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APS NEWS

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HONORS

2019 Nobel Prize in Physics

BY LEAH POFFENBERGER

The Royal Swedish Academy of Sciences has announced the winners of the 2019 Nobel Prize in Physics, recognizing both theoretical and experimental contributions to understanding the universe. This year, the prize is awarded to APS Fellow James Peebles (Princeton University), Michel Mayor (University of Geneva), and Didier Queloz (University of Geneva; University of Cambridge).

Half of the prize is awarded to Peebles for his theoretical insights into physical cosmology that have impacted the trajectory of cosmology research for the past 50 years and form the basis of the current ideas about the universe. The other half of the prize is awarded jointly to Mayor and Queloz for the first discovery of an exoplanet orbiting a solar-type star in the Milky Way in 1995.

"APS and I are delighted that our colleague James Peebles has been awarded the 2019 Nobel Prize in Physics," said APS President and Nobel Laureate David Gross. "Jim is among the fathers of physical cosmology that laid the foundation for the now remarkably successful standard theory of the structure and history of the universe. His many contributions developed the observational consequences of Big Bang theory, calculated the distribution of elements in the universe, and developed the tools that enabled the observation of the cosmic microwave background radiation to test Big Bang theory and measure the properties of the universe."

New physics laureates (L-R): Didier Queloz, Michel Mayor, James Peebles
IMAGE: NOBEL FOUNDATION

Peebles receives the Nobel Prize for his decoding of the cosmic microwave background, left behind by the Big Bang, which provides insight into the infancy of the universe. He laid the theoretical framework, beginning in the mid-1960s, that led to our current understanding of the shape of the universe and its curious makeup

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OUTREACH

Evaluating a Decade of PhysicsQuest

BY LEAH POFFENBERGER

For the past 10 years, middle school classrooms all across the country have had a chance to learn physics with hands-on demos thanks to the APS PhysicsQuest program. PhysicsQuest distributes kits packed with experiment demos, comic books, and a teacher's guide in hopes of inspiring students to be more interested in physics. In the 2018–2019 school year alone, PhysicsQuest reached nearly 184,000 students taught by more than 5,000 teachers.

This year, APS commissioned an evaluation report of the PhysicsQuest program to assess its impact and usefulness to teachers. And the results are clear: Teachers enjoy using PhysicsQuest kits and believe they positively impact their students.

"I think it's a good idea to evaluate successful programs once in a while, and 10 years in to PhysicsQuest seemed like good timing," says James Roche, Outreach Programs Manager at APS. "We were interested in figuring out exactly how teachers used the kits in their classrooms in order to tailor our work toward their goals."

This year's PhysicsQuest kits focus on the achievements of physicist Chien-Shiung Wu.

A sampling of PhysicsQuest users (376 teachers and 351

PHYSICSQUEST CONTINUED ON PAGE 6

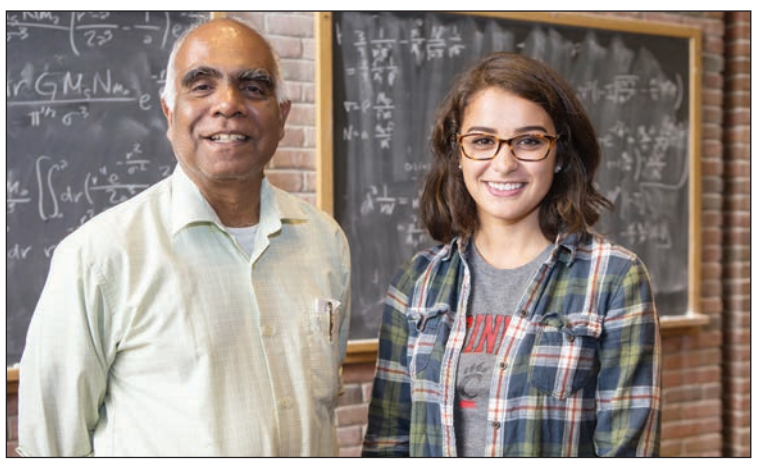
EDUCATION

Students and Mentors in the National Mentoring Community

BY LEAH POFFENBERGER

Pursing a bachelor's degree in physics should be a possibility for all college students, but some groups of students feel more welcome in other fields. According to research conducted by APS, underrepresented ethnic and racial minorities in physics—which includes African Americans, Hispanic Americans, American Indian/Alaska Natives, and Native Hawaiians—are awarded less than 14 percent of physics bachelor's degrees despite making up nearly a quarter of all bachelor's degrees awarded.

In order to improve this situation, APS created the National Mentoring Community (NMC) to match students with local physics mentors. One of these mentor-mentee pairs from the University of Cincinnati, Rohana Wijewardhana and then-undergraduate student Madelyn Leembruggen, shared their experiences in a testimonial following an NMC conference.



Mentor Rohana Wijewardhana (L) worked with Madelyn Leembruggen (R) at the University of Cincinnati as part of the APS National Mentoring Community.

Before joining the NMC, Leembruggen had found herself at a crossroads: follow a life-long goal of doing scientific research or pursue something entirely different. She had begun training in astrophysics, but quickly came to the realization that it wasn't her passion and began to consider another path.

"I thought maybe I would enjoy theoretical physics, but I could not name a single theoretical physicist who was a woman or from an underrepresented background, and I couldn't see myself fitting in with the theorists whose names I did know," said Leembruggen. "At this point I had also convinced myself I did not have the drive or skills to make it through graduate school and began to plan for a career path which seemed, to me, easier."

Fortunately, Richard Grass, the undergraduate director of the University of Cincinnati Physics Department, pointed Leembruggen in the direction of the NMC, where Wijewardhana was in search of a mentee. Wijewardhana had newly joined the NMC after attending the 2015 APS Bridge and NMC Conference and, up until then, had never supervised undergraduate physics students.

"If it were not for my membership in the APS NMC, I would not have started supervising undergraduate research. I had attended

NMC CONTINUED ON PAGE 7

HONORS

2019 Nobel Prize in Chemistry

BY LEAH POFFENBERGER

Two APS members are among the recipients of 2019 Nobel Prize in Chemistry. The Prize is awarded to APS Fellow John B. Goodenough (The University of Texas, Austin), APS Life Member M. Stanley Whittingham (The State University of New York at Binghamton), and Akira Yoshino (Asahi Kasei Corporation; Meijo University) for development of lithium-ion batteries.

Goodenough, Whittingham, and Yoshino will share the prize equally for their separate breakthroughs that contributed to the creation of the rechargeable batteries that power much of today's technology. Lithium-ion batteries also play an important role in the viability of renewable energy use, providing storage for solar and wind power, and powering long-range electric cars. As such, the technology is poised to play an increasing role in mitigating the effects of energy use on climate change.

Whittingham began developing the modern lithium-ion battery during the 1970s oil crisis in a bid to create energy technology free from fossil fuels. He discovered that titanium disulphide made an ideal cathode for a lithium battery. Coupled with the metallic lithium anode, his work resulted in a powerful—although reactive and potentially explosive—battery.

Goodenough, a solid-state physicist, also wanted to contribute to the development of alternative energy storage systems in the 1970s. Building on Whittingham's initial design, Goodenough recognized that a metal oxide could replace titanium disulphide for more powerful, and more stable, batteries. He discovered that cobalt dioxide was the ideal cathode resulting in lighter-weight, high-capacity batteries.

Yoshino made the final breakthrough that resulted in the first commercially viable lithium-ion battery in 1985. He replaced the reactive lithium anode with a

CHEMISTRY CONTINUED ON PAGE 3

Chemistry laureates (L-R): John B. Goodenough, M. Stanley Whittingham, Akira Yoshino

Revised 10/29/19

EDUCATION

Communication and Negotiation Skills Seminar for Women

With support from the National Science Foundation, APS has trained women in physics to host professional skills seminars for students and postdocs at APS-sponsored meetings and at universities and institutions. Professional Skills Development Seminars are highly interactive workshops where participants will learn and practice communication and negotiation skills. For more information, please visit go.aps.org/2oF3InD.

Wiki Scientist Course Will Be Available Soon

Give a voice to the voiceless and impact your field by becoming a Wiki Scientist. Wikipedia gets 500 million views a month, but less than 18% of the biographies on the site belong to women. This statistic came to light when Donna Strickland won the Nobel Prize in Physics in 2018, the first woman in 55 years to be awarded this top honor. Unfortunately, at the time of the announcement, Strickland did not have a biography on the Wikipedia site.

APS members can become pioneers in breaking barriers. Make sure that underrepresented groups in science are no longer living in the shadows while fulfilling the broader impact requirements of funding agencies by participating in the Wiki Scientist courses. Wikipedia experts will provide structured training and guidance as participants add marginalized populations in physics to Wikipedia. Wiki Education will facilitate collaborative work among participants, immersing them in the world behind Wikipedia.

Apply for a scholarship to take the course at no cost and become a leader in engaging members of the physics community to edit Wikipedia. Or, if your institution or grant can support you to enhance your skills for public outreach, a payment of $750 can be made to guarantee a spot on a first-come, first-served basis (up to 5 seats available). Stay tuned to APS emails and social media accounts to learn more about becoming part of the group that changes the face of science. For more information about the course content, please visit wikiedu.org.

THIS MONTH IN

Physics History

November 11, 1572: Tycho Brahe Spots a Supernova

Historical records of supernovae stretch as far back as 185 CE, but one of the most significant cosmic explosions in terms of advancing astronomical knowledge occurred in November 1572. Among those who observed the event was Danish astronomer Tycho Brahe—the last famed astronomer to make observations of the night sky without the aid of a telescope.

Brahe was born into the nobility at his family's ancestral seat of Knutstrop Castle in December 1546. When he was only two, Brahe went to live with his childless uncle, Jorgen Thygesen Brahe—the only one of 12 siblings sent away for his upbringing, although Brahe later noted that his aunt and uncle treated him as a son, and Jorgen ultimately made him his heir. He began attending the University of Copenhagen at age 12, initially studying law. But then he witnessed a solar eclipse on August 21, 1560, triggering his lifelong passion for astronomy.

This was a critical period in astronomy, as the Ptolemaic model of the universe—with a fixed Earth placed at the center of the solar system, and the sun, moon, and planets orbiting around it—was being challenged by the Copernican worldview, in which everything orbited the Sun at the center. During a tour of Europe when he was 15, Brahe witnessed a conjunction of Jupiter and Saturn. He noticed that neither the Copernican nor Ptolemaic models accurately predicted the conjunction. He became convinced that more accurate observations would be key to making better predictions about such events.

Tycho was making observations from an observatory he set up at Herrevad Abbey on the night of November 11, 1572, when he spotted a very bright new star in the constellation Cassiopeia. He was not the only one to do so, but it is known as Tycho's Supernova because he undertook the most detailed study of its properties. Many contemporary astronomers who still subscribed to the Ptolemaic view concluded the object must be in the so-called "terrestrial sphere" (i.e., inside the orbit of the moon), since the heavenly firmament should be unchanging.

Brahe begged to differ, dismissing the naysayers in *De Stella*, his treatise on the new star that he published the following year: "Oh thick wits. Oh blind watchers of the sky." For Brahe, the scientific evidence clearly showed this was a distant star. It was certainly much farther away than the moon since there was no daily parallax against what was then believed to be a background of fixed stars. Nor did said object change its position relative to those fixed stars. So it could not be a planet, either.

We now know this object was a supernova (designated SN1574). Radio astronomers first detected the remnant in the 1950s, followed by optical observations. Astronomers discovered another star in 2004, dubbed Tycho G, which is probably the companion star to the white dwarf that ultimately became SN1574. In 2008, a team of scientists analyzed its light-echo spectrum and declared it to be a Type Ia supernova. The supernova also inspired Edgar Allan Poe's poem, "Al Aaraaf," and self-described "forensic astronomer" Donald W. Olson has argued that the same star is mentioned in Shakespeare's *Hamlet* (the "star that's westward from the pole").

Portrait of Tycho Brahe by Jacques de Gheyn Ii.

King Frederick II granted Brahe an estate on the island of Hven, where he built an astronomical research Institute called Uraniborg (named after Urania, the muse of astronomy). His observation of a great comet from November 1577 to January 1578 inspired him to devise his own Tychonic system, combining what he felt were the two conflicting models' respective strengths. He tried to combine the accuracy and geometrical appeal of the Copernican system, and the rich philosophical aesthetics of the Ptolemaic worldview. The moon correctly orbited the Earth in his model, but he still thought the Sun orbited the Earth.

There is no shortage of entertaining anecdotes about Brahe. He famously lost the bridge of his nose in a sword duel while a student at the

BRAHE CONTINUED ON PAGE 3

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BRAHE CONTINUED FROM PAGE 2

University of Rostock in 1566 and wore a prosthetic for the rest of his life. Legend held that the prosthetic was made of silver or gold, but when researchers exhumed his body in 2010 and analyzed the remains, they concluded it was actually made of brass. Contemporary accounts also hold that Brahe kept a tame elk, which purportedly died after falling down the stairs, having drunk great quantities of beer at dinner.

Brahe fell out of favor with the new King Christian IV in his later years. He left his Hven estate in 1597, shortly after completing a star catalogue providing the positions of 1000 stars. He spent the rest of his life in exile, becoming Imperial Court Astronomer in Prague to the King Rudolf II of Bohemia. Johannes Kepler worked closely with Brahe as his assistant during this time, helping him compile a new, more accurate star catalogue: the *Rudolphine Tables*.

Brahe's death was as colorfully bizarre as much of his life. Kepler reported that they were at a banquet in Prague, and Brahe refused to leave the table to relieve himself, deeming it a breach of etiquette. When he got home, he was unable to urinate, and died 11 days later, most likely from a burst bladder. (The suggestion that he was murdered via mercury poisoning was debunked in the same exhumation analysis that confirmed his brass prosthetic nose.) He supposedly wrote his own epitaph during his final days: "He lived like a sage and died like a fool." He is buried near the Astronomical Clock in Prague.

Further Reading:

J. L. E. Dreyer, *Tycho Brahe: A Picture of Scientific Life and Work in the Sixteenth Century* (Cambridge University Press, 2014 [originally published in 1890]).

L. Jonas et al., "Detection of mercury in the 411-year-old beard hairs of the astronomer Tycho Brahe by elemental analysis in electron microscopy," *Ultrasonic Pathology* 36, 312 (2012).

O. Krause et al., "Tycho Brahe's 1572 supernova as a standard type Ia as revealed by its light-echo spectrum," Nature 456, 617 (2008).

D. W. Olson et al. "The stars of Hamlet," *Sky and Telescope* (November 1998).

CHEMISTRY CONTINUED FROM PAGE 1

carbon material called petroleum coke, which could store lithium ions in a stable manner. His work resulted in a safer high-capacity battery that can be charged hundreds of times.

The Nobel Prize, first awarded in 1901, is widely considered the highest honor in science, economics, and literature. The 2019 Nobel Laureates will be awarded medals at a ceremony in December, along with 9 million Swedish krona (just over $US 1 million), which will be shared equally between Goodenough, Whittingham, and Yoshino.

Additional reading

G. Crabtree and J. Misewich, "The Grid: Ready for Renewables?," *APS News* (December 2010).

F. Schlachter, "All-Electric Cars Need Battery Breakthrough," *APS News* (July 2012).

F. Schlachter, "Change is in the Air," APS News (August/September 2017).

MEETINGS

A Look into the Future with Augmented and Virtual Reality

BY LEAH POFFENBERGER

Millions of Americans wear some form of corrective lenses, with many opting for prescription glasses to fix a variety of vision issues. But some researchers are pushing to make glasses do even more: virtual reality and augmented vision was one of the themes of this year's Frontiers in Optics/Laser Science meeting in Washington, DC, hosted jointly by the Optical Society and the APS Division of Laser Science (September 13–17).

An APS member takes a virtual reality headset for a spin.

Over the course of the conference, experts in virtual reality (VR) and augmented reality (AR) explored the challenges and potential of developing these technologies for a variety of practical uses in several sessions. At the opening session for the VR/AR theme, Douglas Lanman (Facebook Reality Labs), Henry Fuchs (University of North Carolina, Chapel Hill), and David Luebke (Nvidia) provided an introduction to the field. At a special event, Thad Starner (Georgia Institute of Technology), one of the longest continuous users of AR, discussed the social implications of AR and VR.

Lanman's talk on state of the art VR systems primarily focused on meeting the optics challenges that arise when the eye interacts with a computational display that is attempting to mimic reality. Since the display is close to the wearer's eyes and flat, the usual adjustments the eye would make to focus on objects at varying distances aren't effective. VR researchers like Lanman are combining optics research with vision science to help the VR display and the eye work together to create a more realistic display.

"The goal with VR is to follow up on all the optics research that [started with] television to modern times and really make something that's indistinguishable from reality," said Lanman.

VR AND HR CONTINUED ON PAGE 7

FEATURE

Science as a Laughing Matter

BY MATTEO RINI

Throwing paper planes at a science teacher wouldn't go over well in most situations. But that's just one of the norms violated by the Ig Nobel awards, which have been celebrating the quirky side of science for nearly three decades. This year's award ceremony, held on September 12 at the Sanders Theatre of Harvard University, was a surreal experience with wacky acceptance speeches, nearly naked postmen, and scientists dressed up as oddly shaped poo. The 1,100 spectators—which included a number of Nobel laureates on stage—relished the chance to have fun with award-winning research on cockroach magnetism, healthy pizza-eating, and automated diaper-changing.

Since 1991, the Ig Nobel Prize has honored scientific achievements that "first make you laugh, and then make you think," selected from thousands of submissions by the editors of the science humor magazine *Annals of Improbable Research* and by an international group of researchers. Most of the awards have gone out to top-notch scientists—like Andrew Geim, who first won an Ig Nobel prize for levitating a frog and then a Nobel prize for discovering the wonder-material graphene. But a few awards have been purely satirical, like the peace prize that went to the Belarus police for arresting a one-armed man for applauding.

To kick off this year's Ig Nobel ceremony, physicist Melissa Franklin—who announced herself as a professor of "something" at Harvard—gave the audience the green light to launch hundreds of paper planes at the stage. As

Strict time-keeping at the Ig Nobels. Eight-year-old Miss Sweetie Pooh prevents Silvano Gallus, the medicine prize winner, from exceeding his allotted time by yelling: "Stop, I am bored." IMAGE: IMPROBABLE RESEARCH

per tradition, a prominent physicist came out and humbly swept the paper mess away with a large broom. This year, Harvard's Mikhail Lukin stepped in for the dearly departed Roy Glauber, who had been the "Keeper of the Broom" for decades before and after earning a physics Nobel for his work on quantum optics.

Once the stage was clear, soccer-like cheering erupted for the first prize announcement. In a big win for Italy, Silvano Gallus of the Mario Negri Institute for Pharmacological Research in Milan was awarded the Ig Nobel in medicine for "collecting evidence that pizza might protect against illness and death, if the pizza is made and eaten in Italy." In a 60-second speech, Gallus explained how, sifting through big data, he found that pizza consumption is correlated with a reduced risk of heart attacks and digestive-tract cancers—but only in his homeland.

The biology prize went to a group of physicists for the discovery that "dead magnetized cockroaches behave differently than live magnetized cockroaches." The difference is due to cockroaches drying up when they die, which makes their interiors more viscous. That viscosity keeps magnetized particles aligned for longer times than in live insects. The team got the idea to test this difference while using an ultrasensitive magnetometer to study animal magnetoreception. The researchers picked cockroaches because they can sense Earth's magnetic field and "because they are, um, quite abundant in our cafeteria," said coauthor Herbert Crepaz of the Nanyang Technological University in Singapore.

Other award winners included an Iranian engineer who patented a diaper-changing machine and a research group that discovered a

IG NOBEL CONTINUED ON PAGE 6

LETTERS

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

Early Example of Multi-messenger Astronomy

The article "This Month in Physics History" (*APS News*, August/September 2019) described the earliest observations of cosmic rays by Theodor Wulf and Victor Hess. The text states that "[Hess] determined that the intensity increased significantly with height, and his radiation measurements during a solar eclipse effectively ruled out the sun as the source of these cosmic rays."

Those observations by Hess may qualify as the first example of multi-messenger astronomy, since they combined visual astronomy (the solar eclipse, and shielding of the Sun by Earth at night) and particle astronomy (using ionization detectors). Even if Hess did not understand the particle-like nature of the "cosmic rays" he was detecting, he still sensed it was some form of "penetrating radiation" and could conclude that some part of it did not come from the Sun but from elsewhere in the cosmos.

Rolf Sinclair
College Park, Maryland

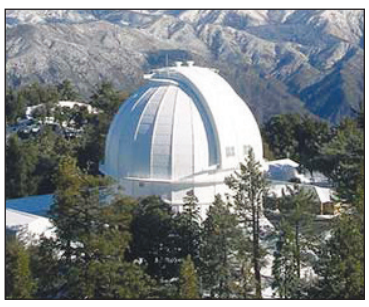
HONORS

2019 APS Historic Sites Selected

Congratulations to our newest historic sites, the Mount Wilson Observatory and the Adler Planetarium!

Mount Wilson Observatory
Los Angeles, CA

At this site, the innovative 100-inch telescope, realized by George Ellery Hale in 1917, empowered astronomers to discover aspects and mysteries of our Cosmos. Edwin Hubble ascertained the distance to Andromeda, proving the existence of galaxies beyond ours. Hubble and Milton Humason amassed evidence that the universe is expanding. Walter Baade identified distinct stellar populations from which to obtain better estimates of the size and age of the universe.



Mount Wilson Observatory

Adler Planetarium, Chicago, IL

Adler SquareAdler Planetarium
Chicago, IL

Since its opening in 1930, the Adler Planetarium has contributed immeasurably to the dissemination of exciting discoveries in astronomy and astrophysics. It is the oldest public planetarium in the Western Hemisphere. The museum houses one of the greatest collections of historic astronomical instruments in the world, spanning nine centuries of human efforts to understand the universe. Millions of visitors have enjoyed vivid sky shows, presentations on space science and interplanetary exploration, hands-on activities, and inspiring educational programs.

GOVERNMENT AFFAIRS

APS Congressional Science Fellows Use Expertise to Impact Policy on Capitol Hill

BY TAWANDA W. JOHNSON

After a year of working on Capitol Hill, the 2018-19 APS Congressional Science Fellows Jennifer Dailey and Abigail Regitsky said they developed an appreciation for the role scientists play in federal decision making and are committed to building on their knowledge of science policy.

"I had been so entrenched in my life in the lab that I didn't even know how science and policy interact. This fellowship was the perfect opportunity to experience how science and scientists are viewed by decision-makers," said Jennifer Dailey, who worked in US Senator Ben Cardin's office. Cardin represents the state of Maryland.

Jennifer Dailey

Abigail Regitsky

Sponsored by APS under the umbrella of the American Association for the Advancement of Science (AAAS) Science & Technology Fellowships, the Congressional Science Fellowships aim to provide a public service by making available individuals with scientific knowledge and skills to members of Congress, few of whom have technical backgrounds. In turn, the program enables scientists to broaden their experience through direct involvement with the policy-making process.

Fellowships are for one year, typically running September through August. Following a two-week orientation in Washington, DC, sponsored by AAAS, incoming fellows become acquainted with their new work environment. After interviews on Capitol Hill, fellows choose a congressional office where they would like to serve.

Just like Dailey, Regitsky was eager to become a Congressional Science Fellow.

"Throughout my educational and career path, I was always motivated by wanting to make the world a more sustainable place. I pursued a PhD because I thought I would work in industry on R&D of sustainable materials. However, as I progressed

FELLOWS CONTINUED ON PAGE 7

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

FYI: SCIENCE POLICY NEWS FROM AIP

New NSF Research Infrastructure Program Issues First Grants

BY MITCH AMBROSE

In September, the National Science Foundation (NSF) announced the first 10 grant awards from a new agency-wide program dedicated to funding "mid-scale" research infrastructure (RI) projects costing between $6 million and $20 million. The awards total $121 million and will support a variety of instrument acquisition and upgrade efforts. NSF received $2.6 billion in project proposals through the first competition and it anticipates issuing awards every other year.

A majority of the first 10 awards will support research in the physical sciences. Among them are a $16 million grant to the University of Michigan that will enable it to boost the peak power of an existing laser to 3 petawatts, which will make the laser the most powerful of its kind in the United States. A $12 million grant to the University of Delaware will support development of a state-of-the-art neutron spectrometer to be installed at the National Institute of Standards and Technology.

Recent reports have urged federal agencies to increase investments in such instrumentation. A National Academies study released in 2017 noted the US now trails other parts of the world in building ultrafast, high-intensity lasers. And an APS study released last year documented that the US hosts fewer instruments for neutron scattering research than facilities in Europe and in the Asia-Pacific region.

Three of the 10 grants will support design studies. One will go to a team at Arizona State University to develop a concept for an x-ray free-electron laser (XFEL) that is far more compact than conventional XFELs, such as the Linac Coherent Light Source at SLAC National Accelerator Laboratory. Another design grant will go to the Event Horizon Telescope team that recently produced the first image of a black hole, supporting their plans for expanding the global telescope network so as to capture "movies" of black holes. The third will advance planning for CMB-S4, a major cosmic microwave background detection experiment.

The new grant program, known as Mid-scale RI-1, is one of two new mechanisms designed to fill a gap between existing agency-wide infrastructure accounts. Toward the end of fiscal year 2020, NSF plans to issue awards from a second program called Mid-scale RI-2 that it is setting up to fund projects costing between $20 million and $70 million. The programs complement NSF's Major Research Instrumentation program, which funds projects at levels up to about $6 million, and its Major Research Equipment and Facilities Construction (MREFC) account, which currently funds projects costing more than $70 million.

Better supporting mid-scale RI is one of the 10 "Big Idea" priority areas that NSF first announced in 2016. NSF created the mid-scale programs after securing support from Congress and the National Science Board, which oversees the agency. In a congressionally mandated report, the board concluded that mid-scale RI is "underrepresented" in NSF's portfolio of facilities investments, which it attributed to "an artifact of budget constraints and the natural limits of what division budgets can sustain."

Through its latest budget request, NSF has proposed using the MREFC account to provide the Mid-scale RI-2 with $45 million for fiscal year 2020. Both the House and Senate have accepted this request in their respective NSF spending bills, with the Senate proposing an extra $30 million.

In justifying the additional resources, the Senate Appropriations Committee wrote that it "commends NSF for its planned investments in mid-scale research infrastructure, including the provision of larger mid-scale instrumentation under the MREFC account after the committee repeatedly directed the foundation to determine how best to support projects of this scale."

The author is Acting Director of FYI.

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MEMBERSHIP UNIT PROFILE

The Topical Group on Data Science

BY ABIGAIL DOVE

The APS Topical Group on Data Science (GDS) is the Society's newest membership unit, minted just six months ago in April 2019. The group is focused on promoting research at the growing interface between physics and data science. This spans big data, machine learning, and artificial intelligence, with relevance to everything from astronomy to high energy physics to materials science.

GDS was founded by current chair Mohammad Soltanieh-ha, a Clinical Assistant Professor at Boston University, with help from chair-elect Jie Ren, a senior scientist at Merck. The idea for GDS was born from perceived shortcomings in the typical data science training that physicists receive.

"We need to educate people about the new data science techniques and tools that are becoming standard in many branches of science," Soltanieh-ha remarked, recalling his own PhD experience in which he educated himself about data science before a stint in the industry. "In physics, data science education is lacking in graduate school curricula and even at the post-doc and faculty level because the techniques are so new."

Echoed Ren, "I work in industry and I see how the trend of data science has impacted everything—from IT to traditional industries like pharma." And yet, "physics is somewhat lagging behind in applications of data science."

While more training in data science is needed in the physics community, Soltanieh-ha and Ren underscored that data science represents a huge opportunity for physicists.

"Data science has roots related to physics in terms of methodology and optimizing large datasets," Ren remarked. "Fundamentally, there's a deep connection, although there is an energy barrier to cross in order to establish formalized data science knowledge in the physics community."

Beyond the relevance of data science to physics research, Soltanieh-ha pointed to the trend of companies in the industry hiring more data scientists.

"Physicists are the perfect match for these positions," he elaborated, drawing on his own experience hiring for data science positions, "they have a good understanding of statistics, solid programming background, and can think critically."

Viewed in this light, a forum like

Mohammad Soltanieh-ha

Jie Ren

GDS is in many ways long overdue. Emphasizing the enthusiasm for a data science-focused platform at APS, Soltanieh-ha recalled that

GDS CONTINUED ON PAGE 6

SCIENCE BOOKS

Here Be Dragons...

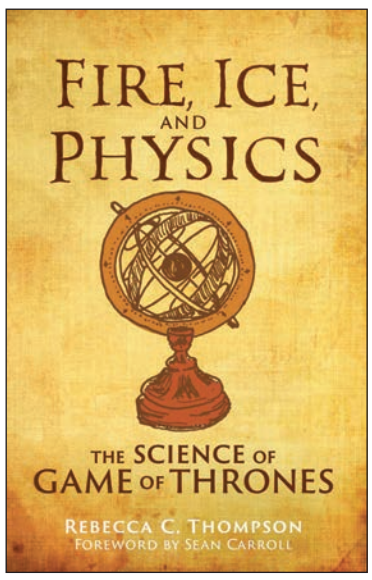
BY DAVID VOSS

Come on, admit it. You've always wanted to understand the neuroscience of zombies, how dragons spit fire, and how long a beheading victim remains conscious. Especially so, perhaps, if you're one of the many fans of the smash hit television series *Game of Thrones*, based on the fantasy books by George R. R. Martin. You now have a reliable guide in *Fire, Ice, and Physics* by physicist Rebecca Thompson, former APS Head of Outreach and now head of Fermilab's Office of Outreach and Public Education.

Taking place on the imaginary continents of Westeros and Essos, *Game of Thrones* features a lot of science fiction, and Thompson deftly escorts the reader chapter by chapter through climate science, the physics of materials, how dragons work ("bats, but with fire!"), and the more gruesome forms of capital punishment. In each case, Thompson contrasts the science of the fictional world with how things work back here in reality.

For example, the story takes place on a planet that is somewhat Earth-like (there are oceans and continents, oxygen, living creatures) but summer lasts ten years and everyone in Westeros is muttering that some dreadful "winter is coming." This is the launchpad for a wonderful discussion of climate science, seasons, elliptical planetary orbits, precession of Earth's axis, and ice ages.

But there is much more, and *Fire, Ice, and Physics* gives an excellent tour through this fantasy world, sorting out what could and couldn't be, and what is based in science.



***Fire, Ice, and Physics* by Rebecca C. Thompson, with foreword by Sean Carroll (MIT Press, Cambridge, MA, 2019).**

OPINION

Discuss Sexual Harassment—But Consider This First

BY LINDA E. STRUBBE, ELECTRA ELEFTHERIADOU, SARAH B. MCKAGAN, ADRIAN M. MADSEN, DIMITRI R. DOUNAS-FRAZER

A recent article by Aycock et al. in the APS journal *Physical Review Physics Education Research* [1, 2] presented survey results revealing that 3/4 of undergraduate women in physics in the US report experiencing sexual harassment. Moreover, gender minorities also experience high rates of harassment [3, 4]. Discussing these issues thoughtfully requires care.

Although the focus of sexual harassment discussions is often on the experiences of straight cis-women, physicists who are gender and sexual minorities (GSM) also experience high rates of sexual harassment. Sexual harassment is often experienced differently by gender minorities, sexual minorities, and straight cis-women. In the APS LGBT Climate Report [4], gender minorities reported the most adverse climate in physics, relative to sexual minorities. The report also found that GSM women experienced exclusionary behavior at three times the rate of GSM men.

Rates of harassment are also particularly high among women of color, for whom harassment may be sexual and racial in nature. In a recent study across racial and gender categories, Clancy et al. [5] found that women of color in astronomy and planetary science experienced the highest rates of negative workplace experiences. Understanding intersectionality (i.e., the experiences of individuals with two or more marginalized identities) is a crucial part of addressing harassment in our field.

Many physics departments and research groups will want to discuss these articles and findings, with the ultimate goal of making our field a positive and harassment-free place. However, when entering these discussions, they need to recognize that most of the women and gender minorities in the department have experienced and may currently be experiencing sexual harassment and bullying, possibly even perpetrated by other participants in those conversations.

For women and gender minorities (and potentially members of other marginalized groups), these conversations are likely to be re-traumatizing and require significant emotional labor; such discussions may well cause them a level of harm. Following a parallel with anti-racism dialogues [6], these discussions may even be unavoidably unsafe for women and gender minorities. For these reasons, discussing the findings of Aycock et al. the way one might discuss a regular paper for journal club or agenda item for a faculty meeting will not work.

Here are a few questions we would encourage organizers of discussions about these papers to reflect on and read more about. Lorimer [7] explains some of these challenges further.

- How will you reduce potential harms women and gender minorities may experience by participating?
- Can you envision an outcome of women and gender minorities participating that would be significant enough that they might choose to open themselves to this potential for harm?
- What role is appropriate for women and gender minorities to play in a discussion? Are there conversations that men should have in men-only environments?
- Is it appropriate to explicitly invite or ask women and gender minorities to participate? What possible power dynamics come into play when people are asked to participate?
- How will the discussion include intersectional experiences of harassment?

We encourage anyone who wants to discuss these issues to start by reading about harassment, oppression, and difficult conversations and to reflect and think critically about what you learn. There are many resources accessible online and in libraries. Experts in anti-sexism and other contexts (e.g., anti-racism [8]) have thought carefully about how to have difficult, potentially re-traumatizing conversations.

Beyond educating yourself, here are a few ideas to help departments start thinking about how to facilitate discussions of sexual harassment.

- Seek out and partner with staff at centers on your campus, such as Women's Resource Centers, Ethnic Student Centers, Gender and Sexuality Centers, or Equity & Inclusion Offices.
- Consider hiring an external facilitator to guide a sequence of discussions over the course of multiple semesters and help with establishing new anti-sexist policies or traditions.
- Think about how you will provide access to mental health professionals during and after a discussion. Ensure there are facilities available for participants if they need to take time out from the main discussion space.
- In advance of a discussion, make sure participants have a good understanding of what they should expect in the discussion, so they can mentally prepare. At the beginning of the discussion, explicitly set ground rules for conversation.
- Consider alternative formats for discussions, such as having groups where men can discuss the article and what they will do about it without asking or expecting women and gender minorities to be present. This is parallel to the idea of caucus groups in anti-racism work [8].
- Familiarize yourself with your institution's policy and procedures around sexual harassment, so you can share that information as part of a discussion.

We close by acknowledging that this is indeed difficult. But being difficult does not mean our community should give up on the greater work our field needs to engage in to create a harassment-free environment for all.

Acknowledgements

We are grateful to Eleanor Sayre

DISCUSS CONTINUED ON PAGE 7

NOBEL PHYSICS CONTINUED FROM PAGE 1

of visible matter, dark matter, and dark energy.

"This year's Nobel Prize recognizes remarkable advances in cosmology and extrasolar planetary science," said APS CEO Kate Kirby. "The pioneering work by Jim Peebles, Michel Mayor, and Didier Queloz has had far-reaching consequences in many areas. We are especially proud of the fact Dr. Peebles is an APS Fellow and longstanding member of APS. We congratulate all the laureates on this well-deserved award."

Mayor and Queloz share the other half of the prize for their discovery of an exoplanet that challenged preconceived notions about planetary systems and jump-started a revolution in astronomy, leading to the discovery of 4,000 additional exoplanets. The planet they discovered, 51 Pegasus b, defied previous ideas about how a large planet, similar to Jupiter, should behave, opening the door to new ideas on where to look for other exoplanets.

"This discovery revolutionized our understanding of planetary science, led to the discovery of thousands of exoplanets, and spurred the search for extraterrestrial life in the universe," said Gross.

The Nobel Prize, first awarded in 1901, is widely considered the highest honor in science, economics, and literature. The 2019 Nobel Laureates will be awarded medals at a ceremony in December, along with 9 million Swedish krona (just over $US 1 million), half of which goes to Peebles, and the other half shared by Mayor and Queloz.

Additional Reading

The following relevant articles have been made free-to-read by APS:

P. J. E. Peebles, "Primeval Helium Abundance and the Primeval Fireball", *Phys. Rev. Lett*. 16, 410 (1966).

P. J. E. Peebles and B. Ratra, "The cosmological constant and dark energy", *Rev. Mod. Phys*. 75, 559 (2003).

B. Ratra and P. J. E. Peebles, "Cosmological consequences of a rolling homogeneous scalar field", *Phys. Rev. D* 37, 3406 (1988).

IG NOBEL CONTINUED FROM PAGE 3

temperature asymmetry in the testicles of French postmen (a "mock" demonstration at the ceremony was instantly censored). The Ig Nobel peace prize recognized a well-meaning attempt to measure the pleasure of scratching an itch, while the physics prize went to a study that explained the cubic-shaped poo of little Australian marsupials called wombats. Two of the physics prize recipients, David Hu and Patricia Yang of Georgia Institute of Technology, achieved Marie-Curie-like status by winning their second Ig Nobels. "While bizarre, this is a very important prize," Hu said. "Many people consider this work the pinnacle of my research."

The winners had to travel to the ceremony on their own dime, but they all received a ten-trillion-dollar award—alas, in the practically worthless Zimbabwean currency. A better reward was receiving a handshake from genuine Nobel winners: Jerome Friedman (physics), Eric Maskin (economics), and Richard Roberts (physiology or medicine) were this year's bemused laureates in attendance.

Unlike most scientific events, the evening was filled with funny interludes—parodies of experiments, zany costumes, and an opera about bad habits. One bad habit that many physicists are guilty of is talking longer than the allotted time. The Ig Nobel ceremony dealt with this problem by having an 8-year-old girl repeatedly yell "Stop, I am bored!" at anyone who went over time. It fit well with the keynote speech's theme: "Life should be long and speeches should be short," which Harvard grad student Cari Cesarotti took to heart in her seven-word explanation of the Large Hadron Collider: "Measure small by building big: Size matters."

The deeper meaning of all the madness was revealed in conversations with both Nobel and Ig Nobel winners. They all felt that humor is a powerful vehicle for communicating science because it strips away the aura of seriousness and complexity that distances science from its audience. "Laughter is an exceptional tool," Friedman said. "It's good for your health, and it's good for your psyche. It allows people to connect with science in a way that wouldn't otherwise be possible."

After all the hoopla was over, Marc Abrahams, master of ceremonies and Ig Nobel founder, closed the ceremony with his signature salute: "If you didn't win an Ig Nobel prize today—and especially if you did—better luck next year!"

Matteo Rini is the Deputy Editor of Physics Magazine*, from which this article was reprinted.*

PHYSICSQUEST CONTINUED FROM PAGE 1

students) was surveyed for the evaluation. A subset of teachers also participated in a focus group to provide additional insight into how the PhysicsQuest kits fit into their teaching.

Each PhysicsQuest kit contains all the necessary components for small groups of students to conduct four different experiments related to an educational comic book, also included in the kit. The kits also come with a teacher's guide to assist in explaining the concepts conveyed by each experiment. Teachers in the focus groups consistently pointed out the value of receiving all the necessary resources for a hands-on lesson in one place.

Overall, teacher responses to the evaluation were positive, with 94 percent of respondents reporting that PhysicsQuest had a positive impact on their students' interest in physics and their enjoyment of learning physics. Teachers also overwhelmingly reported that they would recommend the kits to other teachers. A large number of teachers—85 percent—also reported that PhysicsQuest activities align well with their curriculum.

"PhysicsQuest teaches kids in an easier way than if I had just handed them a piece of paper and taught them myself," said one PhysicsQuest user. "I have a new way to teach them and help them learn faster and better than I think I have in the past."

While teachers were largely positive about their experience using PhysicsQuest kits, they did offer suggestions to improve the learning experience for their students. Kits have long been accompanied by the *Spectra* comics, which follow the adventures of a laser superhero, but teachers indicate that these comics aren't necessarily integral to their students' experience.

"We found that teachers didn't have the time to tie the lessons into the comic book's story but separating these two projects (PhysicsQuest and *Spectra* comics) will help us deliver the kits faster in the future and drive down our printing and shipping costs," says Roche. "It will also allow us to take more liberty with the comic's story."

This year's PhysicsQuest kits are taking teacher suggestions into account and returning to an earlier PhysicsQuest model that included comic books based on real physicists like Nikola Tesla and Marie Curie. Students will learn about real life physics superhero Chien-Shiung Wu and her contributions to physics with four new experiments.

An additional comparison showed that students using the kits were more likely to report wanting to be a physicist than those who did not. This is another reason to return to featuring real-life physicists: One teacher reported that featuring Marie Curie inspired her students. "Quite a few of the girls wanted to become Marie Curie that year," she said.

After a decade of PhysicsQuest, hearing feedback from teachers is integral in continuing the program for future generations of students.

"We're looking to expand the program in many ways: We're getting a lot of great feedback from teachers suggesting topics for activities and are going to be highlighting the work of some really important unsung physicists," says Roche. "Middle school is a crucial time for children to be engaged with physics, so we make sure the activities are accessible to middle schoolers and above."

To request a PhysicsQuest kit or download previous PhysicsQuest manuals, please visit physicscentral.com/experiment/physicsquest/.

GDS CONTINUED FROM PAGE 5

the original petition to form GDS received a whopping 1,200 signatures from members of the APS community—far beyond the 200 required for creating a new topical group. "The demand is there, the need is there, and as APS we should support that," he noted.

Reflecting the increasing relevance of data science across all domains of physics, GDS is already an extremely interdisciplinary group. The group's fast-growing membership of 350 people includes affiliates of over 23 other APS units, covering an impressive 60 percent of all 38 APS divisions, forums, and topical groups. As it stands now, the largest proportion of GDS members hail from the Divisions of Computational Physics (DCOMP) and Fluid Dynamics (DFD) and the Forums for Industrial and Applied Physics (FIAP), Education (FEd), and Early Career Scientists (FECS; see *APS News* January 2019).

Beyond different branches of physics, GDS encompasses an impressive diversity of sectors where physicists work. As Ren put it, "data science uniquely brings people together from all sides: university, industry, government, and non-profit."

To this end, GDS has forged specific partnerships with both FECS and FIAP to inform early-career scientists about the many career avenues inside and outside of academia available to physicists with data skills.

Noted Ren, "we want to show the external community that physicists can do data science, and this skillset applies to physics research as well as anywhere else in industry."

Next year's APS March Meeting in Denver will be GDS' introduction to the broader APS community, and the group has planned a strong lineup of two invited and six contributed sessions. These include a FIAP-partnered session where researchers from Google and IBM will shed light on data science in industry, and a FEd-partnered session on strategies to better integrate data science skills into physics curricula. In addition, GDS is an unofficial partner of the DCOMP-led session on molecular dynamics. GDS' contributed sessions include: Big Data in Physics, Deep Learning for Computer Vision, Machine Learning for Quantum Matter, Machine Learning and Data in Polymer Physics, Emerging Trends in Molecular Dynamics, and Statistical Physics Meets Machine Learning.

GDS is additionally hosting a pre-conference tutorial on active learning and AI, plus a short course on deep learning for image processing applications. Soltanieh-ha explained that the idea behind these pre-conference activities is to help educate people who are new to the data science field, so they can confidently dive into data science sessions when the wider conference agenda begins.

Of particular note, this year's prestigious Kavli Foundation Special Symposium will also be data science-themed. This high-profile session is typically a highlight of each March Meeting—in fact, no other invited sessions are scheduled concurrently to encourage attendance.

Overall, this volume of content is far beyond what is typical for a new topical group, highlighting the appetite within the APS community for more data science-related content. Of course, GDS hopes to boost its offerings in future years as the organization (and demand) continue to grow.

As GDS expands, Soltanieh-ha and Ren envision the organization becoming a hub for data science education. This encompasses educating graduate students and early career scientists about job opportunities in the data science sector, refining data science curricula in physics programs, and bringing together physicists who use data science in their research to share best practices. Noted Ren, "as we see data science start to have a greater influence in our community, we want to have a place for us to talk about methodology and how we can get the right skillset as a physics community. That will benefit our research, whatever it is."

Overall, GDS stands out as a rising star within APS, filling an important niche for the growing number of physicists with an interest in data science. As Ren put it, "this booming field is rocking the entire landscape, and physics isn't exempt from this." More information can be found at the GDS website at aps.org/units/gds.

The author is a freelance writer in Stockholm, Sweden.

NMC CONTINUED FROM PAGE 1

APS Bridge Conferences in 2013 and 2014, and at that juncture my main interest was improving diversity in graduate education," said Wijewardhana. "When I came back from [the 2015 conference] I registered as an NMC mentor and started looking for a mentee."

Wijewardhana became Leembruggen's mentor In May 2016, just after her sophomore year. She started working with Wijewardhana's theoretical cosmology research group studying axions and quickly became a valuable part of the team.

"Her research project was to analyze the collapse of gravitationally bound bubbles of candidate dark matter particles termed axions. Such bubbles are termed axion stars and they become unstable towards collapse above a critical mass," said Wijewardhana "To analyze this problem Madelyn had to use some Lagrangian mechanics, quantum mechanics, and field theory—subjects she was not familiar with at that point. She was a quick learner and a hard worker and within a few weeks acquired sufficient background knowledge to start working on her research project."

Working with Wijewardhana gave Leembruggen new confidence in her abilities as a physicist, bolstering her commitment to completing her undergraduate education and continuing on to graduate school, and resulted in the publication of six papers. She also collected several achievements for her work including taking first prize in the poster competition at the 2016 NMC conference, receiving a Goldwater Scholarship in 2017, and qualifying as a finalist for the Leroy Apker Award in 2018.

Participating in the NMC also impacted Wijewardhana, who gained an appreciation for supervising undergraduate research. Since Leembruggen's graduation and acceptance to a Harvard PhD program, Wijewardhana has been mentoring two more undergraduate students through the NMC.

"I am now...so excited for my future in research and scientific outreach. There are still days when being a woman of color in physics weighs heavily on me. But because I had the extraordinary opportunity to be part of a community as special as NMC, I know I have scores of peers and allies who will go to incredible lengths to push me toward success," said Leembruggen. "I am still here because of all the people who loaned me stamina when I was weary and spoke truth to me when I began to hear lies. I can say with certainty that NMC changes students' lives because it absolutely transformed mine."

For more about NMC, visit aps.org/programs/minorities/nmc/. Registration for the 2020 NMC conference opens November 5. Go to aps.org/programs/minorities/nmc/conference/ for more information.

DISCUSS CONTINUED FROM PAGE 5

and Lucy Buchanan-Parker for helpful suggestions on this article. We would like to acknowledge that much of the writing took place in Vancouver, British Columbia, on the unceded traditional territory of the Musqueam, Squamish, and Tsleil-Waututh First Nations.

Linda E. Strubbe is a Postdoctoral Research Associate at Kansas State University, an Educational Consultant at the University of Central Asia, and Co-Director of the West African International Summer School for Young Astronomers. Electra Eleftheriadou is a Postdoctoral Fellow at the University of British Columbia. Sarah B. McKagan and Adrian M. Madsen are Director and Assistant Director of PhysPort at the American Association of Physics Teachers. Dimitri R. Dounas-Frazer is an Assistant Professor at Western Washington University.

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This special commentary reflects the opinions of the authors and not necessarily those of APS.

FELLOWS CONTINUED FROM PAGE 4

through graduate school, I found myself becoming more interested in making a broad impact through policy rather than focusing on one particular technological solution," she said.

Regitsky added, "The Congressional Fellowship was the perfect way for me to leverage my technical experience to inform policy decisions and to make a career transition from research to policy."

Both fellows recalled key accomplishments throughout their time on Capitol Hill, including connecting with other scientists and using their scientific expertise to address crucial policy issues.

Dailey said one of her main accomplishments was "the extended network of fellow scientists and researchers" that she was able to cultivate as a fellow.

"Nothing in science or policy happens in a vacuum, and through this fellowship, I was introduced to so many incredible people from every discipline and every career stage," she said.

Dailey added, "I also used my skills as a science translator to explain what the recent climate report was telling us about impacts in Maryland. Even after a year of study, I think I still only vaguely grasp the intricacies surrounding drug pricing in this country, but I still felt incredibly accomplished when I was able to use my research and analytic skills to explain flow charts and cause-and-effect chains to help inform discussion on drug pricing legislation."

For Regitsky, who served in US Sen. Tina Smith's office representing Minnesota, a big achievement was helping to develop and launch the Clean Energy Standard Act of 2019. Introduced in May 2019 by Smith and US Rep. Ben Ray Luján, the bill would put the US electric sector on a path toward 100 percent decarbonization.

"I was deeply involved in all aspects of the bill, including engaging with over 50 stakeholder groups; writing summary documents; acquiring cosponsors; and strategizing the bill's rollout," she recalled.

Regitsky added, "During my fellowship, I also helped organize a AAAS Fellows symposium on deep decarbonization as a member of the Energy/Climate Affinity Group. I organized and moderated the panel session on industrial decarbonization, focusing on technologies and policies needed for reducing emissions from the industrial sector."

The positive impact both Dailey and Regitsky made during their fellowships will likely go a long way in making a difference in science policy, according to people who worked with them.

"Jen is one of those people who has an innate thirst for knowledge. During her time with our office, she was eager to dive in to unfamiliar topics and explore and develop policy solutions to address drug shortages, women's health, and the Chesapeake Bay restoration with intensity and gusto. She has also brought an incredible wealth of knowledge to our office and found ways to translate science into what we are doing legislatively," said Lauren Jee, who handles the health portfolio for Sen. Cardin and supervised Dailey during her fellowship.

Pete Wyckoff, the energy and environment policy advisor for Sen. Smith and Regitsky's supervisor, said, "Abigail was an amazing addition to the Smith Office and greatly expanded the capacity of Senator Smith's Energy and Environment Team. Abigail was particularly instrumental in helping to develop two of the clean energy bills that Senator Smith introduced this year."

He added, "In a very short time, Abigail became well known in the clean energy community in DC, and I am sure that the connections she made while she worked in our office helped her land the job she now has as a committee staff member in the House of Representatives."

Regitsky's position will enable her to continue to make an impact on climate change.

"I am now a professional staff member of the House Select Committee on the Climate Crisis. Our committee is charged with developing policy recommendations to the standing committees of Congress on how to decarbonize the economy, as well as address adaptation and resilience to the effects of climate change," she explained.

As for Dailey, she is working as senior analyst at the National Security Analysis Department at Johns Hopkins University Applied Physics Laboratory.

"It feels like a great fit since I can use my new policy know-how to help inform my analyses. I look forward to staying involved with APS policy and outreach groups," she said.

Francis Slakey, chief government affairs officer for APS, said he was thrilled to learn about the fellows' terrific experiences on Capitol Hill.

"We at APS want to make sure that the Congressional Fellows put their technical expertise to excellent use during their fellowships, and it is clear that both Jennifer and Abigail were able to accomplish that goal," he said.

The author is APS Senior Press Secretary.

APS Congressional Science Fellow 2019-2020

Laura Gladstone, the recipient of the APS Congressional Science Fellowship for the 2019-20 calendar year, has chosen to serve as a Fellow for the Minority Staff on the Senate Committee on Homeland Security and Government Affairs. Information about Gladstone's experience will be shared in *APS News* after her fellowship. APS maintains a "hands off" policy with current Congressional Fellows to avoid any conflict of interest.

VR AND HR CONTINUED FROM PAGE 3

AR glasses, which allow the user's normal vision to be merged with images from tiny computer displays already exist, but next-generation AR glasses will have added features, like virtual personal assistants. Such features are being researched by Fuchs' lab at UNC, including a prototype headset for shared telepresence—an AR concept that allows a user to "see" another AR user and their surroundings. This prototype is equipped with eight cameras: four capturing a user's environment, two recording the user's body and another two directed towards the user's face, which are used to recreate body and facial positioning virtually. Since these cameras will collect massive amounts of data, Fuchs notes data privacy and security will play a role in how AR will be used.

Luebke addressed some technical challenges to AR development, some of which overlap with VR, but others are unique to the challenge of melding views of reality and synthetic objects. To create a satisfying AR experience, Luebke says that headsets must have high enough resolution—enough to read a newspaper at arms-length—and embed information spatially into the real world. Novel optics design is necessary to further develop AR, but the potential uses of AR make it worth the challenge.

"We can create an inclusive AR display that supports user needs, such as [vision] disorders, prescriptions, and eye conditions," says Luebke. "Myopia is an epidemic, and AR might be able to help."

In his later talk, Starner discussed many of the applications for the current generation of AR displays, along with the social impacts of wearable devices. As a long-time AR display user, Starner has experienced the transition of AR glasses from bulky, odd-looking headsets to nearly indistinguishable from normal glasses. AR, he says, allows for microtransactions (like checking the time, directions, or a text message) to take less time than checking a smartphone, and therefore wearers will be less distracted by their technology. He also described practical uses for AR, from laptop replacements for doctors, allowing more face-to-face interaction with patients, to real-time captioning for the hard of hearing.

"With technology, misuse is always a risk, but AR can cut down on the amount of time we spend looking down at phones, spending time in the digital space," says Starner. "Any tech can be used for good or bad—[we] try to encourage the good."

For more on the Frontiers in Optics/Laser Science meeting, visit frontiersinoptics.com.

THE BACK PAGE

Can We Inspire Every High-School Student to Take Physics? Texas Nearly Did.

BY MICHAEL MARDER

Public discussion of public education in the United States follows conventional narratives and the narratives focus on failure. From *A Nation at Risk* [1], to *Rising Above the Gathering Storm* [2], and *Waiting for Superman* [3], we learn over and over again "Why the United States' 50-year failure to modernize our education system threatens our economy, social stability, and democracy" [4]. The narrative conventions permit isolated students, teachers, or schools to succeed against the odds, but leave no room for real success.

Physics frequently has a starring role in presentations of the ills of American education. Less than half of US students take as much as one year of high school physics [5], although in Europe and Asia [6] four years of physics is common. The US finds itself in this situation partly because of the shortage of qualified teachers. More than 60% of physics teachers lack either a major or minor in the subject or full teaching certification [7]. Year after year physics ranks near the top of the subjects school district administrators find most difficult to staff [8]. This problem has persisted for decades. Programs to prepare STEM teachers such as Noyce Scholarships [9], PhysTEC [10], or UTeach [11] have led to substantial local increases in teacher production but haven't yet reached the scale needed to change the landscape. That would require coordinated national or state-level policies that are nearly impossible to imagine. Or are they?

The modern wave of Texas education reform began in 1984 with a commission led by Dallas businessman and later presidential candidate Ross Perot [12]. Reform elements included exams for graduation, class size limits, and the legendary "no pass, no play" provision that attempted to set academic achievement on almost the same level as football. The first proficiency exams were followed by successive waves of exams, producing a "Texas Miracle" in education that George W. Bush featured in his successful run for the presidency. The Elementary and Secondary Education Act of 2001, better known as No Child Left Behind [13], exported mandatory high-stakes exams to the whole nation. No policy has so frequently been debunked, so generally reviled, or so durably maintained through bipartisan support as school testing [14].

In April of 2006, Texas Governor Rick Perry called a special legislative session to rework the school finance system. The central bill of the session included a reform of high school graduation plans. There were to be three levels: Minimum, Recommended, and Distinguished. Students would automatically be enrolled in the Recommended plan and would have to opt out to enter either the Minimum or Distinguished Plan. A required element for either Recommended or Distinguished graduation was the 4x4: four years each of English language arts, social sciences, mathematics, and science. The science requirement included biology, chemistry, and physics. It was perverse to do this because it was as well known in 2005 as it is today that there are not enough physics teachers. The main argument for the 4x4 curriculum was that it would make it possible for a typical student to apply to a 4-year college once they graduated, since the curriculum corresponded to college entrance requirements. There was also the fact that the policy sounded like a monster truck, and that never hurts.

Texas education datasets make it possible to keep track of what happened as a result. The response to the law was not instantaneous. If one follows the cohort of students entering high school in Fall 2007 then 51% of them eventually took at least one physics course (see Fig. 1). This was already high compared with national averages, but the rate of physics-taking kept rising and by 2011, 77% of students entering high school that Fall took a physics class before graduation. Economic divides were not eliminated; for the cohort entering high school in 2011, 73% of students eligible for free and reduced lunch took physics, while for those not eligible it was 84%. And there was a gender gap, but in favor of women, 79% of whom took physics versus 75% of men. This accomplishment in providing high school physics went unremarked, unstudied, and unrewarded, and therefore was susceptible to being undone.

Figure 1

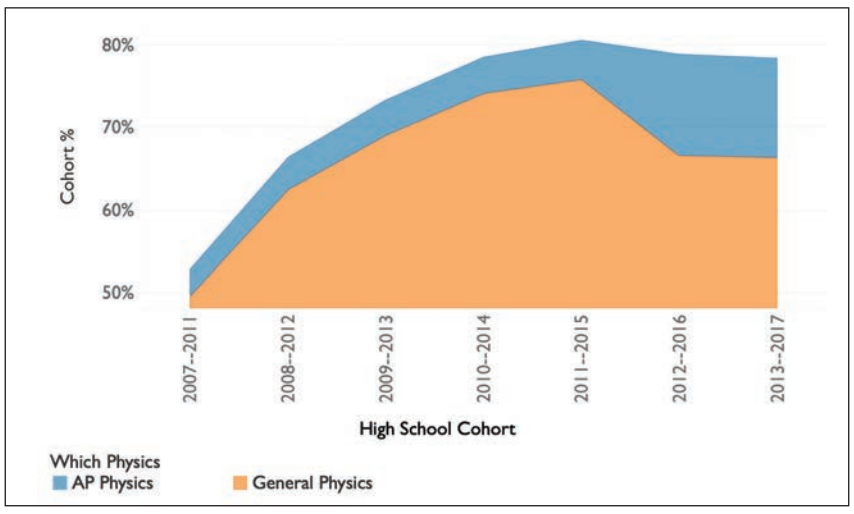
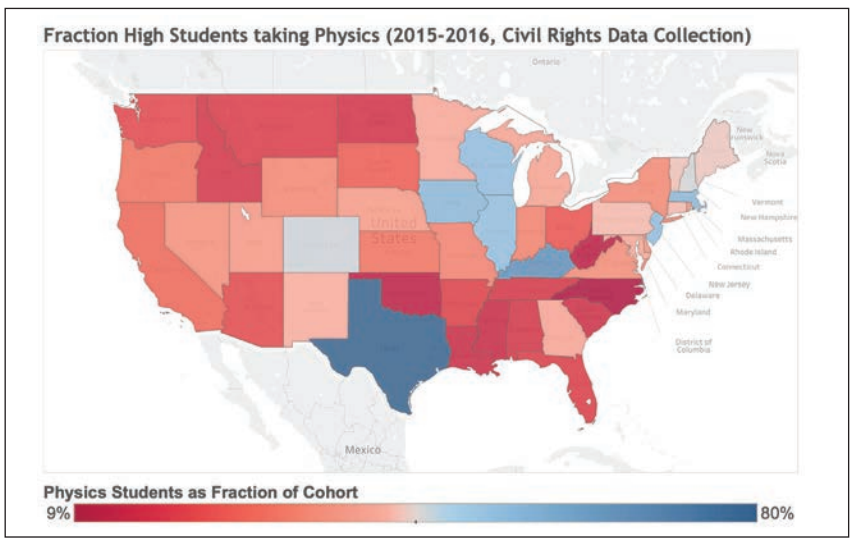


Figure 2



In 2013, Texas returned to curriculum reform. The climate had changed and now was being driven by a backlash against testing. Algebra II was singled out as particularly objectionable [15], but physics and chemistry were also caught up in the general revulsion against forcing students, against their will, to leave open the possibility of going to a four-year college. The default high school graduation plan dropped back to the situation prior to the 4x4, stopped requiring both chemistry and physics, and allowed students to choose between them as previously. High school physics enrollment was bound to drop.

Except that it did not. It dropped only by about 1% for students beginning high school after 2011, and with the introduction of AP Physics I, the share of AP Physics for the 2012 cohort sharply rose, resulting in complete parity of men and women taking AP Physics.

In case there remains a suspicion that the Texas longitudinal dataset itself is flawed we have an independent way to examine the matter. Physics course-taking is regarded as a matter of civil rights, and the US Department of Education requires all states to provide information on physics course-taking, broken down by various under-represented groups [16]. For every high school in the U.S. one can estimate the size of the high school cohort by taking the maximum of 10th and 11th grade enrollment and dividing this into the number of students who take physics. This is not as accurate as following individual student course records year by year as we did in Texas, but it makes national comparison possible. The result appears in Figure 2. This is the only map of the US in which Texas is the deepest blue. In fact no other state comes close to Texas in the fraction of students taking physics. Even Massachusetts, widely regarded as the state with the strongest public education system, has only 55% of its students in physics, while Oklahoma and West Virginia are down at 12%.

The final consolation for a skeptic in view of these data is the assurance that the Texas physics courses, even if they have been offered, must be terrible. Indeed, there is little direct information about the quality of the courses, particularly since a high school physics exam was one of the casualties of the anti-testing movement of 2013.

However, a state where the overwhelming majority of students takes physics provides opportunities for further improvement that otherwise would be inaccessible. For example, OnRamps [17] provides a dual enrollment physics course where high school students can simultaneously earn high school and UT Austin credit. In 2018-2019 there were 4,598 students enrolled in Physics I: 81% qualified for college credit at the end of the year and 59% accepted it, and 2,437 high school students earned a C- or better on the same class activities, homework, and exams taken by upper-division premedical students at a research university. There are 350,000 students in the Texas high school cohort; a large number, yes, but with internet connectivity higher education institutions in the state could be supporting courses for all of them.

Why was Texas able to provide physics to so much larger a fraction of its students than other states? While teacher production in most states has been dropping for the past 5 years at over 3% per year, with particularly sharp drops in New York and Pennsylvania, Texas produces the largest number of teachers in the US and production has been growing [18]. The reason for this is not entirely comforting. More than half the new teachers in Texas come from alternative certification programs, and these are dominated by for-profit companies that provide much of their preparation online. The increase in production from alternative certification programs has more than offset a small decline in production from universities. Furthermore, Texas does not have a standalone physics teaching certificate. Most physics teachers have a science certificate which includes the possibility of teaching biology, chemistry, earth sciences, and physics, although no one has a major in all four of those subjects.

Still, what is most remarkable, and most encouraging, is that once physics became available in high schools across the nation's second-most populous state, and once schools were directed to develop the capacity to offer it to all students, they largely succeeded. And then schools kept offering it, advisors kept recommending it, teachers kept teaching it, and students kept taking it even when the requirement went away.

Most U.S. students still do not take physics. The Texas experience shows this is not inevitable. Students do not take physics because we choose not to give them the chance.

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