May 2019 • Vol. 28, No. 5
aps.org/apsnews

APS NEWS

A PUBLICATION OF THE AMERICAN PHYSICAL SOCIETY

VIEWPOINT

Yes, Sexual Harassment Still Drives Women Out of Physics

BY JULIE LIBARKIN

Editor's note: This article is adapted from a Viewpoint commentary in Physics (physics.aps.org) *accompanying a paper published in the APS journal* Physical Review Physics Education Research.

You may be someone who thinks that sexual harassment is a "thing of the past" or that it's experienced by "only a few" women. These statements don't capture reality. As recently as 2014, a study found that sexual harassment affects the majority of women in science, technology, engineering, mathematics, and medicine (STEMM) [1]. Now, a comprehensive survey of female undergraduates in physics has uncovered a similarly disturbing situation for this group of women at the start of their careers. Aycock et al. surveyed female attendees at the 2017 Conferences for Undergraduate Women in Physics (CUWiP) [2]. They found that nearly three-quarters

IMAGE: JOAN TYCKO

of the roughly 500 respondents had experienced some form of sexual harassment and that these experiences correlated with a sense of not belonging in the field. This finding won't surprise most women in STEMM, but it may shock men in STEMM, who are often unaware of sexual harassment's pervasiveness and damage.

Broadly defined, sexual harassment is unwelcome or inappropriate

HARASSMENT CONTINUED ON PAGE 7

EDUCATION AND DIVERSITY NEWS

The APS Bridge Program Celebrates its First PhDs

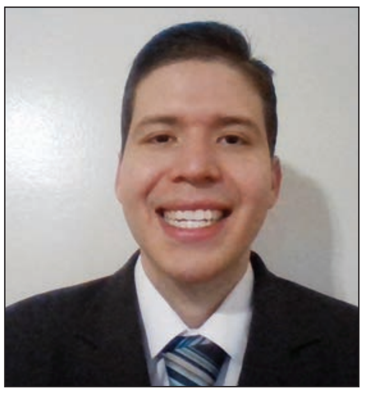
BY LEAH POFFENBERGER

The APS Bridge Program was started in 2013 to address a shortage of PhDs awarded to African American, Hispanic American, and Native American students. Only 6 percent of physics PhDs awarded each year go to underrepresented minority groups, and the Bridge program has been working to promote institutional environments and mentoring to increase this number.

Two Bridge students, Tommy Boykin (University of Central Florida) and Kevin Galiano (The Ohio State University), are both set to receive their PhDs in May, becoming the first Bridge participants to do so. Amid completing their dissertations, submitting conference proposals, and looking forward to the next step in their careers, Boykin and Galiano shared their journeys through academia and their experiences with the Bridge program.

Boykin, who graduated with a bachelor's degree from Berea College in 2013, has spent the

Tommy Boykin



Kevin Galiano

past six years at the University of Central Florida, obtaining his master's in 2016, and conducting research on biological physics. Galiano also graduated in 2013 from the Massachusetts Institute of Technology, taking his experience in condensed matter physics research to Ohio State (OSU), also receiving his Master's in 2016. Now, soon to be equipped with newly minted PhD degrees, Boykin and Galiano are both pursing career opportunities in industry.

Both credit the Bridge program with providing opportunities to pursue their passion for physics—and for Boykin, it was an especially important stepping stone to graduate school.

"I ended up applying to 12 different schools. I actually didn't get into any of them," said Boykin.

BRIDGE CONTINUED ON PAGE 3

APRIL MEETING

News About Neutrinos: The Kavli Foundation Plenary Session

BY LEAH POFFENBERGER

April Meeting attendees gathered early on a Monday morning in Denver for this year's Kavli Foundation Plenary session to hear about recent advances in neutrino physics. The session's three invited speakers provided an overview of the work being done to understand—and use—the elusive neutrino.

André de Gouvêa (Northwestern University) spoke about the theory behind neutrino masses, followed by Susanne Mertens (Max Planck Institute for Physics and the Technical University Munich) who shared the latest experimental research on the minute mass of neutrinos. Marcos Santander (University of Alabama), rounded out the session with his talk titled "Unveiling the High-Energy Neutrino Sky," which focused on using neutrinos to pinpoint astrophysical sources of the cosmic ray flux.

As part of the Standard Model of physics, theorists expected neutrinos to have a mass of zero, a parameter that fits into the known

André de Gouvêa

rules of the model. However, twenty years ago, the discovery of neutrino oscillations—the variation in neutrino "flavors" as they travel, changing between tau, muon, and electron neutrinos—showed neutrinos indeed have mass, albeit very small. As de Gouvêa pointed out, this non-zero neutrino mass is evidence of physics beyond the Standard Model, since "neutrinos having masses requires new ingredients or new rules."

KAVLI CONTINUED ON PAGE 6

INTERNATIONAL NEWS

Fellow Young Physicists—Get Involved in Human Rights

BY CHRISTOPHER A. WATSON

Note: At the APS March Meeting in Boston, the Committee for International Freedom of Scientists (CIFS) hosted a luncheon for students and early career physicists interested in human rights and related APS activities. The following is adapted from remarks delivered at the event.

It has been my perception, in the last few years in particular, that there is a thirst among student and early career physicists to become more involved, both within the scientific community and in society more broadly, and your attendance at this session testifies to that continued commitment. Consequently, I'd like to highlight the opportunities for young physicists in the area of human rights, and especially the APS Committee on International Freedom of Scientists (CIFS): what it does, why and how it does it, and what you all might do to help its mission along the way.

Why is APS interested in Human Rights?

First of all, part of advocacy for science involves advocacy for scientists, and the work of CIFS demonstrates the commitment of APS to that role. Secondly, it lets those scientists who find themselves facing human rights issues know that they do not face them alone. We also feel that it is the responsibility of the Society to take a public position on issues that matter to the community it represents, and taking these actions makes a statement about those principles and values. Finally, and perhaps most importantly, the actions taken by APS and its peer societies and organizations collectively do make a meaningful difference in some cases, resulting in better treatment or even a resolution of the concern.

CIFS was made a permanent standing committee of the APS in 1980, and its charge is to "be responsible for monitoring concerns regarding human rights for scientists throughout the world. It apprises the President, Board, and Council of problems encountered by scientists in pursuit of their scientific interests or in effecting satisfactory communication with other scientists and may recommend to the President, the Board, and Council appropriate courses of action designed to alleviate such problems."

Note that the committee's role is advisory—strictly speaking, we are not the decision makers but rather exist to give advice and recommendations to the President, Board, and Council. Actions (or inactions) that we suggest are not just blindly rubber stamped and implemented but are taken up thoughtfully by APS, which sometimes has already determined a course of action, for example in concert with other professional organizations impacted by or related to the matter at hand.

The statement of purpose makes reference, notably, to "human rights for scientists" and to "problems encountered by scientists." It does not say "physicists,"

Christopher A. Watson

and as such, we find ourselves frequently considering issues that affect scientists in other disciplines, such as climate scientists, geologists, or political scientists.

I should clarify, however, that just because a human rights issue occurs, which happens to affect scientists incidentally, that doesn't *necessarily* mean it falls within our scope or that APS should try to intervene. We try to focus, instead, on issues that substantively impact individuals' abilities to freely pursue science and scientific research or to freely communicate the results of that work.

So, what does CIFS actually DO?

One example involves the fallout of the failed coup attempt in Turkey in July 2016. Following the suppression of that attempt, an estimated 500,000 individuals, including many academics, were

RIGHTS CONTINUED ON PAGE 6

FUNDAMENTAL UNITS

Updating Le Système International

BY ABIGAIL DOVE

On May 20, 2019, the world will officially transition to a revamped system of units, featuring new definitions for the kelvin, the ampere, the mole, and, most famously, the kilogram. Although these changes, approved in November 2018, have received a lot of attention in the scientific press, less well-known is the organization that guided this overhaul of Le Systeme International d'Unités (SI): The International Bureau of Weights and Measures, or BIPM (Bureau International des Poids et Mesures).

Willie E. May is the Outgoing US Representative to BIP IMAGE: NIST

BIPM, the world's authority for all things measurement-related, has its origins in the 1875 Metre Convention in Paris, which aimed to maintain and standardize units of measure internationally. The primary issue in 1875 was establishing universal units of mass and length, which began with the construction of official kilogram and meter prototypes.

Today the modern SI system includes a total of seven fundamental base units, including the second for unit of time, the ampere for electric current, the kelvin for thermodynamic temperature, the candela for luminous intensity, and the mole for amount of substance. These are in addition to the kilogram and the meter (plus several so-called "derived" units grounded in the base units, including coulombs, joules, volts, ohms, teslas, etc.). With 60 member states and 42 associate states and economies, BIPM promotes and advances the global comparability

BIPM CONTINUED ON PAGE 7

THIS MONTH IN

Physics History

May 1618: Kepler's Discovery of Solar System Harmonics

Medieval and Renaissance cosmology was dominated by the notion of a celestial "music of the spheres." It was a compelling metaphor that inspired much of the art, music, and literature of Western Europe for centuries. But astronomer Johannes Kepler laid out a more literal music of the spheres in his 1619 treatise, *Harmonices Mundi (The Harmony of the World)*, suggesting that the planets of the solar system produced tones as they orbited the sun.

Born on December 27, 1571, just west of modern Stuttgart, Germany, Kepler's father eked out a living as a mercenary and abandoned the family when young Johannes was just five years old. It was a spectacular fall in fortunes, since his grandfather had been Lord Mayor of the town. Kepler's mother was an innkeeper and an herbalist (a practice that caused her to be accused of witchcraft some years later). Johannes was a sickly child, but he excelled at math, and came to love astronomy at a very young age. When he was six, his mother took him to see the Great Comet of 1577, and he later vividly recalled his first lunar eclipse at age nine, in which the moon "appeared quite red."

He contracted smallpox, which left him with poor vision and crippled hands, dashing his hopes of being a practicing (observational) astronomer when he left home to attend the University of Tübingen. But his mathematical skills served him well with regard to the theory behind the stars. He learned both the Ptolemaic and Copernican cosmologies at school, and championed the latter. Although he had originally intended on entering the ministry, he became a math and astronomy teacher at a school in Graz upon completing his studies.

While in Graz, Kepler experienced an epiphany about a possible geometric basis of the universe, inspired by the periodic conjunction of Saturn and Jupiter. He created a model in which each of the five Platonic solids was encased inside a sphere; if one then nested them within each other, the resulting six layers would correspond to the six known planets at the time (Mercury, Venus, Earth, Mars, Jupiter, and Saturn). He published these conclusions in his first astronomy treatise, *Mysterium Cosmographicum*, in 1596, when he was just 25.

While the treatise had its flaws, it brought Kepler to the attention of leading astronomers, including Tycho Brahe and Reimarus Ursus. Brahe and Kepler exchanged many letters, in which the former offered some harsh criticisms of the young astronomer's work, including the fact that Kepler had relied on inaccurate data gathered by Copernicus. In 1600, Kepler visited Brahe near Prague, as a new observatory was being built, and gradually earned the latter's trust, gaining access to Brahe's far better data. He ended up moving to Prague, and when Brahe died, Kepler succeeded him as imperial mathematician.

A page from Kepler's Harmonices Mundi IMAGE: WIKIMEDIA COMMONS

Around this time, Kepler also became interested in studying numerological relationships between math, music, and the physical world, again drawing on geometry for his ideas. He believed geometry "provided the Creator with the model for decorating the whole world," and wished to express those proportions in musical terms, like Ptolemy in *Harmonica*—a "music of the spheres" for the Copernican system. (Kepler's contemporary, Robert Fludd, also developed a harmonic theory around this time, and the two fought bitterly over it.)

The greatest and least distances between a planet and the Sun did not follow harmonic ratios, but Kepler reasoned that the points where the planet moved fastest ("converging motion") and slowest ("diverging motion") were probably a more suitable analogue to harmonic vibration.

So, for example, the difference between Saturn's maximum and minimum angular speeds fit a 4:5 ratio, corresponding to a major third, while Jupiter produced a 5:6 ratio, or minor third. Mars was 2:3, Venus was 24:25, and Earth was 15:16. "The Earth sings Mi, Fa, Mi," Kepler explained as the reason for this small harmonic range. "You may infer even from the syllables that in this our home misery [Mi] and famine [Fa] hold sway." Kepler proposed that very rarely, the planets would sing together in perfect harmony, suggesting this may have occurred at the moment of the universe's creation.

The ratios for the diverging and converging motions of Mars and Jupiter was the only intervals that didn't fit the harmonic pattern, resulting in a dissonant 18:19 ratio. (The asteroid belt was not discovered until 1801, so was not factored into Kepler's calculations.) Nonetheless, this work became the basis for Kepler's *Harmonices Mundi*, published in 1619. The tome's fifth and final section described his discovery of the harmonic motions of the planets.

Ultimately this became Kepler's Third Law,

HARMONICS CONTINUED ON PAGE 3

APS NEWS

Series II, Vol. 28, No. 5
May 2019

APS News (ISSN: 1058-8132) is published monthly, except for a combined August-September issue, 11 times per year, by the American Physical Society, One Physics Ellipse, College Park, MD 20740-3844, (301) 209-3200. It contains news of the Society and of its Divisions, Topical Groups, Sections, and Forums; advance information on meetings of the Society; and reports to the Society by its committees and task forces, as well as opinions.

Letters to the editor are welcomed from the membership. Letters must be signed and should include an address and daytime telephone number. APS reserves the right to select and to edit for length and clarity. All correspondence regarding *APS News* should be directed to: Editor, APS News, One Physics Ellipse, College Park, MD 20740-3844, Email: letters@aps.org.

Subscriptions: *APS News* is an on-membership publication delivered by Periodical Mail Postage Paid at College Park, MD and at additional mailing offices.

For address changes, please send both the old and new addresses, and, if possible, include a mailing label from a recent issue. Changes can be emailed to membership@aps.org. **Postmaster:** Send address changes to APS News, Membership Department, American Physical Society, One Physics Ellipse, College Park, MD 20740-3844.

Coden: ANWSEN ISSN: 1058-8132

APRIL MEETING

Shedding Light on the Dark: Public Lecture by Katherine Freese

BY AMANDA BABCOCK

This year's April Meeting in Denver featured a talk by Katherine Freese, the 2019 APS Julius Edgar Lilienfeld Prize Recipient, on the "cosmic cocktail" of the universe, including matter seen and unseen. In a lecture pitched for a general audience—many of whom were from the local community—Freese discussed the hunt for dark matter, evidence for its existence, and how science is trying to get a handle on what it actually is.

Freese started her lecture by walking through the past 100 years of efforts to understand the universe. Starting with Einstein's work on relativity and progressing to the discovery of dark matter and dark energy, Freese painted a colorful picture of unknown particles and unusual phenomena. Among these are the gravitational lensing effects described in Einstein's general theory of relativity. She showed a deceptively simple set of expressions known as the Einstein field equations, which describe the geometry of spacetime as shaped by matter. Freese explained in layman's terms how spacetime warps in the presence of matter, showing two-dimensional representations of this effect.

But we know now that matter is not simply what we only directly observe. So where did the idea of dark matter come from? Cosmologist Fritz Zwicky, sought to solve the mystery of why the galaxies in the Coma cluster were moving too rapidly. While there was clearly a gravitational effect, whatever substance was lending the extra force did not produce light. They proposed the idea of dark matter (which Zwicky called "dunkel Materie"), calling it dark simply because it did not shine.

Freese then took the audience through the evidence that dark matter exists. The one thing known about dark matter is that it has gravity. One instance of dark matter interacting with other massive objects is in the fringes of galaxies. The further from the core of a galaxy, the slower the rotational velocity should be. However, the rotational velocity continues to stay the same, even at the very edges of galaxies, implying the existence of a large halo of unseen matter.

Although we know it is there, we still don't know what dark matter actually is. There are many possible candidates, from sterile neutrinos to WIMP-zillas. Rather than go through them all, Freese started with what dark matter is not. For example, it is not black holes or neutrinos. Supermassive black holes are found in the centers of galaxies but there are not enough of them to constitute the significant part of the universe that is dark matter. Neutrinos are simply too light for them to provide the mass missing from the visible universe. In computer models neutrinos cause a kind of simulated galaxy formation that does not align with current observations.

The two most likely candidates according to recent research are axions and weakly interacting massive particles (WIMPS). WIMPS are theorized to interact gravitationally but also through the weak force, meaning they could be detected through certain kinds of interactions with other particles. Freese detailed the characteristics of WIMPS and the many experiments designed to find them.

Freese described some current and future detectors for WIMPS. Among these was a DNA detector, consisting of a plate of gold with strands of DNA hanging down from it. The idea is that WIMPS passing through would sever the DNA strands where they hit. The direction could be inferred from the breaks in the strands. Another experiment she noted was IceCube at the south pole consisting of a large array of detectors embedded in the 2 kilometer thick ice.

Katherine Freese meets the audience after her public lecture on the "cosmic cocktail."

Freese's discussion on the state of dark matter stimulated curiosity and many questions. The talk concluded with some astute questions from the audience. One youngster asked, "What caused the Big Bang?" Freese's answer: "We don't know. The Big Bang is the limit of our knowledge," adding that this question is "for your future" generation to solve.

A video of the public lecture is available at youtube.com/apsphysics.

The author is a freelance writer based out of Goodland, KS.

HARMONICS CONTINUED FROM PAGE 2

describing the distance relationship between the planets' respective orbital periods and their distance from the Sun. It is typically defined as "the square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit." (Kepler had described the first and second laws in a previous book, *Astronomia Nova*.) In the 1660s, Kepler's Third Law (along with Christiaan Huygens' law of centrifugal force) helped Isaac Newton and Edmund Halley demonstrate the inverse square law of gravitational attraction between the Sun and its planets.

Further Reading:

Brackenridge, J. (1982) "Kepler, elliptical orbits, and celestial circularity: A study in the persistence of metaphysical commitment, Part II," *Annals of Science* **39**(3): 265.

Voelkel, J.R. (1995) "The music of the heavens: Kepler's harmonic astronomy," *Physics Today* **48**(6): 59-60.

Correction

The "This Month in Physics History" in the April issue stated that "Walton noticed the telltale signature of alpha particles after bombarding a lithium target: the lithium broke into two helium nuclei (two protons and four neutrons each)." Astute readers pointed out that each helium nucleus contains two protons and two neutrons each (for helium 4). We apologize for the error.

BRIDGE CONTINUED FROM PAGE 1

"One of my professors from Berea recommended I speak with Ted Hodapp [APS Senior Adviser to Education and Diversity], and he put me in touch with Dr. Talat Rahman [from UCF] who said that they were starting the Bridge Program and that I should apply. And so, I applied, I got in, and then I was actually admitted to UCF."

Galiano found the Bridge Program though his academic advisor at MIT, and his application connected him to OSU, which turned out to be the perfect fit.

"One of the great things about Ohio State is how big its physics department is. What that means is they have a lot of opportunities, a lot of things one could pursue," said Galiano. "I met Professor Jonathan Pelz and Professor Steven Ringel they were both interested in recruiting a student, and they introduced me to their research."

The Bridge Program aims to help underrepresented minority students receive mentoring, have the opportunity for robust research opportunities, and obtain other support before applying to a doctoral program. Currently six Bridge sites, including UCF and OSU, have 167 enrolled Bridge students hoping to complete the program, gain entry into a doctoral program, and earn PhDs in physics.

"Always be talking with someone, whether that's a mentor or an advisor; they can make sure you're meeting certain benchmarks," said Boykin, offering advice to future Bridge students. "I know for me, when I was going through my program, it was so helpful, especially the first time when I took my qualifier—I didn't pass. I talked with one of my mentors. She gave me a piece of cheesecake and said, 'Hey, it's okay.' Six months later, I passed."

Boykin's pursuit of a PhD in physics started in high school after struggling at first, and slowly coming to enjoy his classes. He was inspired by his mother, who was working towards her own PhD at the time, to take his education all the way. His current research on squid proteins with conductive properties that could be used in batteries also harkens back to a childhood fascination with electronics.

Galiano also found that his passion for physics in high school was a way to apply his love for mathematics.

"I enjoyed the mathematics, [so] when I took my physics class, I saw that I was good at it," said Galiano. "I was granted [an APS Minority Scholarship], and I thought, okay, well I guess the best thing would be to pursue a physics career."

At MIT and at OSU, Galiano has been studying traps in electronic materials—defects that cause things like cellphones to break down—through both experimentation and modeling.

Both Boykin and Galiano have successfully defended their dissertations and are looking for the next steps in their careers.

"I want to make sure people know that grad school is hard," said Boykin. "But my life motto is that I'm not willing to let anyone say what I can or cannot do."

For more on the Bridge program, visit aps.org/programs/minorities/bridge/.

APRIL MEETING

New Results Question Controversial Dark Matter Signals

BY LISSIE CONNORS

For something that constitutes around 27% of the universe, dark matter has been hard to catch. As in past years, it was the topic of presentations and debate at the APS April meeting this year in Denver. Efforts to directly detect this strange substance have been largely fruitless, with the possible exception of the DArk MAtter (DAMA/LIBRA) experiment. This detector, located beneath a mountain in Italy's Gran Sasso Underground Laboratory, has captured a multidecadal signal that the DAMA/LIBRA collaboration claims is evidence of dark matter.

Their results have been met with a steady stream of skepticism over the years. Other experiments have failed to replicate the DAMA/LIBRA results. No experiment, however, has put DAMA's methods directly to the test, until now: Two experiments, COSINE-100 at Yangyang Underground Laboratory in South Korea and ANAIS-112 at Canfranc Underground Laboratory in Spain, are now online using sodium iodide crystals, the same material used in DAMA's detectors. While their methods closely follow those at Gran Sasso, neither has reproduced DAMA/LIBRA's signal.

"People have tried to come up with ideas to explain away the discrepancy, but no one has come up with a viable candidate for dark matter that can produce a signal in DAMA but not the other experiments," said Reina Maruyama, a principal investigator on the COSINE-100 experiment. "It could be that we don't know how to think about it as theorists, or it could be that the [DAMA/LIBRA] experiment is wrong."

The existence of dark matter has long been postulated, but what form it takes is still a mystery (see article on page 3). Some researchers suggest it is a widely distributed—but undetected—particle. Another camp argues that dark matter need not exist at all and that alternative theories of gravitation can explain the missing mass conundrum.

Weakly interacting massive particles (WIMPs) are a popular dark matter particle candidate, and experimentalists have designed clever technologies to tease out their signatures. Thought to have formed in the early universe, these particles barely interact with the matter around them, making their detection a formidable task. Based on their abundance, detecting WIMPs should be like shooting fish in a barrel, but based on their properties, it's more like looking for a needle in a cosmic haystack.

Untangling DAMA/LIBRA's mysterious results

DAMA/LIBRA scientists insist their detector is sensitive enough to detect these ghostly particles: It's shielded from cosmic rays and other background signals by 1.5 km of overlying rock, protected by layers of insulation, and submerged in a cocktail of chemicals. Even with all of this protection from the elements, their data must be teased out from an abundance of background noise.

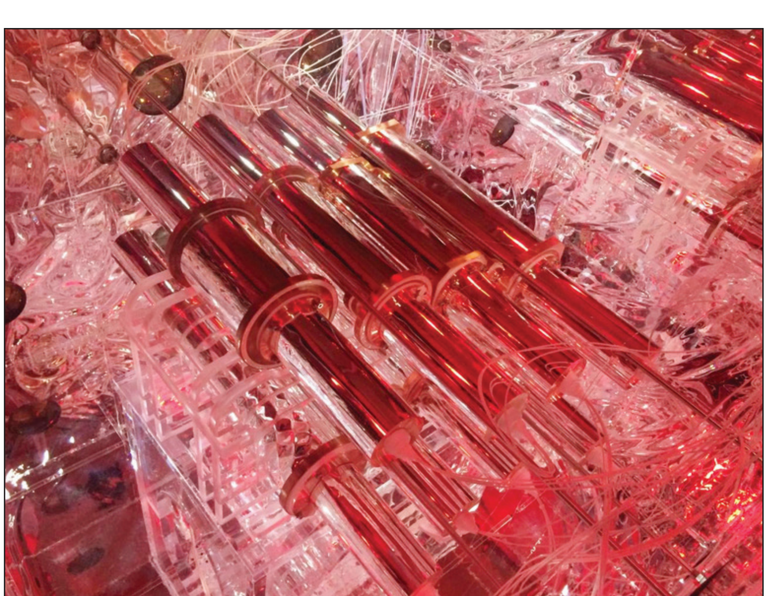
The centerpiece of the detector is over a hundred kilograms of highly purified, thallium-doped sodium iodide crystals. Whenever a subatomic particle interacts with a nucleus inside these crystals, the detector measures a small burst of light. The experiment has collected over 20 years of data using this method, identifying a signal attributable to WIMPs. They've seen an annual modulation in nuclear activity, which peaks in June, then falls in December.

This seasonal effect could be explained by the following scenario: In June, the earth and the sun are traveling in the same direction through the Milky Way, while in December, the earth and the sun are moving in opposite directions. When the velocity vectors of the earth and sun combine in June, they travel faster through the galactic cloud of dark matter, and thus the detector likely interacts with more WIMPs. While it's a plausible explanation, it still doesn't explain why COSINE-100 and ANAIS-112's results aren't similarly impacted.

"Certainly they are detecting something that is modulating", said particle physicist Jodi Cooley, who was not involved with the research. "The question is, is it dark matter that's modulating, or is it some kind of background related to the detector?"

ANAIS-112 recently reported their results in a paper submitted to *Physical Review Letters* based on 1.5 years of data, and found no statistically significant signal of annual modulation. Results from COSINE-100 ruled out the possibility

DARK MATTER CONTINUED ON PAGE 5



Two experiments, COSINE-100 (pictured) and ANAIS, employ the same detector material in an effort to replicate the DAMA/LIBRA signals claimed to result from dark matter. IMAGE: COSINE-100

GOVERNMENT AFFAIRS

Congress Must Lift Budget Caps to Promote STEM Jobs and Avoid Huge Cuts

BY DANY WALLER

Note: The following op-ed was first published in the Louisville Courier-Journal *on April 5, 2019.*

After four years of studying physics and mathematics at the University of Kentucky (UK), I'm deeply worried that my dream of working in academia will fall by the wayside because of the uncertainty surrounding federal funding of U.S. science agencies.

Unless Congress acts, crucial science agencies—including the National Science Foundation, the Department of Energy's Office of Science, and the National Institute of Standards and Technology—will suffer massive cuts in fiscal year 2020, which begins October 1. And those cuts would not only hinder my ability to achieve my dream, but also harm the ability of the state of Kentucky to engage in research that has helped our economy.

Fortunately, U.S. Sen. Mitch McConnell, majority leader and a member of the Senate Appropriations Committee, is in a position to help raise the federal budgetary caps that limit funding as mandated under the Budget Control Act.

The appropriations process, which involves members of Congress making decisions about particular agencies and programs to fund, recently got underway. And I urge McConnell to work with his colleagues to raise the budgetary caps to ensure that students like me don't leave the U.S. for opportunities in Europe and elsewhere, draining our homegrown talent.

Departing the U.S. has crossed my mind, but my heart's desire is to conduct research in my country and help keep the nation positioned as a global technology leader.

I was first drawn to physics during my sophomore year after taking an astronomy class that threw open the door of knowledge for me about stars and planets. My excitement during the class was palpable, leading me to change

Dany Waller

my major from a pre-med biology track to a double major in physics and mathematics.

I will soon graduate, and my long-term goals include becoming a faculty member who oversees undergraduate research labs, sponsoring physics outreach programs and conducting planetary science research.

BUDGET CONTINUED ON PAGE 6

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

Senate Energy Innovation Push Gains Steam

BY WILLIAM THOMAS

Efforts to promote energy innovation are taking shape in the Senate amid a swelling wave of congressional interest in climate change. Key senators have now agreed in principle that a sizeable funding increase is warranted, and several committee leaders are pushing legislation to spur new energy technologies.

In March, Sen. Lamar Alexander (R-TN) proposed a "New Manhattan Project for Clean Energy" that would "double energy research funding" over five years. His proposal also outlines nine "grand challenge" focus areas for enhanced effort: advanced nuclear energy, natural gas, carbon capture, better batteries, greener buildings, electric vehicles, cheaper solar power, fusion energy, and advanced computing.

Alexander has often proposed such large-scale increases in Department of Energy R&D funding, going back to shortly after he joined the Senate in 2003. As recently as 2016, he called for doubling the DOE Office of Science budget and paying for it by ending the wind energy production tax credit.

As chair of the Senate appropriations subcommittee for DOE, Alexander has a strong platform from which to push his plans. However, his budgetary power is constrained by the total amount of discretionary funding allocated to his subcommittee. Although Alexander has often marshaled strong budgets for DOE, he has never realized his more ambitious goals. Now, he is down to his final opportunities, having announced he will not seek reelection in 2020.

Meanwhile, leaders of the Senate Energy and Natural Resources Committee are sponsoring bills that would support the development of new nuclear and fossil energy technologies. They also plan to consider options for promoting renewable energy, energy storage, and other energy technologies.

Committee Chair Lisa Murkowski (R-AK) has reintroduced the bipartisan Nuclear Energy Leadership Act, which would direct DOE to complete two advanced reactor demonstration projects by 2026 and at least two additional demonstrations by 2036, among other provisions. Murkowski and Committee Ranking Member Joe Manchin (D-WV) have also introduced the Enhancing Fossil Fuel Energy Carbon Technology (EFFECT) Act and the Rare Earth Element Advanced Coal Technologies (REEACT) Act. The EFFECT Act would authorize new fossil energy technology programs at DOE and recommend increased funding for them, while the REEACT Act would back ongoing R&D related to the extraction of rare earth elements from coal and coal byproducts.

Manchin is also a sponsor of the bipartisan Utilizing Significant Emissions with Innovative Technologies (USE IT) Act, introduced by Senate Environment and Public Works Committee Chair John Barrasso (R-WY). The bill would promote R&D on technologies that capture carbon dioxide from the atmosphere.

Manchin has argued the U.S. should look for near-term opportunities to export carbon-reducing technologies to countries that are rapidly increasing energy production, often using fossil fuels. Coal plays a significant role in the economy of Manchin's state, which is also home to a branch of the National Energy Technology Laboratory, the focal point for DOE's fossil energy R&D. At a hearing on energy innovation in April, he remarked, "If the solution to the climate crisis leaves West Virginia coal communities behind, then it is not a solution."

The proponents of all these proposals will have to navigate a swirl of ideological currents to see them become law. While an increasing number of Republicans say it is important to address climate change, the party is not in consensus on the matter. Also, although emphasizing energy innovation meshes with the Trump administration's promotion of a "New American Energy Era," the White House has consistently sought dramatic cuts to energy R&D budgets. And Democrats will undoubtedly push to include their own priorities in any major legislation, further complicating the political calculus.

The author is Senior Science Policy Analyst with FYI.

FYI has been a trusted source of science policy and funding news since 1989, and is read by members of Congress and their staff, federal agency heads, journalists, and US scientific leaders. Sign up for free FYI emails at aip.org/fyi.

DARK MATTER CONTINUED FROM PAGE 4

of a signal produced by spin-independent WIMPS, but analyses from 1.7 years of data were found to be consistent both with no modulation, and with DAMA/LIBRA's results. For a more definitive result, both collaborations are collecting more data. If future results from the COSINE-100 and ANAIS-112 experiments continue to contradict DAMA/LIBRA, they may indicate weaknesses in the WIMP theory, or in current detection methods.

"[A null result in COSINE-100] would close any type of loophole that theorists or experimentalists may try to come up with [to explain DAMA/LIBRA's results]" says Maruyama. "It would be more satisfying if we knew what DAMA was actually seeing, but it's rather difficult to explain somebody else's experiment."

With more and more evidence stacking up against the DAMA/LIBRA collaboration's persistent claims of dark matter detection, the case for WIMPs as a dark matter particle is looking increasingly wimp-y.

An expanding world of particles

While it's too early to write an obituary for the WIMPs, new ideas are sparking an exciting revolution in dark matter. Theorists, experimentalists, and astrophysicists are expanding their searches. At this year's April Meeting, 13 sessions were dedicated to the topic alone, featuring researchers across several APS membership units.

"The field of dark matter is exploding," said Cooley.

New ideas and technologies are enabling experimentalists to reach sensitivities far beyond previous dark matter searches. Experiments such as LZ at the Sanford Underground Research Facility in South Dakota and SuperCDMS at Vale Inco Mine in Ontario are searching for WIMPs using alternative experimental approaches. Researchers are getting close to the neutrino floor, where detectors have such high sensitivity that incomprehensibly tiny neutrinos are detected and become background noise. Unlike DAMA/LIBRA and COSINE, SuperCDMS employs super cold crystals to detect vibrations (measured in phonons) to probe the universe for WIMPs. The project will begin data collection in 2020, and promises to provide a valuable new perspective on the dark matter debate.

If these experiments fail to find WIMPs, light mass particles called axions may rise as the most favorable candidate, illustrating an ever-expanding range of particle possibilities.

"We're edging up to that last spot of the WIMP space, then we have this whole new uncharted territory with these light mass particles," said Cooley, a collaborator on the SuperCDMS experiment. "We're starting to develop a portfolio that spans multiple regions to cover a broad spectrum of dark matter candidates, and it feels to me like we could be on the verge of discovering something in the next round."

Lissie Connors is a Science Communication Intern at APS.

MARCH MEETING

Quantum Computing Scientists: Give Them Lemons, They'll Make Lemonade

BY SOPHIA CHEN

At the close of 2018, U.S. quantum computing researchers got their holiday wish. Following a six-month legislative process, President Trump signed the National Quantum Initiative Act into law. The law sets forth a plan to inject $1.2 billion of investment into quantum technologies. This expected infusion of cash, spread over the next five years, will fund the development of new quantum devices, building upon the existing prototype quantum computers from companies such as Google, Intel, and IBM.

Now, the hard part: developing a quantum computer actually capable of surpassing non-quantum technology. So far, researchers have only been able to demonstrate algorithms on their early devices that classical computers can still handle, such as simulating three-atom molecules. At this year's APS March meeting in Boston, researchers discussed bite-size projects for the era ahead. They've already come up with a new acronym: NISQ, for Noisy Intermediate-Scale Quantum Computing.

Researchers still loosely define the term, roughly describing a NISQ computer as one that doesn't have "full-blown error correction," says quantum algorithm researcher Kristan Temme of IBM. All existing quantum computers fall under this description. They can't execute arbitrarily long sequences of logic gates due to hardware limitations. In other words, a naively designed algorithm will result in the hardware delivering the wrong final answer.

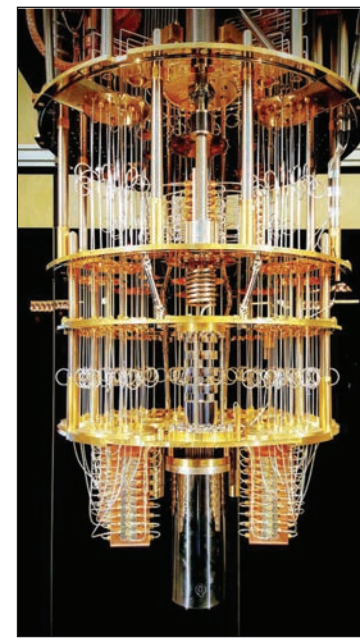
Imagine programming the supercomputing qubits in IBM's computer into an initial quantum state, where each qubit corresponds to some superposition of 1 and 0. To complete some computing task, you would apply microwave pulses corresponding to a sequence of logic gates to manipulate the values of each qubit. However, errors will occur during this process, like a qubit winding up in the wrong superposition. But unlike in conventional computing, which corrects errors by coding redundant data, quantum states cannot be duplicated. And while experts have begun designing special quantum error correction algorithms, they have not yet successfully executed their ideas on hardware. Without error correction, the qubits end up in a final state that does not correspond to what the algorithm developer intended.

These errors arise from many different sources, says Temme. It could be that a logic gate happens to perform badly. The best logic gates perform operations correctly just shy of 100 percent of the time, so in long algorithms, statistical errors add up. In addition, sometimes a microwave pulse will alter the value of a qubit that is not supposed to be part of an operation, a scenario known as crosstalk. On top of these errors, the qubit's information also suffers from a short lifespan. The qubit's quantum-ness, or coherence, only lasts up to about 100 microseconds.

So NISQ researchers have chosen pragmatism: to accept these flawed machines, for now. "The question is, can you still do something interesting with those devices?" says Temme.

He's betting yes. In the last couple years, Temme and his colleagues have published several papers on how to make the most of what they have. The general strategy in the NISQ era is to design algorithms that take the hardware's quirks into account. For example, Temme recommends designing algorithms that use short sequences of logic gates, known as short-depth circuits. "Typically, you go up to a fraction of the coherence time, say 50 percent, and then you count how many gates you can fit in," he says.

Another approach is to design a hybrid algorithm that uses both classical and quantum computers, says algorithm researcher Jarrod McClean of Google. One popular algorithm with chemistry applications approximates the ground state of a molecule. To start, the user first programs an approximation of the ground state into the qubits. The quantum computer improves the initial guess by applying a sequence of logic gates that depends on a set of parameters, analogous to weights in a neural network. Then, the state is fed to a classical computer, which then instructs the user how to tweak those weights in the quantum computer. Then, the entire process iterates in an automated process.



IBM's quantum computers attempt to tackle the problem of noise and error correction. IMAGE: IBM

McClean is trying to figure out how optimize that initial guess for the ground state. Some researchers choose a random state and set of logic gates to start with, because it is more forgiving on the hardware. But this strategy can get buggy, as McClean and his colleagues reported in *Nature Communications* last year. Some random guesses can cause the quantum computer to get stuck and they have identified ways to avoid the logjam.

Researchers are also looking at whether NISQ computers can benefit classical machine learning algorithms. Temme's group has uncovered some tantalizing hints, published in *Nature* in March, that a NISQ machine could be better at classifying certain types of data. They engineered a classical data set to contain patterns that two qubits of a quantum computer were able to classify into two groups easily. While the classification task was simple enough for a classical computer to handle, Temme says the demonstration is a step toward the potential advantage of NISQ.

On the hardware side, researchers still can't tell which type of qubit—superconducting

QUANTUM CONTINUED ON PAGE 6

KAVLI CONTINUED FROM PAGE 1

De Gouvêa proposed several possible ways the neutrino gets its tiny mass: Neutrinos interact with the Higgs Boson much more weakly than other particles; a different Higgs Boson exists that imparts mass just to neutrinos; or neutrinos get their mass from something else besides Higgs bosons. Which answer is correct partially depends on uncovering whether neutrinos are Dirac fermions, with distinct antiparticles like the rest of the fermions in the Standard Model, or Majorana fermions, meaning the particles are their own antiparticles. De Gouvêa cited the need for more data and more experiments to be able to further understand the properties of neutrinos.

Fortunately, experiments are currently ongoing, gathering data in hopes of solving the mystery of neutrino mass. Mertens described three methods of determining neutrino mass—cosmology, direct measurements, and neutrinoless double beta decay—and described the status of experiments in each of these areas. Cosmological probes of astrophysical phenomena, like the cosmic microwave background and formation of galaxies, have already helped to set some upper limits on neutrino mass, and future projects, like the EUCLID space telescope and the BiCEP Array, aim to directly measure neutrino mass. However, Mertens offered a caveat: A number of uncertainties may impact precision in cosmology, meaning lab experiments are still necessary.

One such lab-based method of inquiry is detection of neutrinoless double beta decay, in which two neutrons transform into protons inside a nucleus. Only electron emission occurs (in contrast to normal beta decay) because the neutrinos annihilate each other before they can be emitted. Detecting such decays would indicate that neutrinos are Majorana fermions, but since they only occur about once a year per ton of material, they require extremely large, low-background detectors, like GERDA at the Gran Sasso Laboratory in Italy. Studying the kinematics of single-beta-decay may provide a method of direct measurement of neutrino masses, and results are expected within the year from the KATRIN experiment that will provide an improved neutrino mass result.

Although neutrinos aren't well understood themselves, they do have some known properties, like electric neutrality and very long mean free paths, that make them unique cosmic messengers for studying other cosmic phenomena, according to Santander. With large enough detectors, neutrinos can be used to help determine the source of cosmic rays, which have trajectories distorted by magnetic and electric fields and thus can't be reliably traced to their origin.

Susanne Mertens

Marcos Santander

To detect neutrinos visiting from the cosmos, telescopes have been constructed under water or ice, such as Baikal NT-200 located in Lake Baikal, Russia, and more recently IceCube, embedded in a cubic-kilometer of a South Pole glacier. Santander shared the ingredients for neutrino astrophysics: wide sky coverage, good angular resolution, good timing resolution, and sensitivity to the flavor of neutrinos. Using this recipe for success, IceCube successfully detected a high-energy blazar emission of neutrinos, pinpointing an astrophysical source of neutrinos and cosmic rays in September 2017. Larger, next-generation experiments, like IceCube 2, will improve sensitivity to continue using high-energy neutrinos to study the cosmos.

The April Kavli Session can be viewed on the APS YouTube channel at youtube.com/apsphysics.

BUDGET CONTINUED FROM PAGE 4

As president of UK's Association of Women in Mathematics and Physics, I am also eager to see science students thrive in the field, especially women, who only represent 28 percent of all workers in STEM careers, according to a study by the National Science Foundation.

Additionally, I want to continue to push for a cultural change in STEM, encouraging more women and underrepresented minorities to consider research careers. STEM is an exciting career choice that pays huge dividends. The median salary for workers with a bachelor's degree is $75,948, compared with $55,695 for non-STEM fields, according to a Pew Research Center study.

Other students share my love of science, but they, too, are concerned about their futures as the federal funding issue once again hangs in the balance. I urge McConnell to do the right thing by using his position to support robust and sustainable science budgets.

Why? Science is a sure bet. History has proved that investing in scientific research has benefited the nation in countless ways. From the MRI to the internet to Doppler radar, federally funded research has led to myriad innovations that have positively impacted the lives of Americans.

Since World War II, economists have determined that more than half of the nation's economic growth can be traced to scientific discoveries, according to a report by the American Academy of Arts & Sciences.

Scientific research has also benefited the state of Kentucky. Hummingbird Nano Inc., a Nicholasville-based high-tech start-up company that began in 2012, traces its origins, in part, to support from a joint grant from the National Science Foundation and the Department of Education. The company, whose initial research took place at UK, manufactures components for industries that include telecommunications, biotechnology and aerospace.

I'm proud that UK has played an integral role in Hummingbird Nano's success, and I'm confident that other companies will follow suit, if Congress makes a commitment to continue to support federally funded research in the long term.

The first step toward that goal: raising the budgetary caps imposed under the Budget Control Act. Doing so will give me and other students the confidence we need to pursue our science careers, keep our state's economy strong, and ensure that the U.S. remains globally competitive in a world where other countries are ramping up their own research investments.

Dany Waller, president of the University of Kentucky's Association of Women in Mathematics and Physics, is a senior.

RIGHTS CONTINUED FROM PAGE 1

detained on suspicion or accusation of connections to Fethullah Gülen, who has been accused of orchestrating the coup attempt, or of being involved in the attempt itself, and 86,000 individuals were subsequently arrested. More than 6,000 academics have been dismissed from their jobs, with many forbidden from leaving the country or continuing work at any academic institution.

CIFS has closely followed two cases in particular, those of NASA researcher Serkan Gölge and physicist Ali Basaran. Gölge, a Turkish-American, was detained in July 2016 while visiting family and was convicted in February 2018 on terrorism charges related to the coup. He was sentenced to seven and a half years in prison. Basaran was also arrested in July 2016 but was released without any formal charges being made or a trial. Nevertheless, he has been fired from his university position and banned from doing scientific work or leaving the country, despite having had several offers for research jobs in the US. The APS has co-signed a letter to Turkish President Erdogan with AAAS and six other US scientific societies regarding this broader situation and has written separately about the Basaran case in particular to the President and to the rector of his former university, appealing that he be reinstated or allowed to travel to another country where he might continue his research.

Of course, sometimes it is US officials to whom we must make appeals. One recent example of this concerns Ahmed Abdelbasit. Basit came to the United States in 2016 seeking asylum after being tried in absentia by an Egyptian military court and sentenced to death based on charges that he claims were made in political retaliation for his pro-democracy activism. Having left a career as a doctoral student and professor in Egypt, he took up a job as a high school physics teacher at a school in New Jersey. Then, in early April of 2018, he was detained by ICE authorities and threatened with deportation to Egypt, where he was certain to be executed. APS, along with many other organizations including Human Rights Watch, called for his release and for him to be given asylum, which was finally granted in late August.

CIFS also functions as the Sakharov Prize selection committee, a particularly rewarding aspect of the job. The prize is named for Andrei Sakharov, who made sacrifices to his personal scientific career for his work on human rights, and is awarded to recognize "outstanding leadership and/or achievements of scientists in upholding human rights." It is currently awarded every other year, though we're hoping to make it an annual prize in the near future. The deadline for nominations for the 2020 Prize is June 3, and the nomination process is pretty straightforward—you can find details on the APS website.

And, what can young physicists do NOW?

Communication is the single most important thing: tell your colleagues, your professors, and your students about CIFS so that we can have as broad a reach as possible in monitoring human rights issues. Share with them why you think this work is important, and make yourself available to friends and colleagues in impacted countries who may not be able to report issues directly themselves for fear of reprisal. And tell us when you become aware of a human rights violation that impacts scientists or science students so that we can determine an appropriate course of action. Apply to serve on CIFS or on similar bodies of peer organizations, like the AAAS Science and Human Rights Coalition. Submit nominations for the Sakharov Prize by June, and spread the word about it to colleagues and professors who might know someone who would be a candidate. And as your career develops, seek out opportunities to host academics seeking temporary refuge through organizations like Scholars at Risk or the IIE Scholar Rescue Fund.

Whether you continue your career in academia or in data science, in engineering or in industrial physics, I hope that you will seek out ways to contribute to APS' mission broadly, and to the efforts of our Society and others like it to support and protect human rights in particular. Let's work together to ensure that everyone can enjoy the benefits of scientific progress.

Christopher A. Watson is a physicist at Northrop Grumman Corporation and has served as a member of CIFS since January 2018. He prepared his remarks at the March Meeting in his personal capacity; the views expressed are his own and do not necessarily represent the views of Northrop Grumman Corporation.

QUANTUM CONTINUED FROM PAGE 5

loop, ion, neutral atom, quantum dot—works best. For one, they still haven't settled on clear metrics to compare different devices. Many popular articles quote qubit number to represent how powerful the computer is, but this shorthand can be misleading because it doesn't consider the quality of each qubit, says Temme. A finely tuned 10-qubit computer could be more powerful than an error-ridden 50-qubit one, for example. IBM has developed a metric called "quantum volume," which takes a variety of factors such as qubit number and gate fidelity into account, but other researchers have not adopted it widely.

But with the promise of new funding, you can expect an animated field in the next few years. McClean thinks that the era of noisy quantum computers will last a minimum of five years, depending on when researchers can successfully implement error correction. Meanwhile, they'll make do with what they have.

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

BIPM CONTINUED FROM PAGE 2

of measurements across essentially the entire industrialized world.

The activities of the BIPM are overseen by the International Committee for Weights and Measures, or CIPM (Comité International des Poids et Mesures). Effectively, CIPM operates as BIPM's board of directors, and is comprised of 18 expert members, each from a different member state, to mirror the number of original signatories of the 1875 Metre Convention. Countries currently represented in CIPM include Argentina, Australia, Canada, China, France, Germany, Italy, Japan, Mexico, the Netherlands, Romania, Russia, Singapore, South Africa, South Korea, Switzerland, the United Kingdom, and the United States.

Chemist Willie E. May is the outgoing US representative on CIPM, and Vice President of the committee. As is traditional for the CIPM member from the US, May also served as the Director of the US National Institute of Standards and Technology (NIST) under President Obama after an impressive 45-year career with the institute. (James Olthoff, the NIST Associate Director for Laboratory Programs was elected to CIPM Membership in November 2018 and succeeded May as the US representative on March 20.)

May says that the impending update to the SI system is much more sweeping than just the redefining of previously-arbitrary units: It represents a comprehensive shift from a "classical" to "quantum" SI system, that is "tying metrology to the fundamental physics, to quantum phenomena, to fundamental constants that we lock in place and link to equations." In this new system the base units lose their special status (though they will still be called "base units" out of tradition) because virtually all units will be interlinked via one or more of the SI system's seven foundational constants: the speed of light, Planck's constant, elementary charge, the hyperfine transition frequency of cesium-133, Boltzmann's constant, Avogadro's constant, and the luminous intensity of monochromatic radiation of frequency 540 x 10^{12} hertz. Specifically, the kelvin will be defined in terms of Boltzmann's constant, the ampere in terms of the elementary electric charge, the mole in terms of Avogadro's constant, and the kilogram in terms of Planck's constant.

Importantly, says May, a quantum SI system implies that base units can have experimental realizations, which is impossible in artifact-based metrology (that is, physical objects like standard weights). After all, artifact constants are anything but constant. To this end, the most famous artifact constant—Le Grand K, a cylinder made of platinum alloy under lock and key in Paris—was observed to be diverging in mass from other "daughter" prototype kilograms on the order of one part in 10^7. May recalled that this was one of the last straws leading BIPM to resolve to modernize the system.

Redefining units is not a new endeavor for BIPM. Most notably, BIPM has redefined the original arbitrary meter twice in its history: 1960 saw the redefinition of the meter in terms of the wavelength of the orange-red line of the krypton-86 atom, and it was redefined again in 1983 to its present quantum SI definition in terms of the speed of light.

On whether other aspects of SI are likely to be tweaked in the future, May noted that the new system that will soon take effect is intended "essentially for eternity, as far as we can comprehend," adding, "they are constants, after all."

Of course, that's not to say that all issues in the world of measurement science are solved with the updating of the SI system. May identified biological measurements and issues regarding reproducibility of data as the "next frontiers" of measurement.

Biology is a challenging domain for measurement scientists because, unlike chemistry and physics, where quantitative measurements reign supreme, biology is a "different universe." There is an added (and perhaps even greater) emphasis on qualitative factors—properties of proteins, nucleic acids, and cells, how they interact with one another, and the emergent functional properties that arise from complex networks of these components. To parse these issues, BIPM's working group on Biometrology formed new subdivisions in 2015 to determine frames of reference for the metrology of cells, nucleic acids, and proteins.

As for reproducibility, May alluded to the infamous replication crisis, pointing out that repeating and reproducing results is increasingly difficult in many areas of science—particularly medicine, biology, and the social sciences. This is not currently an active focus area for CIPM, but the organization may eventually want to weigh in since replication is such a fundamental aspect of measurement.

"Measurements affect all of us in some way," noted May, reflecting on the importance of measurement science. "It sounds trivial, but measurements drive innovation and our quality of life worldwide. Our units define the processes we use every day, and somebody has to oversee that process."

The author is a freelance writer in Helsinki, Finland.

HARASSMENT CONTINUED FROM PAGE 1

behavior of a sexual nature that creates an uncomfortable or hostile environment. It comes in various forms, both subtle and overt, but three specific types were considered in the Aycock *et al.* study. "Sexist gender harassment" describes hostile or insulting remarks and actions based on one's gender, such as saying women cannot do physics. By contrast, "sexual gender harassment" refers to sexual remarks or conduct, like commenting on the shape of a woman's body. A third form of sexual harassment is unwanted sexual attention, such as requests for sexual favors or unwanted touching.

Unfortunately, these behaviors are entrenched within societies around the world, and they persist because of permissive institutions, inadequate reporting mechanisms, and the normalization of sexual violence [3]. To change this culture, we need to first assess where we are. Studies of international academic environments suggest that sexual harassment is common [3–5], with as many as 70% of women reporting sexual harassment experiences. Students are most likely to experience harassment by their peers, but the perpetrators can also be faculty and staff [6]. Sexual harassment is often pervasive and continuous: most victims have more than one experience and from more than one person [3].

Despite this extensive scholarship, many people are unaware of the toll sexual harassment takes on its victims. Experiencing sexual harassment increases a woman's likelihood of leaving a STEMM career [3]. And for those women who do stick with their field, harassment hurts their career, economic standing, and well-being [7]. In short, unchecked harassment creates a drain on talent through lost work, lost ideas, and lost people [3].

Understanding the extent and effect of sexual harassment for physics undergraduates is essential because this is the first stage of becoming a physicist. CUWiP are a collection of simultaneous regional meetings run by APS to encourage women to stay in physics. In their study, Aycock *et al.* collected online surveys from 464 female CUWiP attendees—roughly 5–10% of the female undergraduate physics majors in the US at the time [2]. The students were asked if they had experienced sexist gender harassment, sexual gender harassment, or unwanted sexual attention "in the context of physics"—such as in a physics lab, classroom, or at a physics department event. The researchers then analyzed the relationship between these experiences and two variables often correlated with career persistence. One is a "sense of belonging," the extent to which one feels connectedness to or identification with a given community. The other is the "imposter phenomenon," where one largely attributes his or her success to luck, hard work, or preferential treatment rather than ability.

Aycock *et al.* found that experiencing sexual harassment correlated to a negative sense of belonging and an exacerbated sense of the imposter phenomenon. Three-quarters (74.3%) of respondents experienced at least one form of sexual harassment; nearly half (47.9%) experienced multiple forms. Of the women experiencing harassment, 91.3% experienced sexist gender harassment, 34.2% experienced sexual gender harassment, and 32.6% experienced unwanted sexual attention. The findings align with a 2016 study that demonstrated the prevalence of sexual harassment of graduate women in physics [8]. Using regression models, Aycock *et al.* found that only sexist gender harassment was associated with a deteriorated sense of belonging. However, respondents were more likely to attribute their success to hard work, luck, or external perceptions—instead of ability—if they had experienced either sexist or sexual gender harassment.

Does sexual harassment inhibit women from choosing physics as a long-term career, as these results suggest? That's a question worth asking. After decades of effort to bring more women into physics there has been little traction: only about 20% of physics degrees at all levels go to women. Aycock *et al.* recognize that surveys provide only one step towards assessing the damage from sexual harassment and that further study is needed to unpack their findings. For example, we would learn more by asking women who have left physics why they did so.

Studies such as this one are a wake-up call to all members of our community to advocate for change. An effective step can be as simple as calling out problematic behavior. For example, the #MeToo movement on social media—set in motion by activist Tarana Burke in 2006—has been adopted by academics to call out sexual harassment (#AcademiaToo). When bystanders confront a harasser, victims are often empowered to do the same. Considering that workplaces with high incidences of sexual harassment tend to also be uncivil and disrespectful [9], addressing sexual misconduct may therefore improve the culture for everyone.

When sexual harassment goes unchecked, physics loses great people, great minds, and great potential. It's worth noting that sexual harassment disproportionately affects people of color, people with disabilities, and members of the LGBTQ+ community [3]. This may partially explain why the physics community has long been male dominated, and is disproportionately able-bodied and white [10]. It's up to all of us to see the culture as it truly is, acknowledge sexual harassment as an ingrained problem, and take steps to ensure that all physicists have a welcoming and respectful place to work.

References

K. B. H. Clancy, R. G. Nelson, J. N. Rutherford, and K. Hinde, "Survey of academic field experiences (SAFE): Trainees report harassment and assault," *PLoS ONE* **9**, e102172 (2014).

L. M. Aycock, Z. Hazari, E. Brewe, K. B. H Clancy, T. Hodapp, and R. M. Goertzen, "Sexual harassment reported by undergraduate female physicists," *Phys. Rev. Phys. Educ. Res.* **15**, 010121 (2019).

Sexual harassment of women: Climate, culture, and consequences in academic sciences, engineering, and medicine, edited by P. A. Johnson, S. E. Widnall, and F. F. Benya (The National Academies Press, Washington, DC, 2018) [Amazon][WorldCat].

Change the course: National report on sexual assault and sexual harassment at australian universities(Australian Human Rights Commission, Sydney, 2017).

Power in the academy: Staff sexual misconduct in UK higher education (National Union of Students, London, 2017).

M. N. Rosenthal, A. M. Smidt, and J. J. Freyd, "Still Second Class: Sexual harassment of graduate students," *Psychol. Women Q.* **40**, 364 (2016).

L. Howe-Walsh and S. Turnbull, "Barriers to women leaders in academia: Tales from science and technology," *Stud. High. Educ.* **41**, 415 (2014).

R. S. Barthelemy, M. McCormick, and C. Henderson, "Gender discrimination in physics and astronomy: Graduate student experiences of sexism and gender microaggressions," *Phys. Rev. Phys. Educ. Res.* **12**, 020119 (2016).

S. Lim and L. M. Cortina, "Interpersonal Mistreatment in the Workplace: The Interface and Impact of General Incivility and Sexual Harassment," *J. Appl. Psychol.* **90**, 483 (2005).

What does a physicist look like? (Institute of Physics, London, 2016).

The author is a professor in the Department of Earth and Environmental Sciences at Michigan State University.

THE BACK PAGE

Striving for Realism, not for Determinism: Historical Misconceptions on Einstein and Bohm

BY FLAVIO DEL SANTO

Editor's note: This article is adapted from the winning entry in the APS Forum on the History of Physics. The full essay may be found at aps.org/units/fhp.

The most familiar fact about Einstein and quantum mechanics is that he just didn't like it. He refused to use the theory in its final form. And troubled by the fundamental indeterminism of quantum mechanics, he famously dismissed its worldview with the phrase "God does not play dice [1]."

This quote represents the core of a misleading portrait of Einstein as being incapable of accepting quantum mechanics (QM), a theory that he largely contributed to developing, and that "Einstein had turned, in the eyes of many working physicists, from revolutionary to reactionary, and his later views were considered curious at best" [2].

In recent years, however, the tide has turned in views of Einstein's contribution to QM. In what follows, I aim to clarify misconceptions of Einstein's ideas on determinism in relation to David Bohm who developed the first deterministic interpretation of quantum mechanics [3].

Kuhn [4] achieved a historiographical breakthrough in acknowledging Einstein to have been the real initiator of quantum physics (as opposed to Planck). In a famous paper in 1905, Einstein first proposed that light quanta (*Lichtquanten*) are physically real and he himself evaluated this contribution—the only case in his career—as "most revolutionary" [5].

The most drastic historiographical novelty is a reappraisal of Einstein's late critiques of quantum theory, mostly due to Fine [6] and Howard [7, 8], who pointed out that Einstein actually did not write the famous EPR argument against the completeness of quantum theory [9]. Einstein confessed to Schrödinger that the paper "was written [...] by Podolsky. [...] It did not come out in the end so well" [7].

Determinism, realism, and hidden variables

Classical physics gives deterministic predictions, and this invariably led many generations of physicists to believe that natural laws are *deterministic* relations [10]. However, a fixed cause-effect relation does not necessarily entail determinism (natural laws could be inherently probabilistic). Thus, while determinism implies causality, the inverse does not follow.

It was only with the onset of quantum physics that indeterminism became widely discussed. In 1900, in "an act of desperation," Max Planck used the stratagem of dividing into discrete packages the energy that light can exchange with a black body. It was Einstein who took quanta out of the domain of solely optical phenomena into matter [11] and, most remarkably, Einstein himself introduced genuine *randomness* in emission processes of single quanta of light [12,1]. But then, what was Einstein's uneasiness with quantum physics?

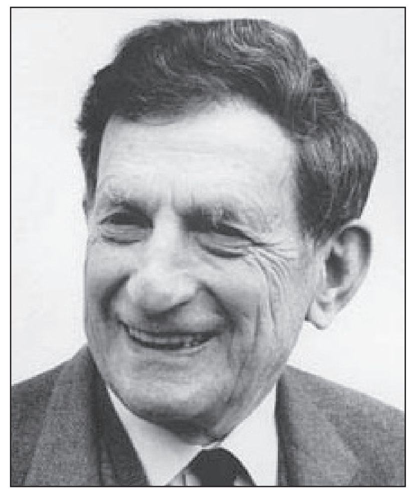
Since 1926, the main element of QM has been the wave-function (or quantum state), Ψ, a mathematical object that encompasses the "physics" of a system. The time evolution of this wave-function is described by the Schrödinger equation. Quantum formalism allows one to compute only the probabilities for different outcomes to occur in an experiment, and there is no way to predict which of them will turn up. QM gives, in general, only indeterministic predictions.

QM also challenges the concept of realism. While quantum objects show both an undulatory and a corpuscular nature, a specific choice of the experimental setting reveals either one or the other of these natures but never both. It thus seems that the choice of an *observer* actively influences the system under investigation, or as sometimes is put, the observer "realizes" reality upon measurement.

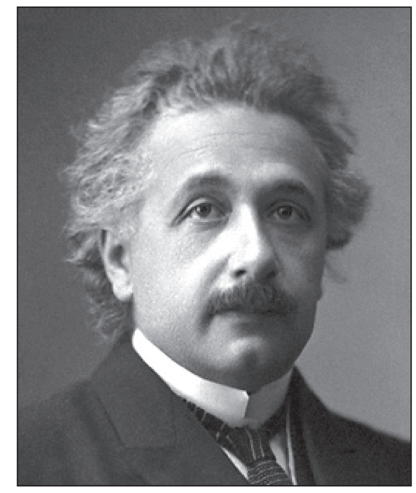
The current probabilistic interpretation of the Schrödinger equation was put forward by Max Born in 1926—for which he won the Nobel Prize—and, again, this was inspired by Einstein [13]. In his pivotal work, Born wrote:

This raises the whole problem of determinism. From the standpoint of our quantum mechanics, there is no quantity that could establish the effect of a collision causally in the individual cases; however, up to now, we have no clue regarding the fact that there are internal properties of the atom [...]. I myself tend to abandon determinism in the atomic world [14].

These "internal properties" that could in principle deterministically complete QM are referred to as *hidden variables*. Stimulated by Born's interpretation, Einstein himself devised a hidden variable model as early as 1927.



David Bohm



Albert Einstein

This model allowed one to determine, given the knowledge of certain *hidden* parameters, the actual trajectories followed by particles. In this paper, however, Einstein is reluctant to explicitly give a realistic interpretation to Ψ, because, as he noted before, a function living in a "many-dimensional coordinate space does not smell like something real" [8].

Einstein himself prevented his paper from appearing in print [15], and in the following years, he became increasingly critical towards any further attempt of synthesizing the quantum and wave conceptions. Even when American physicist David Bohm developed his celebrated deterministic *hidden variables* model [3] which reproduces all the predictions of QM, Einstein maintained that this was untenable. So, despite Bohm's model having virtually achieved the goal of Einstein's 1927 paper, the latter wrote to Born:

Have you noticed that Bohm believes...that he is able to interpret the quantum theory in deterministic terms? That way seems too cheap to me [16].

What we learn from Einstein's involvement in the hidden variable program is that his main concern was definitely not determinism. His own early incomplete attempts, and Bohm's consistent interpretation all retrieved determinism, however they were not enough for Einstein. The fact that they all relied on a wave-function living in a configuration space, made them despicable to Einstein, in so far as they clearly did "not smell like something real." Sacrificing a tenable form of realism was a too high price to pay for Einstein, even if determinism was so restored.

Popper put forth the view that physics is based on realism, but it is fundamentally indeterministic. In 1950, he presented his ideas on indeterminism in front of Einstein and Bohr. In discussions, Popper tried "to persuade [Einstein] to give up his determinism" [17]. Yet, later he stated:

The attribution to Einstein of the formula 'God does not play with dice' is a mistake. Admittedly, he was a strict determinist when I first visited him in 1950 [...]. But he gave this up [...]. Einstein was, in his last years, a realist, not a determinist [18].

Even Pauli maintained: *Einstein does not consider the concept of 'determinism' to be as fundamental as it is frequently held to be (as he told me emphatically many times) [...] Einstein's point of departure is 'realistic' rather than 'deterministic'[...]* [19].

Given Popper's aversion towards determinism, he also did not champion Bohm's interpretation. In the book that collects his mature views on foundations of QM, Popper indeed stated:

In spite of Bohm's realist and objectivist programme, his theory is unsatisfactory [...]. It is [...] bound, like all other deterministic theories, to interpret probabilities subjectively-[...] [20].

In an unpublished letter, however, Bohm firmly replies to Popper that, like Einstein, his main concern was realism and that determinism was used merely instrumentally:

I certainly think that a realistic interpretation of physics is essential. [...]. However, I feel that you have not properly understood my own point of view, which is much less different from yours than is implied in your book. Firstly I am not wedded to determinism. It is true that I first used a determinist version of [...] quantum theory. But later, [...] a paper was written, in which we assumed that the movement of the particle was a stochastic process. Clearly that is not determinism. [...] The key question at issue is therefore not that of determinism vs. indeterminism. I personally do not feel addicted to determinism, but I am ready to consider deterministic proposals, [...] if they offer some useful insights [21].

In conclusion, contrarily to the standard story, neither Bohm nor Einstein were staunchly committed to determinism and they would have accepted fundamental indeterminism in exchange for realism.

The author is at Institute for Quantum Optics and Quantum Information, Austrian Academy of Science, Vienna and the Basic Research Community for Physics (BRCP).

References

[1] Stone, D. A. (2013). *Einstein and the Quantum: The Quest of the Valiant Swabian*. Princeton University Press: Princeton.

[2] Sauer, T. (2013). In Sauer, T. and Wüthrich A. (eds.), *New Vistas on Old Problems*. Berlin: Edition Open Access, pp. 105-119.

[3] Bohm, D. (1952). *Physical Review*, 85(2), 166.

[4] Kuhn, T. (1978). *Black Body Theory and the Quantum Discontinuity: 1894-1912*. Oxford: Oxford University Press.

[5] Jammer M. (1992).In Tarozzi, G. (ed.). *Il paradosso della realtà fisica. Le interpretazioni dell'argomento di Einstein-Podolsky-Rosen.* Modena: Mucchi Editore.

[6] Fine, A. (1986). *The Shaky Game: Einstein, Realism and the Quantum Theory.* Chicago: University of Chicago Press.

[7] Howard, D. (1985). *Studies in History and Philosophy of Science Part A*, 16(3), 171-201.

[8] Howard, D. (1990). In *Sixty-two Years of Uncertainty* (pp. 61-111). Boston: Springer.

[9] Einstein, A., Podolsky, B., and Rosen, N. (1935). *Physical Review*, 47(10), 777.

[10] Falkenburg B., and Weinert F. (2009). In: Greenberger D., Hentschel K., Weinert F. (eds) *Compendium of Quantum Physics*. Berlin: Springer.

[11] Einstein, A. (1907). *Annalen der Physik*, 327(1), 180-191.

[12] Einstein, A. (1916). *Verhandlungen der Deutschen Physikalischen Gesellschaft*. 18: 318–323

[13] Pais, A. (1982). *Science*, 218(4578), 1193-1198.

[14] Born, M. (1926). *Zeitschrift für Physik*, 37, 863(2), 228.

[15] Belousek, (1996). *Studies in History and Philosophy of Modern Physics*, 27, 473-461.

[16] Baracca, A., Bergia, S., and Del Santo, F. (2017). *Studies in History and Philosophy of Modern Physics*, 57, 66-79.

[17] Popper, Karl R. (1976). *Unended Quest: An Intellectual Autobiography*. London: Routledge

[18] Del Santo, F. (2018). *Studies on History and Philosophy of Modern Physics*, 62, 56-60.

[19] W. Pauli letter to M. Born. In Born, M. (1971). *The Born-Einstein Letters*. New York: Walker and Company.

[20] Popper, K. R. (1982). Edited by William Bartley, III, *Vol. III of the Postscript to the Logic of Scientific Discovery: Quantum Theory and the Schism in Physics*. London: Hutchinson; Totowa: Rowman and Littlefield.

[21] D. Bohm to K. Popper *13.07.1984. PA, 278/2.* PA, Popper's Archives, Box/Folder: 278/2. AAU, Klagenfurt/Hoover Institution, Stanford. With the Permission of University of Klagenfurt/ Karl Popper Library.