His tireless and effective work to provide research experiences to undergraduates was always impressive. Homer was always an inspiration to me, and I will sorely miss him."

Homer Neal spoke from personal experience about diversity and inclusion. In an interview with *APS News* (February 2016) he recalled growing up in segregated Franklin, Kentucky in the 1950s. He and a friend who was white had developed an interest in amateur radio, but because Neal was black, they were pressured by the town's residents to break off the friendship. "We were both astounded, and agreed to stop our communications," Neal said. "But it did teach me that basically when individuals are working on a scientific project together, the color of one's skin doesn't matter. It mattered to others, but it didn't matter to us."

Foundation Helps Advance New Ideas in Physics

By Leah Poffenberger

The discovery of the Higgs boson in 2012 completed the Standard Model, but this monumental step in physics research led to a new question: What's beyond the Standard Model?

To help stimulate new ideas and create innovative technologies to explore problems in fundamental physics, the Gordon and Betty Moore Foundation has initiated a set of awards in partnership with APS designed to bring people together who can move basic research forward. The Gordon and Betty Moore Foundation Fundamental Physics Innovation Awards will provide varying levels of funding in three categories: Lectureship awards, Visitor awards, and Convening awards.

"These awards are for coming up with ways to do fundamental research with limited funding," says Theodore Hodapp, Director of Project Development at APS. "We're not building the next huge particle detector but working on developing theory and cost-effective small-scale experiments." An example of such an experiment, Hodapp says, would be using pulsar data to study dark matter: Already-collected data doesn't require the construction of an expensive new detector.

"The foundation supports basic science and we seem to be on the verge of big changes in how we understand fundamental aspects of nature," says Ernie Glover, science program officer at the Foundation. "New tools such as atomic sensors will allow bright, creative scientists to innovate and find solutions to the important mysteries facing fundamental physics."

The deadline for the first review cycle for the Fundamental Physics Innovation Awards is July 15. However, applications can be submitted at any time throughout the year for review; the next deadline is October 15. Both experimentalists and theorists with novel ideas for detecting dark matter, unlocking secrets of dark energy, exploring physics beyond the standard model, or addressing other problems in fundamental physics are encouraged to apply.

Lectureship Awards of up to $2,000 serve to support researchers who wish to take short trips to hold seminars on their work to broaden awareness of proposed or existing approaches for probing new physics.

Visitor Awards serve a similar purpose, but support longer, 1- to 6-week-long trips with funds between $5,000 and $10,000. These longer visits promote collaboration and exchange of ideas among researchers who may not otherwise have the opportunity to work closely together.

The Convening Awards—the largest award amounts of $75,000 or $25,000—enable small scientific meetings to bring experts together for discussions and presentations in hopes of sparking new ideas for the future of physics.

"This is a very exciting opportunity for APS to help provide financial support, in partnership with the Moore Foundation, to advance fundamental science," says Hodapp. "Our connections with the majority of academic researchers make this an obvious good fit, and well in line with our mission to advance the knowledge of physics."

For more information visit aps.org/programs/innovation/moore

LIGO continued from page 1

ment should support science. As he handed the photograph to Córdova, Weiss said, "You've done very well."

The APS Historic Site plaques will be mounted on rock native to the respective LIGO observatory locations outside the front entrances to the observatories' visitor buildings.

The author is APS Head of Public Relations.

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the ball so much—because they responded to air resistance differently than most soccer ball designs. Balls experience air resistance differently depending on their surface, which changes on different ball designs due to the length of their seams or the texture of the material. You can quantify a ball's response to air resistance with three numbers—a drag coefficient for each spatial dimension. These coefficients change depending on the speed of the ball.

As a ball reaches a critical speed—which differs based on ball design—its drag coefficients decrease drastically until suddenly leveling off (see figure). This speed signifies a transition in the ball's behavior known as the drag crisis, and it occurs when air flow over the ball changes from smooth to turbulent. This transition occurs at slower speeds for balls with rougher surfaces. A beach ball, for example, experiences smooth air flow at higher speeds than a dimpled golf ball—or a typical 32-panel soccer ball.

Air flowing over the Jabulani ball, they found, switches from smooth to turbulent when it reaches about 50 miles per hour. This is roughly the speed of free kicks and corner kicks—which meant that during these common kicks, airflow over the Jabulani would switch from smooth to turbulent suddenly, causing its erratic wobble. In contrast, other soccer balls they studied experience the drag crisis at much lower speeds. For example, they found that the onset of turbulent airflow occurs at about 30 miles an hour for the Brazuca, the subsequent ball redesign in 2014, which meant that the Brazuca didn't suffer the same fate during free kicks.

Jabulani's problem was that it was too smooth. It needed to transition to turbulent flow at a slower speed. Goff points out that the Spanish team, the 2010 World Cup champion, heavily relied on a strategy of short-range passes that could avoid the Jabulani's aerodynamic problems altogether.

As for the Telstar 18, Goff and his collaborators tested it soon after Adidas released it last November. In a paper published in May, they reported that the ball experiences the drag crisis at a reasonable 30 miles per hour, similar to its predecessor, the Brazuca. The Telstar 18's seams are longer than the Brazuca's, but they're also narrower and shorter, amounting to an overall similar roughness. However, the ball won't behave identically to the Brazuca: Goff modeled trajectories for the ball and also found that for long-range kicks, the new ball will travel about 10 percent less distance.

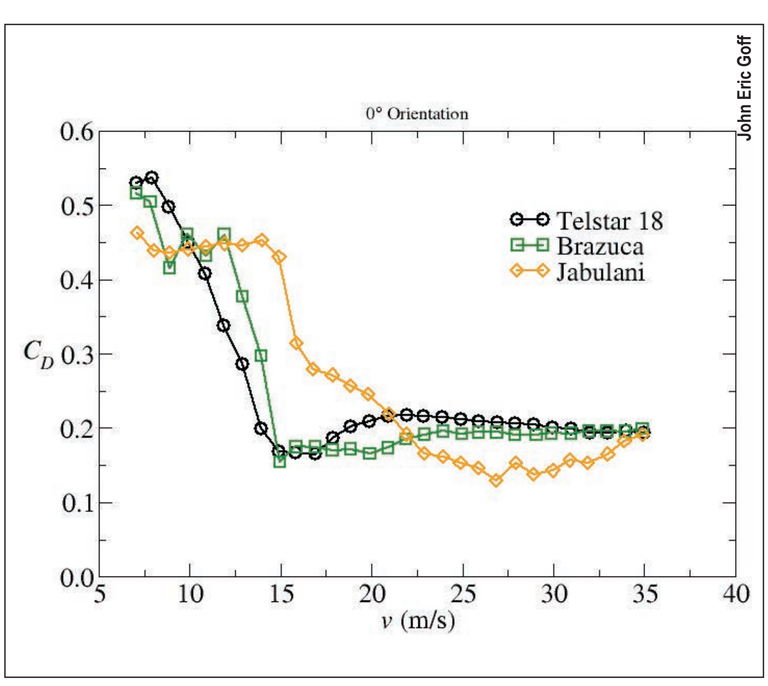
Overall, though, the Telstar 18 is pretty similar to the previous model, says Goff. Argentine star player Lionel Messi is quoted as liking the ball, according to a FIFA press release, but still, not everyone is happy with the latest redesign. "I bet you as much as you like that we'll see at least 35 goals from long range [in Russia], because it's impossible to work out," Spanish goalkeeper Pepe Reina told Spanish sports site *AS*. "And it's covered in a plastic film that makes it difficult to hold on to." And for all its similarities to the Brazuca, some players griped about that one too—because they don't like change. "There will always be somebody complaining about the new ball," says Goff.

So why keep re-designing the soccer ball when players hate change?

Money, says Goff. Your local sports store likely carries FIFA-approved replicas of the Telstar 18 for $164.99—and "people want to buy them," he says. In 2013, Adidas signed a deal to exclusively supply the World Cup ball until 2030, which they have done since 1970. According to Reuters, the company made $2.4 billion dollars in soccer sales during the last World Cup year in 2014.

If Adidas is going to keep redesigning the ball, Goff has some advice. If it were up to him, FIFA should make sure the ball's drag crisis occurs at a consistent speed from year to year, regardless of whatever bells and whistles the new designs might have. "That would be a good standard," he says.

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



Drag coefficients (C_D) for three different balls: the 2010 Jabulani, 2014 Brazuca, and 2018 Telstar 18, as a function of speed. The "drag crisis" occurs where the coefficient is a minimum.

News from the APS Office of Government Affairs

Two APS Student Members Lead National Petition Drive to Oppose Congressional Legislation

By Tawanda W. Johnson

Two APS student members, working with the APS Office of Government Affairs (APS OGA), wrote op-eds highlighting harmful loan provisions in legislation pending in the U.S. House of Representatives. Those op-eds became the tip of the spear in a national petition campaign that drew more than 1,300 signatures from fellow students and other members of the scientific community.

Introduced last year in the House, the PROSPER Act (Promoting Real Opportunity, Success, and Prosperity Through Education Reform) Act would eliminate Grad PLUS loans and include federal loan caps that may make the loans insufficient to cover the cost of attendance at many colleges and universities. The students' op-eds are highlighted within the petition that will be delivered to U.S. Senators Lamar Alexander, of Tennessee, and Patty Murray, of Washington, by the end of the month. Alexander and Murray serve on the Committee on Health, Education, Labor, and Pensions. The House version of PROSPER is awaiting a full floor vote while the Senate is crafting its version of the bill.

"I'm overjoyed to see so many people uniting against a bill that could be so harmful to students pursuing a better future," said Justin Powell, a graduate student at Lincoln Memorial University who protested the bill in an op-ed in the *Knoxville News Sentinel*.

In his piece, Powell included the following:

"The legislation, which caps the amount of federal money graduate students could borrow at $28,500 and drastically alters current repayment plans, would mean that I could not afford to attend graduate school, keep a roof over my family's heads—including my wife and daughter—and put food on the table. As a student working on a master's degree in life science research at Lincoln Memorial University, my loans cover costs for tuition, books, housing, food and other miscellaneous items—far more than what the loan cap would pay for on an annual basis. In order for my family to actually prosper, I suggest that our U.S. senator, Lamar Alexander, work with his colleagues to prevent the loan restrictions from becoming law. Alexander serves as chairman of the Committee on Health, Education, Labor, and Pensions and will play the key role in the bill's fate in the Senate."

During a recent interview, Powell added, "I could not have afforded a portion of my education if this bill had been enacted when I started school. I believe that we need to expand education, not limit it. Therefore I wanted nothing more than to help get the word out, and APS graciously helped me accomplish my goal."

Shua Sanchez

Shua Sanchez, a physics Ph.D. student at the University of Washington, who wrote an op-ed in *The Spokesman-Review* protesting the PROSPER Act, said, "As a Ph.D. student with student debt, I know that decreasing the accessibility and quality of student loans would be detrimental to the ability of many young and promising scientists to succeed in academia today. I wrote my op-ed to help explain that issue and motivate people to get involved in protecting the opportunities of STEM students with lesser financial security."

Sanchez explained in his op-ed how crucial the loans are that would be eliminated by the PROSPER Act:

"I am a first-generation Ph.D. student studying physics at the University of Washington, where 14,000 other graduate students pursue advanced degrees. As a freshman undergraduate, I took out several thousand dollars in subsi-

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SIGNAL BOOST

Signal Boost is a monthly email video newsletter alerting APS members to policy issues and identifying opportunities to get involved. Past issues are available at go.aps.org/2nr298D. To receive Signal Boost and learn more about grassroots activities, contact Greg Mack at mack@aps.org.

Join Our Mailing List: visit the sign-up page at go.aps.org/2nqGtJP.

FYI: Science Policy News From AIP

U.S. Policymakers Grapple with China's Emergence as R&D Power

By Will Thomas

The emergence of China as an international leader in science and technology has been a long time coming, but only more recently has it become a flashpoint for U.S. policymakers.

According to the National Science Board's Science and Engineering Indicators, Chinese public and private spending on R&D has been growing on average by 18 percent annually since 2000, compared to 4 percent annually for the U.S. The board predicted this spring that China could overtake the U.S. this year.

China also aims to take an early lead in emerging industries such as advanced manufacturing and materials and biotechnology by intensively coordinating research, technology development, and industrial production through government programs such as "Made in China 2025."

Meanwhile, the Department of Defense (DOD) warns that strategic investment by China and other "near-peer" adversaries in fields such as hypersonic propulsion, directed energy, and artificial intelligence could enable them to match U.S. military forces in combat. To counter this threat, DOD has been working to increase the pace at which it transitions cutting-edge technologies into the field, and the Trump administration has tapped former NASA head Michael Griffin to oversee these efforts.

Similarly, Chinese accomplishments in quantum information science, such as its demonstration of entanglement between photons on a satellite and on Earth, have raised the specter that China could gain an advantage in quantum encryption and computing. Congress is responding with legislative measures to spur quantum R&D, including a proposal to establish a National Quantum Initiative partly modeled on the National Nanotechnology Initiative launched in the early 2000s.

Policymakers have also become anxious about China's aggressive pursuit of American intellectual property (IP) and other technical knowledge. While cyberespionage and patent infringement have long been sore spots in U.S.–China relations, the government is now also focusing on preventing researchers from bringing IP and expertise from U.S. labs to China.

Notably, last month the Trump administration allowed U.S. con-

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The APS Topical Group on Plasma Astrophysics

By Michael Brown

The APS Topical Group on Plasma Astrophysics (GPAP) was formed in 1999 to provide an intellectual home for plasma physicists who have an interest in astrophysical phenomena. At present, GPAP has 400 members from broad backgrounds and includes scientists at both universities and national labs. The topical group serves as a bridge between the APS Division of Astrophysics (DAP) and the Division of Plasma Physics (DPP), which organizes the annual meeting for GPAP.

GPAP members are engaged in many exciting research areas, particularly laboratory astrophysics. Laboratory astrophysicists try to uncover fundamental plasma physics processes that might be at play in astrophysical settings. They ask scientific questions such as: "What happens when plasma waves collide?" "What happens when you stir plasma?" and "What happens when you compress plasma?"

To answer these questions, three laboratory astrophysics experiments have been designed by GPAP members and provide good examples of current work. First is an experiment performed at UCLA by Greg Howes from the University of Iowa on what gives rise to plasma turbulence. Next is an experiment by Cami Collins in the lab of Cary Forest at the University of Wisconsin that gives insight into what happens to plasma on galactic scales. Last is a recent experiment by Manjit Kaur in my lab at Swarthmore in which we probe the equation of state in a magnetized plasma.

Building blocks of turbulence

A hallmark of turbulence in electrically conducting or magnetohydrodynamic (MHD) fluids is the spectral transfer of energy in both spatial and temporal frequencies, from large and slow scales to small and fast ones. The typical picture of turbulent dynamics is that energy is introduced into the system at large spatial scales (i.e. low spatial frequency k) by either stirring or interaction with boundaries. The fundamental nonlinear process by which large-scale structures bifurcate in plasmas is due to the interaction of two counter-propagating Alfvén waves [1]

An Alfvén wave is one of the three normal modes of oscillation in MHD, along with fast and slow magnetosonic waves. MHD turbulence theory predicts that the collision of two Alfvén waves transfers energy nonlinearly to a third wave that has both higher spatial and temporal frequencies. Howes and his team refer to this interaction as the fundamental building block of astrophysical plasma turbulence.

In experiments carried out at UCLA, Howes and coworkers launched counter-propagating Alfvén waves in the magnetized plasma column at the Large Plasma Device (LAPD). After mapping out the resultant fields, the researchers discovered the signature of a nonlinear daughter Alfvén wave with the correct properties, just as predicted.

Stirring plasma in the lab

Astrophysical plasmas at galactic scales (e.g., accretion disks formed as black holes draw matter from companion stars) are stirred and sheared by differential rotation. These objects are typically flow-dominated in the sense that the kinetic energy density far exceeds the magnetic field energy density. By contrast, most laboratory plasma experiments are magnetically dominated, since a strong magnetic field is necessary to confine hot plasma, and typically lab plasmas are nearly at rest. In order to study fundamental processes of flow-dominated plasmas, Collins and the Forest group at the University of Wisconsin have developed a technique to stir unmagnetized plasma in the lab. For her work on this project, Collins won the 2015 Marshall N. Rosenbluth Outstanding Doctoral Thesis Award.

This technique is based on using **J×B** torques at the edge of the device to stir unmagnetized plasma [2]. A magnetic field is supplied by azimuthal rings of permanent magnets of alternating polarity,

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International News

Supporting Physics Education in Ethiopia

By Abebe Kebede

How can we expand the reach of physics in Africa? I was motivated to share my opinion on this and the thoughts that came to me during the sessions organized by the APS Forum on International Physics at the 2018 APS March Meeting. Let me begin by asking you, the reader, to look again at any of the photos that you took at this meeting during an invited talk or a coffee break.

In your photos, and your memories from the meeting, you will see that there will be lots of international attendees, but almost no Africans. International participants were mostly Chinese, Indians, and Europeans. This is because of a concerted effort by graduate school recruiters to attract and to enroll students from China, India, and Europe. Think about it: a continent of over a billion people that has little representation in major physics meetings. School recruiters probably share a common misconception that there is not much physics going on in Africa. In general the wider mass media has done a good job in marketing Africa as a continent of war, poverty and suffering. A graduate recruiter will have a "better" chance getting the best and most prepared students elsewhere. In my view this attitude and misconception may deny U.S. institutions access to the best and brightest.

Contrary to general belief, African physics is a thriving enterprise, maintaining strong collaborations with European institutions such as the International Center for Theoretical Physics (ICTP) in Trieste, Italy, and the International Programme in Physical Sciences (IPPS) in Sweden. There are also smaller but pointed collaborations and initiatives, mostly led by individuals and interest groups that trace their origin back to the continent. These activities include QuarkNet in Physics Education, the African School of Fundamental Physics and its Applications, the African School of Physics, and many more. Within the continent strong research and education groups are emerging; the list includes the African Institute of Mathematical Sciences, the next Einstein Initiative, the Africa Laser Center, and strong advocates for a Synchrotron Light Source for Africa. In terms of organizations there are growing national physical societies and the African Mathematical Union, the African Union of Pure and Applied Chemistry, and the African Materials Research Society. In terms of publications I am aware of the *African Review of Physics* (ICTP), the *South African Journal of Physics*, and similar national journals.

My observation here is a bird's-eye view of physics in Africa. An introductory geography lesson teaches us that Africa is not a country, but rather a huge continent with over 50 countries, and each country has its own physics program. In the near future, with the help of the APS and its partners around the world, as well as the African physics community, it will be possible to learn the full extent and reach of physics in the continent. Despite the dynamic physics activities and the potential growth of the field in the continent, there are huge problems at the departmental and school level that limit the growth of the field.

NCA&T students showing off their completed RadioJove circuit boards, used to monitor ionospheric disturbances. A similar project was carried out at the Gondar School of Science and Technology in Ethiopia.

I have traveled to many countries, including Benin (2001), South Africa (2000, 2005), Nigeria (2008), Zambia (2009), and Ethiopia (2002-2018). In these countries, with the exception of South Africa, the universities and the schools I visited have a lot in common, including lack of resources and isolation. International organizations are connecting with African-based interest groups to achieve some organizational goals. Unfortunately these groups are not necessarily working to address the central problems that limit the participation of aspiring young African physicists and students. These are hard problems that require organizations and prominent individuals to make a case with decision makers.

This brings me back to Ethiopia, where I am attempting to change the situation of physics in very small ways. Perhaps the greater APS community can use activities like mine as a resource (see the website sirius-b.ncat.edu). Educational resources such as books and computers can easily be made available to schools and universities in Ethiopia by marshalling concerned communities and using already established memoranda of understanding between U.S. and Ethiopian universities. It should be noted that merely providing educational resources is not enough. We have to be involved in shaping the physics programs at all levels. We also must add value to develop the work space for U.S. students and academics by providing seamless logistics to conduct research and educational activities in Ethiopia.

Starting in about 2001 we began online campaigns to organize the Ethiopian Scientific and Academic Network (ESAN) with the intention that they become active participants in supporting the education programs in Ethiopia. At this time the online networks provide services to thousands of students, staff members, and university administrators. Out of this came the general thinking that "Ethiopia is Where Ethiopians Are." Ethiopians began supporting the education enterprise in Ethiopia in all subject areas. Within ESAN is the Physics in Ethiopia community, with a specific goal to provide support to physics students, academics, and physics departments. In addition to providing educational resources, members of the ESAN community participated directly in organizing high-end workshops in space weather, high-performance computing, astronomy, and material physics. The Ethiopian Physical Society in North America provides scholarships and awards to students and faculty for their outstanding work.

Some of our notable activities include the establishment of a temporal school called the Gondar School of Science and Technology that ran from 2010-2014. The school has focused on advances in space exploration and astrophysics. It became a platform for international collaboration in these fields. Most of the cost of the school was covered by the University of Gondar. The conveners were supported by their own institutions. The program was extended to local universities. It had empowerment and women-in-physics programs and information sessions on graduate and career opportunities. The school provided advanced courses and hands-on training in the use of Radiojove, which are sudden ionospheric disturbance monitors, and remotely controlled telescopes around the world. It also had a huge outreach component where local high schools and colleges participate in unique hands-on projects.

What is unique about Ethiopia is that in some of the universities the majority of undergraduate students in physics are women. For example, at the University of Gondar at this time there are 200 physics majors and 185 of them are women. Many

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in experiments exploring alternatives—mean the WIMP hypothesis has fallen by the wayside?

Not exactly: "What's really going on is a diversification of ideas," says Dan Hooper, a senior scientist at Fermi National Accelerator Laboratory. "WIMPs aren't going away as an idea; people are still very interested in them. But I think we're much more open minded now to a greater diversity of theories."

The secret could be that dark matter particles are much less massive than the hypothesized WIMP range, making it difficult for many detectors to catch their more subtle interactions. "Light" dark matter could help explain why traditional WIMP experiments have failed to capture their prey, but it has also opened up the field of dark matter research to a host of novel experiments.

One dark matter alternative that's been generating excitement recently is the axion—theoretically much lighter than a WIMP, and something that wouldn't be detected in the particle-scattering type experiments typical for direct dark matter detection. "In contrast to WIMPs, axions are very light," says Daniel Bowring, a scientist on the Axion Dark Matter Experiment (ADMX). "People talk about WIMPs having masses between 10 and 1000 GeV—for the axion, we're looking for masses all the way down to μeV."

While axions aren't a new concept, they've gained some traction, partially thanks to recent ADMX improvements that might finally make it possible to spot the tiny particles.

Is it a particle or not a particle?

Despite dark matter's uncertain character, many experts agree it's definitely out there. "The overwhelming majority of cosmologists, particle physicists, and astrophysicists agree that dark matter almost certainly exists," says Hooper. "We see evidence for it virtually everywhere we look in the universe."

Since dark matter makes itself known through its gravitational effects, some theorists propose that what we call dark matter isn't a new form of matter at all, but gravity behaving in a modified way. "I think the evidence is quite strong for the particle hypothesis [rather than] some kind of modified theory of gravity," says Cooley. "But [we shouldn't] shut down research into alternate ideas—it could be that we're not right. But I would place most of my money on it being a particle."

The argument for dark matter being a particle and not the result of modified gravity is that this unknown particle could answer other questions about physics: Both the traditional WIMP model and axion models help explain other mysteries of the universe.

For instance, there is the so-called "WIMP miracle." Says Hooper, "We have this idea that whatever dark matter is, it was made in the Big Bang and it was maybe in equilibrium with all the normal kinds of matter that existed. Eventually, it froze out and stopped interacting with normal matter. [So] if there were a particle that had an interaction kind of like the weak nuclear force and had a certain mass, then you could do these calculations and you would find about the right amount of dark matter emerging from the universe."

But the axion, despite having a much different mass than WIMPs, also fits into other physics puzzles. "The reason that people are so interested in axions is that they solve more problems than just dark matter … they solve curiosities of the Standard Model," says Bowring. "In fact, the axion was named after a cleaning detergent because it 'cleans up the Standard Model.'" Axions fit into a model of spontaneous symmetry breaking that helps explain CP violation—a phenomenon that may be behind our universe being more matter than anti-matter.

It's also entirely possible that it's not just WIMPs or axions or some other dark matter candidate, but a whole host of particles swirling around the universe. "We're writing more papers about what we call hidden sectors where there's not just one kind of dark matter particle but a whole bunch of different kinds of particles," says Hooper. "They may be related or interact with each other, but they don't really interact much with other forms of matter. They're interesting and in the reasonable range of possibilities."

Complementing rather than competing

Finally seeing one of these particles will answer questions about what dark matter is made of. "These dark matter particles are streaming through Earth at all times; they're all around us," says Cooley. "We're trying to capture one of them interacting in one of our detectors here on earth."

According to Cooley, the United States has put its biggest investments in dark matter research into three different—but complementary—technologies: liquid xenon time projection chambers and Super CDMS technology for WIMPs, and ADMX for axions. "Between these three technologies we really cover a broad spectrum of ideas," says Cooley. "The U.S. also puts in a modest amount of money into smaller projects… novel technologies that are pushing the boundaries that will perhaps be used to explore dark matter in the future."

Liquid xenon detectors, like the Xenon1T experiment at the Italian Gran Sasso National Laboratories, are cylinders full of ultracold xenon, positioned to catch a wayward dark matter particle interacting inside the detector. In theory, should a WIMP—or another sufficiently massive dark matter particle—pass through the detector, it will produce tiny but measurable bursts of light.

The technology behind Super CDMS (cryogenic dark matter search), has been around for a few decades, but a new and improved version is currently being deployed at Snolab in Canada. "The technology is built upon these germanium and silicon crystals at very cold temperatures—the crystal lattice is very, very still and we wait for dark matter interactions to come in," says Cooley. These in turn cause vibrations in the crystals. This technology results in high sensitivity and good resolution, which means it can look for more than just WIMPs: "This is giving us the ability in future generation experiments to look at very light dark matter particles," says Cooley.

Since ADMX focuses on tiny axions rather than WIMPs, it relies on a different method of looking for dark matter particles. "The axion should couple very weakly to electromagnetism, which means in the presence of very strong magnetic fields the axion converts to photons—and the frequency of those photons is set by the axion mass," says Bowring. "Since we don't know the axion mass, we don't know the frequency of the photons beforehand—it's like we have a radio that we're tuning to pick up a very faint radio station." Recently, ADMX announced it had reached the sensitivity necessary to discover these faint frequencies—it's just a matter of finding them.

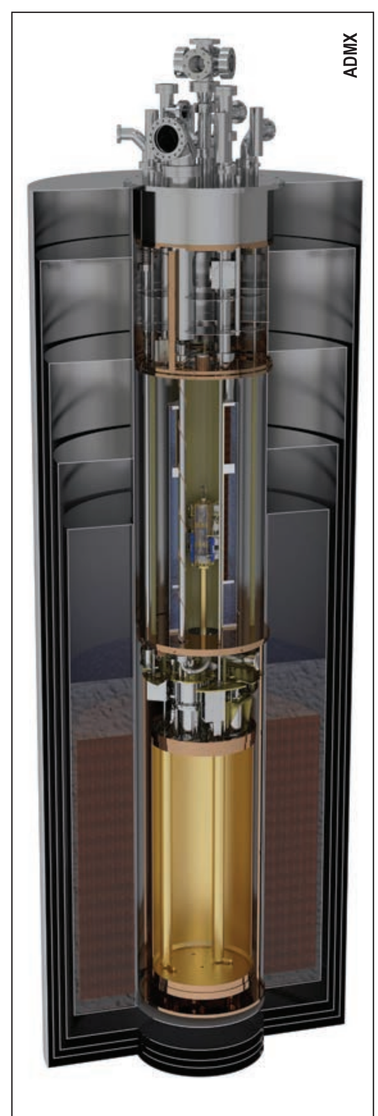
More of a trickle than a bang

When one of these detectors—or one of many other approaches to direct dark matter detection—finally catches a glimpse of dark matter, it won't be met with immediate fanfare. "Just one observation isn't going to send everyone home thinking we've done it—there's usually a period where people are skeptical and have many different interpretations and opinions," says Hooper. "Only as different measurements come together will a real answer begin to emerge from the data … more of a trickle than a bang."

To really say whether dark matter has finally been unmasked will take signals from multiple detectors to confirm it's not a fluke. The discovery of the Higgs boson was quickly confirmed, since both ATLAS and CMS—the two large detectors at the Large Hadron Collider at CERN—saw the same thing. One experiment at Gran Sasso called DAMA/LIBRA claimed a detection, but it hasn't been reproduced elsewhere.

So far, most people agree we haven't found dark matter yet, but it's a good time to look. "Right now is an exciting time, because everybody is thinking about where we should go next with new frontiers opening up," says Cooley.

She says that keeping up the rate of progress in dark matter detection requires investment, both in established detector technologies and bright new ideas. "It's like an investment portfolio: there's a main amount of money to put into what you're doing now," she says, "but you can't neglect what comes next."



The ADMX detector looks for light dark matter particles called axions.

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tions that have no obvious short-term implications for the classroom.

As with any other subfield of physics, cumulative progress depends on a knowledge base of trustworthy results—traditionally provided by an archival journal. Around the time of the 1999 Statement, PER was in a situation in which rapid growth was outstripping the ability of other journals, such as the *American Journal of Physics*, to support the field.

It was within this context that founding editor Bob Beichner, working with the APS Forum on Education and the American Association of Physics Teachers, conceived of *Physical Review Physics Education Research* (PRPER). The journal began publication in 2005. The initial Editorial Board was chaired by Nobel laureate Carl Wieman and included five other well-respected researchers. Board members continue to be among the leading international figures in PER.

PRPER has and continues to accept articles that cover the full range of research related to the teaching and/or learning of physics. The journal has grown substantially along with the field of PER. In 2006, its first full year, the journal published 14 articles, compared with 75 articles published in 2017. The journal has also grown from a largely U.S.-centric journal to a truly international journal; currently, about 45% of articles received are from non-U.S. authors.

In addition to supporting knowledge development within the field of PER, PRPER seeks to be a resource for physics teachers, and so PRPER is distributed online with free open access. This was an important feature of the journal from the very beginning since the founders felt that knowledge about the learning and teaching of physics should be freely available to a worldwide audience. Once a paper is accepted after thorough peer review, authors with financial need may request a full or partial waiver of the article-processing charges. There is a complete separation between funding and editorial functions; at no time do the editors know which authors have requested or been granted waivers.

Although published by PER researchers for PER researchers, most articles are not overly technical, and thus the journal can be a useful resource for non-PER physics instructors who want guidance about a teaching/learning issue. There have been many important findings published in the journal.

For someone new to the journal, a useful way to learn about a particular area of PER is to look at our focused collections. These are collections of new research articles on a particular theme. There are currently four published collections and two more underway.

After focusing primarily on introductory level physics for decades, PER now has much to say about upper-level physics as well. For example, the 2015 focused collection on *PER in Upper-Division Physics Courses* [2] contains 19 research articles related to specific upper-division courses, such as quantum mechanics, as well as to topics that cut across multiple upper-division courses, such as students' abilities to apply mathematics in physics.

Most recently, PRPER featured a focused collection published in June 2018 highlighting the current state of the field of physics education research as it relates to astronomy education research.

Editors' suggestions are another journal feature. These are designed to help readers identify high-quality innovative articles. Suggestions are based on referee recommendations, with the final decision made by the editors. For example, a recently selected article that focused on graduate admissions procedures argues that emphasizing innate talent over other factors may be limiting the diversity of admitted students [3].

The field of PER has grown dramatically in the 13 years since the first issue of PRPER was published. There has been a huge expansion in the number of PER researchers, as well as the topics studied within PER. Strong physics education is essential for a strong physics community. We are delighted that PRPER is the central home for research-based knowledge related to physics education.

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3. Scherr, R. E., Plisch, M., Gray, K. E., Potvin, G., & Hodapp, T. (2017). Fixed and growth mindsets in physics graduate admissions. *Physical Review Physics Education Research*, 13(2), 020133.

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forming a cusp magnetic geometry. Interspersed between the magnet poles are alternating anodes and hot cathodes to draw current. The resulting localized $\mathbf{J}\times\mathbf{B}$ force generates a torque on the plasma near the wall.

These ideas have been applied to a device called the Big Red Ball (BRB) at the University of Wisconsin-Madison, which is newly funded by the U.S. Department of Energy as a national user facility. The BRB is a flexible, 3 meters in diameter spherical plasma machine capable of generating arbitrary flow patterns. Some experiments proposed on BRB include driving a large-scale dynamo and studying collisionless magnetic reconnection.

Magnetothermodynamics

Little is known about what happens in astrophysics when hot, magnetized plasma is compressed and expanded. The equation of state (EOS) of an ideal gas relates pressure, volume, and temperature of the gas, but charged particles in plasma need not obey an ideal gas EOS, particularly if there is a strong magnetic field. Motion of charged particles parallel and perpendicular to the background magnetic field need not be coupled. Indeed, magnetized plasmas are often described with two different temperatures, $T_\parallel$ and $T_\perp$. To complicate matters, there are adiabatic invariants, one associated with $T_\parallel$ and the other with $T_\perp$ (the magnetic moment), that are separately conserved. For astrophysical events such as the solar wind, the EOS is unknown, if one exists at all.

My plasma physics group recently published a paper detailing the study of thermodynamics of compressed magnetized plasmas, referred to by the authors as magnetothermodynamics [3]. The paper reports experiments in which a parcel of magnetized, fully relaxed, non-axisymmetric plasma is generated in the lab and compressed against a conducting cylinder that is closed at one end. The plasma parameters such as temperature, density, magnetic field, and volume are measured during compression, and a PV diagram is constructed to identify instances of associated ion heating during these compression events. The MHD ideal-gas-like EOS is inconsistent with their observations, but an EOS related to the adiabatic invariants is consistent.

New things are in store for GPAP: leadership has recently turned over, and in the coming months, we will resurrect the group's newsletter. Stay tuned for announcements regarding student travel grants—we offer five $500 grants. We encourage any APS member interested in plasma astrophysics to join GPAP by visiting aps.org/membership/units/joinunit.cfm. For more on GPAP go to aps.org/units/gpap/

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universities in Ethiopia are coming online and beginning to reveal their programs to the world. For the sake of the inquiring reader, I visited websites of three physics departments (Addis Ababa, Bahir Dar, and Haramaya) where one can see the type of research and the people in the research. One can also see the absence of women in the faculty in relation to the high number of female physics majors in some of the campuses.

Through our ESAN online community we plan to facilitate collaboration between the U.S. and its Ethiopian counterparts in several areas, including graduate recruitment, faculty development, and creation of the working space for short-term visits by U.S. physics students and academics. In addition we are conducting an international campaign seeking support to ship thousands of books and computers to schools and universities in Ethiopia. The APS community may take this opportunity to participate in donating high-quality books, computers, and funding to cover the shipping cost. Thanks to efforts of volunteers, collaborators, and donors, we were able to ship so far sixty-four thousand books, some used computers, and soccer balls to several schools in Asela Arsi, Adama University and University of Gondar. The collaborators include Books for Africa, Wake Forest University School of Public Health, Society of Physics Students at North Carolina Agricultural and Technical State University, former Peace Corps Volunteers to Ethiopia, the Asela Arsi School Development Network (AASDO) and ESAN.

The need for books, computers, educational supplies, and libraries is huge. This collaboration, particularly with AASDO and ESAN groups, will have great results. The books are managed and shipped by a U.S.-based NGO, Books for Africa. Further information can be obtained from Dr. Abebe Kebede. Email: Abkebede@gmail.com.

Additional Reading

1. Ethiopian Scientific and Academic Network (sirius-b.ncat.edu/esan/)
2. African Scientific and Academic Network (sirius-b.ncat.edu/esan/)
3. APS Physics in Africa Session 2003 (sirius-c.ncat.edu/asn/aps-africa/index.html)
4. Physics in Africa Survey (saip.org.za/index.php/physics-in-africa-survey)
5. Physics Departments in Africa (de.physnet.net/PhysNet/africa.html)
6. Ethiopian Physical Society (ethiopianphysicalsociety.org/)

The author is Associate Professor of Physics at North Carolina Agricultural and Technical State University, USA. He completed his Ph.D. work at Temple University. His academic work includes electronic and magnetic properties of transition metal oxides, heavy fermion systems, and Kondo insulators. Recently he has made significant contribution to space-science education and research at his school and throughout Africa. He is the editor in chief of a new journal, the African Journal of Physics. *He is also the founder and coordinator of several scientific and academic groups including, the Ethiopian Physical Society, the Ethiopian Space Science Network, The African Scientific and Academic Network, the Ethiopian Scientific and Academic Network. Abebe is a life member of APS, a Fulbright Specialist, APS Journal Reviewer, APS Minority Speaker, and organizer of Physics in Africa sessions at the 2003 and 2009 APS March meetings and at the 2002 National Society of Black Physicists Conference. He can be contacted at Abkebede@gmail.com, or visit his website at sirius-b.ncat.edu*

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dized Stafford loans to help fund my education. Under the current Higher Education Act, my loan has not accrued any interest, and as a graduate student I am not required to make any payments until I finish my degree. These provisions make a graduate education possible, as it allows thousands of students each year to begin an advanced degree program without having to simultaneously pay off large loans from their undergraduate degree."

He added, "However, if the PROSPER Act were to become law, graduate students would face new stringent income-based repayment plans and loan interest would begin accruing immediately. Yearly and lifetime borrowing caps would also be put in place, which would leave many students unable to find adequate funding to continue their degrees. These changes will drastically decrease access to higher education for millions of students, and especially to advanced-degree programs like my own. To remedy this problem, I urge our U.S. senator, Patty Murray, to work with her colleagues to prevent this legislation from becoming law. As the ranking member of the Health, Education, Labor and Pensions Committee in the Senate, she will play an integral role in the bill's fate."

"APS OGA is delighted about the number signatures on the petition," said Greg Mack, manager of grassroots advocacy.

"The fact that so many people signed the petition speaks to the understanding of the negative impact of this bill and what it would mean for future STEM students and their careers," added Mack. "We hope that members of Congress listen to their voices, and act accordingly, by working with their colleagues on legislation that does not increase the financial burdens of graduate education."

If the PROSPER Act were to become law, it would eliminate loans that make graduate school accessible for many students, according to the petition against the bill.

"It would be a step toward restricting graduate school to only those students who are wealthy enough to afford it on their own," said Francis Slakey, APS chief government affairs officer.

"That's unacceptable—Congress should never tell students that they are too poor to achieve their dreams," he said.

The author is APS Press Secretary.

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sular officials to shorten the duration of visas granted to Chinese students who study certain "sensitive" subjects, which reportedly include aviation, robotics, and advanced manufacturing.

Congress, meanwhile, is focusing on Chinese talent recruitment programs that offer high salaries and research funding to entice Chinese expatriates and non-Chinese researchers to work in China. The largest of these programs, the Thousand Talents Program, has supported more than 7,000 scientists from around the world over its ten-year history. However, the FBI has warned such programs also serve as conduits for economic espionage.

A provision in the House of Representatives version of an annual defense policy bill would allow DOD to deny funding to research groups that include individuals who have participated in a recruitment program operated by China, Iran, North Korea, or Russia. The measure has bipartisan support, but there is pressure to modify it to avoid unintended consequences for researchers and universities.

Some lawmakers and scientific community leaders are more broadly worried that efforts to stem the flow of knowledge and talent to China could curb productive scientific relations and discourage Chinese students from studying in the U.S. There are also fears it could lead to discrimination and false accusations against Chinese and Chinese American students and researchers.

Responding to Congress and the administration's focus on Chinese espionage, Rep. Judy Chu (D-CA), who chairs the Congressional Asian Pacific American Caucus, recently warned that "It is dangerous to categorize an entire country of people as a threat to our national security," and urged ending "overly broad and xenophobic attempts to build a case that Chinese students and employees should be viewed with more suspicion than others."

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Quantum Mechanics as a Stimulus for American Theoretical Physics

By Shaun Datta

Note: This article is adapted from an essay selected as a runner-up in the APS Forum on the History of Physics Essay Contest. The full essay is available at aps.org/units/fhp/essay/

"In 1920-1925, there were very few people [in the United States] who understood the theoretical quantum physics of the time … and then things changed very suddenly. [During the late 1920s] America came of age in physics, for although we did not start the orgy of quantum mechanics, our young theorists joined in promptly." – John van Vleck [1]

The heroes of seminal quantum theory were almost exclusively European. Munich, Göttingen, and Copenhagen dominated the early developments of quantum mechanics, most notably the Bohr model of hydrogen, matrix mechanics, and the Heisenberg uncertainty principle. Quite simply, "The principal language of quantum mechanics was German" [2]. While Europe dominated quantum theory, pragmatic American universities like Caltech excelled in experimental physics [3]. In the late 1920s, however, the growing American appetite and capacity for theory heralded a shift in the quantum center of gravity.

Before the 1920s, U.S. institutions were not structured to appreciate or accommodate basic theoretical physics research. The national ethos was to focus on matters of practical utility, placing "a relatively low value on work that was not immediately useful or profitable" [1]. This perhaps explains why pragmatically minded American experimentalists were "world-renowned," their "experimental competence and achievements rank[ing] high by any standards" [1]. Top American universities such as Caltech and the University of Chicago boasted adept laboratory physicists, having collectively housed three Nobel prizewinners in a span of just over two decades [4]. In contrast, nurturing theorists of a similar caliber faced logistical obstacles, among them a lack of funding, geographic isolation from European hubs of quantum theory, and professors who garnered respect as teachers but not research scientists. [1] John Slater at Harvard and Frank Hoyt at the University of Chicago bemoaned that their academic seclusion from Europe was a handicap; unlike Germans and Danes, Americans "normally had to wait at least one additional month until they could read the articles in German physics journals" [1]. While this would not typically be a prohibitive delay, nascent quantum mechanics developed at a breakneck pace, and European theorists' month-long head start was difficult to overcome.

Despite these shortcomings, the promise of developing the new quantum mechanics motivated a wave of young American physicists to pursue theory, perhaps because "So many of the main contributors" whose work Americans emulated "were still in their twenties" [2]. Additionally, reputation was at stake: The advent of new quantum theory made it apparent to some Americans that "Their university departments would have to develop strong theoretical components, especially in quantum theory, if the experimental sections were to retain their vitality" [1].

The surge of interest in quantum theory among American physicists prompted new research funding that enabled institutional changes, such as postdoctoral fellowships and the creation of research centers like the Institute for Advanced Study that could attract a critical mass of theorists together to collaborate. Importantly, the camaraderie World War I had built between moneyed "philanthropic, industrial, and government officials" and academics who had been consultants on wartime technologies harnessed a sense of trust that "projects without immediate practical applications" could nonetheless be worthwhile [1]. The Rockefeller and Guggenheim Foundations gave funds for prestigious fellowships that gave newly minted, competitively selected American physicists the opportunity to tackle open research problems immediately upon earning their degrees [1]. At Princeton, philanthropists Louis and Caroline Bamberger endowed the Institute for Advanced Study with a $5 million gift, creating an institution whose pursuit of knowledge had "no view to its immediate utility" [5].

On account of these funds and the departure from the strictly practical culture of pre-1920s experimental physics, American theoretical physics became a viable career for the first time. Physicists made effective use of this new funding

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by traveling between the U.S. and the centers of quantum theory in Europe. Wickliffe Rose of Rockefeller's General Education Board established a research exchange between American and European scientists, typically experimentalists, so that each could learn from the other's comparative advantage: theory in Europe, and "superior American equipment" in the U.S. [1]. Funded exchanges facilitated academic cross-pollination that alleviated some of the chronic "isolation felt by almost every quantum theorist in America until the late 1920s" [1].

For those who did not leave the U.S., the free flow of researchers also helped maintain excitement about the development of quantum theory. Some Americans did not even need to travel abroad to discuss the day's physics headlines, as Robert Millikan "soon arranged to have at least one leading European theorist visit Caltech every year to lecture and to participate in research" [1]. Pioneers of quantum theory visited the Pasadena campus so that Caltech physicists could stay apprised of key developments in atomic theory and radiation. Even Einstein, who by the 1930s was already a celebrity, lectured at Caltech during the winter terms from 1931-1933 [6]. Similarly, on the other coast, Max Born lectured at MIT from 1925-1926 and kept its physicists abreast of the ongoing developments [2]. Werner Heisenberg himself even came to America in 1929 as a missionary for the gospel of the Copenhagen *geist*, though he did not sway many Americans from their focus on phenomenology [7].

Underpinning the modernization of American theoretical physics research were scholar-politicians, reputable intellectuals who brought foreign research talent to the American academic job market and created a comprehensive quantum mechanics curriculum. In doing so, they restructured American universities to foster discoveries in quantum theory. The famed European physicists who lectured at Caltech "were drawn to Pasadena by Millikan's fame, charm, and persistence," and were further incentivized by substantial compensation from external donors [1]. Each leading American institution had its champion for the development of competitive theory departments: John Tate at the University of Minnesota, Arthur Compton at the University of Chicago, Harrison Randall at the University of Michigan, and so on [1].

Thanks to the new outpouring of American research funds, scholar-administrators could afford to reel in "big fish" from Europe. These administrators, adept scientists in their own right, "obtained permanent positions at their universities for over a dozen of the most accomplished European theorists" [1]. Some academic leaders exploited the free flow of physicists between Europe and the U.S. by attracting and facilitating emigration to the U.S. by Jewish physicists and others marginalized in Europe by "static academic hierarchies" and Jewish faculty quotas [1]. These foreign physicists were often compelled to leave their home countries to avoid persecution, although it should be noted that the U.S. did not entirely welcome Jews and other minorities either, enacting immigration quotas targeted especially at Jews and East Asians in the Immigration Act of 1924 [8]. Nonetheless, physics department leaders and administrators persistently recruited top foreign talent to their departments.

The influx of stalwart theorists to the U.S. from abroad transformed American universities into venerable powerhouses of quantum theory within the span of a few years. Among the emigrants that improved the standing of American theoretical physics were Samuel Goudsmit and George Uhlenbeck, who came to the University of Michigan. The Dutchmen had famously discovered electron spin, a property that had at first been misunderstood by even Wolfgang Pauli [1]. Princeton also welcomed two Hungarians, Eugene Wigner and John von Neumann. Wigner later won the Nobel Prize in Physics for, *inter alia*, his study of the strong nuclear force and quantum mechanical symmetries, which he carried out shortly after coming to the U.S. [4]. While at Princeton, von Neumann crafted his magnum opus, *Mathematical Foundations of Quantum Mechanics,* widely considered "the most comprehensive mathematical explanation of quantum theory" [1].

Scholar-administrators also created original coursework in quantum mechanics so that their students could graduate with a working knowledge of modern developments, and thus paved the way for comprehensive American theoretical physics training. For physicists such as Slater at MIT, this was "a matter of both personal and national independence" [3]. Slater created MIT Course 8, developing lecture notes on atomic spectra and spin physics. Similar curricular development began as early as 1919, when Harvard's Edward Kemble first taught a course on quantum theory [1]. A decade later, the prominent physicists of the day started to generate new pedagogy in earnest, creating extensive graduate courses on quantum mechanics and shortly thereafter on the early results in quantum field theory. With this curriculum, American-trained physicists were equipped to make original contributions to quantum theory.

Once these American physicists had effectively promulgated quantum mechanics to a generation of young scientists such as William Shockley of Bell Labs and Robert Bacher of the Manhattan Project, they in turn developed new techniques and applications of quantum theory, as in the case of Slater's influential work in quantum chemistry [3]. Unlike some European counterparts, Americans largely retained their "pragmatic-positivist philosophy," perhaps because it aligned with American sensibilities derived from a tradition of observable, experimental physics [7]. These American theorists thus not only sowed the seeds of theoretical physics institutions in the U.S., but also contributed volumes to the later development of quantum theory, as in the case of quantum electrodynamics by Richard Feynman and Julian Schwinger. American theoretical physics was born out of the quantum revolution that began in Europe, but has now lived and thrived in the United States for almost a century.

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