Celebrating the International Year of Quantum Science and Technology

Join APS in advancing quantum education and outreach in 2025.

INTERNATIONAL YEAR OF Quantum Science and Technology

APS News

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Quantum physics for fifth graders? One research team thinks so.

A team in Virginia is working with local teachers to develop quantum physics lessons for elementary students.

BY LIZ BOATMAN

Quantum mechanics is one of the most challenging topics a physics student can encounter. So why is a team of researchers from George Mason University in Virginia working to bring quantum physics topics into elementary school classrooms?

"We're at the beginning of the second quantum revolution," says Nancy Holincheck, assistant professor in GMU's College of Education and Human Development and lead investigator of the Quantum is Elementary project. The first revolution included the invention of the transistor, which now powers nearly every modern electronic device. "It's

Quantum Ed continued on page 5

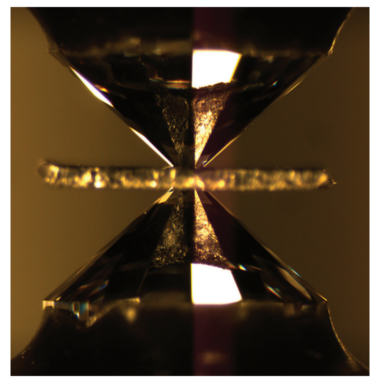
As part of the Quantum is Elementary project, elementary school teachers collaborate on a classroom-friendly quantum science lesson, "Quantum Chutes and Ladders." Credit: Xiaolu Zhang

Superconductivity experts speak up for hydride research

An independent analysis of data on the hotly debated superconductivity of certain hydrogen-rich compounds, or hydrides, concludes that the phenomenon is likely genuine.

BY MATTEO RINI

The search for superconductivity in hydrogen-rich compounds known as hydrides has been an emotional rollercoaster ride for the scientific community. Excitement mounted a few years ago, as hydride experiments had physicists imagining that a Holy Grail, room-temperature superconductivity might be within reach. But the field was shocked in 2023 by allegations of malpractice and fraud. Now a group of physicists — leading superconductivity experts who aren't involved in hydride research — has offered an independent assessment of the available body of work on these materials. In a paper published in



Researchers have used diamond anvils, like the one shown here, to explore hints of superconductivity in hydrides. Credit: S. Jacobsen/Northwestern University

Hydrides continued on page 5

APS Global Physics Summit 2025 promises record-breaking experience for attendees

The Joint March Meeting and April Meeting will offer crossover scientific sessions, a quantum festival, and more.

BY LIZ BOATMAN

More than 15,000 people are expected to attend the APS Global Physics Summit. Credit: Simone - stock.adobe.com

In March, the city of Anaheim, California, will host the largest gathering of physicists the world has ever seen. Coming on the heels of APS' 125th anniversary, the Society will bring its two hallmark gatherings together in a Joint March Meeting and April Meeting for the first time since 1999, when 11,000 physicists from around the world gathered in Atlanta to celebrate APS' centennial.

This year's event, dubbed the APS Global Physics Summit 2025, expects more than 15,000 attendees across all areas of the discipline — record attendance for an event with record numbers of abstract submissions and exhibitors. "It will be great to have all of physics come together in one place," says March Meeting Chair Kenneth Brown.

APS Summit continued on page 3

PRX Quantum's chief editor talks early inspirations, 2025 plans, and tips for senior scientists

Katiuscia Cassemiro and her team are propelling the quantum community into the next century.

BY CYPRESS HANSEN

Quantum science and technology is perhaps one of the fastest growing fields in physics today. Quantum cryptography promises a new era of information security, while quantum computing is expected to revolutionize industries like pharmaceuticals, materials science, and finance. Even simple, everyday problems like optimizing traffic flow could one day be answered by quantum algorithms.

The next decade will likely bring dramatic advancements for the quantum community, and under the guidance of Chief Editor Katiuscia Cassemiro, *PRX Quantum* stands ready to serve as the field's most impactful journal. As Cassemiro and her team prepare for the International Year of Quantum Science and Technology in 2025, we sat down with Cassemiro to talk about her own scientific journey, hot topics in quantum research, and what's slated for the 2025 APS Global Physics Summit.

Quantum science isn't exactly "entry-level" physics. What drew you in as a young researcher?

At the time I was in college, quantum mechanics was definitely not as trendy as it is today. But one thing that fascinated me was this short book by Richard Feynman called "QED: The Strange Theory of Light." It was just beautiful, describing very simple daily things, the daily natural phenomena, but through the lenses of quantum mechanics. I just found it very intriguing.

I also liked that quantum research experiments are tabletop. In other areas like nuclear physics, you have these big expensive facilities, big accelerators, and you don't really fully control the entire experiment. But in quantum science, it was the other way around. Everything can be done on top of a table. You have full control and it's all there in front of you. I liked that you could see the entire process.

I was [also] in a very good laboratory with people who knew their topics very well, and that made our discussions and conversations more exciting and more fruitful.

Cassemiro in Death Valley during the 2023 APS March Meeting in Las Vegas. Photo credit: Katiuscia Cassemiro

You began in quantum research and eventually pivoted to editing. Has this changed your relationship with the field?

Yes. Even as a researcher, I had my eye on an editing career because it's an opportunity to see science more broadly, and also to be participating actively in the process. As an editor, you have to move away from technical, detailed knowledge, but you gain broader knowledge and more connections with the community.

My role is definitely different now — there is more emphasis on making sure that published research in my field is solid, that researchers trust and engage with our review process, and that our curation reflects the top results. I think we have achieved these goals because our readers send positive feedback. Moreover, *PRX Quantum* has strong submissions and the highest impact factor among journals dedicated to quantum science and technology.

Chief Editor continued on page 4

Physicist makes space for space careers

Laura Forczyk turned her physics degree into a thriving consultancy business for the space industry.

BY ALAINA G. LEVINE

A tearful day in Alabama cemented Laura Forczyk's career aspirations. When she was in 7th grade, Forczyk attended a weeklong Space Camp for astronomy enthusiasts in Huntsville, where she completed mock missions and practiced serving as a "payload specialist" for the storied program.

The camp also left her with a sense of clarity about her future. As the 14-year-old waited for her flight home, she found herself in tears. "That was my place. That was my people," she recalls. From then on, "I wanted not just a career in astrophysics, but also in the space industry as a whole — and I didn't even know [then] it was called the space industry," she says.

Forczyk delivered on that mission. Today, she runs several businesses, all of which aim to make the space industry accessible to everyone. Her consultancy, Astralytical, which she launched nine years ago, helps established companies like Blue Origin, young startups, government entities, and nonprofits design and implement strategies for success in the space sector. Projects include a mission review for NASA and market research, product development, and strategic planning for companies looking to advance into this arena.

"All kinds of people can work in space," says Forczyk. "I help them figure out how." Credit: Laura Forczyk

For many of her clients, Forczyk gathers and scrutinizes data on industry challenges, like delayed orbital launches, and then identifies logistical and policy-based solutions. "We do space policy analysis," she says. For example, "what are the policies in place to alleviate some of the congestion out of [Cape Canaveral], or [increase] launch availability of other spaceports around the country?"

Forczyk also serves as a space career coach for lawyers, scientists, engineers, and beyond. "My goal is to help individuals … who have that passion for space realize they can work in space no matter their background, no matter who they are, by applying their own talents to whatever the job is," she says. "All kinds of people can work in space, and I help them figure out how."

Her bachelor's and master's degrees in astrophysics come in handy. "When I was a student, I was told that a physics degree is a fantastic foundation for any career, and I took that to heart," she recalls. "I realized that I could learn very difficult things … In graduate school, when I passed [the physics comprehensive exam], I had the confidence that I could do anything."

After completing several internships with NASA as a student, Forczyk researched the commercial space industry as a lead analyst for NewSpace Global and served as the president of the Florida Space Development Council. Both experiences helped her understand the economic and workforce development needs of the space sector. She then worked at what's now the International Space Station's National Laboratory in Melbourne, Florida, where she supported more than 50 microgravity research experiments in space and assessed the scientific merit of ISS utilization proposals.

It was after a stint at Swiss Space Systems, where she managed operations at Kennedy Space Center, that Forczyk realized she could offer

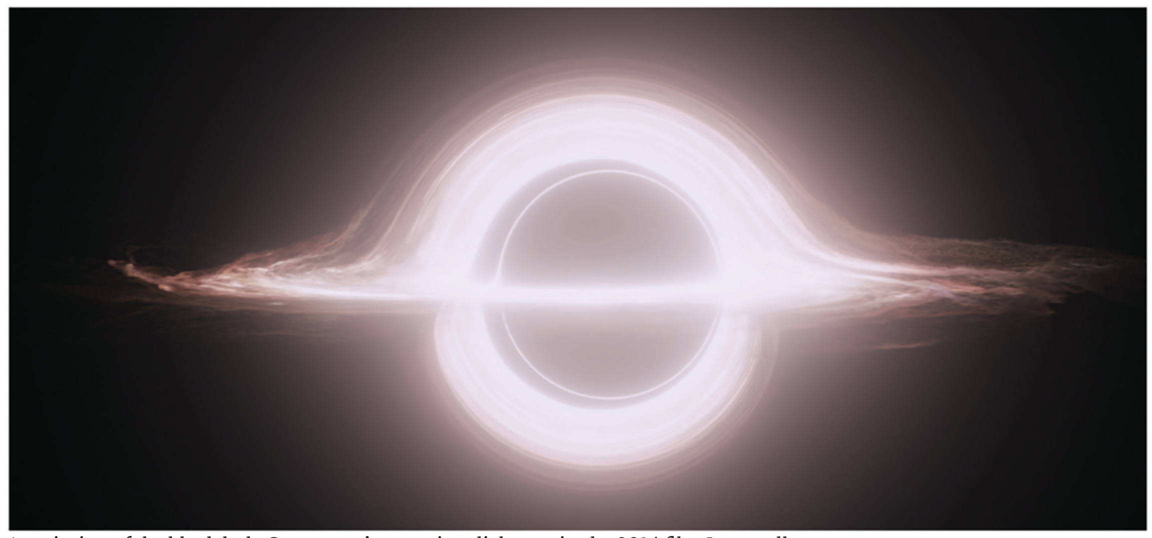
Space Careers continued on page 5

THIS MONTH IN PHYSICS HISTORY

Feb. 22, 2015: *Interstellar* wins Academy Award for Best Visual Effects

The film's visualization of a fictional black hole was both iconic and grounded in science.

BY ERICA K. BROCKMEIER



A variation of the black hole Gargantua's accretion disk seen in the 2014 film Interstellar. Credit: DNEG/Warner Bros. Entertainment Inc./Oliver James et al., 2015, Class. Quantum Grav. 32 065001

In the 2014 film *Interstellar*, humanity is on the precipice of extinction from drought and famine. A team of astronauts travel through a wormhole near Saturn to find a new home planet in a distant galaxy, a perilous journey in which team members explore inhospitable exoplanets and, in the film's climax, the protagonist plunges into a black hole.

Directed by Christopher Nolan, *Interstellar* is one of the decade's most notable science fiction films. The movie was nominated for five Academy Awards, and four visual effects supervisors received the prize for Best Visual Effects.

While *Interstellar's* Academy Award recognized a range of technical and artistic achievements across its 700 visual effects shots, one of its most notable visuals is Gargantua, the massive black hole at the center of the film's fictional galaxy. Grounded in theoretical physics, the efforts that went into visualizing Gargantua not only led to the creation of a new tool for black hole visualizations, its fortuitous timing — just before LIGO detected gravitational waves and a few years before the Event Horizon Telescope published the first image of a black hole — helped usher in a new era of public interest in black hole science.

The story behind *Interstellar* began in the mid-2000s with a short story co-written by Kip Thorne, a theoretical physicist and co-recipient of the 2017 Nobel Prize, and film producer Lynda Obst. The treatment — akin to an outline for a film script — detailed how black holes and wormholes could be featured in a story in a scientifically accurate way.

After Steven Spielberg backed out to direct another film, Nolan joined the project and, working alongside his brother and screenwriter Jonathan Nolan, rewrote much of the treatment, said Thorne. "It's very much the Nolan brothers' movie, but the thing that was a constant through the whole thing was the science," Thorne said. "Within a matter of a few hours of conversation [with Chris], it became clear that we were both eager to work with each other to get this really interesting science [into the film]."

For the film's visual effects, Nolan turned to visual effects company Double Negative (now DNEG), where Oliver James, currently DNEG's chief scientist, had previously worked on effects for other Nolan films, including *Batman Begins* and *Inception*. James became interested in helping with the black hole and wormhole simulations for *Interstellar* and connected with Thorne, the film's scientific advisor, to figure out how to translate Einstein's general relativity equations into a film-quality visual effect.

Part of the challenge for visualizing the black hole was that the standard filmmaking technique for ray tracing — the process of modeling how light interacts with surfaces — relied on shooting rays of light at an object. But based on what had been theorized about the gravitational field of black holes by scientists, individual light rays would be pulled apart by Gargantua's tidal forces, a visual effect that made it challenging to render a smooth image using the visual effects software.

"I remember asking [Kip] a very precise question about whether he could give us an equation of a ray of light that starts at a distant star, orbits around a black hole, and ends up in observer's eye," James said. "That precision must have hit the right note, because 24 hours later, I received a paper that outlined a simplified version of his answer." James used the equation to create rough early visuals, which the team then refined with Thorne's input.

The method for generating IMAX-quality images of Gargantua used Thorne's calculations, which integrated all the paths followed by light rays together instead of tracing the paths of individual rays. This integration allowed the team to generate high-resolution, flicker-free renderings of the black hole. Known as the Double Negative Gravitational Renderer, the team's paper on how to render images in curved space-time is still used by computer graphics professionals and by the physics community to generate high-quality black hole visualizations, said Thorne. The team also published their methods for visualizing the film's wormhole.

The team's paper on how to render images in curved space-time is still used by computer graphics professionals and by the physics community to generate high-quality black hole visualizations, said Thorne.

The creation of Gargantua also revealed insights about how a black hole bends, or lenses, light: It forms a complex "halo" with an accretion disc visible above, below, and in front of the black hole.

"The first time I saw the image of Gargantua with the thin accretion disc around it, I was momentarily

Black Hole continued on page 3

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Biden administration amends H-1B and J-1 visa rules and narrows S&T agreement with China

The changes came in the administration's final weeks.

BY THE FYI TEAM

US updates rules for H-1B and J-1 visas

The Department of Homeland Security issued a series of visa policy updates near the end of the Biden administration that could impact STEM professionals and students looking to work or study in the U.S. A final rule published in December focuses on "modernizing" the H-1B program, which offers visas to skilled workers. For instance, the rule updates the criteria whereby nonprofit and governmental research organizations can hire workers using H-1B visas without being subject to the annual numerical cap on the program. Previously, such organizations were exempt from the cap only if their "primary mission" was research, but the new rule says that they can qualify if research is a "fundamental activity" but not their primary mission.

Credit: Walter Cicchetti - stock.adobe.com

The new rule also states that H-1B visa applicants must hold degrees that are "directly related" to the job they want to perform. Some organizations, including APS, petitioned DHS to drop that language, arguing that it could unduly exclude people whose degrees are highly relevant to the work in question but the connection is not obvious from the degree name. DHS declined to drop the language but added a clarification that the intent is for there to be a "logical connection" between the degree and the job. DHS insists that the "directly related" criteria is consistent with longstanding agency practice and is meant to address situations in which the job qualification criteria are overly broad.

"Assertions that a position can be satisfied based on studies in any STEM degree field would generally indicate that the position does not require a 'body of highly specialized knowledge' but, rather, general mathematical or analytical skills," DHS notes.

Also in December, the State Department made a major update to its criteria for determining whether J-1 visa holders must return to their home country for at least two years after completing a work or study program in the U.S. before they can apply for another visa. The new criteria removed dozens of countries from this requirement, including China and India. The department stated that this change will "significantly streamline the visa process for these exchange visitors, making it possible for those who qualify for work visas to continue contributing their talents to U.S. businesses and U.S. innovation." J-1 visas are often used by visiting research scholars.

US and China narrow scope of S&T cooperation agreement

The U.S. and China struck a deal in December to extend their bilateral science and technology cooperation agreement by five years but narrow it to only cover basic research. The agreement explicitly excludes work related to developing critical and emerging technologies and includes "new guardrails for implementing agencies to protect the safety and security of their researchers," according to the State Department. The agreement also adds "newly established and strengthened provisions on transparency and data reciprocity." As this edition went to press, the text of the agreement had not yet been made public.

The previous agreement lapsed in August 2023 amid a stalemate in negotiations and increased tensions between the two countries. Some Republican politicians criticized the Biden administration's negotiating posture and pushed to add new congressional oversight mechanisms to the process. Rep. John Moolenaar (R-MI), chair of the House Select Committee on the CCP, condemned the extension, stating that renewing the agreement in the final days of the Biden administration "is a clear attempt to tie the hands of the incoming administration and deny them the opportunity to either leave the agreement or negotiate a better deal for the American people."

FYI is a trusted source of science policy news, published by the American Institute of Physics since 1989.

APS Summit continued from page 1

Brown, a physicist at Duke University, is the meeting's first-ever chair from the Division of Quantum Information. A lucky coincidence, he says, given that 2025 is also the International Year of Quantum Science and Technology.

"There are a bunch of APS units that don't clearly fit into the March or April Meeting," says David Garfinkle, chair of April Meeting. "In this year's format, they won't have to decide which meeting to go to."

Garfinkle, a physicist at Oakland University, says attendees should think of the Global Physics Summit as "adjacent meetings with lots of crossover." The typical March Meeting sessions and exhibitor hall will all be in the Anaheim Convention Center; just next door, in the Anaheim Marriott hotel, April Meeting attendees will find their usual scientific tracks. And for the first time, the 'splashy' physics types — soft matter physicists and those who study living systems and polymers — will have a breakout meeting in the Hilton Anaheim.

"The idea is that everybody should be able to go to any session," says Garfinkle. "It will be very easy for people to go back and forth" between the meeting's three 'campuses.'

Brown is excited for all the scientific sessions that the Joint March Meeting and April Meeting will offer. "There are a bunch of sessions that wouldn't have been possible without having the two meeting committees working together," he says.

For example, the Division of Quantum Information partnered with the Division of Nuclear Physics to plan multiple sessions, like "Radiation Effects on Superconducting Qubits and Sensors." And the Division of Particles and Fields collaborated with the Division of Computational Physics to deliver a session called "Electronic Structure Theory for Dark Matter Detection."

The summit will also offer a Quantum Festival to celebrate the 2025 International Year of Quantum, established by the United Nations last summer. The festival will kick off with a public-friendly Quantum Jubilee on Saturday, March 15, at the City National Grove of Anaheim with two performances, "Tinguely Entangled" and "Quantum Voyages," and science demonstrations, circus performers, and talks by at least one Nobel laureate and a NASA astronaut. Themes will span the quantum wonders from the subatomic to the cosmic, with QuantumFest continuing all week long.

Some of the summit's features will be familiar events for March Meeting attendees, but novel highlights for April Meeting attendees, says Garfinkle. For example, the "Special Session with Nobel Laureates" will feature recipients of the 2024 Nobel Prizes in Physics and Chemistry. And childcare will now be available to every attendee. "I think this will really help a lot of our early-career physicists," says Garfinkle.

By combining the "Kavli Foundation Special Symposium" — typical of the March Meeting — with the plenary style of the April Meeting, the summit will offer two avenues into cutting-edge physics. "Exploring the Cosmos" on Wednesday, March 19, will feature physicists Nathalie Palanque-Delabrouille, Sarah Vigeland, and Suzanne Staggs, who will share the latest from the Dark Energy Spectroscopic Instrument (DESI), the NANOGrav Pulsar Timing Array, and the Simons Observatory, under construction in the Atacama Desert of Chile — the world's highest telescope at an elevation of over 17,000 feet.

For "It's a Quantum World" on Thursday, March 20, which Brown named in a nod to Disney's "It's a Small World" ride in the nearby Magic Kingdom, attendees can expect talks that highlight "how all the different parts of physics are touched by quantum mechanics." Brown is excited for attendees to hear from physicist Ekkehard Peik, famous for unlocking the physics needed to drive the world's first nuclear clock.

Attendees can also catch the public lecture by Katherine Freese of University of Texas at Austin, who will be speaking about dark matter — still undetected, but theorized to be the gravitational glue holding together galaxies. "She's really good at connecting with audiences," Garfinkle says.

With so many special events and activities, and more invited sessions — "the heart and soul of the meeting" — than ever before, Garfinkle says he expects some may find it hard to choose. "It all looks great to me."

Liz Boatman is a materials scientist and science writer based in Minnesota.

Speaking out at APS

A message from APS leadership.

As a member-driven organization, it is vital that APS reflects the wishes of its community. Therefore, APS undertook a comprehensive effort to understand what our members expect when the Society takes a public position. This process included surveying all current and recently lapsed members and conducting focus groups with a diverse range of participants. The findings were clear: members expect APS to make public statements only on those topics that impact the scientific community, the study and practice of science, and areas where our expertise in physics can provide tangible societal benefits.

The results reaffirm many long-standing positions APS has supported, including the importance of access and inclusivity within our Society, physics education, and the scientific community. This initiative represents a significant step in ensuring that our public statements are consistent with and reflective of our membership. Through this work, we can continue to contribute meaningfully to the broader dialogue while remaining true to the values of the physics community.

Black Hole continued from page 2

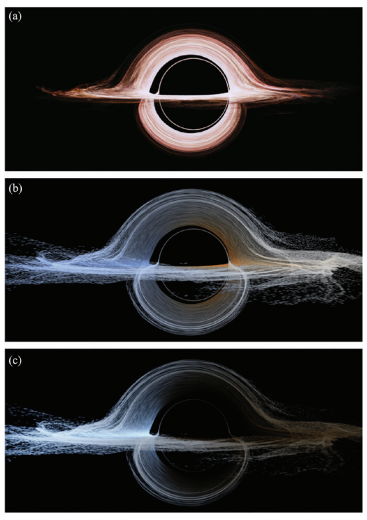
surprised, then realized that I've seen this before," said Thorne. "Jean-Pierre Luminet had done visualizations very early on in the era of what I call the golden age of black hole research — back in the 1970s — to see what a black hole with a disc around it would look like."

Interstellar earned $681 million globally during its original release, and along with its box office haul garnered numerous news articles about the science underpinning the film, led to Library of Congress lectures and calls for its inclusion in school science lessons, and inspired a number of time dilation memes. The film's recent return to cinemas for its 10th anniversary is now the highest-grossing IMAX re-release of all time.

Five years after Interstellar, scientists at the Event Horizon Telescope Collaboration published the first-ever image of a black hole, and then, in 2022, an image of the black hole in the center of the Milky Way. One major difference between the simulated and real images is its asymmetric shape — with the side closest to the viewer brighter while the far side is dimmer —caused by the Doppler effect. The black hole's asymmetry can be seen in the Event Horizon images but was not included in the Gargantua simulation, said Thorne.

The first picture of a black hole, released in 2019. Credit: Event Horizon Telescope Collaboration

"It's fortuitous that the movie came out during a very fruitful period in black hole science," added James. "LIGO got its first results, then the Event Horizon Telescope produced its images. In that sense, [our simulations] sort of anticipated



A moderately realistic accretion disk (a) with Doppler-shifted and gravitationally shifted colors, (b) with its specific intensity shifted in accord with Liouville's theorem, and (c) depicting what the disk would look like to a nearby observer. Credit: DNEG/Warner Bros. Entertainment Inc./Oliver James et al., 2015, Class. Quantum Grav. 32 065001

those results."

Thorne said that he hopes to see more complex astrophysics featured in Hollywood films in the future, particularly phenomena like colliding black holes and spaghettification. "Space-time dynamics is really a huge playground for both astrophysicists and filmmakers that goes so far beyond what you see in *Interstellar*," he said.

For James, one of the biggest impacts of the work beyond the film itself is "the way that it changed public perception of what a black hole might look like," shifting away from how previous depictions of black holes had been akin to "vague whirlpools in space," he said.

James recalled that, while working on *Interstellar*, he thought the wormhole would end up being the visual effects star. "No one really talks about the wormhole now," he said. "My conclusion is that, by doing the black hole with such scientific rigor, it created its own life — a little story within the film that took [the black hole] outside the boundaries of the movie."

Erica K. Brockmeier is the science writer at APS.

Chief Editor continued from page 1

What are the exciting frontiers in quantum science and technology you're paying close attention to?

It's tough to pick a few, and we are often surprised. In recent years, the contributing community has grown tremendously. We don't just have quantum mechanics physicists — we now have computer scientists, we have engineers, we have people working with chemistry, materials, and so on. And it's because of this rich combination of people from different backgrounds that we are able to push the field forward.

For example, dark matter is one of the big mysteries out there, and it's not technically within the scope of *PRX Quantum*. But people are trying to use quantum sensors just to get a hint of what dark matter is. Another innovative system that's gaining increased attention is the fluxonium qubit — a modification of the industry-standard superconducting transmon that's adding new knobs to the engineering toolbox.

There is also a lot going on with applying artificial intelligence to quantum science. While many studies are mostly concerned about automating routines, others are asking ingenious scientific questions on how the two domains together can address challenging issues. We also see intense research into new materials, like 2D materials.

Big breakthroughs are tough to come by, but we are seeing a lot of big results when people push boundaries in other fields by applying quantum tricks to specific systems. Sometimes the breakthrough is with neutral atoms, other times it's superconducting qubits or some error correction protocol. But generally, the question we are asking at PRX Quantum is, what are the results that are going to be the foundation of future research?

2025 is the International Year of Quantum Science and Technology. Do you have big plans?

Yes, and it's also the five-year anniversary of *PRX Quantum*, so it's a very opportune coincidence. First, we are preparing a collection of freshly published papers that we believe will be on people's minds for several years. We are thinking the ideas in these papers could shape the next several decades of quantum research — there are some amazing results to share. We will also be inviting the authors of some of these papers to a special session at the 2025 APS Global Physics Summit in March.

The Summit will be a big celebration for us. We'll have a session on the history of our field, and we'll have a few Nobel Laureates coming for that. Another session will be focused on how the tools and ideas from quantum information have shaped other fields. We're also partnering with the APS Division of Quantum Information to present an award for the most impactful doctoral thesis in quantum science. We have a big party planned during the conference, too.

If you could sit down and chat with each author of *PRX Quantum*, what would you say to them?

The number one thing in my mind is always, tell me how you felt about the process and what you like to read in the journal. I want to know everything that you liked about the review process, and everything you thought could have been better. I'm always curious to understand and make sure that we are conducting the best possible review process. Was it fruitful? Has the paper improved? Of course, I know our process is rigorous and our referees are very qualified, but I am interested in people's perceived experiences. I'm also curious about how our readers interact with the papers we publish.

I always ask these questions when I meet with authors throughout the year. In a project initiated by our board members, we are visiting many institutes around the world to discuss the review process with the quantum community, especially the younger generation. We're not just welcoming them and asking for their help as referees, but also sharing submission tips and best practices and so on.

I would also encourage senior researchers to work together with their junior members when reviewing papers. Even though journals in the Physical Review portfolio have been accepting joint reports for a long time, it's not well-known that you can include your students and postdocs when you referee a paper. It's very simple to file a joint report. You simply say, "I wrote this report together with such and such." It doesn't have to be super formal.

> "We don't just have quantum mechanics physicists — we now have computer scientists, we have engineers, we have people working with chemistry, materials, and so on." — Cassemiro

Cypress Hansen is a science writer in the San Diego area.

Doctoral programs in physics can provide more support for Black women

Recent research, supported by the APS Innovation Fund, highlights the challenges that Black women face in physics.

BY TAWANDA W. JOHNSON

Credit: Andre Hunter

To improve their experience in Ph.D. physics programs, Black women need academic advisers to understand the unique challenges they face in STEM, help them obtain tutorial assistance, and improve access to mental health resources, according to recommendations from a recent study.

In the study, titled "Amplifying Voices: Journey to a Ph.D. Through the Lens of a Black Woman in Physics," researchers examined the experience of Black women in physics Ph.D. programs, many of whom encounter racism, sexism, and financial and mental health challenges while pursuing advanced degrees.

The research team — Camille Coffie, a physics professor at Spelman College; L. Trenton Marsh, assistant professor of urban education at the University of Central Florida; Jacquelyn J. Chini, a physics professor at The Ohio State University, and Itunu Illesunmi, a professor of social work at the University of Northern Iowa — received funding from the APS Innovation Fund, which supports collaborative projects that advance physics education and community.

More than 2,000 people in the U.S. receive doctoral degrees in physics each year, but fewer than 0.5% of them are awarded to Black or African American women, noted Coffie, the lead researcher, in a recent webinar.

"Most of these women initiated a Ph.D. in physics, but they were often forced out, pushed out or what we call mastered out," said Coffie.

Thirteen women participated in the study, which began in January 2023, using a qualitative research method called "photovoice." Participants were asked to take photographs, documenting their social landscapes, ideas, and experiences about their Ph.D. journey.

For example, one participant photographed a cemetery to "mourn the graduate experience that [she] wanted to have." In a focus group, the participant noted that she felt she did not receive enough support in her Ph.D. program, even when she was grieving two deaths in her personal life. "All of the tombstones are a portion of me that is grieving — something being piled on top of the grief," she said about the photo.

Another participant photographed her sneakers with the laces triple-tied, expressing anxiety about tripping over them in a lab — a mistake she felt she would be judged more harshly for as a Black woman.

In another, a woman photographed herself in front of the mirror, taking out her braids. "Whenever we had to take our initial picture, I remember people making comments like, 'Her hair is so big — like she's covering up our faces,'" the participant said, an example of the microaggressions she experiences in her program.

Some participants highlighted their own resilience. Despite having few supportive faculty members in her program, one woman photographed a diamond ring, an allusion to the way that diamonds are formed: under intense pressure. "When we talk about diamonds under pressure … it's not always a smooth process," said Ilesanmi.

The researchers suggested several recommendations to improve Black women's experience in Ph.D. physics programs, including improving relationships with faculty advisers, increasing access to tutorial services and mental health services, and providing more opportunities for Black women to participate in fellowships, research, and assistantships. Other recommendations touched on non-academic issues related to the graduate experience; for example, policies that offer students more affordable healthcare, an enduring challenge for many in graduate school, would provide support.

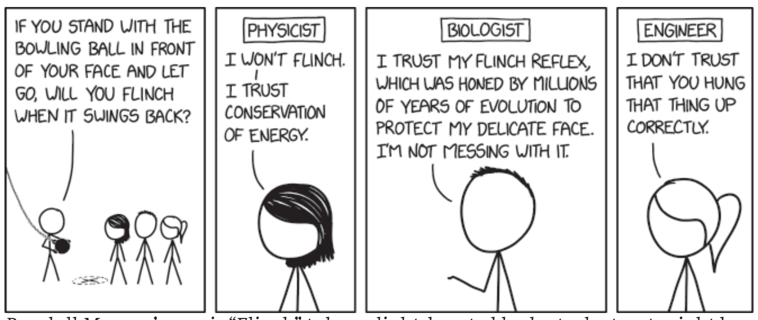
The researchers plan to turn their findings into a digital resource. "It's important when working with Black women to broaden your perspective and think about the different barriers they may face that may be unique when compared to other students," said Coffie.

Tawanda W. Johnson is the senior public relations manager at APS.

During monthly coffee hours, researchers examine the origins of trust in science

Jackie Acres, who helped design the coffee hours, reflects on the event series and the nature of trust.

BY JACKIE ACRES



Randall Munroe's comic "Flinch" takes a light-hearted look at why trust might be difficult even among scientists. Credit: xkcd comics

For a long time, I took my trust in science for granted. The scientific method made sense: Scientists make observations and test ideas with experiments. Some ideas persist through time, while others are altered or rejected. That never bothered me — that's the process.

Then in 2020, COVID-19 swept the globe, sparking the largest pandemic in more than a century. Public health experts took the stage. The world held a magnifying glass to the process of science.

For many, COVID-19 tested the limits of trust in science. Consider a hypothetical: You're a small business owner. When COVID-19 hits, scientists on the news urge people to stay home, and your revenue dries up. The science seems to change frequently. You spot social media posts that voice skepticism of lockdowns.

Suddenly, trusting the science feels a lot harder.

This was a common sentiment for many people, including friends of mine. I empathized with them, and I wanted to understand the roots of scientific mistrust and how people overcome it.

This inspired my involvement in the APS Science Trust Project, an initiative to help scientists understand and counter misinformation. This past summer, I worked with APS to design and facilitate monthly Science Trust coffee hours — now "community hours" — which are open to anyone. We wanted to invite open discussion about how trust develops; how trust is broken, including through misinformation or disinformation; and how we can individually or collectively build trust.

In May, we started with definitions. What do we understand "science" and "trust" to be? What drives trust? Do we trust some science fields or findings more than others, and if so, why? We discussed these questions as a group, sometimes with no easy answer.

In June, we learned about the role of empathy in trust. Brian Tibayan, a science communicator and graduate student, spoke about how important empathy is to communicate science, and to understand why and how people's beliefs and stances develop. Instead of a one-way connection where science is bestowed, empathy encourages a two-way connection wherein science is shared via dialogue.

In July, we focused on Wikipedia, a source many people trust. (APS periodically hosts Wiki Scientist workshops to train scientists to write and edit to Wikipedia pages). We talked with Aaron Halfaker, a senior scien-

Science Trust continued on page 6

Space Careers continued from page 2

more to space companies and professionals if she struck out on her own. "I felt like my physics background enabled me to go pursue any career that I wanted," she says. In 2016, she launched Astralytical.

Much of her work centers on market analysis and data-driven insights. "It's using my physics skills to think critically and also to be able to give these companies real technical feedback on their ideas, their products, and their market fit," she says.

Forczyk visits a lunar crater. *Credit: Laura Forczyk*

Forczyk is also an avid science communicator. She is active on social media, and as an expert in the space business, she is frequently quoted in international media, including *The New York Times*, *The Los Angeles Times*, NBC News, Vox, and National Geographic.

And for physicists considering a career in space? No need to cry about it. "If you are still alive," she says, "it is not too late for you to go pursue any direction of career that you wish."

Alaina G. Levine is a professional speaker, STEM career coach, and author of Networking for Nerds *(Wiley) and* Create Your Unicorn Career *(to be published in 2025).*

Quantum Ed continued from page 1

hard to imagine where we might go ... but it seems very likely that understanding quantum concepts will give students an advantage," she says.

The team's work with young students comes at a time of great interest in quantum science. Many innovations, like quantum computers, are still largely unrealized, but nations around the world are investing billions of dollars into quantum technology and the educated workforce it requires. And the United Nations recently proclaimed 2025 the International Year of Quantum Science and Technology, an education and awareness campaign for the burgeoning field, and a campaign for which APS strongly advocated.

Programs geared toward elementary school children are in their infancy. But for Holincheck, "quantum is an opportunity to help students develop complex thinking skills," like probabilistic thinking, she says. Students generally understand deterministic thinking: If I drop my pencil, it will fall to the ground. But in quantum physics, it's impossible to exactly define the position of particles, like the atoms that comprise a pencil, at a precise time. Instead, physicists use probability distribution functions — probabilistic thinking.

The team's Quantum is Elementary project, funded by a National Science Foundation grant, is designed around a set of key research questions. What knowledge base do elementary school teachers need to feel comfortable teaching quantum concepts and to design curricula for diverse learners? What knowledge base do students need to learn those concepts, and how do students make sense of quantum science as they learn?

To answer these questions, the GMU research team selected 10 teachers out of a pool of applicants from local elementary schools to participate in a multi-year project. "We didn't anticipate so much interest," she says, but it allowed the team to prioritize teachers at Title I schools — schools that receive federal funding because they tend to have more students from low-income backgrounds. The researchers also offered teachers a stipend for participation.

"We had teachers with a pretty solid understanding of science, and even some understanding of quantum, and then we had people who were excited but knew nothing about quantum," says Holincheck. Last spring, the researchers had the participants complete a quantum physics bootcamp to ensure everyone in the cohort had at least the same fundamental understanding of quantum topics.

Next, the researchers sorted the teachers into teams, and each team worked to develop a lesson that could introduce a fundamental aspect of quantum science, like superposition or entanglement. Starting in 2025, the teachers will pilot the lessons in their classrooms. The GMU team will capture data from these pilots to inform their research.

One of the teachers supporting the project is Marin Moore, a fifth grade teacher at the Ferdinand T. Day Elementary School in Alexandria, Virginia. Like many elementary teachers, Moore, who majored in economics during college, is responsible for teaching every subject in her students' curriculum — including science.

Moore considers herself "a huge science nerd," in part because her father is a plasma physicist. But for many educators, teaching science lessons is daunting. "The fifth grade science curriculum gets very content-heavy," she says, and the required content is set by Virginia's science standards, which don't include quantum physics. This is a challenge for teachers who want to incorporate additional topics, like the frontiers of science, into their classrooms.

Quantum physics "allows students to explore something they haven't seen before ... and they can just be curious," Moore says. "The opportunity for children to figure out, lets students know there's room for them in science too."

Most students who learn quantum concepts do so in high school courses that require advanced math, so most miss out.

For the research project, Moore's team developed a set of mini-lessons designed to teach text structures — how writers present ideas to their readers, like sharing thoughts in chronological order or comparing concepts. The teacher team used AI to write sample texts for the lessons, which are formally a part of her students' language arts curriculum, but they explicitly chose quantum physics as the topic set. It's a two-in-one approach, giving Moore the chance to bring quantum concepts into her classroom, even though it's not part of the prescribed science standards.

Ahead of the formal classroom pilot, Moore has already tried out the sample texts with her own fifth graders. "They'll have to read the texts a few times" and help each other understand, she says, but it's been exciting to see that they're

After a training bootcamp, Quantum is Elementary teachers developed pilot lessons on quantum science for elementary school classrooms. *Credit: Xiaolu Zhang*

doing so voluntarily. "They want to understand it," she says.

Holincheck says the GMU team's research project grew out of foundational work by the National Q-12 Education Partnership, another National Science Foundation project, which is compiling resources and teaching tools for elementary, middle, and high school classrooms. The project identified a clear need for teachers "to bring quantum into K-12 in new ways," she says.

"There's a beauty, a wonder to science, that often doesn't make it into the way we teach it," largely because of the emphasis on standardized testing and prescribed curricula, she says. Most students who learn quantum concepts do so in high school courses that require advanced math, so most miss out.

That's why Holincheck designed her team's study not only to support elementary science teachers, but also to develop new quantum physics lessons tailored specifically to elementary students — lessons like those developed in Moore's project. Other teacher teams in the cohort have developed lessons based on exercises on the possible effects of measurement, quantum encryption, and quantum superposition. For example, the team used the concept of superposition — where a particle can exist in all possible positions, or realities, until it is measured — as a metaphor to encourage students to think about the complexity of their own emotions. After all, a person can experience more than one emotion at once.

The research is very new. But for Holincheck, early lessons like these are important not only for quantum education, but for students' broader interest in science.

"Elementary experiences ... have a lasting impact on how students see themselves, their identity," Holincheck says. "If we want to change what STEM looks like, to make sure it's accessible and relevant to students across races and ethnicities, and linguistic and disability levels, we can't wait until high school."

Liz Boatman is a science writer based in Minnesota.

Hydrides continued from page 1

Nature Reviews Physics, they conclude that there is overwhelming evidence for superconductivity in hydrides.

"The more I read the foundational literature, and the more I learned about the way that results were being repeated, the more it became clear to me that hydride superconductivity is completely genuine," says Andrew Mackenzie of the Max Planck Institute for Chemical Physics of Solids in Germany and the University of St Andrews in the U.K.

Mackenzie was one of the initiators of the group's work. "At conferences last spring, guys my age were having lots of young people coming up to ask: What's going on in hydrides?" he says. After a communal discussion at a superconductivity meeting in Berlin in August, he and other researchers thought that something needed to be done to address young researchers' concerns. They organized a group that would review available data with the goal of delivering an objective evaluation of hydride superconductivity claims, says Jörg Schmalian of the Karlsruhe Institute of Technology in Germany, one of the article's cosigners.

The group of 15 scientists includes some of today's most prolific superconductivity researchers working in the U.S., U.K., Canada, Germany, and Japan. To ensure an impartial examination of the scientific facts, only people who had never worked directly on hydrides were consulted, Schmalian says. "Initially I didn't know what my judgment would be." But after a few weeks of reviewing the literature, he concluded that the superconductivity finding looked genuine. "I assume other members of the group had similar experiences," he says. The researchers examined the data independently, with some subgroups formed to assess specific technical aspects. All the consulted experts supported the report's conclusion, Mackenzie and Schmalian say.

The scientists examined two pieces of evidence for superconductivity based on measurements of electrical resistance and of magnetization. Specifically, a superconductor should both exhibit zero resistance and exclude a magnetic field from its interior.

In analyzing data, the group accounted for unique difficulties with fabricating and measuring hydride samples. "The uncertainties ... are higher in the hydrides than in any previously studied materials class," the group writes. The materials' inhomogeneity, in particular, means that only some islands within a given sample may be superconducting, so the resistance measured between electrodes only vanishes if there is a connected superconducting path between them. The challenge for magnetization measurements is that minuscule amounts of material have to be measured in diamond-anvil cells that apply extreme pressures. The magnetization signal from the cell — many millions of times the mass of the sample — may thus mask the sample signal.

The group concludes that, despite the experimental challenges, the resistance measurements of several teams as well as the magnetization measurements by one team (led by the late Mikhail Eremets at the Max Planck Institute for Chemistry in Germany) indicate an overwhelming probability that hydrides indeed host superconductivity.

Some of the data analyzed by Mackenzie, Schmalian, and colleagues come from the group of Sven Friedemann at the University of Bristol, U.K. "We faced strong doubts in the community," Friedemann says. "As a consequence, we struggled to secure funding and acknowledgment for our work. So, we are pleased to see the central message of this review article confirming the credibility of the research field."

"It is significant that a group of highly respected theorists and experimentalists, none of whom is directly linked to hydrides, made a strong effort to restore the reputation of the field, while highlighting the technical challenges connected with hydride experiments," says Lilia Boeri, a theorist at Sapienza University of Rome who has worked on delivering predictions for superconducting hydrides.

One researcher, however, takes issue with the analysis. Jorge Hirsch at the University of California, San Diego, has been a vocal skeptic of hydride superconductors, having flagged problems in results that are now discredited. "I was surprised and disappointed to see this [new paper]," he says. "I speculate [they wrote] it because hydrides being superconductors would establish the validity of BCS theory, in which they firmly believe." Hirsch disputes the widely accepted Bardeen-Cooper-Schriffer (BCS) theory for conventional superconductors. And regarding hydride magnetization measurements, he has recently raised concerns about the data from Eremets' group.

Settling all doubts over magnetization measurements may require new experimental methods. A promising technique uses nitrogen vacancies as sensors, Mackenzie says. The vacancies are implanted into the same diamond-anvil cell used to apply pressure to the hydride samples, thus overcoming the problem associated with probing magnetization at high pressure. Earlier this year, scientists using this approach claimed to have observed simultaneous electrical and magnetic signatures of superconductivity in a cerium hydride. Mackenzie, Schmalian, and colleagues, however, didn't include these magnetization results in their analysis. "We wanted to be conservative, as it's a new technique," Mackenzie says. "But that class of experiments holds tremendous promise, and we encourage people to read the paper and follow up on that intriguing work."

Mackenzie and Schmalian stress that confirmation work has been — and will continue to be — crucial to the field. "The gold standard of judgment in any field of discovery is when your colleagues are interested enough to go and try to do the same things themselves, and they get the same answer," Mackenzie says. Schmalian says that researchers should reflect on the incentives, such as citations, for scientists who do the important work of checking previous results. "The community could be a bit more gracious to [them]," he says.

Both Mackenzie and Schmalian say the key issue for them is responding to the young people who approached them for advice on hydrides. "If you're interested in high-pressure superconductivity and are wondering whether you should work on it, the objective facts say that you should be well advised to go and do it," Mackenzie says. "I believe that the discoveries that have been made in hydrides are some of the most important [ones] that I've witnessed during my time as a researcher."

Matteo Rini is the editor of APS' Physics Magazine, from which this article is reprinted.

BACK PAGE

It's the world's quantum year. How will you celebrate?

For the International Year of Quantum Science and Technology, scientists and students can help with festivities.

BY PAUL CADDEN-ZIMANSKY

Imagine the following scenario: Intelligent aliens arrive on Earth and begin a dialogue with humans about our species. One question we might expect to field is, "What is your best understanding of the rules governing the physical universe?"

A likely reply would be "quantum mechanics," a theory of wide-ranging applicability that has generated our most accurate, experimentally verified predictions.

But then comes a follow-up question from the aliens: "How many years does each person spend learning this quantum theory?" Our honest reply would be "zero." The average person is taught almost nothing about quantum mechanics in school or out of it. To the aliens, this might seem paradoxical: How can our species possess such important knowledge, but spend so little time teaching it to one another?

It's not like quantum mechanics is new. In fact, 2025 marks 100 years since its initial development. But for the average person, "quantum" most likely has made an impression as something obscure, niche, or unintelligible — a word invoked to fill plot holes in science fiction or make products seem both mystical and scientific, rather than a theory that underlies our deepest understanding of natural phenomena and has been instrumental to so many technologies.

This paradox has attracted attention on the global stage. For the first time in its 78-year history, the United Nations General Assembly put quantum mechanics on its agenda: All countries of the world resolved to proclaim 2025 the International Year of Quantum Science and Technology (IYQ).

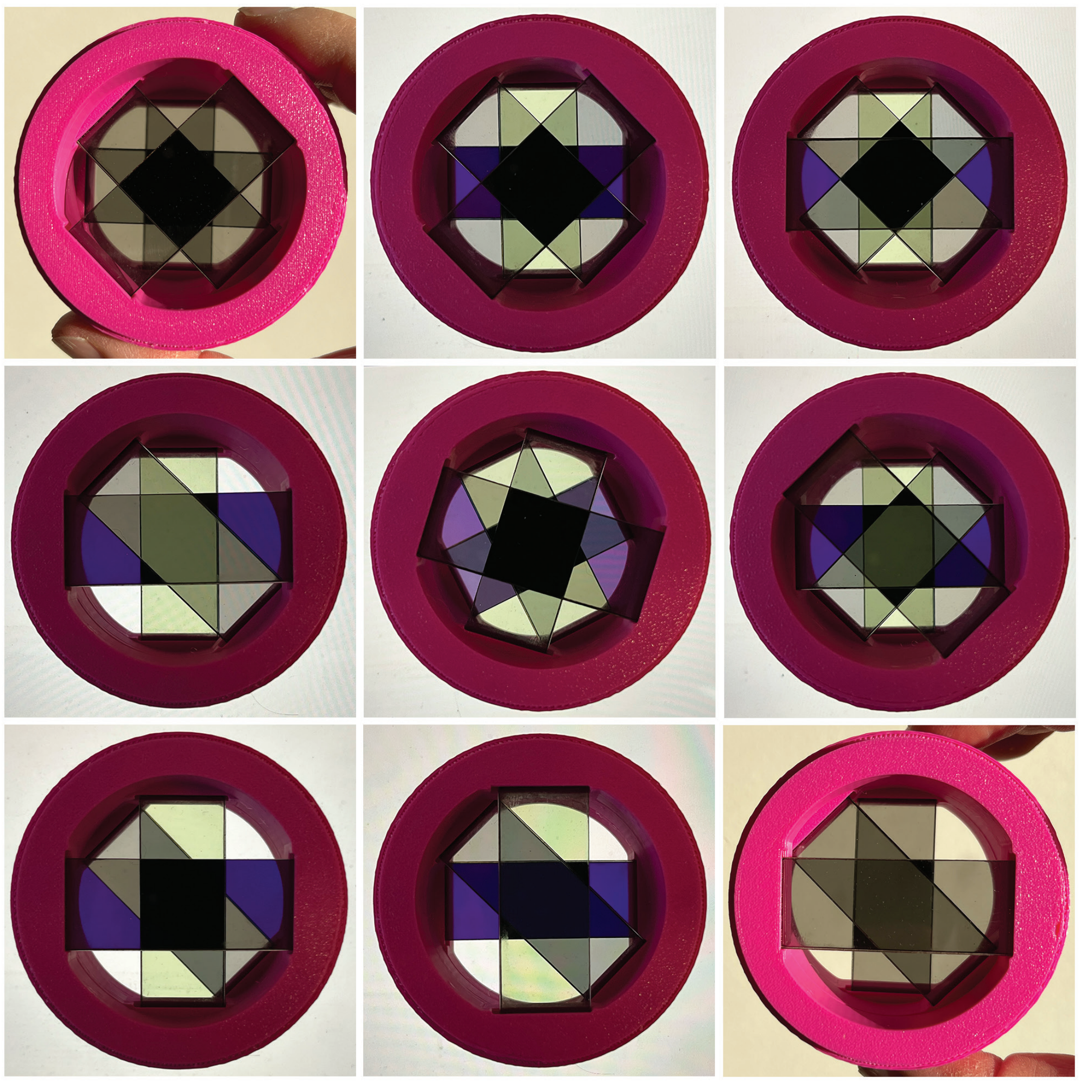
The official U.N. resolution recommends that IYQ "be observed through activities at all levels aimed at increasing public awareness of the importance of quantum science and applications." However, the resolution also stresses that the costs and implementation of all activities should be met from "voluntary contributions."

In other words, for the 2025 centennial of quantum mechanics, the world's nations want to shrink the knowledge gap between those who know something about quantum science and those who do not, and they are hoping that someone, somewhere, can step up and help.

This is where the readers of APS News come in. Today, only a small percentage of people grasp how central quantum science has become to our understanding of nature and to our technology, and readers of this publication are disproportionately members of this group. To make the year a success, the people in this group should take time in 2025 to help others share in this understanding.

If your reaction to this request is to create a public-facing quantum event or post online resources, thank you. (You're encouraged to use the IYQ logo to brand your efforts and submit events or resources at the main IYQ website quantum2025.org to be promoted.)

But if you're unsure how and whether you can help with this global request, let me address a few sticking points I commonly encounter when people weigh whether to do outreach projects.



The quantum kaleidoscope, an educational toy designed for the International Year of Quantum Science and Technology. The different light effects produced by the crossed polarizers can teach concepts like quantum state, quantum measurement, and superposition. Credit: Paul Cadden-Zimansky

First, you might feel an aversion to doing outreach, or believe you're not very good at it. Aside from the standard responses — "You might like it if you try it" or "You get better with practice" — your self-assessment might be entirely correct. But even if you're not doing the outreach, you can still be a helpful facilitator for those who do.

I've encountered many physics students at both the undergraduate and graduate levels who are keen to introduce others to their field through outreach, but who don't get the sense that this work is valued in their academic or research environments. In these cases, small acts that set the tone matter. Think of an instructor who gives students an assignment to explain a quantum concept in a non-technical way, a PI who sets aside 1% of their group's time for a public-facing project, or a department head who allocates resources for people at their institution to use on quantum outreach. All are materially helping with the global effort and signaling to others that they value this work, even if they're not doing it directly themselves.

A second hesitation is that explaining quantum science to others is hard to do. The challenging nature of the topic is the main reason why it's largely absent from schools. However, we're not necessarily aiming to teach quantum mechanics to the public. Rather, we're just trying to improve people's awareness of the importance of quantum science and give them one or two things to hold onto about how it affects their lives.

I find it useful to compare quantum mechanics to DNA, the importance of which has also come to the fore over the past 100 years. Most people are not microbiologists, but they know DNA exists, understand that it's central to biology in general and their own biology in particular, and are aware of a few facts about it and its impacts. Their knowledge may not be deep or technical, but their awareness is a starting point from which they can learn more.

In getting to the same place with quantum mechanics, which is central to our understanding of the physical world in general and to many things around us in particular, a challenge is that unlike DNA, quantum mechanics is not a physical object one can point at; it's an abstract set of rules. Here, I think the most useful approach is to start by pointing to an object or process — something relevant to you or your audience — and explaining how and why quantum mechanics helps us understand it more deeply.

In thinking about things to point to and stories to tell, a third trap that people sometimes fall into is worrying about what is and isn't quantum. A question like, "Why does the sun shine?" can be addressed without invoking anything quantum, but it is also the case that quantum science can deepen our answer. A quantum computer is so called because it exploits aspects of quantum entanglement in its operation, but it can mislead people into thinking that the "classical" computers they use every day have nothing to do with quantum science, when, in fact, their operational principles, from the processor to the screen, have been aided in their creation and refinement by quantum understanding.

Rather than think about what is or isn't quantum, think about how quantum science has been helpful. In the spirit of a 100th birthday party where you would reflect on all the large and small ways the centenarian has touched your and others' lives, consider some of the ways quantum science has touched the world around you (or might in the future) and help others see this.

A final objection to outreach is that you don't know enough about quantum science to communicate it to others. But understanding a vast topic like quantum science and technology is not binary. No one is an expert in all things quantum; you just have to know one or two things more than the person you're talking to. You may not understand how quantum mechanics is relevant to the working principles of solar fusion or transistors, but if you understand that it is relevant, this information is still valuable to communicate.

In fact, foregrounding your (and humanity's) ignorance about quantum science is often a better place to start than playing the role of an authoritative expert. Collectively, we've explored the surprising quantum landscape for a century, but there is still much we don't know or understand; many possibilities and advances await discovery. It is not just the quantum accomplishments of the past 100 years we can share, but the excitement and promise of an unknown future.

In considering what you might do to help, keep in mind that the grand scale of a global year might make it seem as though the U.N. is expecting commensurately grand events. While there are large-scale events being planned, starting with the IYQ opening ceremonies in Paris, don't discount the impact that small, intimate events and gestures can have. Setting up an informational table for an hour in a public area, posting a few "Did you know" quantum facts on a message board, or advertising your willingness to answer basic questions from students, journalists, or anyone else can start lots of conversations.

In a world where the success of information transfer is often measured in millions of views or clicks, the deepest impression is often made through in-person interactions between just a few people. Simply sharing a story or fact — one that might bolster a person's appreciation for the workings of the world, one that they can then tell others — can cause knowledge to spread well beyond the initial interaction.

Here's one fact I've used recently: When you stand outside in the sun, you're hit by around a billion trillion photons (i.e., light quanta) each second. Every 10 seconds or so, one of the photons that hits you is arriving from one of the most distant galaxies we've ever discovered. It's only because we now know these quanta exist — and have developed technology, now deployed in telescopes, that can carefully count them — that we're able to image these faraway galaxies for the first time in just the past year.

There are more than 100 years of quantum stories to choose from, many of which haven't been widely communicated. Consider it your gift for a global birthday party to tell one of them this year.

Paul Cadden-Zimansky is an associate professor of physics at Bard College and a global coordinator for the International Year of Quantum Science and Technology. Learn more about IYQ at quantum2025.org.

Science Trust continued from page 4

tist at Microsoft, on the process of maintaining quality in Wikipedia articles. Currently, all large language models are trained from Wikipedia. However, if Wikipedia editors use LLMs to generate more content, this could introduce inaccurate information, copyright infringement, or libel into Wikipedia articles.

In August, we discussed artificial intelligence. We heard from William Mapp, a CTO at Qlarant; Shane Bergin; a physics professor; and Julian Mintz, a physics graduate student. The variety of perspectives inspired a rich discussion of topics, from AI's environmental impacts to whether scientists should use AI in their research or classrooms. We, like many others, were concerned about how much AI will change our lives.

I'm grateful for the opportunity I had to shape discussions on science trust, particularly with other people passionate about the topic. One of my personal goals with the project was to encourage attendees to reexamine their own relationships with science and trust — not to break that trust, but to study it through the lens of someone outside science.

Trust in science may not come easily to everyone. But with empathy and communication, I hope we can build that trust and build a better world together.

Learn more about or sign up for the Science Trust community hours.

Jackie Acres is a visiting assistant professor of physics and biophysics at Whitman College in Walla Walla, Washington.

Opinion articles on the Back Page are member commentary; their views are not necessarily those of APS. To respond to an opinion piece or pitch your own (we welcome both), email letters@aps.org.