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Physics

Reporting on Research from the *Physical Review* Journals

By Jessica Thomas

This July 14th, while France admires fireworks for its national holiday, the editors of *Physics* will open a bottle of champagne (maybe two) and celebrate the publication turning 10. While younger than most of the journals in the *Physical Review* collection—which celebrates its 125th birthday this year—*Physics* has covered a lot of ground and is now much valued by the physics community.

Like the "front half" of many print journals, *Physics* highlights newsworthy papers—in this case, from the *Physical Review*—providing context for results that would otherwise be obvious only to specialists. The difference is that *Physics* doesn't live inside any one journal, but instead exists as a separate online publication. And all the articles in it are free-to-read, with no journal subscription required.

125 YEARS

Why *Physics*? That was the question David Voss, the founding editor of *Physics* (now editor of *APS News*), asked in his first editorial. The answer then and now remains the same: to help physicists keep up with the field as a whole. Researchers understandably write their papers for other experts, using specialized language to concisely convey their results. But would you know the meaning of "charmoniumlike structure" if you weren't a particle physicist or "valley degeneracy" if you didn't study semiconductors? Even if you had an encyclopedic mind, digesting the more than 300 papers per week published in the *Physical Review* journals would be a tall order.

Physics therefore serves as a filter, offering one or two new stories per day on papers our editors think the community will want to know about. Our storytellers are experts, journalists, and *Physics* staff writ-

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VOTE 2018 APS General Election

Members should watch for an email with voting instructions. Those who are elected will begin their terms on January 1, 2019. Information on voting, and the candidates' full statements and biographical information, are available at **go.aps.org/aps-vote-2018**

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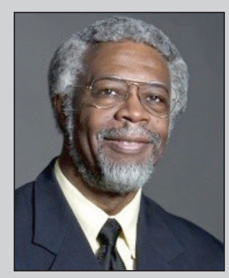

Edward (Rocky) Kolb
University of Chicago

Voting will run from July 2 until August 10.

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Getting a Running Start in Physics

By Leah Poffenberger

In February 2016, Karna Morey was a high school sophomore at track practice when his coach brought him an article about a new physics discovery: the first detection of gravitational waves by the Laser Interferometer Gravitational-Wave Observatory (LIGO). Now a senior at the prestigious North Carolina School of Science and Mathematics (NCSSM), Morey is contributing to gravitational wave research himself.

At the 2018 APS April Meeting, Morey presented his work on predicting the type of gravitational waves that will be measured by the future Laser Interferometer Space Antenna (LISA). The work was done in collaboration with Zach Nasipak and Charles Evans at the University of North Carolina-Chapel Hill, and Jonathan Bennett at NCSSM. "As part of my research, I looked into making potential modifications that will further the accuracy of the existing models," said Morey. "Compared to the previous models [ours] actually performed a lot better than we thought it would."

This kind of gravitational wave

Karna Morey

prediction is crucial for future detections: theoretical models become templates that possible gravitational–wave events can be compared to. Morey's improved modeling technique could contribute to LISA's detections of gravitational waves caused by extreme mass ratio inspirals—a phenomenon where two black holes, one much bigger than the other, orbit around one another, sending out gravitational waves.

These waves aren't detected by LIGO on Earth, but LISA, which will be constructed in space and scheduled for launch in 2034, may be able to spot them. To gain the

MOREY continued on page 4

Physicists for Human Rights

By Amanda Babcock

2018 APS April Meeting, Columbus, OH—This year's APS Andrei Sakharov Prize was presented during the April Meeting Awards Ceremony on Sunday, April 15th. The honor is awarded every two years to one or more scientists in recognition of their leadership and achievements in advocating for human rights. This year's award showcased two individuals whose work has spanned decades: Ravi Kuchimanchi and Narges Mohammadi.

Kuchimanchi was in attendance at the awards ceremony. However, Mohammadi is currently imprisoned in Iran. Nayereh Tohidi accepted the award on her behalf. Tohidi is a professor of gender and women's studies and director of Middle Eastern and Islamic studies at California State University, Northridge.

Both Kuchimanchi and Tohidi spoke in a session Monday morning. Tohidi read an open letter from Mohammadi that she translated from Persian.

A river in India

At the beginning of Ravi Kuchimanchi's work in human rights is the story of a river in India. In the summer of 2000, after completing his postdoc, Kuchimanchi volunteered with Save Narmada, a movement to protect the villages of the Narmada valley from imminent flooding caused by nearby dam construction. The villagers said the flood waters would affect many more people than the government predicted.

Kuchimanchi was able to confirm that not only were the flood levels issued by the authorities incorrect, but they were off by a full three meters. This meant disaster for tens of thousands of people, driving them from their homes. Even worse, the incorrect levels would leave many without the right to rehabilitation funding provided by the government. Bridging this disconnect between the government and the local people would become the basis for Kuchimanchi's work with the Association for India's Development (AID).

Kuchimanchi founded AID while a grad student at the University of Maryland. "We had a learning attitude," Kuchimanchi said. And the learning curve was steep. "We thought that either AID would exponentially grow, in which case we would spend all our lives on it. Or it would exponentially decay, in which case we wouldn't have to put in much effort," he said. "As it turns out, it exponentially grew."

In the twenty-seven years since its founding, the organization has grown to at least 800 volunteers and more than 100 projects organized by 36 chapters across the United States. The work has absorbed most of Kuchimanchi's life. He says he is unable to focus on both human rights work and physics research at the same time. The concentration required of physics makes any other consideration difficult, but he emphasizes

Ravi Kuchimanchi

Narges Mohammadi

the importance of finding time for both. When not working for caste parity in India, he is conducting research on parity in physics.

Kuchimanchi shows deep compassion for the people he is working to help. One case he highlighted is the ongoing agrarian crisis in India. "In the past 10 years, 150,000 farmers have committed suicide in India." He described crippling debt from loans taken out to buy pesticides, fertilizer,

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Revised 06/15/18

Spotlight on Development

Mini-grants Make Room for New Ideas in Outreach

By Leah Poffenberger

For many people, engagement with physics ends when they walk out of a high school or college physics classroom. But a science-literate public is important to informed decision-making in an increasingly technological world.

Each year, APS awards its Public Outreach and Informing the Public Grants, often called mini-grants, to fund projects aimed at engaging all ages, from kindergarteners to senior citizens. These selected innovative, original, and sometimes experimental projects can receive up to $10,000 to kick-start public outreach campaigns to educate—and often amaze—their audiences.

Since its conception in 2011, the public outreach grants program has supported a wide variety of projects, from physics videos to museum exhibits to a physics-based escape game (which involved locking willing participants in a fictional laboratory and where they used physics-based clues to win the game and escape). Each group that receives a grant is required to present the results of their projects at the APS March Meeting to share what worked—and what didn't—which can help future outreach endeavors.

Funds for the mini-grant program jointly come from the National Science Foundation (NSF) and APS and are awarded based on project proposals. However, the 2018 mini-grants may be some of the last: NSF funding is running out and won't be renewed for this program. In the coming months, APS will be looking for ways to replace external funding and continue supporting innovative outreach efforts. (For information about ways you can help, please contact Irene I. Lukoff, APS Director of Development: lukoff@aps.org or 301-209-3224.)

Projects are selected for funding by APS Head of Public Outreach Rebecca Thompson and the APS Committee on Informing the Public, a group of public outreach and engagement experts from a variety of backgrounds and institutions. This year, eight proposals

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Small muon detectors will allow visitors to Letchworth State Park in New York to learn about cosmic rays. The program was funded by APS outreach mini-grants. These detectors were originally designed by CosmicWatch.

Education and Diversity Update

2019 PhysTEC Conference. Save the date!

The conference will be on Saturday, March 2 - Sunday, March 3, 2019 at the Westin Boston Waterfront Hotel in Boston, MA. For more on the event, check the website, which will be updated as information becomes available: phystec.org/conferences/2019/

This Month in Physics History

June 30, 1908: The Tunguska Event

On the morning of June 30, 1908, the sparse populace—mostly indigenous Evenki natives and Russian settlers—in a remote region of Siberia saw a bright column of light streak across the sky. Ten minutes later, there was a flash of light and a burst of sound, accompanied by a powerful shock wave strong enough to break windows hundreds of miles away. A farmer named Sergei Semenov was one of the few eyewitnesses to the entire event while having breakfast just 40 miles from the epicenter. "Suddenly the sky appeared like it was split in two, high above the forest, the whole northern sky appeared to be completely covered with blazing fire," he recalled. "At that moment, I felt a great wave of heat as if my shirt had caught fire." Then there was loud bang and a "mighty crash," and Semenov found himself thrown several feet from his chair.

Leonid Kulik

The impact showed up on multiple seismometers around the world, in some places measuring as strong as 5.0 on the Richter scale. For several days after, the night skies glowed over Asia and Europe. In the U.S., both the Smithsonian Astrophysical Observatory and the Mount Wilson Observatory measured a sharp decrease in atmospheric transparency that lasted for months, because of all the suspended dust particles in the air after the blast.

Fallen trees mark the site of the Tunguska asteroid impact

While the spectacular event certainly garnered its share of media coverage, particularly by Russian newspapers, it would be more than a decade before the first scientific expedition succeeded in analyzing the blast site. Russian mineralogist Leonid Kulik led a team to the Podkamennaya Tunguska River basin in 1921. He was conducting a survey for the Soviet Academy of Sciences, and heard the many local accounts of the explosion. Believing it had been caused by a giant meteorite, he convinced the Soviet government to fund an expedition to the region to possibly salvage any meteoric iron. But the harsh conditions of the Siberian wilderness foiled his team's efforts to reach the blast area.

Kulik's team made the arduous journey to Tunguska in 1927, hiring local Evenki hunters to guide them to the impact site. He was surprised, upon arrival, to see that there was no impact crater. However, a five-mile swath of trees was scorched, all their branches blown off, yet still standing upright. A similar phenomenon occurred in Hiroshima, Japan, after the detonation of a nuclear bomb in 1945, and scientists have estimated the Tunguska event released the energy equivalent of about 185 such bombs. Further away, trees had fallen away from the center of the blast in a radial pattern.

Over three successive expeditions, Kulik noted several small "pothole" bogs that he assumed were meteorite craters, but when he finally drained one of the bogs (dubbed the "Suslov crater"), an old stump at the bottom proved it could not be such a crater. His team also took several aerial photographs; although the negatives were destroyed in 1975 (part of a Soviet initiative to get rid of hazardous nitrate film), the prints were carefully preserved for future study.

The local natives attributed the blast to Agda, the god of thunder, to punish the Evenki tribe for their internal disputes. They proclaimed the blast site a sacred space and guarded it zealously from outsiders—one reason it took nearly two decades before the first scientific expeditions arrived. Scientists have narrowed the likely candidates down to two possibilities over the ensuing decades.

Some scientists concluded the object that exploded in the atmosphere was a comet (possibly the Comet Encke). This notion was first proposed in 1930 by British astronomer F. J. W. Whipple—a hypothesis supported in part by the glowing skies observed after the blast. The dust and particles that caused the glow could have been debris from the disintegrated comet's tail. A 2010 expedition studied the Tunguska site using ground-penetrating radar and found evidence that a huge piece of ice formed the Suslov crater, in keeping with the comet hypothesis. Critics of this idea argue that a comet traveling through the atmosphere at such a shallow trajectory would have disintegrated well before it entered the lower atmosphere. Comet proponents have countered that it could have been an extinct comet, with a stony mantle that enabled it to remain intact until it reached the lower atmosphere.

Today there is strong consensus that the body causing the Tunguska event was most likely an asteroid-like object, a theory bolstered in 2001 by a study showing an 83% probability (based on orbital modeling of the atmospheric trajectories of the Tunguska object) that the object came from the asteroid belt and followed an asteroid-

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News from the APS Office of Government Affairs

On Capitol Hill, Students Extol Value of APS Bridge Program

By Tawanda Johnson

In 2009, Brian Zamarripa Roman found himself facing difficult times. After discovering his passion for physics as a high school junior, his father suddenly passed away, leaving Zamarripa Roman to help his mother raise his three siblings while attending college at the University of Texas at El Paso.

"I had to work at Burger King and sell used car parts to help make ends meet for my family," he recalled of his struggle. "I was in an engineering program and ended up with a D in the first design course. I switched my major to physics and excelled and went in search of a Ph.D. But when graduation came around, I was distracted. I had missed the deadlines to apply for the [Graduate Record Exam] and for graduate schools."

Zamarripa Roman and two other students who participate in the APS Bridge Program (APS-BP) recently shared their inspiring stories with members of Congress on Capitol Hill. They met with Rep. Barbara Comstock (VA-10th), Rep. Joaquin Castro (TX-20th), and Sen. Todd Young of Indiana, and visited other congressional offices as well.

Part of the APS education and diversity activities since 2012, the Bridge Program is an effort to increase the number of physics Ph.D.s awarded to underrepresented minority students, including African Americans, Hispanic Americans, and Native Americans. APS aims to achieve this goal by creating sustainable transition programs and a national network of doctoral-granting institutions to support and mentor students and enable them to successfully complete Ph.D. programs.

Qualified applicants are students who either missed the deadlines for applying to graduate school or were rejected from every program to which they applied but showed promise for acceptance. In both cases, the program enables students to retake coursework or gain valuable research experience to become better prepared for physics Ph.D. programs.

Members of Congress and their staff were delighted to hear how the Bridge Program had positively impacted the students' lives. "They all were very receptive and interested in hearing our stories," said Zamarripa Roman. Added Francis Slakey, chief government affairs officer for APS, "It's important for Congress to hear these students' stories and see how lives are transformed by a program supported by the National Science Foundation."

In Comstock's case, she was so engaged during the meeting that she delayed the start of another meeting on her schedule to spend more time talking to the students. She also snapped a picture with the students and posted it on Twitter.

Since its inception, a primary goal of the Bridge Program has been to increase the numbers of physics Ph.D.s awarded to underrepresented minority students each year by 30 (the number needed to make the fraction of physics Ph.D.s awarded to underrepresented minorities equal to the fraction of bachelors degrees awarded to underrepresented minorities.)

"During the past six years, the program has placed more than 150 students into supportive graduate programs. In 2017 alone, 46 students were placed into graduate programs," said Erika Brown, APS-BP manager. "A number of our students have been awarded competitive fellowships through their institutions and various government funding agencies. Several have even published first-author papers in the top journals of their respective fields, and of science as a whole."

Brown added, "Our student retention rate ranges between 80% and 85%, which is higher than the national average for physics Ph.D. programs (about 60%). We are so pleased with the success of our students, and are thrilled by the prospect of our first Ph.D.s graduating in the next year."

Zamarripa Roman's life took a turn for the better after he applied to the APS-BP and was accepted at

CAPITOL HILL continued on page 5

L-R: Dylan Smith, U.S. Rep. Barbara Comstock (VA-10th), Michelle Lollie and Brian Zamarripa Roman were all smiles as they discussed the positive impact of the APS Bridge Program.

Physicist Pinpoints Urban Gunfire

By Katherine Kornei

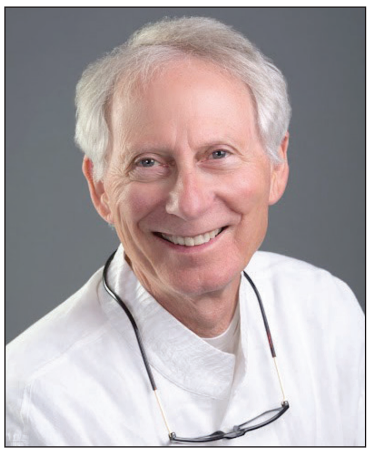
Robert Showen remembers working in Menlo Park, a tony city in California adjacent to East Palo Alto, the murder capital of the nation in the 1990s. It was then that the space physicist realized his acoustics work at Stanford Research Institute might have utility far beyond academia. "I thought we could tell the police where gunfire occurred just using our knowledge of the propagation of acoustic waves," he says.

In 1996, Showen founded ShotSpotter to do just that. After getting permission from a city's government, the company installs breadbox-sized acoustic sensors on buildings on telephone poles to record sound. When a noise resembling gunfire is picked up, the signal is sent to ShotSpotter's review center in Newark, California, where acoustic experts analyze the noise. Based on differences in the timing of the signal recorded by different sensors, the ShotSpotter system can pinpoint the location of the gunfire with a precision of better than 25 meters. This technique is known as multi-lateration, although it's more commonly referred to as triangulation. Less than a minute after the gunfire occurs, ShotSpotter alerts local first responders like police.

ShotSpotter's acoustic data can also reveal more than just a shooter's position. Roughly half of all gunfire events consist of multiple shots, says Showen, in which case ShotSpotter's sensors can compute both the velocity of the shooter and the direction he or she is moving. The police can use this information to decide how many vehicles to send to the scene, which can help keep officers safe.

ShotSpotter's sensors were first installed in Redwood City, California. Today, the technology can be found in over 80 cities across the United States and several sites overseas. In 2016, the company analyzed over 70,000 incidents of gunfire. The data reveal an alarming trend: citizens report roughly only 20% of the gunfire picked up by ShotSpotter sensors. People become accustomed to gunshots, says Showen. It's this acceptance of violence that Showen and his team are trying to combat.

Showen and his colleagues have also used ShotSpotter technology to curb illegal poaching. In 2012, a team installed a dozen ShotSpotter acoustic sensors in South Africa's



Robert Showen

Kruger National Park to hone in on gunshots fired by rhinocerous poachers. Rhinos are killed for their horns, which are prized in traditional Chinese medicine. One night, the system picked up two shots. Using the accurate location of the gunfire, local officials found a set of tracks that led them to the poachers.

One of ShotSpotter's ongoing technological challenges in urban settings is that buildings can both block and refract sound waves, says Showen. It'd be useful to get three-dimensional maps of cities to train our detection algorithm, he says.

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

AI Makes Inroads in Physics

By Sophia Chen

2018 APS April Meeting, Columbus, Ohio — These days, artificial intelligence (AI) drives many aspects of our lives. It powers Google and Facebook, and it's even found a foothold in medicine to help doctors make diagnoses.

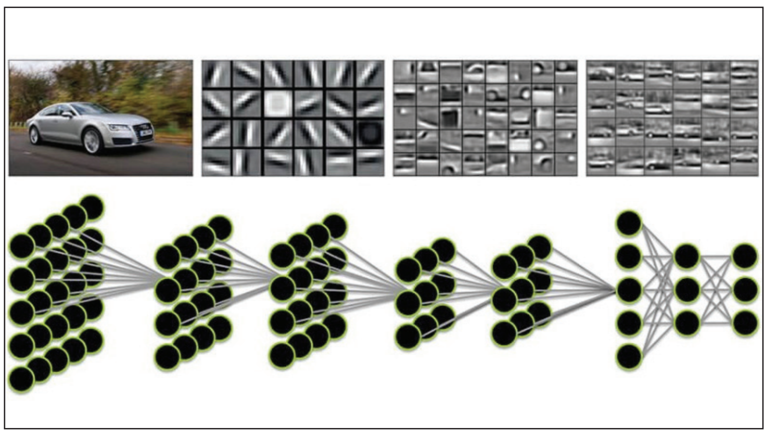
But despite its budding ubiquity everywhere else, AI has been a hard sell in physics.

Take Eliu Huerta of the University of Illinois at Urbana-Champaign, for example, who is part of the Laser Interferometer Gravitational-Wave Observatory (LIGO) collaboration. It took Huerta about a year to convince the rest of the collaboration that AI could speed up LIGO's analysis of gravitational wave candidates "It was a journey," he told *APS News*. This February, Huerta and his graduate student, Daniel George, published a paper on their AI-based analysis pipeline.

"People do a bit of naysaying without asking questions," says Brian Nord of Fermilab, who is part of a team that has used deep neural networks, an AI technique, to identify new astronomical objects in telescope data. AI algorithms demonstrate huge leaps in computational efficiency, but physicists are wary of using them, he says, because their fundamental mechanisms are still largely unclear.

"The skepticism is healthy," says Nord. "But I think there's dismissal that comes with the skepticism. I would love for people to ask questions, hard ones. But sometimes … people just say, 'I don't believe you.'"

At the 2018 APS April Meeting, several physicists armed with tangible results, including Nord, Huerta, and George, made the case for AI in physics. "It's harder to dismiss



Each layer of a deep neural network recognizes increasingly complex features in images (from left to right). Researchers are using similar systems to analyze physics data. Adapted by Brian Nord from Lee, Grosse, Ranganath, and Ng/Stanford University

[AI] when you see the benefits it brings," says Rohan Bhandari, a graduate student at the University of California, Santa Barbara who has developed a deep neural network for analyzing Large Hadron Collider (LHC) data.

Nord's group is using AI to discover gravitational lenses, massive celestial objects—such as galaxies—whose gravity bends light. These objects leave signature distortions in telescope images that AI can help quickly identify. Understanding those distortions could help answer questions about dark matter, dark energy, and the expansion of the universe.

Neural networks alleviate the tedium of conventional techniques used in the hunt for gravitational lenses: Just a few years ago, "[we] sat in front of our screens, and looked with our eyes through many, many hundreds of square degrees," said Nord at a press conference on AI in physics research.

Huerta and George have developed a deep neural network to speed up LIGO's signal identification process. For its first discoveries, LIGO identified gravitational wave candidates using algorithms that match detector signals to hundreds of thousands of "templates"—simulated signals of black hole or neutron star collisions. These algorithms offer a tradeoff: You're more likely to detect a gravitational wave if you compare the signal to as many templates as possible, but more templates take longer to process. More powerful computers could do a better job managing high numbers of templates, but LIGO is already using supercomputers—it's hard to get much more computational power. "[The community] is really desperate to reduce the number of templates they use," says Huerta.

So Huerta and George developed a processing pipeline using a neural network that could identify a signal more quickly with less computational power. Instead of comparing signals to templates in real time, the neural network learns the entire library of templates beforehand. "You only need to do the training once," says George. They found that the neural network-based method was thou-

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MOREY continued from page 1

desired sensitivity in the right frequency range, LISA will consist of three spacecraft, separated by 2.5 million kilometers in a triangular formation.

Morey gave a poised presentation at the APS April Meeting, but just over a year ago, he attended a conference on theoretical gravitational wave modeling and was overwhelmed. "The people there talked about all these things that sounded really interesting, but they were using words and equations that seemed so complex I didn't think I could ever begin to understand them," recalled Morey. "It was intimidating, but at the same time it was incredibly intriguing."

Rather than allow the complexities of studying gravitational waves, black holes, and the universe to scare him off or postpone his start in research, Morey dug deep, voraciously reading textbooks and published papers and working on his own projects.

That work paid off for Morey at the April Meeting: he saw some of the same people present again, and this time he understood almost everything. "One of the coolest things as a high school student that I've experienced is going from knowing nothing to knowing something," said Morey. "I'm very far from being even close to a lot of the experts in my field, but it's been incredibly rewarding to go from knowing nothing to knowing how beautiful and interesting the work that's being done in my field is."

This April Meeting was likely the first of many for Morey as he embarks on his physics career: He will attend the Massachusetts Institute of Technology in the fall and wants to go to graduate school. However, before grad school, Morey also plans to spend a year teaching math and science through the Peace Corps to share his love of physics with others. "I've been lucky to get the opportunities that I've had so I think it's important for me to give back to the world," said Morey. "In life, I want to combine my love for physics with something that helps other people achieve their goals or find their passion." And Morey already sees the importance of passion in physics: He encourages other young researchers to seek out projects that "really makes you want to get out of bed every day because you want to work on it," because "physics research can be really, really hard."

Morey credits his early entrance to physics research, and the success he's already achieved, to the support of his mentors, his school, and his family and friends. "Whenever I have victories in my research, whether big or small, I think of myself and those victories as the result of standing on the shoulders of the giants around me," said Morey, quoting Isaac Newton. "I'm incredibly thankful for all those people and for APS for providing me with this amazing opportunity to study physics and learn more about the world around me."

TUNGUSKA continued from page 2

like trajectory. A 2013 analysis of fragments taken from the site, along with studies of resin from trees in the impact area showing high levels of materials common to rocky asteroids, also supported the hypothesis that the object was an iron meteorite. As for the lack of a crater, the asteroid probably disintegrated from huge increases in pressure and temperature as it passed through the atmosphere, so much so that no significant remnants of the body survived.

Perhaps the best evidence for the asteroid hypothesis comes from a similar, but smaller, explosion on February 15, 2013, in the Ural district of Russia, with a shock wave powerful enough to also shatter windows. Scientists determined that event was caused by an asteroid spanning 17 to 20 meters in diameter, with a mass of about 11,000 tons.

Further Reading:

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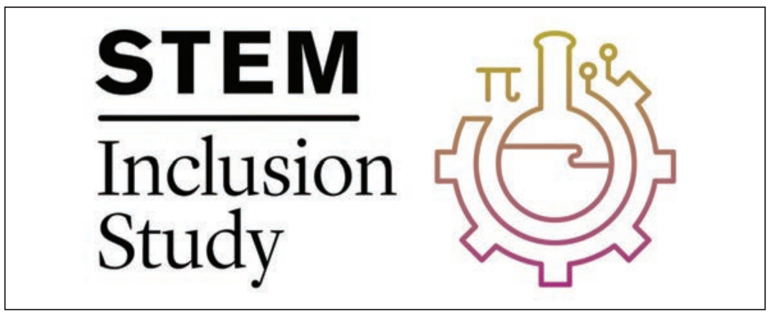
Climate Check: Assessing the Environment in the Physics Workplace

By Leah Poffenberger



Promoting diversity in STEM fields is a hot topic, but some physicists may still receive a cool reception in the workplace. That's the message of a new NSF-funded survey of APS members released by researchers at the University of Michigan and Temple University. The survey was conducted by the Survey Research Center at the University of Michigan's Institute for Social Research.

As one part of a larger STEM Inclusion Study, the survey was designed to assess the current climate for traditionally marginalized groups in STEM by investigating the day-to-day experiences of a representative sample of 1500 non-student members of APS. The results provide new insight into the progress that physics workplaces have made towards being diverse and inclusive.

The full STEM Inclusion Study will analyze results from similar surveys of members of over a dozen other STEM organizations, which will provide insight into how climates differ among STEM fields. Once the survey phase of the project is complete, participants can volunteer for in-depth interviews with the research team. And in the summer of 2019, the heads of each participating organization will meet to discuss the results of the overall survey and make plans for improving the climate in STEM for marginalized groups across all disciplines.

In general, APS members rated their workplaces more positively than negatively. However, a concerning trend exists: Women, minorities, LGBTQ (lesbian, gay, bisexual, transgender, and queer) individuals, and people with disabilities reported encountering negative day-to-day experiences more than their colleagues who are men, white, non-LGBTQ, and without disability, respectively. For all measures of the workplace environment, women were significantly more likely than men to report negative perceptions.

The results also send a signal to academia: physicists working in for-profit companies reported a more positive climate for marginalized groups than physicists working in universities.

"Perception does matter," says Monica Plisch, Director of Education and Diversity at APS. "Negative perceptions can affect work—using brain bandwidth to worry can impact job-creativity and impede innovation."

Understanding the ways in which a work climate may be inhospitable to certain groups is an important step to facilitating change. "We are excited to partner with APS for this study," says University of Michigan sociologist Erin Cech, who along with Temple University sociologist and science studies scholar Tom Waidzunas is one of the study's principal investigators. "This partnership allows us to send data back to participating organizations, where the information can have the most impact. It's also a sign APS is serious about supporting its diverse constituents."

The STEM Inclusion Study survey included a variety of questions aimed at assessing three indicators of climate: experience of inclusion and marginalization; experience of professional devaluation and respect; and reports of fairness in one's workplace. All analyses included controls for education level, work experience, age, employment sector, and other demographic factors.

The first survey section ranged from questions about inclusion such as "I feel like I fit in with other people at my workplace" to questions about encounters with overt marginalizing behavior like "I was harassed verbally or in writing in the last year." Overall, feelings of inclusion were high and instances of marginalization were low, but women were significantly more likely to experience marginalization and harassment on all measures. LGBTQ respondents were less likely than their non-LGBTQ peers to report feeling like they fit in with their colleagues; more likely to worry their mistakes were more visible than mistakes of others; and more likely to have heard coworkers make negative comments or jokes.

The second part of the survey focused on whether physicists feel that their professional expertise is devalued in their workplace, asking whether participants agreed with statements like "In my workplace, my work is respected," "I am held to the same standards as others for advancement," and "I have to work harder than my colleagues to be perceived as a legitimate professional." Again, results were mostly positive: On average, respondents felt respected in the workplace and believed they were held to the same standards for success in the workplace. Yet, women were less likely than men to report that their professional expertise was respected in their workplaces across all measures. And women, Hispanic, Asian, Black, and LGBTQ participants all were more likely than men, whites, and non-LGBTQ persons to agree that they had to work harder than their colleagues to be perceived as a legitimate professional.

These survey questions were constructed to measure systemic differences in the experiences of employees across demographic groups when controlling for education level, experience, employment sector, and age. Such a design is considered "the gold standard in understanding climate issues within professional occupations," according to Cech.

Assessing these reports of workplace experiences across groups is a more accurate way to understand climate than asking questions such as "what is your experience as a woman in physics," Cech noted.

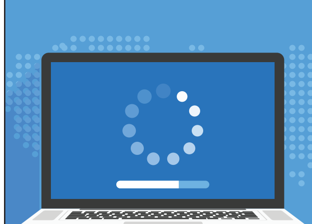
The third section of the survey analyzed reports of workplace fairness aggregated by job sector, measuring the proportion of respondents employed in each sector who witness certain behaviors in their workplaces. Reports of witnessing unfair behavior in the workplace were generally low, but respondents working in the university sector were significantly more likely to state they had seen poor behavior.

One striking statistic was the proportion of "respondents by sector who reported witnessing person(s) being treated differently due to gender in the last three years." Across all employment sectors, 33% witnessed differential treatment of a colleague due to gender in the last three years. When analyzed by sector, 35% of respondents working for universities reported witnessing biased treatment by gender—a statistically significant difference from the for-profit sector average of 25%.

"Physics departments can have climate issues due to cultural assumptions and cognitive biases about what a physicist doing cutting-edge research looks and acts like," says Cech. "In industry, there's often a broader variety of professional backgrounds working together and more multifaceted definitions of excellence, which improves the climate for everyone."

A copy of the results of the survey of APS members can be obtained at aps.org/apsnews, and more about the study is available at www.steminclusion.com

Correction



In the correction on p. 3 of the May 2018 *APS News*, the description of the 1988 Nobel Prize in Physics erroneously stated that "the only Fermilab laureate is Leon Lederman, for his work with Melvin Schwartz at the University of Chicago." In fact, the laureates were Leon Lederman, Melvin Schwartz, and Jack Steinberger "for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon neutrino." As stated by the Nobel Foundation, "the experiment was planned when the three researchers were associated with Columbia University in New York, and carried out using the Alternating Gradient Synchrotron (AGS) at Brookhaven National Accelerator Laboratory on Long Island, USA." We apologize for the error.

CAPITOL HILL continued from page 3

the University of Central Florida (UCF) in 2015. After completing the APS-BP there, he was accepted at UCF to work on his Ph.D. "The mentorship through the Bridge Program has been so valuable to me," he said. "We are a community, and I appreciate that so much. I'm not alone. I have other students who are like me in this program, and we are making a difference by helping each other achieve our goals."

After Zamarripa Roman finishes his Ph.D., he plans to pursue a postdoctoral position, conduct physics education research at the collegiate level, and eventually get involved with science policy. "Science policy will help me make a difference with important research programs that are funded by the federal government," he said.

After realizing that a career in finance was not for her, in 2009 Michelle Lollie found herself reading a published paper about quantum teleportation. With her attention captured by the paper, she immediately knew she wanted a career in physics. In 2012 she enrolled as an undergraduate in the Rose-Hulman Institute of Technology, where she experienced a wake-up call in the form of academic rigor. As she remembered, "It was the hardest four years of my life, but being at Rose-Hulman enabled me to build up both the mathematical and psychological skills I needed to succeed in the physics field."

Next, Lollie applied to 12 graduate schools and was rejected by all of them. She then applied to the Bridge Program and was accepted at Indiana University, where she established strong bonds with mentors and fellow participants. "When you have academic insecurities, and you have struggled, you really need a good support system," she advised.

She went on to Louisiana State University (LSU) for her Ph.D. Lollie gives a lot of credit to her mentor there, physics professor Jonathan Dowling, who has "played a vital role" in her pursuit of a Ph.D. in physics. He served as her adviser while she completed an undergraduate research experience. Dowling was also instrumental in helping Lollie land a fellowship doing quantum optics research this fall. "I'm a woman of faith, and I believe I was destined to study physics. I plan to work with advanced quantum technologies for defense research," she said.

The Bridge Program has been a light in the life of Dylan Smith, who endured a dark period after his mother and father were diagnosed with serious health problems. Smith was a junior in high school when he learned of his mother's condition, and his father had to retire early on a lower pension.

With the help of "a generous amount of need-based financial aid and merit-based scholarships," Smith enrolled as a student at Colgate University, but his experience there wasn't a bed of roses.

"I bombed mechanics. I got a C-," he recalled. "It took a couple of years at Colgate to really figure out what I needed to do to really succeed. I attended professors' office hours, got tutored, and worked with the right people on assignments."

Although Smith's GPA rose above a 3.0, he realized that it might not be high enough for graduate school, and he lacked the experience to be successful in a graduate program. He remained relentless in pursuing his goal, but unfortunately was rejected from every school he applied to. Offering a ray of hope, Beth Parks, his senior research adviser, suggested Smith apply to the Bridge Program.

He took her advice, and thanks to the program, he was able to attend DePaul University from September 2014 through June 2016. While there, he gained a better understanding of physics and improved his interpersonal skills through his job as a teaching assistant.

"My time at DePaul also enabled me to learn how to more effectively and competitively apply to Ph.D. programs. I learned that establishing some sort of contact, either by email or in person, months before application deadlines, was important," recalled Smith. "Perhaps the greatest thing that my two years at DePaul afforded me was the opportunity to think about what I really wanted to study and focus on within physics."

In 2016, Smith was accepted into a Ph.D. program at the University of Michigan, where he is working toward his career goal. "I plan to become a medical physicist," he said. "I want to work in a hospital in radiation oncology. None of this would have been possible if it hadn't been for Beth Parks letting me know about the Bridge Program. It's hard to convey just how grateful I am, and how lucky I was for everything to work out the way it did."

How Big Is the Proton, Really?

By Sophia Chen

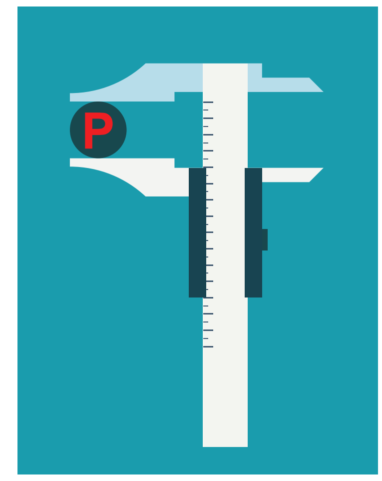
2018 APS April Meeting, Columbus, Ohio—In 2010, Randolf Pohl's team measured the size of the proton with the highest precision yet. But the result befuddled them: the proton radius—or more specifically, how far its positive charge extends—came out to 0.84 fm, about 0.04 fm smaller than all prior measurements. The particle's width seemed to have shrunk by 4 percent.

"It caught everybody off-guard," says David Newell, who chairs the Committee on Data for Science and Technology (CODATA), the international group which publishes the recommended values for fundamental physical constants every four years.

To this day, physicists do not understand the source of this discrepancy. In a presentation at the April Meeting this year, Pohl, who works at the Johannes Gutenberg University Mainz, discussed recent experiments for resolving the so-called proton radius puzzle.

Following the 2010 measurement, several groups have delivered some corroborating values, and some have reported conflicting ones. In 2017, Pohl's group used a different setup to make a measurement that also indicated a smaller proton radius. But earlier this year, a group in France reported a larger proton radius. Independent researchers have also re-analyzed experimental results to no avail. For example, a 2012 independent analysis of Pohl's 2010 data agreed with Pohl's prior numbers. "This proton radius puzzle is getting even more puzzling," said Pohl during a press conference at the meeting.

As with any puzzle, researchers are excited about the prospect of new physics. "The discrepancy is very serious from a theory point of view because we cannot explain it within the Standard Model," says Krzysztof Pachucki, a theorist at the University of Warsaw in Poland. Pohl's landmark 2010



proton measurement was the first to use muonic hydrogen—a proton orbited by a muon, the electron's heavier cousin—whereas prior experiments used regular hydrogen. The discrepancy between the two methods could hint at an error in quantum electrodynamics theory, which describes how these particles interact.

But it's not clear what the error could be, says Pachucki. The dis-

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sands of times faster than template matching.

Soon, says George, they will use the neural network to help LIGO, its European counterpart Virgo, and conventional telescopes collaborate in real time. If LIGO or Virgo can identify and locate a gravitational wave quickly, they can then advise telescopes to observe the same location. These gravitational wave detections can then be paired with the images made with conventional optical telescopes to provide rich physical data about the event in this new era of "multi-messenger" astronomy.

AI can be applied to more than astronomy: Researchers have also begun to use AI to process particle collider data. Bhandari presented his work on a deep neural network for analyzing complicated signals known as jets produced in the LHC. These signals are produced during proton collisions, when constituent quarks and gluons interact via the strong force. Bhandari's neural network helps to calculate the jet's momentum, which is used to calibrate the detector.

Fast data processing techniques will be even more necessary in the future, Bhandari pointed out, because they anticipate a massive increase in data from a proposed upgrade of the LHC. "From 2010 to 2017, we collected 230 petabytes of data, and it's going to keep growing very quickly," said Bhandari during the press conference. Nord's field, cosmology, is also expecting a data deluge in the next few years from current cameras—such as the Dark Energy Survey—and new tools, like the Large Synoptic Survey Telescope, which is currently under construction.

Bhandari thinks that physics applications could also help AI researchers understand how the algorithms work. Right now, experts can't fully explain how the algorithms learn and extrapolate patterns. You can, in principle, write down the equations for the neural network's operations. But the operations contain so many parameters that it's difficult to infer what each step is doing. "As physicists, we're good at looking into black boxes," says Bhandari. "Detectors are also sort of black boxes. … How do you understand a detector? You do systematic tests to characterize it. Neural networks can be treated in the same way."

And the black box is becoming greyer: "It has pieces I can pick apart," says Nord. Researchers have run tests on image recognition neural networks, where they have determined which parts of the algorithm are identifying hard and soft edges in pictures.

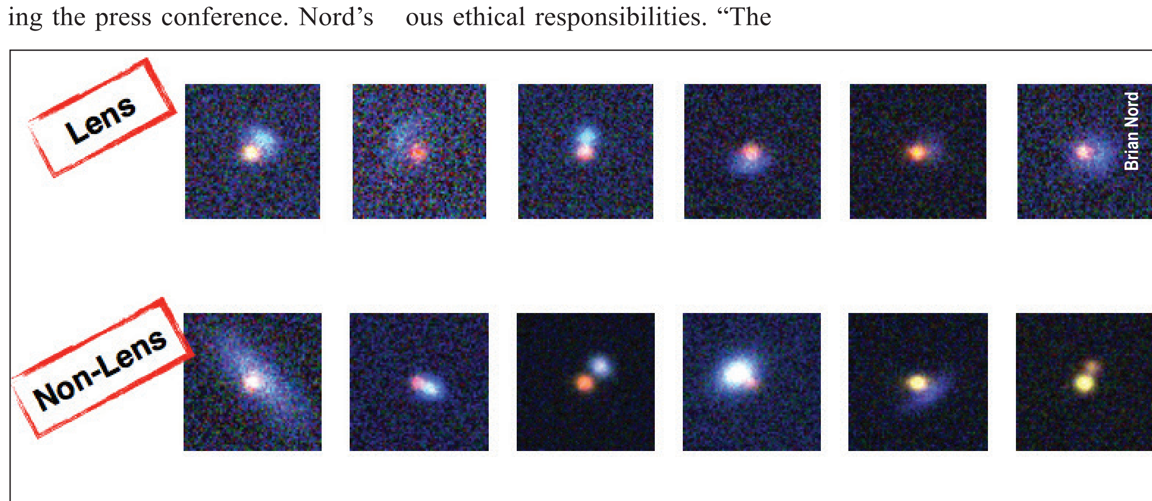
Developments in AI for astrophysics observations could easily transfer to other applications, but as Nord pushes for physicists to try these algorithms, he also emphasizes that the work comes with serious ethical responsibilities. "The amazing thing about these cross-cutting technologies is that they apply so generally," says Nord. "But that's also the peril of them."

One plausible peril, says Nord, is misuse of obscure or proprietary AI algorithms by governments. Courts in several U.S. jurisdictions are using AI to predict the risk of future crime in bail and parole decisions, and according to a 2016 ProPublica investigation, the predictions have been biased against blacks compared to whites. Police in Shenzhen, China, use AI-powered facial recognition to publicly shame and fine jaywalkers. And University of Washington researchers have shown how to use AI to make fake videos of President Obama speaking, which indicates that the technology could be used to create fraudulent media for malicious purposes.

Nord started using AI in his research partly because he was worried about its potential for misuse. He wanted to educate himself on the technology in order to participate in the policy conversation around it. "If we're not in the room where the decisions are made, who is going to represent us?" he says.

AI is already everywhere, says Nord. It's a powerful tool that can help physicists with their research. And in return, maybe physicists can help shape the technology for the good of society.

The author is a freelance writer in Tucson, Arizona.

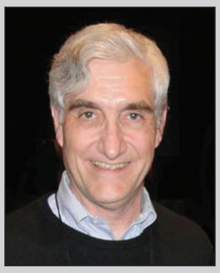


Fermilab researchers taught a neural network to distinguish between gravitational lenses and other objects using images (above) as a training set.

ELECTION continued from page 1

Treasurer

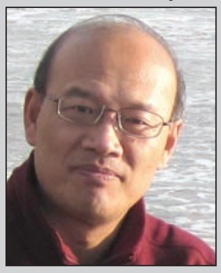
Jim Hollenhorst
Agilent Technologies



Jim Baird
University of Alabama in Huntsville

International Councilor

Enge Wang
Peking University and Chinese Academy of Sciences

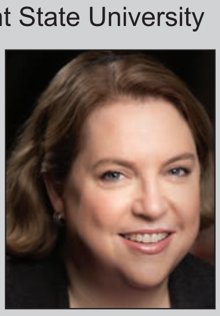


Guowei He
Chinese Academy of Sciences

General Councilor

Marcelle Soares-Santos
Brandeis University

Robin Selinger
Kent State University



Chair-Elect - Nominating Committee

Kevin McFarland
University of Rochester

Nora Berrah
University of Connecticut

JOURNALS continued from page 1

ers, who are asked to explain a new result and why it matters. What were the researchers after? What special thing did they do to succeed? What can the field do with this result?

This method of highlighting papers isn't unique—journals like *Science* and *Nature* have been doing it for decades. What gives *Physics* its own flavor is that the stories are culled from the *Physical Review* journals, which publish incredibly diverse research. There are the big topics—like topological phases, quantum computing, and dark matter searches. But there are also surprising and quirky studies, like physics models for financial markets, experiments that yield laundry advice, tricks with Bose-Einstein condensates, or a "macroscopicity scale" that ranks a quantum superposition of cats as a 57.

Physics has evolved since its launch. Initially, it featured only expert commentaries known as Viewpoints or editor-written summaries called Synopses, plus longer review-style articles, or "Trends." In 2011, *Physical Review Focus*, a pioneering website that had featured physics stories written by journalists since 1998, was incorporated into *Physics* as a section called Focus. And in 2012 we used our knowledge of interesting papers to issue a weekly "tip sheet" of top stories to journalists.

Mining the pages of the *Physical Review* journals has given us no end of great stories. But physics is more than papers, and we want the publication to reflect the people, debates, and events behind the reported research. *Physics* therefore regularly features interviews with physicists, news stories from conferences, and pieces about the influence of physics in the arts, and the publication will continue to grow in volume and diversity in the coming years.

A question we are often asked is how we decide which papers to cover. For ideas, credit largely goes to the editors of the *Physical Review* journals who suggest recently accepted papers and explain why the results matter. We complement these suggestions by keeping a close eye on the journals.

We are also fortunate to have a bank of international experts who give input—either from the review process or from an email or phone call—and help us make a decision. Some results—such as the discovery of a new atomic element and the first detection of gravitational waves—are obvious choices. But science is usually more incremental, pushing forward in fits and starts. So when considering a paper we ask: what is the advance and how influential is it likely to be?

We also leave room for results that are simply fun, weird, or curious. But in all cases, we ask the same question: Will physicists appreciate a tale about this paper even if they know nothing about the topic?

To that, one might ask: Is it worth trying to explain the latest result from CERN to a condensed matter physicist, or the observation of a new spin liquid to a cosmologist? We think so. At the end of the day, all physicists are trying to understand how the world works, reining it in with a little bit (or a lot) of math. Sharing their discoveries—big or small—is a reminder of this unifying trait.

As *Physics* editors, we've had front-row seats to many great findings over the last 10 years and we're looking forward to more of the same in the next decade. So, thank you to all of the storytellers—the science writers, editors, and, at last count, the nearly 800 scientists who have contributed their time to explaining research.

Jessica Thomas is the Editor of Physics *(physics.aps.org)*

If you are interested in receiving the weekly Physics newsletter, go to "Email Alerts" on physics.aps.org.

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crepancy might vanish by introducing new particles, but the options are "very artificial," he says.

It's also possible that the discrepancy is simply the result of experimental error, according to Pohl. The strategy now is to make more proton radius measurements, but with different techniques. This way, each measurement will not suffer from the same systematic uncertainties—and collectively, any hint of new physics will be more convincing.

Researchers have a variety of techniques to choose from. First, they need to decide which proton-containing specimen they want to use for their measurement. Generally, they need to use a system simple enough for theory to model precisely. The simplest system is hydrogen, but they can also use its isotope deuterium, whose nucleus consists of an additional neutron. Or, they can substitute a muon for the electron in these systems. In addition to muonic hydrogen, Pohl's group has also measured the proton via muonic deuterium: a muon orbiting a deuteron. According to Pachucki, singly ionized helium (He^+) is a promising system because its theory is relatively well-understood. "The theory for He^+ is as accurate as for hydrogen," he says.

Researchers also have to choose how they will measure the proton's radius. The two primary options are electron scattering or spectroscopy. In a scattering experiment, electrons are beamed at the hydrogen or deuterium sample. As the electrons approach, the protons deflect them and the amount of deflection is related to the size of the proton.

Alternatively, they can also measure the proton radius by precisely measuring the energy levels of the system through spectroscopy. If they take this route, they have to choose which energy transitions to study. Researchers have chosen a variety of energy transitions that involve different setups and data analysis techniques.

In 2010, for example, Pohl's group used a spectroscopic method: by means of laser probes they measured a gap between energy levels in muonic hydrogen called the Lamb shift. The Lamb shift refers to a small difference between two states in hydrogen-like atoms originally predicted to be of equal energy by early quantum mechanics theory. This energy gap exists, in part, because the electron behaves as a quantum "cloud" that extends even inside the atomic nucleus. "It literally means that an electron orbiting a proton in hydrogen spends some time inside the proton," says Pohl. Because the size of the energy gap depends on the size of the proton, measurement of the Lamb shift yields the proton radius.

To achieve the precision necessary for this measurement, every component of the experiment must be thoroughly understood. For example, any external electromagnetic fields might affect the measurement, and the output of the lasers has to be characterized with exquisite precision. "It's really fun stuff," says Pohl. "You learn something new every day." But this level of detail also meant that it took Pohl's collaboration about ten years to deliver their 2010 measurement.

CODATA's most recent recommendation for the proton radius value, which is an average of many prior experiments, did not incorporate any of the smaller values in its calculation. In November 2014, at a meeting near Paris, with Pohl, Pachucki, and Newell among the attendees, the group decided not to include them. Ultimately, Pohl suggested that they not include the aberrant values. He pointed out that the primary application of the CODATA value is to study regular hydrogen, and all discrepant radius values resulted from the muonic systems.

But now that argument no longer holds. In 2017, Pohl's group used regular hydrogen and also measured the smaller proton radius.

CODATA will meet again in France later this year to discuss the next standardized value of the proton radius, to be released in May 2019. "In my opinion, we cannot ignore the information in front of us," says Newell. He thinks they need to incorporate the discrepancy into their recommendation—which will mean a less precise value for the proton radius. "When we expand uncertainties it annoys the hell out of everybody, but it brings attention to the problem," he says.

The author is a freelance writer in Tucson, Arizona.

RIGHTS continued from page 1

and seeds. The cost of maintaining their livelihood overtakes any profits gained, and more than 50% of livelihoods in India depend on agriculture.

AID's work to support farmers and their families, to teach organic farming practices, and bring in sustainable technology is only one among the many projects of the organization. The goal of restoring caste parity remains at the forefront of the organization.

"We were connecting the privileged class with the underprivileged," Kuchimanchi said. "If we made that connection, something beautiful would emerge."

Behind the walls

On the northern end of Tehran, a wall runs the length of a street where casual passers-by go about their daily business. In one place, a blue sign declares in both Persian and English: "Evin House of Detention." Behind this wall, physicist Narges Mohammadi has spent more than 1000 days.

The road to Mohammadi's imprisonment begins with two arrests during her time as a graduate student at Imam Khomeini International University. While studying physics, she founded the student organization "Illuminating Student Group." The student organization worked to shed light on complex issues, including those of human rights.

Mohammadi describes the motivation for starting her human rights work in her open letter. "I felt compelled to join the struggle for freedom. What we experience is a decades-old tyranny, that cannot tolerate freedom of speech and thought. In the name of religion, it restricts and punishes science, intellect, and even love. It labels as a threat to national security and toxic to society whatever is not compatible with its political and economic interests. It considers punishing unwelcome ideas as a positive thing."

In 2003 Mohammadi joined the Defenders of Human Rights Center (DHRC), an organization founded by five lawyers, including Nobel Peace Prize recipient Shirin Ebadi. She later became the vice president and a spokeswoman of the organization. In 2008 government representatives raided the office of the DHRC and officially shut down the organization.

In 2009, she was arrested a third time, ostensibly for her involvement with the DHRC. After just a few days out on bail, she was arrested again and this time sentenced to 14 years in prison. This sentence would be reduced to 10 years only to be increased to 16 years in May 2016.

From behind the walls of Evin Prison, Mohammadi describes the treatment of political prisoners. She writes, "They use 'white torture' on political prisoners: keeping suspects in solitary confinement is a routine and prevalent procedure. They confine a human being, alone, to a tiny cell for an unlimited and indefinite period of time, in a small space without light or proper air, where there is no sound, smell or movement." The statement continues to describe verbal and physical abuse, forced medications, sleep deprivation, and many other things to induce fear.

The APS Sakharov Prize was awarded to Narges Mohammadi, who is imprisoned in Iran. Nayereh Tohidi accepted the prize from 2018 APS President Roger Falcone on behalf of Mohammadi.

During her time in Evin Prison, Mohammadi's health has been in decline. Her imprisonment has been punctuated by periodic releases for treatment. Her most recent release in October 2015 ended after just 17 days when she was taken back into custody against medical advice. An appeal for her release in September 2016 resulted in the 16-year sentence being upheld.

Mohammadi writes, "I will not be silent in the face of human rights violations. In order to institutionalize human rights and achieve peace between the people and the state, I shall endure my deprivation of freedom and rights, even though separation from my children is nothing less than death for me."

At this point while reading, Tohidi's voice filled with emotion. She paused to steady herself before continuing with Mohammadi's letter, "I am a woman and a mother, and with all my feminine and maternal sensibilities, I seek a world free from violence and injustice, even if I have suffered injustice and violence tens of times."

Though Mohammadi is imprisoned, the news of her award reached her. As Tohidi and others who know her point out, knowing she received the award has given Mohammadi strength and provides a sense of solidarity.

"Sitting here in prison," Mohammadi's statement concludes, "I am deeply humbled by the honor you have bestowed on me and I will continue my efforts until we achieve peace, tolerance for plurality of views, and human rights."

Taking action

Shelly Lesher, chair of the Committee on International Freedom of Scientists (CIFS), concluded the session, eliciting equal parts shock and inspiration. Shock, because she detailed several active cases of human rights violations, and inspiration because she evoked hope by telling the audience how they could act. Reporting human rights violations, hosting a scholar at risk, and even just signing up for the CIFS network of scientists are all places to start.

Staying informed topped the list. Lesher pointed the audience in the direction of several websites, including the CIFS website for active cases. Additionally, reporting human rights violations of scientists further raises awareness.

Universities can incorporate human rights discussions into physics. Lesher pointed to Kuchimanchi's talk and how AID was formed during his graduate school days as an example of how this could be done. Further, universities can host scholars at risk. This does not necessarily require huge resources; these scientists typically do not want permanent positions. The goal is to take their skills back to their home countries when they are able to return.

Perhaps the biggest takeaway from Lesher's talk is simply to get involved.

"Physicists have always been involved in human rights work," Lesher said. "The need is great, greater than it's been in years. And you can be involved at any stage in your career."

The author is the Science Writing Intern at APS in College Park, Maryland.

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made the cut.

Two of the selection committee's favorite proposals will take particle physics into places people might not expect: state parks and libraries. One winning team will take muon detectors to Letchworth State Park in New York, allowing visitors to learn about cosmic ray muons and discover how the number of muons reaching Earth changes at different areas of the park. "State parks already have a lot of science in them, like environmental science or biology," says Thompson. "This project adds physics to the science that's already there."

Another group will use their mini-grant funds to bring cloud chambers—visually stunning particle detectors that allow onlookers to spot particle interactions—to libraries. "We love doing things with libraries, since they're already a hub of learning," says Thompson. "This project will bring physics to an informal educational space that doesn't usually have much science."

Proposals for innovative public outreach projects come to the selection committee from many different groups, from national labs to universities to independent science outreach groups—but applicants don't have to be outreach experts to get funds to try something new. Students at the University of Waterloo were responsible for one popular and incredibly successful event called Light at the Museum which drew in more than 40,000 visitors with displays of the science of light.

Most other grant programs for outreach projects either give out large sums of money—like NSF grants for $1 million for established programs—or small grants in the neighborhood of $1,000, designed to help pay for a project that's getting the bulk of its funding elsewhere or a small one-time event, like a public lecture. The APS mini-grants cover a funding range in between these amounts to provide a space for new ideas to establish themselves and, hopefully, grow into larger programs.

"We like to fund projects that haven't been tried before, and at this level of funding, we can be experimental," says Thompson. "There's freedom for projects to be spectacular failures, but that allows us to figure out what might work next time."

Receiving a mini-grant from APS often provides an additional boost to projects beyond the funding, notes Thompson. "Giving a project the APS stamp of approval helps to send a message that physics outreach isn't just something to do on the weekends," says Thompson. "Even just putting together an application for the grant can rally a department around a project."

For more on the outreach activities at APS, visit aps.org/programs/outreach/

2018 History of Physics Essay Contest

The Forum for History of Physics (FHP) of the American Physical Society is proud to announce the 2018 History of Physics Essay Contest.

The contest is designed to promote interest in the history of physics among those not, or not yet, professionally engaged in the subject. Entries can address the work of individual physicists, teams of physicists, physics discoveries, or other appropriate topics. Entries should be 1500-2000 words, and while scholarly should be accessible to a general scientific audience.

The contest is intended for undergraduate and graduate students, but open to anyone without a Ph.D. in either physics or history. Entries with multiple authors will not be accepted. Entries will be judged on originality, clarity, and potential to contribute to the field. Previously published work, or excerpts thereof, will not be accepted. The winning essay will be published as a Back Page in *APS News*, and its author will receive a cash award of $1000, plus support for travel to an APS annual meeting to deliver a talk based on the essay. The judges may also designate one or more runners-up, with a cash award of $500 each.

Entries will be judged by members of the FHP Executive Committee and are due by September 1, 2018. They should be submitted to fhp@aps.org, with "Essay Contest" in the subject line. Entrants should supply their names, institutional affiliations (if any), mail and email addresses, and phone numbers. Winners will be announced by December 1, 2018.

The Back Page

A Life in Teaching and Turbulence

By Katepalli R. Sreenivasan

Note: This article is based on closing remarks delivered by the author at a conference celebrating his 70th birthday. The text has been edited for length and clarity.

Most of you are younger than me—some, a lot younger. So perhaps you will not dismiss me entirely when I make three points on my own conduct.

- The first is that, for many years now, I have tried not to be the smartest person in the room. I admit that I may have tried to be so at one time, and may even have succeeded at various levels, but it became clear to me that I wasn't learning much by being so. This change in outlook was not hard to come by because it was becoming intrinsically truer as time advanced but it took some modest practice. My most ineffectual interactions have been those in which I was overtly aggressive.
- The second is that some 25 years ago, I resolved that if anyone wishes to talk to me about their careers or personal lives, I would give them the most honest advice I can and support them in the best way possible. The lower in hierarchy they are, the more attention they deserve. I have said no to meetings with visiting vice chancellors and ambassadors if an undergraduate in distress wanted to see me urgently. My criterion has never been the perceived importance of the person in question but her or his needs. Even if the problem vexing the person may be generic, it is special to her or him—and I have tried to remember that as well as I can.
- Third, I have been fortunate that several opportunities have come to me in my life—some of which include higher positions than those I ended up holding. I have remained truthful to a personal system of making choices by always asking two questions, (a) Is it worth doing; and (b) am I the best person for doing it? The answer to (a) involves a value system built into oneself; so perhaps you would come to a different conclusion on what may be worthy. I have no quarrel with that, but urge you to contemplate quietly when you are faced with choices and decide to pursue one actively. My own choices had no relation to the importance of the title of the job, or the money or prestige it brought, or even to the inconvenience that the job caused me and—I am somewhat embarrassed to admit—even to my family. The answer to (b) requires an understanding of one's own strengths and weaknesses. This, in turn, requires life-long introspection, which all of us should practice: It is equally unsatisfactory whether we oversell our strengths or understate them.

Let me now say a few words about turbulence as a field of research. I want to add a few comments on the dynamics of how we, as a community, work together—or ought to work together—to make progress. I embed a few words of advice to the younger participants.

Turbulence consists of a number of fascinating problems (and is *not* just one "unsolved problem in classical physics"). The precise problem on which each one of us works depends on:

- one's natural and acquired tastes;
- financial support one generates;
- one's own abilities and skills;
- the extent to which one is willing to interact with and learn from others;
- one's environment; etc.

I will particularly make a few remarks on how to increase the visibility of the field; each of us benefits if our chosen field thrives. One set of my remarks deals with internal dynamics of the community and the other concerns external perception.

Internally, we hear complaints that: (a) there isn't enough research money in turbulence; while there may be decent resources to remain productive at some level, sufficient resources are not available if one wants to break new ground (such as extending important parameter ranges by some orders of magnitude to settle a vexing question); (b) not enough positions exist for current graduate students and postdocs; (c) inadequate scientific recognition comes even to those who have accomplished something substantial; (d) the field is hard intellectually and tough in terms of how it treats its young and old alike; and so forth.

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Externally, people often ask questions like: Are you still working on Kolmogorov scaling (or some other topic, such as convection or boundary layer transition)? You still can't predict the pressure drop in a pipe? If I give you all the resources needed, will you really be able to improve aircraft flight, gas turbine engines, energy distribution, weather prediction, or climate change? (None of them is an imaginary question.)

The truth is that one cannot answer these questions glibly with internalized responses: one cannot, for instance, simply assert that "a mere 1% reduction in drag will save the industries certain billions of dollars each year." People who ask such questions are usually serious and wish to know if there are problems whose solution will produce a first order impact on some large-scale endeavor or a neighboring field. It is true that most of these "outside" people are usually ignorant of the progress that has been occurring in turbulence, but it is essentially our responsibility to communicate this progress to an intelligent outsider. It is only by changing the way in which we function that we may hope to influence this perception.

It takes time to make visible progress in the field and it appears that every dozen or so years the same specific questions come up in another form. It is not that we are running in circles without gaining anything along the way; we have obtained in these years a better understanding of some aspects due to new theories, better simulation tools or new experimental technology. Take the turbulent Rayleigh-Benard problem. So much has happened in the last twenty years: new experimental results, powerful simulations, new diagnostics, new theoretical ideas, yet it looks to an outsider that one is still working on the same old problem. We ought to learn better skills in presenting our work without being defensive.

Another problem is that many communities who use turbulence as part of their bread and butter work are indifferent to advances in turbulence. Atmospheric scientists and astrophysicists, for example, get working answers from certain approximations, that as turbulence experts, you will swear on your Ph.D. theses are not even remotely logical; climate scientists can't even relate to the time scales that interest you; aircraft designers are quite content with elaborate computational fluid dynamics methods. If you want them to take you seriously, you have to take on the task of convincing them that resources spent on you are useful to them at some level.

One characteristic of science is the seamless number of cross-relationships among its components. Connecting our facts with neighboring observations and theory is what makes it possible to understand them more deeply and interpret them more meaningfully; to a first approximation, if it doesn't connect, it does not exist. This comment certainly applies to turbulence, and it is by following this maxim that we influence how others outside the field perceive the importance of our field. Thus:

a. Turbulence work must connect better with the rest of science—physics, mathematics and modern technologies. For instance, we may think that quantum mechanics has nothing to do with continuum fluids (and that would be mostly true), but many of its methods and concepts help us set forth our ideas in interconnected ways; as an example, opening one's mind to large-scale Bose-Einstein condensates will enable you to see a whole host of interesting problems in vortex dynamics and turbulence. In this respect, I am strongly in favor of a broader education for our graduate students, including, as examples, physics, biology, statistical mechanics and artificial intelligence. Accommodating a few basic courses in a few of these subjects, instead of adding another specialized course in fluid mechanics, is well worth the effort. I likewise think that we should publish occasionally in broader journals, instead of crowding towards one or two top journals in your narrow specialization, because the very task of explaining to a wider audience enlarges one's perspective.

b. We should not fragment ourselves. One shouldn't think that all those who work on problems other than one's own are wasting time and resources. Even if you are a practically oriented person (as most of us are), you should show a certain amount of active generosity of spirit towards those who seriously want to understand something different. It is true that there will never be enough resources to do everything, and so we have to build some consensus on the most profitable directions, but this does not come by one conversation in a meeting or a know-it-all stance of a self-selected few; it comes from a sense of mutual respect and generosity of spirit that prevails in the background; it comes from an environment that the established people have to create in order to ensure that new people with new ideas feel secure and appreciated. This means that all of us must spend modest amounts of time in dialogues with each other instead of dismissing those with different views off-handedly; this means that we have to listen to timid but intelligent voices instead of succumbing to those few who are habitually pushy or counting papers in journals of high impact factor or be impressed by grant dollars someone generates.

c. I would like to say a few words about our reputation as a tough community: many internal battles that were fought in the last fifty years have meant very little in hindsight but have ruined interpersonal relationships and diminished all those involved. This aggression occurs really because some people think that we are all part of a zero-sum game. First of all, you should not accept this premise; indeed, most successful people have never been limited by this fallacy. Secondly, please give full credit to the guy that went before you; don't make it sound like you have reinvented the wheel. Cite other people's work in your talks; be generous towards their contributions; don't make it sound like only your research area is the path to understanding; and don't yield to the temptation of diminishing others just because you get an opportunity to do so.

I have no doubt that better days lie ahead for turbulence; its importance alone ought to be an argument in favor but it is never enough. I side with Hilbert's optimism that extolled the notion that "We must know; we will know," instead of the pessimism of the famous Latin maxim that "We do not know; we shall not know."

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