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## Proposed F-1 visa change could limit students to four years in the U.S.

APS is bracing for upheaval in U.S. academic programs.

BY KENDRA REDMOND



Students on the main quad at the University of Illinois Urbana-Champaign. A recent Trump administration proposal would introduce new limits on the visas used by most international students to study at U.S. schools. Credit: Adobe Stock/Leigh Trail

n August, the U.S. Department of Homeland Security announced intentions to revamp the visa program through which most international students enter the country. Among the changes, DHS proposed limiting students' length of stay to four years, a move directly

at odds with the six-year average it takes to complete a physics Ph.D. in the U.S. After four years, students would need to apply for an extension.

"Such a policy would fundamentally impact graduate education in the U.S.," says a Caltech astrophysicist who requested anonymity. He

came to the U.S. as an international student to attend a top-ranked astronomy Ph.D. program, earning the degree in about five years.

"The excellent students that get admitted to U.S. universities are typically people with other options," he says. If this change is implemented, "many will choose to take their talents elsewhere."

The proposed rule change would apply to nonimmigrant academic students on F-1 visas and exchange visitors on J-1 visas, a category that includes many postdocs and visiting scientists. Currently, people with F and J visas can remain in the country as long as they are engaged in authorized activities, a period known as the duration of status. Effectively, a full-time student making sufficient progress toward a degree can stay in the country until they complete their education.

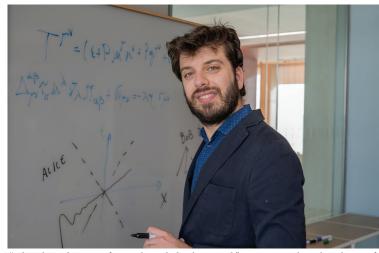
The new DHS plan eliminates the duration of status, stipulating that F and J visa holders be approved for no more than four years. Students un-

Duration of status continued on page 7

# The Valley Prize winner making sense of the world's fastest fluids

As a graduate student, Lorenzo Gavassino solved a problem that had puzzled physicists since the 1980s.

BY SOPHIA CHEN



"I do science because, for me, knowledge is an end," says Gavassino, the winner of the 2026 Valley Prize. Credit: Lorenzo Gavassino

t its fastest, the water in the Niagara Falls flows at 30 meters per second. Lorenzo Gavassino, the 2026 recipient of APS' George E. Valley Jr. Prize, studies fluids that move a million times faster. The prize, awarded annually to an early-career individual for an outstanding scientific contribution to physics, honors Gavassino's theoretical research insights into these socalled relativistic fluids.

Relativistic fluids are "substances that move very fast, close to the speed of light," or exist in extreme

Valley Prize continued on page 7

# The quiet winner of the Nobel Prizes in science

Great research does not come free.

BY LIZ BOATMAN



Credit: Elia King/APS

very October, the Nobel Prizes honor science's greatest minds — including this year's winners in physics, John Clarke, Michel H. Devoret, and John M. Martinis, who demonstrated that 'quantum character' can be observed at the macro-scale using a circuit made of superconductors.

Throughout history, laureates have given us the blue LEDs that light our phones, fiber optic cables that carry internet traffic, and neural networks that power artificial intelligence. They have detected ripples in spacetime, developed life-saving vaccines, and revealed how stars forge the elements from which we are made.

But there's another unsung winner: federal funding.

Since World War II, the federal government has funded basic research across universities and labs.

Nobel Prize continued on page 6

# Hitoshi Murayama, winner of APS Lilienfeld Prize, on understanding the universe

Murayama, founder of Tokyo's Kavli Institute and chair of the decadal P5 report on particle physics, believes that science is for everyone.

BY LIZ BOATMAN

heoretical physicist Hitoshi Murayama has spent his career studying the fundamental building blocks of matter — tiny particles like quarks and neutrinos. And like many scientists, he's crossed continents to do it.

"I hope people can see that science can't be owned by a particular country, company, or university," says Murayama. "It's a common pursuit for everybody."

Murayama is the recipient of the 2026 Julius Edgar Lilienfeld Prize, which annually recognizes a scientist for outstanding contributions to physics and exceptional skills in lecturing to diverse audiences. Murayama is recognized for his work in "theoretical and experimental particle physics, as well as inspirational public outreach and effective science advocacy."

"It certainly is a great honor, especially looking back at the past recipients — they are all big names," says Murayama. The prize is also awarded by APS as a whole, rather than an APS division, he notes. "It's a recognition from the physics-wide community, and that makes it all the more special."

Born in Japan, Murayama lived in divided Germany for part of his childhood. After completing his doctorate in physics at the University of Tokyo, he left Japan in 1993 for a postdoctoral position at the Lawrence Berkeley National Laboratory in California, joining the physics faculty at the University of California, Berkeley, in 1995.



"Science is about how we try to understand ourselves," says Murayama. "Anybody can relate to that." Credit: Hitoshi Murayama

APS News spoke with Murayama to learn more about what inspires him, his perspective on the role of science in society, and his hopes for the future of physics.

This interview has been edited for length and clarity.

#### Which scientists have been your biggest inspiration?

Growing up in the 1960s, Japan was often criticized, especially by the United States, for stealing technologies and mass-producing cheap goods but not inventing anything. When Sin-Itiro Tomonaga received the Nobel Prize in 1965, I was able to see somebody who was innovative and creative and original — and he was coming from Japan, in the area of theoretical physics. That was a major part of my inspiration.

#### What's it like being split across the U.S. and Japan?

Logistically, it's complicated, because it's always a long trip there and back. But I was able to expand Japan's scientific horizon by founding the Kavli Institute for the Physics and Mathematics of the Universe (IPMU), which now has not only theoretical physicists involved, but also experimentalists, astronomers, and mathematicians. Now, I see where my field sits within the scope of the broader scientific landscape. Talking to people from other areas, like mathematics, I end up finding answers to my own questions.

IPMU has also had an impact on Japanese academia. For example, it started the system of dual

Lilienfeld Prize continued on page 5

# Wiki Scientist helps physicists build street cred on Wikipedia

The training teaches physicists how to share their access to knowledge. First, they must learn proper etiquette.

BY NYLA HUSAIN

he world's largest online encyclopedia hardly needs an introduction — but if you could use a refresher, check out its Wikipedia page.

A ubiquitous entity on the web, Wikipedia is used by just about anyone who wants to learn something online. It can be a starting point for an upcoming school report as much as a venture into a rabbit hole to stave off boredom (ever heard of the list of lists of lists?). But it's also a global community devoted to sharing accurate, unbiased, and freely accessible knowledge.

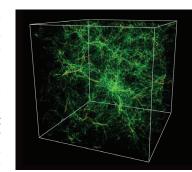
In theory, it's simple to join: Anyone with an account can edit Wikipedia. But for those committed to doing it the right way — that is, not the vandals — it can be daunting to know where to start.

For members of the physics community, that's where the American Physical Society's Wiki Scientist courses come in. The six-week program, offered by the Society's Office of Public Engagement in partnership with Wiki Education, teaches physicists how to add and edit content to Wikipedia pages for a variety of physics-related topics, from its history and people to its concepts and theories.

> "I didn't realize how big the community was and how interactive people are," said Healy.

Since 2020, Wiki Scientist instructors have coached over 200 participants to contribute to more than 650 Wikipedia pages and create almost 100 new ones, according to the course's public dashboard. This year, to commemorate the International Year of Quantum Science and Technology, they're updating several pages — including favorites like magic wavelength, atom interferometer, and stimulated Raman adiabatic passage — and drawing from sources like the Quantum Foundations Collection, an assemblage of research papers pivotal to the development of quantum mechanics over the past century.

Wiki Scientist participants come from both industry and academia and range in career level from undergraduate students to career physicists and retirees. "A couple of professors said that they already did a Wikipedia component in their classes," said Meghan Healy, the community and operations specialist at APS and Wiki Scientist's organizer. "They wanted to learn more about the Wikipedia side



A computer simulation of warm-hot intergalactic gas — one of many topics that APS Wiki Scientists have updated on Wikipedia. Credit: Princeton University/Renyue Cen

of things - how to update it and how relevant it is for their classes — which was really cool."

The program has hosted courses with a variety of themes. Last year, participants updated pages related to plasma physics: think stellarators and the warm-hot intergalactic medium. The year before that, it was climate and energy: think thin-film solar cells and climate change in Illinois. They've filled dozens of pages with the accomplishments of lesser-known physicists from around the world, both past and present – Facundo Bueso Sanllehí, Hisako Koyama, and Ilham Al-Qaradawi, to name a few.

But once participants got some practice under their belts, there was no limit to what they could edit. Some dabbled in topics that interested them personally, while others used their newfound skills to share their expertise. "In last year's course, someone was super interested in this one biophysics application of plasma," said Healy. "He worked with it in his actual job, so he obviously knew a lot about it and wanted to improve the existing article."

It can be valuable for scientists to contribute their expertise to Wikipedia. But first, they need to learn the ropes. After familiarizing themselves with Wikipedia's editing interface, guidelines, and policies including its five pillars — new editors must learn to navigate the complex etiquette of shared authorship in its vast volunteer community.

"When you start editing with Wikipedia, no one asks you what your qualifications are, or what degrees you have, or what your job is," said this year's Wiki Scientist instructor. Editors discuss and debate edits on talk pages, where their sole credibility lies in the edit history posted on their user profile for all to see. "New editors start with zero edits. You have no credibility whatsoever." But by learning the community guidelines and editing and citing material

Wiki Scientist continued on page 4

#### THIS MONTH IN PHYSICS HISTORY

# November 1966: Syukuro Manabe makes the first modern climate model

Manabe, who won the 2021 Nobel Prize, developed models that forecast the warming effects of greenhouse gases.

BY KATHERINE BOURZAC

n 1946, a year after the creation of the first programmable modern computer, mathematician John von Neumann had an idea: scientists should use the machine to predict the weather.

Neumann formed a meteorology group at Princeton University and got to work. In 1950, after more than 24 hours of runtime, the ENIAC computer generated a 24-hour forecast based on a simplified model of the atmosphere.

The forecast arrived late and wasn't entirely accurate, but the government took notice of this promising work. In 1955, the U.S. Weather Bureau created the General Circulation Research Section, headed by Joseph Smagorinsky, with the goal of modeling the atmosphere and, hopefully, better predicting the weather. (The section was later renamed the Geophysical Fluid Dynamics Laboratory, or GFDL.)

Smagorsky recruited Syukuro "Suki" Manabe, a promising meteorology Ph.D. grad from Tokyo University, to work on the project.

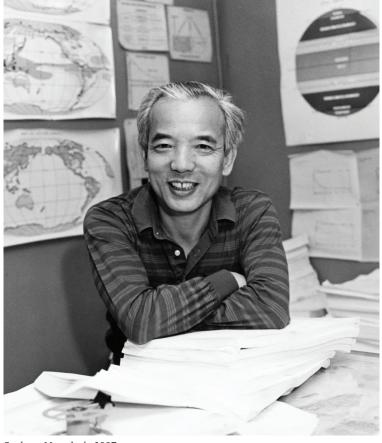
Smagorinsky "wanted to build a global numerical model," Manabe recalled in a 2005 interview — an ambitious vision. But the climate is remarkably complex, and representing its multiple interconnected physical processes with the team's "feeble" computer was a challenge. "If we put everything in the model at once, the computer couldn't handle it," Manabe said. "I was watching the model blow up all the time."

For example, to describe how gases and heat move, the team needed to determine whether they could couple the equations of motion with equations describing energy transfer from radiation. They'd then need to run the model and generate a realistic description of how temperatures are distributed in the atmosphere, across its layers and around the globe.

This kind of complex prediction was a lot to ask of early computers, especially in the early stages, when the team just needed to see whether their basic approach was working.

Manabe decided to simplify things. He and his colleague Robert Strickler started by modeling how heat transfers and gases move through a vertical column of the atmosphere. Because this model looks only at motion along one axis, up and down, it's described as one-dimensional.

The model worked: "I was pleased to get a nice stratosphere and near-perfect surface temperature," Manabe said. The two published a paper on this work in 1964.



Svukuro Manahe in 1997.

Credit: Princeton University, Office of Communications, Robert P. Matthews

To test the one-dimensional model, Manabe and his colleague Richard Wetherald decided to look at the effects of different concentrations of carbon dioxide and other greenhouse gases. "Before I coupled this simple model with the three-dimensional one, I wanted to see how sensitive the model is to cloudiness, water vapor, ozone, and to CO2," Manabe later recalled.

"I realized that CO2 is important," he said. "As it turned out, I changed the right variable and hit the jackpot." When the duo doubled CO2 in their model, global average temperature increased by about

Manabe and Wetherald submitted their findings to the Journal of the Atmospheric Sciences on Nov. 2, 1966, and the study was published the following year. It's widely regarded as the most influential climate change paper ever published, and laid the foundation for all modern climate models.

"I had no idea how important the idea of greenhouse gases would become," Manabe said in a 2015 interview. "I had no idea it would have such a great impact

Global warming wasn't a completely new idea: In the mid-1800s, scientists like John Tyndall and

Svante Arrhenius realized that burning fossil fuels could cause global warming. But Manabe's contemporaries disagreed about the magnitude of CO2's warming power. "At the time, no one cared about global warming," he said. "Only gradually people began to realize that global warming is reallv an issue."



Manabe (center) speaks with colleagues Kirk Bryan and Joseph Smagorinsky at Princeton University in 1969. Credit: Photo courtesy of the Geophysical Fluid Dynamics

Despite the simplifications in their model, Manabe and Wetherald's estimation of the climate's sensitivity to carbon dioxide concentrations still stands today.

Manabe's model included two key factors that others had over looked when estimating the greenhouse effect, says atmospheric physicist Joanna Haigh, an emeritus professor at Imperial College

Climate model continued on page 4

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### Trump's higher ed compact, supercomputers at national labs, and more

The latest science policy news.

BY THE FYI TEAM



Los Alamos National Laboratory is one of three national labs at which new supercomputers will be built in the coming years, according to the DOE.

Credit: Los Alamos National Laboratory

# DOE to build nine new supercomputers at national labs

The Department of Energy announced nine new supercomputers, to be built at three national labs in partnership with technology companies. Some will be operational as early as next year, and one at Argonne National Lab is planned to be the largest AI supercomputer within the lab system, DOE said. In their announcements, the labs said the new computers will accelerate scientific AI models and discoveries.

The announcements do not note how much of the funding for each supercomputer will come from the private partners, which include HPE, Nvidia, AMD, and Oracle.

DOE's announcement for the Oak Ridge National Lab supercomputers states that "with more than \$1 billion in public-private investment, DOE, together with AMD and HPE, is delivering new AI capacity in record time." The announcement from Los Alamos National Lab states that "the project will be supported through anticipated future funding, contingent upon the availability of appropriations."

# Conservative colleges poised to sign Trump higher ed compact

While most universities invited to sign the Trump administration's Compact for Academic Excellence in Higher Education have rejected the offer, two small conservative-leaning colleges have expressed interest in signing the agreement: New College of Florida, a small public liberal arts college, and Valley Forge Military College in Pennsylvania.

Trump's higher ed compact, which promises preferential access to federal funding in exchange for commitments to the Trump administration's political agenda, has been criticized by many higher education leaders. A statement by the American Council on Education and other university groups said the "compact's prescriptions threaten to undermine the very qualities that make our system exceptional."

# Former DOGE employee now head of naval research

Rachel Riley, a Department of Government Efficiency official who pushed for deep staff cuts at the Department of Health and Human Services, is now in charge of the Office of Naval Research. Riley replaced Rear Adm. Kurt Rothenhaus, who is now commanding the Naval Information Warfare Systems Command.

Riley was a partner at McKinsey prior to becoming a senior adviser at HHS, where she reportedly recommended laying off nearly 8,000 employees — a move that was scaled back significantly and has been temporarily blocked by a federal court.

The Office of Naval Research manages a \$2.5 billion annual budget and plays a central role in setting the facilities and administrative costs, or indirect costs, covered by federal research grants. The Trump administration attempted to significantly cut indirect cost rates earlier this year but was blocked by courts. University groups have been pushing a new financial model to split costs.

# DOE renews quantum research centers

The Department of Energy renewed its five National Quantum Information Science Research Centers in early November, awarding \$625 million in funding over five years, including \$125 million from fiscal year 2025. The total matches the funding targets set in the National Quantum Initiative Act that established the centers in 2018. Each NQI center is led by an Office of Science national lab. Congress has expressed interest in reauthorizing the NQI Act. The House Science Committee advanced bipartisan reauthorization legislation in the previous Congress, but the bill did not reach a vote in the full

Meanwhile, the Defense Advanced Research Projects Agency has selected 11 participants to advance to the second stage of the Quantum Benchmarking Initiative, which aims to assess whether a useful quantum computer can be produced by 2033. The selected companies, which include IBM, IonQ, and Atom Computing, will develop detailed R&D plans for quantum computers. The Wall Street Journal reported last month that the latter two companies were considering deals with the Trump administration to exchange equity for at least \$10 million in funding awards. The Commerce Department denied the

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# Quantum science makes for happy campers

With support from the APS Innovation Fund, a group of tweens and teens spent 10 days at a science retreat in Oklahoma.

BY AARON RAGAN-FORE



 $Campers\ test\ paper\ planes\ in\ a\ competition,\ trying\ to\ improve\ the\ planes'\ aerodynamics,\ stability,\ and\ duration.\ Credit:\ Nikita\ Kundu$ 

any kids decide early in their schooling whether they are 'science people.'

"By high school, people have decided that they don't like science, somehow," says Mario Borunda, an associate dean at Oklahoma State University. This makes it important to "catch people early on, when they might be still interested."

Intent on reaching young people, Borunda teamed up with Derek Meyers and Julius de Rojas to apply for — and receive — an APS Innovation Fund grant to sponsor a ten-

entanglement," says Borunda. "Then from 10 to 11:30, they would do an ac-

music and sports facilities. "We wanted students to get a feeling of

"We wanted students to get a feeling of what it's like to be a college student," Borunda says, a revelatory notion for some of them.

tivity related to that — so when they were doing the photoelectric effect, then they started making their own spectrometers."

The immersive, residential component of the experience was key

what it's like to be a college student," Borunda adds, a revelatory notion for some of them.

"They're playing with the equipment; they're living in the dorm for a week," Borunda says. "They were able to see what the grad students are doing, what some of our undergrads are doing, and they can see themselves coming to school."

On the last day, when parents arrived, they were treated to poster presentations on the students' research, as well as a workshop on making college affordable and attainable.

Borunda is also proud that the camp could host several Indigenous students. "Oklahoma has a high population of Native Americans, and we have so few of them going into STEM," he says.

Cultural context plays a strong role in these students' camp experience, he adds. Whereas the apparent contradictions of quantum science can be tricky to square through a Eurocentric scholarly lens, "people in this culture wouldn't have had a problem with this duality of things."

Aaron Ragan-Fore is a head of communications at APS.



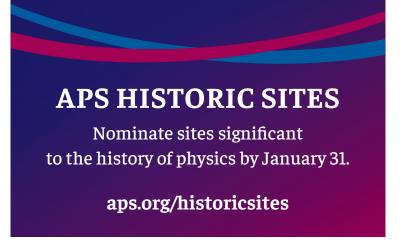
Credit: Nikita Kundu

day, residential quantum science learning camp for sixth through ninth graders.

The team was one of six grant recipients for the fund this year, all of them aligned with the 2025 International Year of Quantum Science and Technology. The other winning projects run the gamut from K-12 instruction to innovative uses of quantum technologies. All six focus on addressing challenges that face the physics community.

Borunda's camp took place this June, when 12 students lived, learned, and played together on the Oklahoma State campus in Stillwater. The camp's lectures were complemented by hands-on activities. A morning lecture might center on "chemical bonding, formation of materials, or

to its success, Borunda says. The students also toured other spaces important to undergraduates, like



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## APS student members weigh futures in both industry and academia

At career fairs this year, early-career physicists are exploring all their options.

BY AARON RAGAN-FORE



Denuwan Vithanage at the Molecular Collisions Lab at Wesleyan University. "For the younger people or people who are starting, it's very important to go to conferences and networking events," he says. "I see the importance of knowing people, networking, the value of that more and more each day." Credit: Denuwan Vithanage

s a child, Jessica Doan dreamed of the careers many kids do. Maybe she'd be a cowgirl one day, she thought, or a police officer. But the San Francisco Bay Area native — shaped by research on the Apollo missions and the film Interstellar — settled on a career that's no less exciting, and enrolled at San Diego State University as an astronomy major.

Doan applied herself academically, pursuing a summer internship in particle physics research and a senior research project on inflationary cosmology. Her path to graduate school seemed intuitive. "I was very complacent in where life was going to take me," she says.

But in early 2025, her senior year, Doan was beginning to think through other options —including careers in telescope data analysis or science communications, which did not require advanced degrees.

#### Physicists as problem-solvers

Doan is not alone in considering a pivot to an industrial track. With federal funding for labs and universities facing threats, industry offers an attractive alternative for job-seekers.

"If you're in a traditional research role, and you think that might be at risk, you're going to have to broaden your perspective and look at industry and think about things that are mayal meeting in Portland, Oregon, in

"I was there not only just to do the regular go-to-DAMOP to meet and greet, but also to hire, to look sition," Oteiza says of his trip to the Pacific Northwest. "I did chat with

for a new candidate for a sales poseveral people who are very interested in moving out of traditional academic research because they were concerned about where academia

ing up a circuit or figuring out where to put a thermocouple."

#### A community of career guidance

Those are skills that Hill values, so she invested her own time at the DAMOP meeting by serving as an APS Career Mentoring Fellow, counseling students in 1:1 sessions on how to make themselves more marketable.

At DAMOP, Denuwan Vithanage, a Wesleyan University Ph.D. candidate, was one of Hill's mentees. Vithanage has always intended to enter the industry workforce after his Ph.D., so in his meeting with Hill, "I asked [for] some advice to craft my CV, to convert it to a resume" that would be appropriate for the sector, he says.

"A career in industry would be more aligned with my personal goals rather than a career in academia," he says, in part because the earning potential can be higher right after graduation. "I would be very happy to do research in an industry setting."

Besides, he notes, with the Trump administration's scrutiny of university resourcing, industry might be a safer bet in the short term. "I think whatever decisions they're making right now [are] affecting more academic in-



Jessica Doan (center) with peers at her May 2025 commencement. "I cannot emphasize enough on how mentorship has helped me create and target goals for my physics career," she says. "There are many different types of mentors — professors, industry professionals, and other, more experienced students." Credit: Jessica Doan

was going these days."

And why would a trained physicist be a match for a sales role?

"Physics trains you how to solve problems, how to gather data, ana-



DAMOP attendees in Portland, Oregon, meet with Career Fair industry representatives. Credit: Midhat Farooq/APS

be more applied, more business-oriented, more defense-oriented," says Eduardo Oteiza, vice president of sales at Vescent, a Denver-area tech solutions provider for the quantum industry. "There are many startup companies that are trying to commercialize ideas in AMO [atomic, molecular, and optical] physics, and it is still being funded, fortunately."

Vescent employs physicists in a variety of roles. For example, the company has a "whole R&D team that investigates new technologies," Oteiza says. And to recruit for those sorts of opportunities, Oteiza and his colleagues frequently take Vescent's show on the road. He staffed a booth at the Career Fair at the APS Division of Atomic, Molecular, and Optical Physics (DAMOP) annu-

lyze the data, come to a conclusion, and implement that," Oteiza says, referring to the average physics graduate as a "problem-solver."

"If you're going to design a new kind of product into the market, you need those skills," he adds.

Kristen Hill, director of product management for CO2 lasers at the Washington-based company Novanta, agrees. She identifies "grit" in physics students and early-career job seekers, a trait that's critical in her line of work.

"Say you want to measure this one particular thing, but there might not be a tool that exists to measure it," she posits. "In addition to understanding [the] phenomena, you also need to design the equipment, whether it's, you know, solderstitutions, not necessarily the private sector," he says.

Vithanage had attended previous DAMOP meetings, but "when I registered for 2025, and they had this career fair, I was like, 'Okay, I feel lucky because I'm actually looking for jobs in the near future."

Vithanage also found value in a DAMOP session on accessing APS career resources, as well as the chance to network with exhibitors.

As for Jessica Doan, the astronomy student, she eventually applied and accepted admission to an Italy-based astrophysics and space science program through the Erasmus Mundus Joint Master Program — a decision, she says, that helps her keep her head down through the current administration's review of higher education.

"With the current reduction in research funding, research groups who may have been able to admit more graduates to their institution must have stricter budgets to last a while, which means there are even fewer graduate positions open for the foreseeable future." she says. "It definitely does play a part in me thinking that I would like to pursue a career in Europe more so than in America."

While Doan is excited about the academic track, she's glad she thought through all her options, including moving into industry. With help from APS, she was able to consider both paths.

Aaron Ragan-Fore is a head of communications at APS.

Climate model continued from page 2

London. One factor was the socalled "convective adjustment," which accounts for how gases in the atmosphere move in response to incoming solar radiation and the reflection of heat from the ground.

The other factor key to Manabe's model is water vapor. When the atmosphere warms, it can hold more water vapor, which is a greenhouse gas. This causes a positive feedback loop: The warmer the atmosphere gets, the more water vapor it can hold, and the warmer it gets. As a result, scientists who made "dry calculations" underestimated the warming effect of CO2, says Haigh.

Tapio Schneider, a climate mod-

el to cover the globe, and he led GF-DL's efforts to couple their atmospheric model with ocean models. GFDL moved to Princeton University in 1968 and became part of the National Oceanic and Atmospheric Administration (NOAA) two years

Now a professor emeritus at Princeton, Manabe shared the 2021 Nobel Prize in Physics for his work on climate modeling.

According to the 2024 United Nations Environment Program Emissions Gap Report, the planet is on course for an average temperature increase of 2.6 to 3.1°C in this century. To limit that increase



Manabe holds up a chair he autographed — a tradition for Nobel Prize winners - at the Nobel Prize Museum in Stockholm, Sweden, in 2022. Credit: © Nobel Prize Outreach, Photo: Clément Morin.

eler at Caltech, says this kind of work requires good intuition. After years of experience working on climate models, scientists build up knowledge that helps them make hypotheses and decide what to leave out and keep in. But when Manabe did his work, he didn't have that kind of experience — climate models didn't exist.

"Why was Einstein sure the speed of light was constant? With Suki it was similar," Schneider says. The model was accurate in part because Manabe assumed that relative humidity would stay constant. "How did he know what to simplify? He just guessed, and he got all these key things right."

Schneider says the Manabe paper is so important, and so simple, that he has his students recreate the model. Today's computers are at least 1012 more powerful than the one Manabe used in 1966, but his model still works, and serves as a powerful teaching tool.

Manabe soon expanded his mod-

to the 1.5°C pledged in the Paris Agreement, the world needs to cut emissions by 42% by 2030 and 57% by 2035.

Now, says Schneider, climate modelers can help people understand how these changes will play out locally. How likely are extreme weather events? How can localities plan for this and protect themselves? In the 1960s, atmospheric modeling was about studying an interesting physical process. Today, says Haigh, "it's almost existential.'

Modelers have access to a tremendous amount of data, powerful computers, and new computing tools, like machine learning. "It's on us to rethink how to use the resources we have," he says. "Suki made good assumptions. Now we have data to test all of these things."

Katherine Bourzac is a writer based in San Francisco.

Wiki Scientist continued from page 2

properly, he added, "That's how your expertise, your qualifications start to get known and acknowledged."

That kind of pressure is what makes getting started the hardest part. But "anyone can contribute and make good-faith efforts to improve Wikipedia," said a 2024 participant in a testimonial. "It isn't as scary as it seems, and you won't break anything!" In this year's cohort, Sandy Auttelet (Wikipedia alias: TheTactileTutor) aims to use the training to spread a similar message, producing shortform videos for her tutoring business to help students feel more comfortable checking the validity of sources on Wikipedia's physics and math pages.

Seasoned and newbie editors alike work together to fill gaps, fix inaccuracies, add reliable sources, and monitor recent changes to pages on their watchlists. The bots help, too. Healy noted that during APS Public Engagement's Science Trust Project coffee hour last summer, computer scientist and Wikipedia tool developer Aaron Halfaker described the machine learning models that act as the

platform's quality control, filtering new edits — about 160,000 per day – to remove the "obviously bad" ones within five seconds. The rest of the "bad" edits, which are often ambiguously bad — reasonable-sounding but inaccurate additions like "the monarch butterfly is Canada's national insect" — are flagged and removed by community members within minutes to days.

"I didn't realize how big the community was and how interactive people are," said Healy. "People actually really work together." Along with talk pages, Wikipedians convene on village pump discussion boards and WikiProjects, where teams of editors work together to manage subject areas like physics — and even the American Physical Society.

With that kind of support network, Wiki Scientist participants leave the course feeling wellequipped to continue contributing to Wikipedia to help make and keep it a trusted source of knowledge, and reliable sources, for physics and beyond.

Nyla Husain is the science communications manager at APS.

Lilienfeld Prize continued from page 1

appointments, and it allowed the salaries to be adjusted for new faculty hires. It had a major systemic effect, and research there today is flourishing.

#### What other contributions to science are you proud of?

My most recent contribution was chairing P5, the long-term planning committee for particle physics, already polluted by radio waves cell phones, Wi-Fi, TV, and technology are making it increasingly difficult to listen to faint sounds from distant objects. The best place to go is the far side of the moon, where there's no radio coming from our planet.

For example, the stars being studied by the James Webb telescope may have been born when the



"Talking to people from other areas, like mathematics, I end up finding answers to my own questions," says Murayama. Credit: Hitoshi Murayama

meant to guide the Department of Energy and National Science Foundation in how they implement programs for the next 10 years. That was a difficult process because our community is so creative — we had to say no to many great ideas. The fact that we managed to keep the community together was deeply gratifying.

One of the nine popular science books you've authored is What is the Universe Made Of?, published in 2011. What do we know about the universe now that we didn't then?

When I wrote that book, the Higgs boson hadn't been discovered. When I was younger, I hated the idea of the Higgs boson. I was hoping that it didn't exist, but I was

universe was only several hundred million years old. We haven't seen anything before then, except for the cosmic microwave background. In between, there is a period we call the 'dark ages.' But they weren't really dark — we just haven't detected the radio waves yet because they're so faint. With a telescope on the moon, we might be able to do it.

#### You've also been involved in the KamLAND project. What's that been like?

We were looking at neutrinos from the nuclear power plants in Japan. The experiment was designed to observe whether neutrinos oscillate. Since the discovery of neutrinos, no one had seen this behavior. but with KamLAND, we were able to

#### "Science is about human curiosity [and] how we try to understand ourselves," says Murayama. "And anybody can relate to that."

proven wrong. And of course, as a scientist, I'm happy that I was proven wrong.

The remainder of the book is about dark matter and dark energy. That was unknown back then, and it's still unknown today. That hasn't changed, but we are learning a lot — not what it is, but mostly what it may not be.

#### On those topics, what has been vour most important contribution?

Presenting something that can be searched for concretely is a part of the job of being a theoretical physicist. In 1998, I came up with a version of supersymmetry that was concrete enough for experimentalists to look for it. I admire experimentalists because they can talk directly to the universe and hear

They didn't find anything, so, in a sense, I was proven wrong. But that's great — I heard back from the universe. It was an important contribution in my mind.

You've worked on the Scientific Strategy Committee of the **National Astronomical** Observatory of Japan since 2019. What can we look forward to in astronomy?

Now that the Artemis project is ongoing, we could bring radio telescopes to the moon. Our planet is see them disappear and reappear.

One policy of the collaboration was that you had to work on the instrument, so I took shifts and cleaned. I walked into the mine and got into the stainless-steel experiment tank, which had to be incredibly clean, with radioactive contaminants less than the level of 100-16 — a mind-bogglingly small amount. I took a piece of cloth and a bottle of alcohol, and then I would wipe, wipe, wipe. It was interesting for me, as a theoretical physicist, to see what it takes to get meaningful

In your 2014 address to the United Nations celebrating CERN's 60th anniversary, you said that "CERN embodies this idea that basic science unifies people from all nations." Can you

I believe that science is for everybody. Not everyone thinks that way, especially in our current environment. But science is based on human curiosity. When we ask questions like, "Why are we here?" and "Where did we come from?", that tells us that science is about how we try to understand ourselves — and anybody can relate to that.

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

# When science is the only shareholder in publishing

The Physical Review journals — home to highly cited and Nobel prize-winning studies — are integral to the physics community.

BY ERICA K. BROCKMEIER

hen researchers at the Dark Energy Spectroscopic Instrument compiled new evidence that dark energy may evolve over time, they knew it could reshape the standard model of cosmology. They also knew where to share their results: The team presented their work at the 2025 APS Global Physics Summit and submitted their papers to Physical Review D.

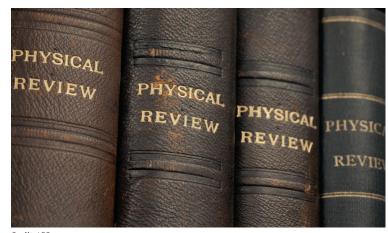
DESI's results are an example of the high-impact research published by APS' Physical Review journals, long integral to the physics community. The journals date back to 1893, when the inaugural issue of *Physical* Review was published. The portfolio expanded in 1929 to include Reviews of Modern Physics, which offers a forum for in-depth reviews, and, in 1958, Physical Review Letters, which publishes short reports on major results across all fields of physics.

After Physical Review was split into discipline-specific journals — Physical Review A, B, C, and D in 1970 and Physical Review E in 1993 — the portfolio expanded into other subfields, including physics education and applied research. It now includes 17 international peer-reviewed publications.

According to the 2024 Journal Citation Reports, APS journals are top research publications. Its flagship journal Physical Review Letters, or PRL, remains the most-cited journal in multidisciplinary physics, with 518,700 citations of PRL papers per year. This equates to around one citation every minute.

PRL also has an h index — a measure of how many papers have a certain number of citations — that is 30 more than the next-highest physics journal, evidence that the journal "publishes a very large number of really great papers," says Robert Garisto, the chief editor.

And while PRL's impact factor is not as high as other physics journals, Garisto said that the sheer size of the journal means its impact factor is not being propped up by a small number of highly cited papers.



Credit: APS

the Nobel Prize in physics or chemistry. The 13-year streak began with the 2011 Nobel Prize in chemistry, awarded for a 1984 paper on the discovery of quasicrystals. The paper had been turned down by chemistry journals, but its importance was "immediately recognized" by PRL editors, Garisto said.

"We're Ph.D.-trained tists, and as editors, we have an open-minded approach," said Garisto. "The start of [the journal's recent] streak was because we gave that paper a home."

PRL published the 2017 Nobel Prize-winning gravitational wave observation by LIGO and Virgo as well, a discovery whose publication and promotion had to be carefully guarded by Garisto's team.

APS' journals are also home to some of the world's most highly cited papers, which form the backbone of fundamental research in a range of fields. Of the top ten most cited papers ever, two were published in Physical Review B and one in PRL.

The fourth-most-cited paper ever, "Generalized Gradient Approximation Made Simple," has been cited nearly 175,000 times since it was published in 1996. Kieron Burke, the interim dean of the School of Physical Sciences at the University of California, Irvine, co-authored the paper along with Matthias Ernzerhof while working as a postdoc in the lab of John P. Perdew.

submitting research to journals like PRL is the ability to have equations — the lingua franca of physics front and center in the paper. "Good equations should not be in the supplemental info," he said. Being able to speak in this language helps researchers communicate across fields and "tell a physics story."

APS and its journals are also vital to the physics community, said Rachel Burley, APS' Chief Publications Officer. "We have deep connections with the community, our members, those who publish research with us and read our journals," she said. "That integration makes us unique."

As part of its commitment to the community, in 2024, APS partnered with the Institute of Physics Publishing and the American Institute of Physics Publishing to create the Purpose-Led Publishing coalition. The coalition — which promises to put purpose above profit - supports the physical science community through a range of initiatives, including sponsoring the APS global physics summit satellite sites. The partnership is also collaborating on developing AI tools to assist peer reviewers.

APS is focused on meeting researchers' needs in a shifting publication landscape, from changing open science requirements to calls for greater transparency across the peer review and publication process. For example, APS recently earned the top score in an open science assessment by the Sponsoring Consortium for Open Access Publishing in Particle Physics, launched a transparent peer review pilot program for PRX Energy, and revamped the journals' websites to make them more accessible.

PRL, now more than 65 years old, is also working to support the next generation of researchers, says Garisto. The journal now allows joint submissions, which let researchers to simultaneously share their work with specialists and general readers, and it recently launched "End Matter" appendices and an inaugural Collection of the Year.

"We publish some of the best papers in physics ever, but we also publish papers from all areas of physics - both fast-moving and slow-moving [fields]," said Garisto about what sets PRL apart from other journals. "It's a journal where most [submitted] papers get peer reviewed, and that's very unusual for a highly selective journal."

Many scientists agree. For Burke's highly cited DFT paper, PRL was always "our loadstar of the best physics," Burke said. "And even though I went off to chemistry, for many years I always used it as my own measure of [whether] I am still doing decent physics."

Erica K. Brockmeier is the science writer at APS.



For years, APS Physical Review journals have had an unlikely mascot: Each journal has its own unique duck, which APS event participants can collect. Credit: APS

"We publish 2,500 to 3,000 papers a year, and we also don't shy away from publishing all areas of physics, [including] areas that are moving a little bit more slowly," he said.

APS' flagship journal is also home to many Nobel prize-winning papers. According to a 2019 analysis of the research cited for the physics prizes awarded between 1995 and 2017, more than 25% had been published in PRL.

The journal recently celebrated a major streak: Every year between 2011 and 2023, the Nobel committee cited at least one key PRL paper by the laureate that contributed to

At that time, density functional theory — a method to calculate the electronic structure of atoms, molecules, and condensed phases of material — was "beginning to show some signs of success and impact," Burke said. A decade after publication, Burke noticed that the study was garnering a lot of citations, which he attributes to the ease of using the method, the paper's clear explanation, and the growth of fields like materials science and chemistry.

While Burke has since become more involved in chemistry, he said that one of the biggest draws to

Nobel Prize continued from page 1

This investment has paid dividends. The National Science Foundation has supported 271 Nobel Prize winners throughout their careers; the National Institutes of Health has supported at least 174.

Below are the stories of a few of these laureates, including this year's winners.

2025: Clarke, Devoret, and Martinis quantize a macro-circuit with public dollars

In the International Year of Quantum Science and Technology, perhaps it's no surprise that the recipients of this year's Nobel Prize in Physics received the honor for experimental work demonstrating 'quantum character' — quantized energy states and tunneling behavior — in an electrical circuit.

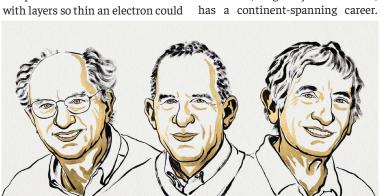
But their circuit was nothing like the microcircuits in a cell phone, composed of nanoscale transistors

and quantum circuits that power advanced computing. The National Science Foundation — which awards billions of dollars every year to basic research — remains one of the biggest investors in quantum computing.

More than a decade after the 1984 paper, Clarke leveraged that work and a 1997 NSF grant of just \$281,897 to craft an experiment capable of  $searching \, for \, axions \, {\color{red} --} \, hypothetical$ fundamental particles believed to hold the clue to dark matter.

Then, in 2002, Clarke partnered with a team of multi-disciplinary UC-Berkeley scientists and engineers to explore a new type of quantum computing processor design. The \$4.6 million in NSF funding led to 55 publications, revealing deep insights into quantum dots, fullerenes, superconductors, and

Devoret, originally from France,



The winners of the 2025 Nobel Prize in Physics — from left, John Clarke, Michel H. Devoret, and John M. Martinis — supported their research with federal funding, like hundreds of other Nobel Prize winners. Credit: Ill. Niklas Elmehed © Nobel Prize Outreach

almost tunnel right through. By contrast, this year's winners built a simple circuit big enough to hold in the hand. Instead of using common circuit components like wires and resistors, they used superconductors — materials with no electrical resistance when cooled to their unique critical temperatures.

In September 1984, the team of three — Clarke, the research group lead at the University of California, Berkeley; his postdoc Devoret; and his grad student Martinis — published their observations of "resonant activation" in the special circuit design in APS' journal Physical Review Letters. "None of this work would have happened without the two of them," Clarke said. All three scientists are APS Fellows and members.

A year after that discovery, the trio reported additional findings, including the measurement of macro-scale quantum tunneling behavior in the same circuit design. This work was largely supported by the Office of Basic Energy Sciences in the U.S. Department of Energy.

Today, macroscopic quantum tunneling has moved from basic physics to widespread application. It forms the basis of ultraprecise measurements in meteorology, neuroscience, and the geosciences; specialized imaging technologies in ultra-low-field MRI machines;

But in his first U.S. faculty position at Yale in 2010, he secured \$315,000 in NSF funding to extend his earlier work to superconducting nanowires. In 2021, he partnered with colleagues from four American uni-

funding. In 2005, Martinis secured \$1.2 million for deeper study of metal-dielectric interfaces, critical for confining charge carriers in circuits in quantum information and microwave devices. The collaborative effort culminated in 12 publications in a few years, revealing insights into electron tunneling behavior, entanglement phenomena of superconducting qubits, and more.

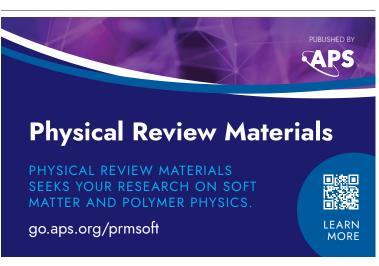
tinis said the field's growth is "most exciting." With "a thousand or more scientists who are working on quan tum computing and superconducting qubits," he says, we are one step closer to commercializing quantum computing technology — a reality made possible by federal funding.

2024: With NSF support, Hopfield

versities, leveraging \$1.8 million in NSF support to found a multi-institutional center for the study of quantum devices — bridging the gap between theory and real-world applications. Martinis' research program at the University of California, Santa Barbara, has also benefited from NSF

Interviewed about his prize, Mar-

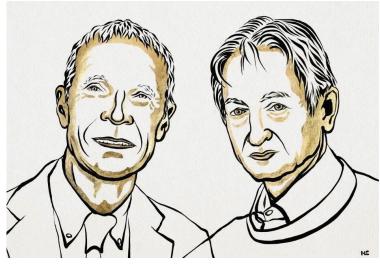
lays the groundwork for AI



The 2024 Nobel Prize in Physics recognized physicists John J. Hopfield and Geoffrey E. Hinton for their work on artificial neural networks. Hopfield's contribution was his 1982

2010 to 2014. Erik Winfree received the 2006 Feynman Prize in Nanotechnology for his work in DNAbased computing.

Today, Hopfield's seminal work



The winners of the 2024 Nobel Prize in Physics — from left, John J. Hopfield and Geoffrey E. Hinton. Credit: Ill. Niklas Elmehed © Nobel Prize Outreach

invention of a computer network architecture that could save and replicate patterns, like a simple brain.

That breakthrough emerged from years of NSF support: The agency ultimately awarded Hopfield and collaborators more than \$2.5 million in grants over nearly three decades, funding his work on the physics of biology.

Hopfield began his career at AT&T's Bells Labs, where colleagues in the theory-focused department encouraged him to work with Bell's experimental groups. This laid the foundations for Hopfield's work with David G. Thomas on compound semiconductors, which earned the duo the 1969 APS Buckley Prize and Hopfield an election to APS Fellow-

By then, Hopfield had departed Bell Labs for academia, first at UC-Berkeley and then Princeton. By the mid-1970s, he felt he had "run out of problems" in condensed matter physics and pivoted to the inner workings of the brain, including the mechanisms of memory and learning.

Over the next 11 years, from 1975 through 1986, NSF awarded Hopfield five grants totaling more than \$800,000 to support his research on neural networks.

After a stint at Caltech, Hopfield settled back at Princeton, where he ioined forces with Leif Finkel at the University of Pennsylvania. In 1998, they secured a \$1.6 million award from NSF for the study of "neuromorphic knowledge systems."

But Hopfield — now 93 — led not only great science. He also supported great scientists. At least four of his doctoral students are APS Fellows, elected for contributions ranging from advances in supercomputer architectures to protein folding

> As Hopfield said in 2024 after his Nobel win, "the science which advances technology is the science that gets done for curiosity's sake much earlier."

theory. One of these four, Bertrand Halperin, has followed particularly closely in Hopfield's footsteps, having won the Buckley Prize and APS Medal and secured nearly \$4.5 million in NSF funding for studies focused on electron behavior in confined geometries, like quantum dot nanoparticles.

Another graduate student, David J. C. MacKay, was the chief scientific advisor to the U.K. Department of Energy and Climate Change from on neural networks has captured 29,267 citations and inspired a wave of technological innovation. But these impacts were never imagined from the beginning, when federal agencies first funded Hopfield.

As Hopfield said in 2024 after his Nobel win, "the science which advances technology is the science that gets done for curiosity's sake much earlier."

#### 2024: The bucks behind Baker's computational protein design

Also in 2024, half of the Nobel Prize in Chemistry was awarded to David Baker, an American biochemist, for the use of computational Washington had learned so much about these folding mechanisms that they were able to design the first synthetic protein, Top7, with a novel topology — the initial demonstration of a scientist's ability to design a protein with a specific 3D structure from scratch.

By 2019, Baker's team had received nine more NSF awards, totaling \$5.2 million over two decades.

During that time, his research group developed an algorithm for predicting the 3D structures of proteins, known as Rosetta. From that, they created Rosetta@home, software that allowed users to donate their own computers' processing power for number-crunching toward the design of new protein structures. To make it more interactive for users, the team created a gamified version known as Foldit.

In 2011, Foldit players helped decode the structure of an HIVlike virus that affects monkeys. In 2012, they re-engineered an enzyme to drastically accelerate its rate of activity in synthetic reactions. By 2019, players had designed four enzymes that researchers were able to grow in the lab.

This work ushered in a new paradigm: the use of algorithms, software, and (increasingly) artificial intelligence to predict and discover new proteins capable of doing whatever their designers want them to do, like treat cancer or clean up environmental contaminants.

To date, Baker has authored over 600 scientific papers as indexed by Google Scholar and co-founded more than 20 startups, which



One of the winners of the 2024 Nobel Prize in Chemistry, David Baker. Credit: Ill. Niklas Elmehed © Nobel Prize Outreach

methods in protein design.

Proteins — biological structures sequenced from combinations of 20 molecular building blocks known as amino acids — form the basis of all known life. Sometimes, proteins can be disrupted by DNA mutations, causing disease. Humans have also harnessed proteins synthesized by other organisms, like yeast or E. coli, for food or medicine.

But the story of Baker's work with proteins starts with a computer, not a lab.

In 1999, he received his first NSF grant. With an award of just \$312,500, Baker studied how two proteins 'fold' from their amino acid sequence into their biochemically active structure. After four years, Baker's team at the University of

have delivered new vaccines, cancer treatments, and medical therapies. Icosavax, founded in 2017, was acquired by vaccine-maker AstraZeneca in 2023 for \$1.1 billion, and Sana Biotechnology, founded in 2018 to use engineered cells as a form of medicine, is now worth over \$800 million.

"I think protein design has huge potential to make the world a better place," Baker said after his Nobel win. "And I think we're just at the very beginning."

Indeed, the therapeutic tools that Baker's work has inspired began with a simple idea — that the amino acid sequence of a protein could predict its structure — and one NSF grant.

Liz Boatman is a materials scientist and science writer based in Minnesota. Duration of status continued from page 1

able to complete their degree in that time period would have to apply for an extension of stay with the U.S. Citizenship and Immigration Service. Without an extension in effect by the end date on their visa, they would be out of status even while actively pursuing a degree.

The comment period for the proposed rule change has closed, and no timeline for a decision has been announced.

The visa process is already marked by uncertainty, fees, paperwork, and hard-to-get appointments, says a graduate student from India pursuing a Ph.D. in materials science and engineering at a U.S. university in the Mid-Atlantic. "Even if you have a visa — you have everything — if there's something suspicious about you at the border, you can be turned away."

The four-year limit isn't the only visa rule in flux. DHS's proposal would also prohibit graduate students from changing programs and reduce the time they have to prepare for departure from 60 to 30 days. Also, in the last several months, DHS has unexpectedly cancelled select student visas, suspended visa interviews in some countries, and introduced an additional \$100,000 fee for new H-1B visa petitions.

Among international graduate students, there's a growing sense that you can't express your ideas freely or make any mistakes, says a materials science and engineering graduate student from Latin America. The U.S. has good infrastructure for innovation, she says, but a rising fear is competing with research productivity.

"If I had known how the trajectory of this country was going," says an international graduate student from a Caribbean nation who earned his bachelor's degree in the U.S., "I might have put in a little more effort to research a new place, a new country [for graduate school]." The second-year student says that four years is just not realistic for an experimental degree, something many international students come to the U.S. to pursue.

The length of your Ph.D. program depends on how well your project works, how hard you work, and luck, says Artem Abanov, a physics professor and associate head of the department's graduate program at Texas A&M University. In 20 years of teaching, he's never seen a physics student go from a bachelor's degree to Ph.D. in four years. Ph.D. projects are unpredictable by nature, he says. "If it were predictable, it would not be research."

Abanov was a physics graduate student in Moscow when the Soviet Union collapsed, and he followed his research advisor to Texas A&M. A Ph.D. and two postdocs later, he landed a faculty position at the university, where he's been since. This story has been common in science, he says. But if you tell students that in four years, they'll have visa problems, "that's a huge deterrent," he says. "People just would not come."

And even if some international students want to come, departments may decide it's too risky to invest in students who might not be allowed to finish their degrees, Abanov says.

"This is fundamental upheaval to the system," says Michael Wittmann, head of education at the American Physical Society. Over the last five years, around 47% of the physics doctorates conferred by U.S. institutions went to noncitizens, according to American Institute of Physics surveys. If the U.S. becomes less desirable for these students, there will be fallout across the pipeline, Wittmann says.

Around 70% of the international students on temporary visas who earn doctorates in the U.S. in sci-

ence, engineering, and health fields stay in the country to work and conduct research, according to a 2024 National Science Board report. APS



The proposed rule change would apply to nonimmigrant academic students on F-1 visas and exchange visitors on J-1 visas, a category that includes many postdocs and visiting scientists.

expects that under the proposed change, departments would be under threat, research productivity would slow, and gaps would emerge in the STEM workforce.

"If this policy is enacted, it will be an enormous boon for universities in Europe and across the world, not to mention for the economies," the Caltech astrophysicist says. "After they graduate, many of these students currently go on to make key discoveries, launch start-ups, design new technologies, lead cutting-edge medical research, and educate the next generation of Americans."

In September, APS submitted a public comment to DHS opposing the proposed changes to duration of status and encouraged members to do the same. And more recently, APS led several scientific societies and federations in filing an amici curiae brief, a kind of expert opinion to the courts, in support of a lawsuit brought against Secretary of Homeland Security Kristi Noem and others by the Presidents' Alliance on Higher Education and Immigration and the Association of Independent Colleges and Universities in Massachusetts. The suit alleges that the current administration has adopted arbitrary, unlawful policies that damage the system by which international students pursue higher education in the U.S.

The societies filed the brief in early October. It reads, in part, "an unreliable, inconsistent, or capricious U.S. visa process hampers the U.S.'s ability to attract the best and brightest international scholars and harms the nation's scientific dominance, innovation, and economic competitiveness."

Wittmann hopes DHS will extend the four-year limit or discard the proposed rule changes, but "we have to act like it's what they plan to do," he says. To that end, APS is developing a detailed toolkit to help departments navigate a scenario in which the new rules take effect.

Funded by the Gordon and Betty Moore Foundation, the toolkit will be integrated into the EP3 Guide, Effective Practices for Physics Programs. Bennett Goldberg, a physics and astronomy professor at Northwestern University, and Jenny Samaan, a higher education consultant, are currently interviewing members of the physics community to identify potential consequences and explore solutions, says Wittmann. They hope to release a white paper before the end of the year and debut the toolkit at the Global Physics Summit in March

"The killing of research productivity is the major threat to the physics enterprise," Wittmann says. "This is going to be a difficult time, requiring creative solutions that need to focus on the well-being of the students."

The views expressed by scientists in this article are their own and do not reflect the official positions or policies of their universities.

Kendra Redmond is a writer based in Minnesota.

Valley Prize continued from page 1
environments like under inten-

environments, like under intense gravity, says Gavassino, 30, a postdoctoral researcher at Cambridge University in the UK.

These substances may seem otherworldly, but physicists have had experimental access to relativistic fluids for more than two decades. In 2000, researchers at the Relativistic Heavy Ion Collider in New York and the Large Hadron Collider in Switzerland created the first labbased quark-gluon plasmas, which are extremely hot states of matter whose constituent quarks and gluons move near the speed of light. Since then, physicists have regularly created quark-gluon plasmas at both colliders.

By studying quark-gluon plasmas, researchers can better understand the early universe, which, according to standard cosmology theory, was filled with the material within a few microseconds after the Big Bang. This quark-gluon plasma then condensed into the matter-filled universe we know today.

More recently, the observation of gravitational waves also sparked momentum in relativistic fluid dynamics research. In 2017, the Laser Interferometer Gravitational-Wave Observatory collaboration detected a gravitational wave from two neutron stars colliding for the first time. The interior of a neutron star, which is under immense gravity, qualifies as a relativistic fluid.

As a theorist, Gavassino builds the mathematical framework to explain experimental results and observations and guide future hypotheses. Unlike conventional fluid dynamics, researchers can't just study relativistic fluids in a beaker. "All the measurements are very indirect," says Gavassino. "There are many things to clarify still, due to the fact that we have less experimental control."

Sometimes, his projects aim to explain a specific experiment or observation. Other times, he studies general scenarios involving relativistic fluids meant to probe their fundamental behavior.

In 2022, while a Ph.D. student at the Nicolaus Copernicus Astro-

"Progress in physics means I create a new understanding that contains all the previous ones," says Gavassino.

nomical Center in Warsaw, Poland, Gavassino caught the attention of other researchers when he solved a long-standing fundamental problem in relativistic fluid dynamics. Because the equations that govern relativistic fluids are so complex, researchers use approximations to solve them. However, many conventionally used approximate equations implied strange results — imagine a glass of water that accelerates close to the speed of light. The equations implied that the water would explode "without any clear reason," says Gavassino.

In his work, Gavassino showed that these explosions were a consequence of the equations permitting signals in the fluid to travel faster than the speed of light. Previously, researchers had thought this was permissible as long as the signals were weak. "I proved that no matter how small it is, the very fact that [signals travel faster than light] is the cause for the explosions," says Gavassino. With his paper, he resolved a problem that researchers

have puzzled over since the 1980s.

Yet his entry into relativistic fluid dynamics research was "complete randomness," he says.

As a child growing up in Saronno, Italy, near Milan, Gavassino was drawn to wide-ranging topics, from dinosaurs to Greek mythology. He attended a science-focused high school. Philosophy was an early interest: he studied Kant, Schopenhauer, and Kierkegaard, among others. But the wide-ranging ideas were "confusing," he says. Different philosophers offered opposing pictures of the world, "sometimes in ways that are almost irreconcilable," he says. Philosophers are, for example, still debating the basic definition of existence.

Physics felt like steadier ground. "Progress in physics means I create a new understanding that contains all the previous ones," says Gavassi-

ingful regardless of its potential for technology. "I do science because, for me, knowledge is an end," he says.

In fact, he published a paper on time travel in 2024, while a postdoc at Vanderbilt University. "It was a fun exercise that I did in my spare time," he says. He investigated a hypothetical space-time that curves on itself to form a closed loop, enabling a traveler on this loop to time travel.

But time travel should be impossible, as illustrated by the well-known grandfather paradox: If you went back in time and killed your grandfather before your parents were born, you would prevent your own birth. But if you were never born, you could never travel back in time in the first place.

Gavassino resolved the paradox for this loop. Using arguments involving entropy and quantum mechanics, he showed that in such



Gavassino sees science as "a branch of philosophy whose way of going about things I find satisfactory and more relaxing, and less confusing." Credit: Lorenzo Gavassino

no. "There is not a rejection of the previous idea. The vision of Einstein contains the vision of Newton."

He sees science as "a branch of philosophy whose way of going about things I find satisfactory and more relaxing, and less confusing," he says.

Gavassino attended the University of Milan for his undergraduate and master's degree. He started his master's studies doing research in biophysics. After the project didn't pan out, he asked Pierre Pizzochero, a professor in nuclear astrophysics, if they could work together. "He said, 'Sure, open this book. If you find something in there that interests you, I can find a thesis for you," says Gavassino.

The book was on relativistic fluid dynamics. "I liked it," says Gavassino. "There was not a big plan behind it. I started, and then I continued."

To Gavassino, science is mean-

a warped spacetime, seemingly irreversible events like a grandfather's death could be temporary. Discover and Popular Mechanics featured the work, while physicists largely ignored it. "All these journalists contacted me about this, whereas I never had a single discussion about it with a colleague," he says. "For me, it was just a game. It's not particularly useful for anything."

Still, Gavassino takes the game seriously. The time travel paper includes rigorous proofs and formal equations, just as he does in his more mainstream relativistic fluids research. "I think that the creation of knowledge, the understanding of the universe, is something of intrinsic value," he says. "It's something to pursue for the thing itself."

Sophia Chen is a writer based in Columbus, Ohio.

# Physics Today magazine announces new website

physics Today, the popular physics magazine that APS members can opt to receive as a membership benefit in print or online, debuted a new website in October. Print readers will see the new design reflected in the January 2026 issue of the magazine.

Initially, online readers will not need to log in to the website to read stories. In the future, subscribing users will log in via an upgraded authentication system to access unlimited articles — including the magazine's 77-year archive. Non-subscribing readers will have access to a limited number of articles each month.

Questions? Contact the *Physics Today* team at https://physicstoday.aip.org/contact.

#### **BACK PAGE**

## How "big tent" particle physics is reshaping physics research

Particle physics used to rely mostly on accelerators and theory. Not anymore.

BY MARIA SPIROPULU AND MICHAEL TURNER

n the morning of July 4, 2012, Fabiola Gianotti and Joe Incandela stood before a packed auditorium at CERN to announce the discovery of the Higgs boson. Scientists across the globe had tuned in. In the United States, researchers woke in the middle of the night to watch.

One of us, Maria, a member of the CMS experiment, was in the auditorium. The other, Michael, was in Colorado at the Aspen Center for Physics with a room full of theorists, who stayed up into the wee hours of the morning to hear the electrifying news.

The discovery, which completed the Standard Model, was a triumph of particle physics and science. But who, exactly, had done the discovering?

Of course, there was no single person: 3,172 authors were listed on the ATLAS collaboration's discovery paper alone, which allotted 24 pages just to names. As a result, the discovery of the Higgs boson was hailed as an example of the successes of collaborative "big science."

But the discovery not only showcased big science. It was a harbinger for a new style in particle physics. It required particle physicists, yes, but also engineers, accelerator scientists, computational scientists, and low-temperature physicists. In other words, the Higgs discovery showcased the "big tent" of people and ideas needed to understand the fundamental nature of matter, energy, space, and time.

This big tent reveals how profoundly particle physics has changed, and how the field is reshaping the very nature of physics research.

#### The explosion of particle physics

Today, the particle physics tent is enormous. It attracts condensed matter, gravitational, and atomic, molecular, and optical (AMO) physicists, along with astronomers, computational scientists, accelerator physicists, and engineers. Other researchers in the field focus on quantum information science, artificial intelligence, and machine learning.

This explosion did not happen overnight. Twenty-five years ago, elementary particle physics was about particles and forces, done by experimentalists using accelerators and theorists making sense of it all.

Then the questions began changing. The Standard Model, with the Higgs boson at its center, beautifully explained the known forces and particles, but it couldn't account for what cosmologists were seeing: dark matter holding galaxies together, dark energy accelerating the universe's expansion, and evidence of cosmic inflation. These concepts were instead central to another standard model, the LambdaCDM model of cosmology.

Suddenly, understanding matter and energy meant grappling with the structure of space, time, and the universe. Particle physics alone — at least, as it was then organized — couldn't answer these questions.

So the field expanded, and cosmologists and astrophysicists joined the tent. The Standard Model began mingling with the LambdaCDM model, uniting the big questions about matter and energy—the particles and their interactions—with big questions about



A postdoc, Olena Karacheban, installs new instrumentation for the CMS experiment at CERN in July 2021. CERN, located outside Geneva, Switzerland, is one of many facilities where fundamental research in particle physics is taking place. Credit: CERN

space, time, gravity, and the origin of the universe. This unification also pulled in theorists — string, gravity, and quantum information — who were themselves grappling with the nature and origin of space and time.

Meanwhile, AI, machine learning, and big data, tools used by many subfields, have dissolved traditional boundaries. Techniques pioneered in one area migrate to another. For example, analysis of large datasets in accelerator experiments and cosmic surveys use AI and machine learning, generating ideas that then cross back to computer science. And statistical techniques pioneered in astrophysics and cosmology are now routinely used in collider experiments.

As new questions arise, they require new approaches. Dark energy,

structures, can also be studied by telescopes — but revealing its fundamental nature, and searching for the yet-undiscovered particles that comprise it, requires ultra-sensitive detectors in deep underground laboratories, shielded from cosmic rays. These experiments draw on techniques from optical and radio astronomy and condensed matter physics, as well as new quantum sensors developed by particle physicists.

Research on neutrinos also relies on diverse tools. We confirmed neutrinos' existence with nuclear reactors. Accelerators revealed that the strange particles come in more than one type. And we used underground detectors to learn that neutrinos have mass and oscillate between types. (These discoveries led to four



A person shines a headlamp on the wall of the recently excavated expansion drift at the Sanford Underground Research Facility in South Dakota. SURF is home to the Deep Underground Neutrino Experiment (DUNE), currently under construction.

Credit: "Ex Profundo, Scientia," by Adam Tomjack/Sanford Underground Research Facility

the mysterious energy form that makes up 70% of the universe, can only be studied with telescopes that look deep into space and far back in time. Dark matter, which holds together galaxies and all cosmic

#### Nobel Prizes.)

There are still big neutrino mysteries: Are they their own antiparticles? What explains their tiny masses? Do their interactions violate matter/antimatter symmetry and

explain the absence of antimatter in the universe today? Answering these questions requires the search for rare nuclear decays, neutrino beams from reactors and accelerators, and telescopes that probe the influence of cosmic neutrinos on the growth of structure in the universe.

Other mysteries, including the unification of the forces and particles, demand high-precision measurements. For example, the electric dipole moment of the electron offers a window into physics beyond the Standard Model. The search for fifth forces and deviations from Newtonian gravity at short distances may reveal clues about the unification of gravity with the other forces of nature. And all these efforts are pulling in new researchers, including condensed matter physicists, AMO physicists, and precision measurement scientists.

For researchers navigating particle physics today, especially those early in their careers, these big shifts in the field are impacting jobs, institutions, and scientists themselves.

#### Research opportunities

First, the expanding tent creates a broader array of global opportunities for researchers than existed a generation ago. Particle physicists today might work on an accelerator experiment at the Large Hadron Collider in Switzerland; study neutrinos at Fermilab in Illinois; map dark energy with powerful telescopes at Chile's Rubin Observatory; hunt for dark matter at an underground laboratory in South Dakota or Italy; or measure the polarization of the cosmic microwave background at the South Pole.

There is enormous diversity not only in the experiments, but also in timescale and team size. Some projects, like cosmic surveys and collider research, have longer timescales and bigger teams. Smaller experiments and theory projects typically have smaller teams and timescales. This variety enables researchers to be involved in multiple activities at the same time or throughout their careers.

Consider Bruce Winstein, who shifted from studying subatomic particles with accelerators to studying the cosmic microwave background, bringing with him techniques and collaborators from particle physics. Or Barry Barish, who started his career at an accelerator, conducted research at an underground laboratory, and then headed the successful search for gravitational waves at LIGO, for which he shared the 2017 Nobel Prize.

#### Interdisciplinary scientists

Second, these new pathways are producing a different kind of scientist. A researcher who has worked on both a collider collaboration and a dark matter experiment, for example, emerges with unusual versatility: expertise in state-of-the-art instrumentation and tools, including machine learning and AI techniques; the ability to navigate both massive international teams and small, nimble groups; and the fluency to move between subdisciplines, making connections that researchers entrenched in a single domain might miss.

Beyond its benefits for science,

this interdisciplinary style is good for scientists. Training organized by skills and techniques, rather than rigid field boundaries, tends to produce researchers who are highly adaptable, and highly employable. After all, many pressing scientific problems today — from climate change to quantum computing to AI — don't observe traditional disciplinary boundaries. Particle physicists trained in the big tent develop the creativity that is valued in both academia and industry, especially for emerging fields and technologies.

#### **Evolving institutions**

Third, the big tent model is reshaping institutions themselves. Physics departments are moving away from traditional subdiscipline silos — separate groups for, say, particle physics and condensed matter physics — and organizing instead around larger themes, like quantum measurement, nanoscience, or big data. Individual, faculty-led groups become specialized, but their interests and activities move across themes. Researchers interact and share ideas more often.

Theory offers a concrete example of this reshaping. Today at many institutions, theory is organized not by subdisciplines, but in cross-disciplinary centers where researchers use the same mathematical tools. The ten new theory institutes funded by the Leinweber Foundation follow a model like this. And one of us, Michael, benefitted early in his career from two pioneering theory centers, The Kavli Institute for Theoretical Physics at the University of California, Santa Barbara, and the Aspen Center for Physics. Both facilitated work across traditional silos — astrophysics, condensed matter physics, and particle physics — by bringing theorists together for workshops and meetings.

### A humbling lesson for scientists

Particle physics is a humbling field. In exploring the mysteries of the universe, we confront our smallness within it, the strangeness of nature's rules, and the limits of what we know. But for us, there is another humbling revelation: No single approach, no single set of tools, can answer the most fundamental questions. Understanding the origins of space and time, the nature of matter and energy, the destiny of the cos-- these challenges demand more minds, perspectives, and creativity than any one discipline can provide.

For researchers, this means something concrete. This community needs expertise from across the physical sciences. If you're drawn to big questions about the universe but haven't seen yourself in traditional particle physics, the tent is bigger now. And it needs you.

Maria Spiropulu is a particle physicist at the California Institute of Technology. Michael Turner is a cosmologist at the University of California, Los Angeles, and professor emeritus at the University of Chicago. Spiropulu and Turner co-chaired the recent National Academies study "Elementary Particle Physics: The Higgs and Beyond," which put forward a 40-year vision for the field of particle physics.