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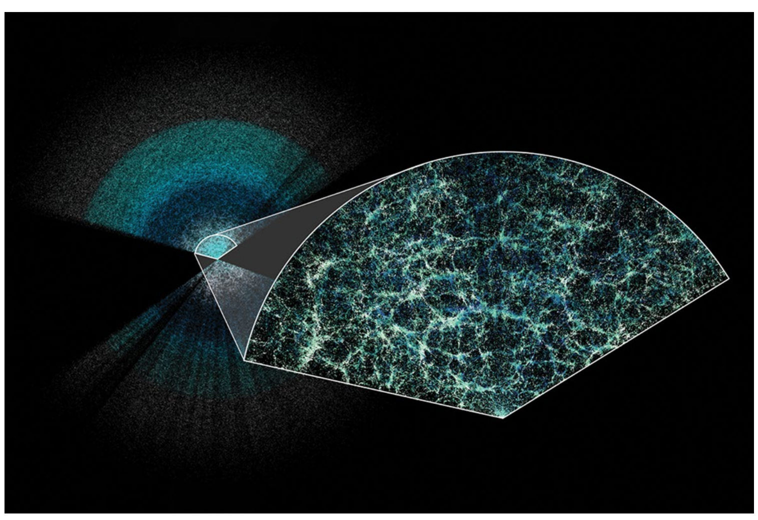
High-Precision Map of the Universe Defies Conventional Cosmology

Analysis of the most precise three-dimensional map of the universe delivers hints of a tension with the standard model of cosmology.

BY DAVID EHRENSTEIN

Analysis of a new high-precision map of millions of galaxies hints at a conflict with the standard model of cosmology known as the lambda cold dark matter model, or ΛCDM. Last week, at the APS April Meeting in Sacramento, California, the Dark Energy Spectroscopic Instrument (DESI) collaboration reported that their results favor a model in which dark energy — the force accelerating the expansion of the universe — has properties that change with time.



Earth is shown at the center of this slice of DESI's full 3D map of the universe. The magnified section reveals the underlying structure of matter, like galaxies. Credit: Claire Lamman/DESI collaboration; custom colormap package by cmastro

Researchers have previously proposed versions of dark energy that conflict with ΛCDM's assumption of fixed properties, but the new results are the best indication so

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Peace Prize Laureate, Imprisoned in Iran, Honored at March Meeting

Narges Mohammadi, an Iranian physicist and activist, has fought for human rights for decades.

BY KENDRA REDMOND

As a crowd of March Meeting attendees from around the world gathered in a Minneapolis auditorium to honor the 2023 Nobel laureates, Narges Mohammadi remained in Iran, behind bars.

If the world had been different, she might have been sitting amidst research colleagues, applauding the 2023 physics and chemistry Nobel laureates who spoke at the meeting. Instead, after celebrating the physical science winners, the physics community honored her — physicist, engineer, dedicated activist, and 2023 Nobel Peace Prize recipient — for her human rights legacy and personal sacrifice.

"No one is alone when we speak to their bravery," said Francis Slakey,

Narges Mohammadi. Credit: Voice of America/Public domain

the APS chief external affairs officer, in an opening remark on the importance of sharing Mohammadi's story.

Mohammadi grew up in Iran in a family that supported democracy and valued education. After the 1979

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March Meeting Brings Squishy Science to Minneapolis Families

An afternoon of physics — and, well, cotton candy.

BY KENDRA REDMOND

Children and grown-ups of all ages enjoyed Squishy Science Sunday, including the author's kids (center). Credit: Left: Andrew B. Croll; center, right: Kendra Redmond

Cries of "Ew!" and "Slimy!" aren't the responses most APS meeting presenters hope to receive, but Squishy Science Sunday volunteers accepted the feedback with a grin. Throughout the four-hour public outreach event, kids of all ages poked and prodded, smushed and mixed, and played and created while exploring the softer side of physics.

The most overheard utterance? "That's so cool!"

Held in Minneapolis on the first day of APS March Meeting, the event drew families from the local community to the meeting venue. The goal was to highlight the big physics meeting happening in their town and expose them to science, says Shubha Tewari, a faculty member at the University of Massachusetts Amherst and the event's lead organizer.

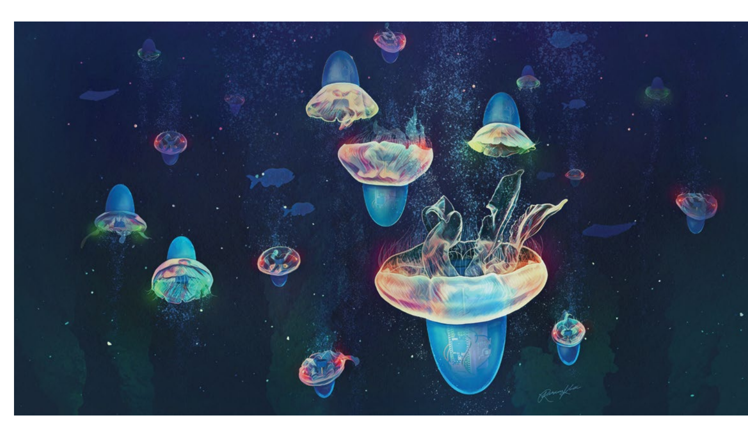
Squishy Science continued on page 4

From Mudskippers to Jellyfish, Aquatic Animals Inspire Robot Designs

For the APS March Meeting, early-career scientists shared their work on waterborne fauna.

BY SOPHIA CHEN

Fish, water-hopping bugs, and jellyfish may traditionally be the purview of biologists, but this year's March Meeting in Minneapolis featured plenty of research on aquatic animals, particularly their locomotion. Interdisciplinary collaborations aim to incorporate these findings into designs for more effective robots. Here are a few projects that piqued our interest.



An artist's depiction of "biohybrid" jellyfish, each equipped with a small electronic device that enables them to swim faster. Credit: Caltech/Rebecca Konte

Jellyfish cyborgs

Simon Anuszczyk, an aeronautics engineering graduate student at Caltech, and his adviser, Caltech engineer John Dabiri, have developed an electronic system that affixes to real jellyfish and makes them swim faster. That's right: They created a jellyfish cyborg.

Jellyfish move by contracting their umbrella-shaped bells, propelling water in the opposite direction. The Caltech team's device, a dome-shaped "hat," delivers small electric pulses to the animal's bell, causing the jellyfish to contract with higher-than-normal frequency. The stimulus allowed their jellyfish to swim 4.5 times faster than their natural speed of about one centimeter per second.

So far, the team has run tests on a previous version of the biohybrid jellyfish in the ocean. For this model, they've run tests in a tank six meters deep and plan to study it in the ocean.

The group chose jellyfish because they are "the most efficient animal in the world," says Anuszczyk, in terms of energy consumption per distance traveled per mass. Jellyfish also live in every ocean and can swim to great depths.

This makes them useful picks for the team's ultimate goal: to deploy these jellyfish for undersea applications. For example, only a quarter of the ocean floor has been mapped with modern, high-resolution technology. If the team's devices were equipped with special sensors, jellyfish could collect data in previously unexplored parts of the ocean, or help monitor the effects of climate change.

"We might study the carbon cycle in the ocean or ocean acidification by attaching a pH sensor onto the jellyfish," says Anuszczyk.

The group worked with bioethicists while designing their cyborg. Jellyfish lack a centralized nervous system and pain receptors, Anuszczyk says. And in their experiments, they found that the jellyfish did not release mucus, a typical stress response, and healed from any damage within 24 hours of the device being removed.

Amphibious fish

Once a day, Divya Ramesh and her colleagues drop fish food into the aquariums in their lab, feeding a menagerie of three unusual species: the ropefish, bichir, and mudskipper. All are amphibious fish whose specially adapted ways of breathing allow them to survive on land, from a few hours up to days.

"We study amphibious fishes because they're so capable of moving across the water-land interface," says Ramesh, a graduate student in mechanical engineering in Chen Li's Terradynamics Lab at Johns Hopkins University. Each species does it differently. The ropefish slithers like a snake, while the bichir assists its slither with its fins, akin to a human army-crawling. The mudskipper propels itself using its pelvic fins like a person using crutches — the only animal known to move like this.

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‘People Want to Help Us’: Ukrainian Student Attends March Meeting

With an APS travel grant, Polina Kofman joined 13,000 physicists in Minneapolis.

BY LIZ BOATMAN

Polina Kofman, currently studying in Portugal, hopes to someday earn her doctorate from B. Verkin Institute in Kharkiv, Ukraine. Credit: Polina Kofman

Theoretical physicist Polina Kofman might be drawn to the “peculiar and exotic,” but some things she does the old-fashioned way.

“I prefer to write equations on paper, old style,” she says. For trickier work, she turns to Wolfram Mathematica or Python.

Lately, she’s been using these tools to study the peculiar and exotic world of qubits, the most basic units of information in a quantum computer. When experimenting with a qubit, a physicist is manipulating “a quantum two-level energy system” — in this case, “ground and excited,” she says. “It’s quite a hot topic right now.”

> Her story is important to share, “for Ukrainians to see they are not alone,” Kofman says — that “people want to help us.”

Kofman, whose research today focuses on the interaction of qubits with graphene, recently presented her work at the 2024 APS March Meeting in Minneapolis, Minnesota. Although she arrived from Portugal, Kofman is a Ukrainian graduate student, hoping to someday return home to receive her doctoral degree from Ukraine’s B. Verkin Institute for Low Temperature Physics and Engineering.

The institute is in Kharkiv, a city in northeastern Ukraine that became a major target during Russia’s 2022 invasion. Russian strikes remain a threat, displacing and upending life in a city whose prewar population numbered 1.5 million.

Until she can return to Ukraine, Kofman calls the University of Lisbon’s Instituto Superior Técnico home. To support her trip to Minneapolis, she received funding from the APS Distinguished Student Program for Ukraine. The program — supported by the Alfred P. Sloan Foundation — covers up to $2,000 in travel expenses to APS and other meetings for graduate students and postdocs impacted by Russia’s invasion. Recipients can also use the award to attend meetings virtually.

The meeting was “an important step in my career,” she says, and a great opportunity to connect with theoretical physicists tackling similar systems.

Kofman has been studying qubits for four years, starting in the last year of her bachelor’s program at V. N. Karazin Kharkiv National University in Ukraine. Since then, interest in quantum computing has skyrocketed, making her work particularly interesting, she says.

In Kofman’s theoretical work, she studies the interaction of a qubit with graphene. Graphene is a sheet of carbon atoms laid out in a honeycomb pattern, an arrangement that gives it a unique combination of mechanical, electrical, and thermal properties. The material’s inherently 2D nature makes it “an ideal material” for study relevant to quantum computing, she says.

Of the strange effects she’s found, one has captured her curiosity in recent months. In her work presented at the March Meeting, Kofman explored the behavior of a qubit-graphene system in an electric field defined using a quasi-static approximation — where changes in the field strength are applied so slowly that, at any given time, they can be considered constant.

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THIS MONTH IN PHYSICS HISTORY

May 1, 1953: In AD-X2 Controversy, Allen Astin and APS Defend Federal Science Against Political Interference

Astin upheld his agency’s rigorous consumer testing results — and was fired for it. Then the nation’s scientists found out.

BY KENDRA REDMOND

At an APS meeting on May 1, 1953, Allen Astin, physicist and director of the National Bureau of Standards — today the National Institute of Standards and Technology — took the stage. Before an audience of some 500 fellow physicists, he delivered a powerful speech about the bureau’s core values.

“Tonight, I plan to speak as the Director of the National Bureau of Standards,” he said, “and attempt to explain why I and the other members of the organization believe in the Bureau and the importance of its operation to the national welfare and security.”

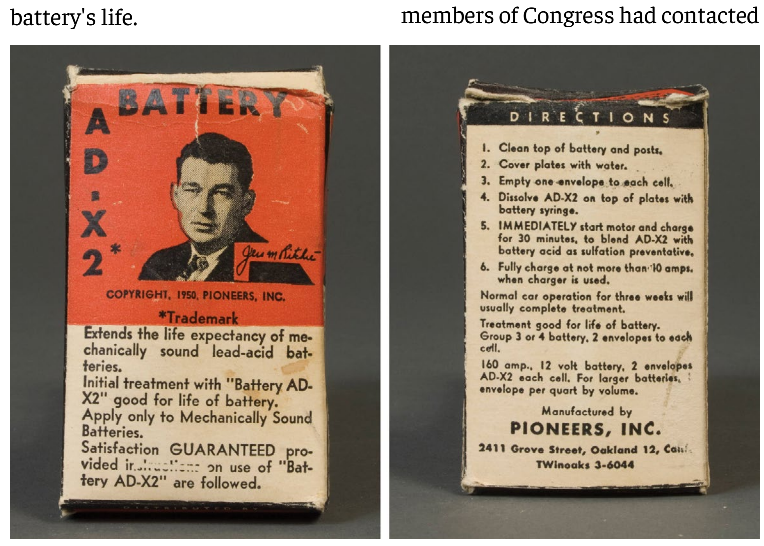
Physicist Allen Astin, left, and businessman Jess Ritchie. In a protracted dispute, Astin became the unwitting face of government science. Credit: NIST

Astin didn't say it directly, but everyone knew the impetus for the lofty talk. Less than six weeks earlier, the U.S. Secretary of Commerce had fired Astin after he stood by the bureau’s scientific findings in the face of opposing political interests. Outraged, hundreds of bureau staff threatened to quit alongside him, and he was temporarily — and later permanently — reinstated.

The episode capped a yearslong tussle between the science agency and the bullheaded seller of a disproven product. It also forced the American public to grapple with a vital question: To which principles were U.S. government scientists beholden?

The saga had begun five years earlier, with a small, red packet of powder.

In 1947, a charismatic California businessman named Jess Ritchie began selling a car battery additive, dubbed “AD-X2.” With lead in short supply in the years after World War II, Ritchie claimed that his powder could double or triple a lead-acid car battery's life.



Jess Ritchie’s battery additive AD-X2. Credit: NIST

But scientists at the National Bureau of Standards had already studied battery additives nearly 20 years earlier. “These materials do not charge storage batteries,” a 1931 notice from the bureau read, “nor do they materially improve the performance of the batteries.”

For Ritchie, the notice was a problem. So in April 1948, he asked the bureau to exempt AD-X2 from the notice. The bureau, having already studied the issue, declined. But Ritchie had customers in powerful positions. Later that year, the Better Business Bureau and a U.S. senator from California climbed into the ring, asking the bureau to test AD-X2.

Already testing another additive, bureau scientists added AD-X2 to the lineup. The results were the same: The powder, a mix of sodium and magnesium sulfates, had no measurable impact on battery performance, which the bureau reported in a new notice.

Ritchie responded in protest, organizing a letter-writing campaign among his supporters. By early 1952, multiple federal agencies and a congressional committee had all requested new tests on AD-X2, and 29 members of Congress had contacted the bureau about the additive.

The pressure fell squarely on Astin, a respected bureau scientist who had become acting director six months earlier. “He was quiet — very reserved,” says historian Nelson Kellogg, in the NIST documentary *The AD-X2 Controversy*, of Astin. “He saw himself primarily as a bench scientist, and then as an administrator of an army of bench scientists.”

Astin agreed to test AD-X2 one more time, this time using a procedure Ritchie said was sure to reveal its merits. Recognizing the political sensitivity of the situation, Astin personally supervised the test in May 1952.

When the results were in, even Ritchie could not distinguish between the batteries that had received AD-X2 and the controls, Astin later testified.

Ritchie raised complaints about the test and, with the support of a Senate committee on small business, pushed for yet another test, this time conducted by the Massachusetts Institute of Technology. The results were inconclusive, but Ritchie and his supporters promoted them as favorable. Ritchie claimed that he and AD-X2 were being persecuted by the bureau.

The controversy played out publicly, making headlines in *The Washington Post* and *The New York Times*. The press pitted Ritchie, the self-made man, against the Goliath government trying to squelch him. Public sympathy fell on Ritchie's side, but Astin remained quiet, trusting the bureau's integrity to speak for itself.

By April 1953, the U.S. Post Office had barred Ritchie’s materials from the mail over concerns of false advertising. But Ritchie had a strong new ally: Sinclair Weeks, recently appointed Secretary of Commerce. The newly elected Eisenhower administration had campaigned on supporting small businesses, and Weeks intended to fulfill that promise.

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Satellite Events Connect Physicists Around the World to the March Meeting

Sites in seven countries expanded opportunities to participate and collaborate.

BY MCKENZIE PRILLAMAN

Many physicists know that the APS March Meeting took place in Minnesota this year. Fewer might have realized that the meeting also took place nearly 8,000 miles away — in the Philippines.

"We rarely get those kinds of collaborations or partnerships internationally," says Andrea Rose Franco, an undergraduate physics student at the University of the Philippines Diliman and vice president of the UP Physics Association (UPPA). So when she received an email from APS in December asking if UPPA could host a March Meeting event, she was thrilled, she says.


Attendees of the March Meeting satellite site in Islamabad, Pakistan, show off attendance certificates. Credit: Hassan Shahzad/The National Centre for Physics

The Philippines was home to one of seven satellite sites in Asia, Africa, and South America that held an event for the local physics community with support from APS. These events help scientists outside of the United States participate, and they strengthen APS' partnerships abroad, says Michele Irwin, the senior international programs manager at APS.

The COVID-19 pandemic, which curbed travel and in-person gatherings for many, first sparked the idea for satellite events. "We wanted to give people an opportunity to be involved in the March Meeting without having to necessarily travel," says Irwin.

The 2022 March Meeting, the first meeting with the pilot program, had four satellite sites. That number nearly doubled this year, with sites in the Philippines, Nepal, Cameroon, Brazil, Pakistan, Jordan, and Hong Kong. Each local event looked different.

In the Philippines, Franco and her co-organizer Thoreenz Soldevilla arranged a virtual session to introduce UPPA and give two early-career scientists an opportunity to present their undergraduate research. "It's a way for us undergrad students to demonstrate our skills," says Soldevilla, an undergraduate in physics at the University of the Philippines Diliman and external affairs associate at UPPA.

In early May, the duo will hold a watch party of some virtual sessions from the March Meeting — with a local physicist present to help explain the science — as part of UPPA's annual Physics Month events, which aim to make physics more accessible to the public.

Meanwhile, at the three-day, in-person satellite event in Jordan, about 100 researchers from nearly a dozen institutions gathered to watch live-streamed sessions during the March Meeting, says organizer Gihan Kamel, a principal scientist at the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME). But the highlight of the local meeting was a virtual session that spotlighted women in physics.

"I've been the only woman scientist at SESAME for something like nine years now," Kamel says. While another woman recently joined the institution as a researcher, Middle Eastern women face many constraints from family, tradition, culture, and religion, Kamel notes.

But Kamel recognizes that the gender gap in science is an issue worldwide. So she invited women from across the globe, all of whom have ties to SESAME, to discuss their professional paths and research. They have "different perspectives, different issues, different difficulties," Kamel says. "But at the end, we are all sharing the same problem." This is the second year Kamel

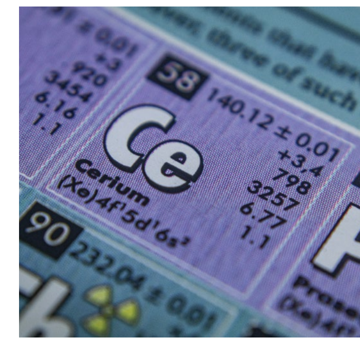
Satellite Sites continued on page 5

Heavy Element Quandary in Stars Worsened by New Nuclear Data

A widening gap between the cerium-140 abundance predicted by theories and that measured in observations of certain stars indicates a potential need for updated models of element formation.

BY KATHERINE WRIGHT

Astrophysicists have a cerium problem — models predict that certain stars should contain much less of this heavy element than astrophysical observations find. Recently performed experiments at CERN's neutron time-of-flight (n_TOF) facility have widened the gap between theory and observations by 20%. The researchers behind the work, published in *Physical Review Letters* in March, say that the results highlight the need for high-accuracy measurements of the nuclear properties of atoms, as well as for updated nucleosynthesis models of element formation. "Our experiment made the problem worse," says Simone Amaducci of the INFN Laboratori Nationali del Sud, Italy. "That was unexpected, but it's also interesting because it means there is something we don't understand about how nucleosynthesis happens."



New experiments indicate that cerium-140 is significantly more likely to capture an incoming neutron than previously thought.

Most of the universe's heavier elements form in stars via one of the so-called neutron-capture processes, in which an atomic nucleus absorbs one or more neutrons. In the slow neutron-capture process, or "s process," the absorptions are spread out in time. As such, each absorption event results in either a stable nucleus with the same number of protons but one additional neutron or an unstable nucleus, which then radioactively decays to produce the nucleus of the next element in the periodic table — the one with one additional proton.

Using currently available models of the s process, researchers have correctly predicted the abundances of elements as heavy as barium (56 protons), lanthanum (57 protons), praseodymium (59 protons), and neodymium (60 protons) in stars that are known to be enriched via the s process. But the models appear to break down for cerium (58 protons), as the abundance predictions for this element in some low-mass, low-metallicity globular cluster stars have disagreed by up to 30% with observations. "This discrepancy is very strange, as the theory works for the neighboring elements," says Sergio Cristallo, a team member who works on prob-

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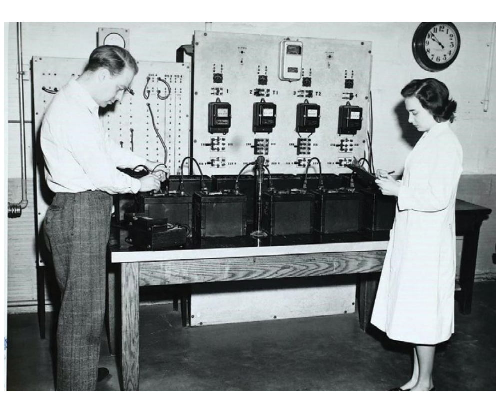
Ritchie, Weeks maintained, was the hapless victim of a biased bureau. He asked for Astin's resignation on March 24 and announced it on March 31, the opening day of a Senate committee hearing on the matter. Ritchie's company "has suffered severely at the hands of certain bureaucrats," Weeks testified. "It is a wonder they are in existence at all after five years of struggle."


National Bureau of Standards staff studying whether battery additives like AD-X2 impact a battery's performance or life. The studies revealed again and again that additives made no difference. Credit: NIST

For many scientists, the news of Astin's firing was deeply unsettling. Enrico Fermi, then president of APS, assembled a committee to investigate, and wrote to the APS Council. They decided to act. Their argument was essentially, "We have to act in this political matter in order to preserve our apolitical stance," says Joseph Martin, a Durham University science historian. APS began working on a statement.

The Federation of Atomic Scientists, the Washington Academy of Sciences, the International Electrochemical Society, and other organizations and individual scientists did the same, calling out the dangers of political overreach in government science. Nearly 400 bureau scientists said they would leave alongside Astin, a loss that would have hobbled the bureau's work.

When the press caught wind of the firing and the backlash from the science community, the press narrative did an about-face. Astin, not Ritchie, became the victim — a civil servant of integrity refusing to bow to political pressure. "The tides change," says Martin.

In response to what *Time* magazine at the time called "the ensuing hullabaloo of scientific outrage and threatened resignations," Weeks temporarily reinstated Astin and agreed to let the National Academy of Sciences review the AD-X2 tests and have the final word.

On May 1, the APS Council approved a forceful statement. "It is the duty of a scientist to investigate scientific and technical problems by openly-stated objective methods without shading his conclusions under political or other pressures," it read. "On this principle the progress of science depends. We have never doubted that the work of the Bureau of Standards has been conducted in this spirit."

That same day, Astin delivered his speech to APS attendees, outlining the bureau's values and thanking APS and others for their support. "We are sincerely grateful," he said.

In the fall of 1953, a National Academy of Sciences report upheld the bureau's work without reservation. Weeks fully reinstated Astin, who served as the director for another 16 years.

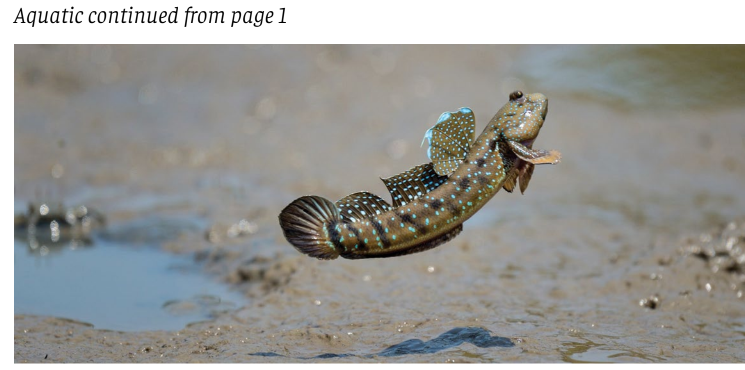
The experience was a political awakening for APS and the U.S. science community, Martin says. Scientists had engaged with politics before, but this was "perhaps the first incident where there's this mobilization directly against the prevailing political currents that is successful," he says. "The scientists are actually quite surprised that they're effective."

They didn't win it all. Weeks never officially recognized that the bureau was right about the additive, and the fraud order against Ritchie was lifted anyway. Still, the political win was crucial for the science community. A 1961 article in *Science*, citing the end to the AD-X2 affair, called it "a landmark in the preservation of scientific integrity against governmental whims and commercial exploitation."

Kendra Redmond is a writer based in Minnesota.

For the National Institute of Standards and Technology, the AD-X2 story — and Allen Astin's unwavering support of the agency's scientific work — is a celebrated part of NIST's history. To learn more, watch NIST's short film, The AD-X2 Controversy, *at nist.gov/ad-x2.*

Aquatic continued from page 1


Mudskippers can move on land using their pectoral fins and even jump to attract mates.

Recently, Ramesh has studied how the animals move on mud of varying wetness. As the mud gets wetter, the mudskipper slows down. But the ropefish and bichir move just as fast. On drier mud, the ropefish and bichir lift their bodies to reduce drag.

But fish aren't always cooperative. "The animals get tired and don't want to move," says Ramesh. To conduct their research more consistently, collaborator Gargi Sadalgekar, also a grad student in mechanical engineering at Hopkins, created a robot that could move like all three species. The team's goal is to eventually develop robots that can navigate water, land, and the muddy in-between. Such robots could monitor soil properties near rivers or deliver first aid to people injured or stuck in these environments, says Ramesh.

The work has also shaped how Ramesh sees the world. "If I see any animals when I go outside, I start analyzing their movement," she says, even that of her own dog. "He doesn't run like other dogs," she says — his gait includes an unusual gallop. "Why?"

Water striders

Ishant Tiwari, a postdoc at Georgia Institute of Technology, studies *Rhagovelia*, or water striders, which exploit high surface tension to walk on water. The bugs first captured Tiwari's attention shortly after he moved to Georgia, when he saw the insects on a hike. Wanting to study how the insects moved, he and his colleagues captured a few in a net and brought them back to the lab in a box full of dried leaves.

Analyzing their behavior in a tank, Tiwari and his colleagues found that the insects move with a characteristic "run-and-tumble" motion — runs of straight lines followed by random changes in direction. Curiously, scientists most commonly associate "run-and-tumble" movement with bacteria like *E. coli*. Tiwari says this is the first instance he's seen of a macroscopic animal moving this way.

Researchers think this movement pattern helps bacteria explore a space to find food, but the specifics aren't clear. "We are studying how this could be an efficient way of searching," says Tiwari.

These studies could inspire more efficient search-and rescue algorithms, like those used by the Coast Guard to quickly find people lost at sea. "These algorithms would eventually be translated to patterns of movement for robots," he says. This research is still in its early stages, but "that's the dream."

Sophia Chen is a writer based in Columbus, Ohio.

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Analyzing the electric field around the graphene, Kofman found that it might exhibit a transistor-like response under the right conditions. Ubiquitous in modern electronics, transistors are small, semiconducting 'gates' that regulate current flow or amplify signals. In Kofman's case, the graphene affects the optical and electronic behavior of the system by, for example, increasing the localized strength of the electric field.

But there's much more to explore with this system, she says. "I'm about half of the way."

To advance her work, and in the hopes of eventually securing a faculty position in Ukraine, Kofman is excited about the research collaboration supplement — up to $5,000 in total — offered by the APS program. The supplement supports a research visit for an awardee, in addition to attending a scientific meeting. So after the March Meeting, Kofman headed to New Orleans to spend the remainder of March exploring the dynamics of multi-qubit quantum systems with Denys Bondar, a theoretical and computational physicist at Tulane University.

APS programs like this rely on sustained financial contributions from the community, including organizations like the Sloan Foundation, to support students like Kofman. "I'm thankful for this program, and that I am here," she says.

Kofman knows that not every graduate student or postdoc in Ukraine has been able to find or take advantage of the opportunities she has had. But her story is important to share, "for Ukrainians to see they are not alone," she says — that "people want to help us."

Liz Boatman is a science writer based in Minnesota.

Learn how you can support APS programs like the Distinguished Student-Ukraine Program and other global initiatives at aps.org/about/support.

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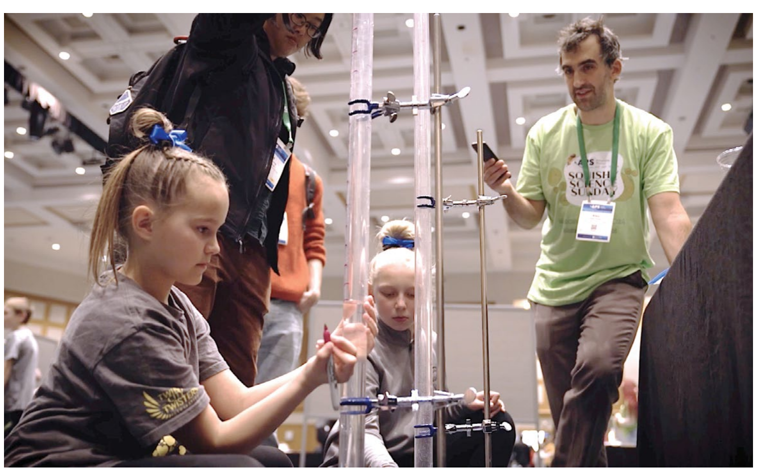

Averi, 10, visits an interactive booth. Credit: APS TV / WebsEdge Science

And people did come — several hundred of them. Twin Cities families, APS members with and without kids, and even gymnasts attending a nearby competition explored biophysics, polymers, soft matter, and statistical physics through nearly 50 tables of hands-on activities. They also enjoyed visual displays and lightning talks on topics like the physics of superheroes and exploding hydrogels.

Many of the most energetic attendees had yet to take a physics class, and some had yet to see a kindergarten classroom, but that didn't dampen their enthusiasm. "This is directly up his alley," said Minneapolis parent Josh Przybylski, watching his four-year-old try to yank a rod out of a jar of sand. Rachel Turner buckled her youngest into a stroller as her other kids played with bubble wands. Even if they don't understand everything, she said, "my goal is just to get them excited about science."

Ariel Ayangwo and her five young kids happened upon the event by pure luck. While on a walk, they stopped by the convention center to see if anything fun was happening and ended up spending the afternoon. Her oldest couldn't decide which activity was the most fun — "There's so much good science!" — but a clear favorite emerged from the younger crew: Augsburg University's live demonstration of crystalline sugar turning into an amorphous solid — that is, fluffy, melt-in-your-mouth cotton candy.

While his kid was elbows-deep in an experiment, another parent, Alan Barnicle, commented on the event's uniqueness. "I love that [the people leading the activities] are actually physicists in labs and universities across the world," he said. "There is value in that."

To fully take advantage of the scientists who had descended on their city, attendees were encouraged to visit an "Ask a Physicist" table. One student stopped by to ask Alex Klotz, a professor at California State University, Long Beach, "What's a physicist?" Klotz kept it simple: "You know when you ask your parents why? Physicists get to the bottom of the whys." The student's eyes lit up, he said.

Many volunteers said those lightbulb moments were the most rewarding part of the experience. Volunteer Bharath Venkatesh, a postdoc at the University of California, Santa Barbara, loved seeing attendees express their curiosity and ingenuity while playing with magic sand. "Kids have been coming up with experiments," he said.

Six APS units brought Squishy Science to life with the support of APS and several sponsors. More than 100 APS members kicked off their meeting experience by volunteering, and Tewari hopes the event will become a March Meeting tradition.

"It's really important for us as a community of scientists to engage with the public," Tewari said. "Not only to inform the public about what we do, but also to let them know that we care about the problems of the world and that the things we are doing will have a direct impact on the lives of everyday people."

As the event drew to a close, Sarah Degner Riveros told her nine-year-old they'd have to head home soon. He'd been racing from table to table for four hours, returning again and again to his favorite station — making "sushi" out of Rice Krispie Treats topped with homemade boba —and even offering to teach other kids the activity. "Today was really fun," he said.

His mother agreed. "I think he might have found his thing."

Kendra Redmond is a writer based in Minnesota.

Total Eclipse Darkens Sky Across North America

The solar eclipse in four cities. Clockwise from top: Dallas, Texas; Indianapolis, Indiana; Washington, D.C.; and Kerrville, Texas. Credit: NASA, clockwise from top: Keegan Barber, Joel Kowsky, Bill Ingalls, Aubrey Gemignani

On April 8, 2024, millions of people across the continent watched the sky plunge into darkness as the moon passed between the sun and Earth. This was the first total solar visible in North America since 2017 — and the last until 2044.

For many, those few minutes of totality represented more than a mere coincidence of size and distance. Rather, it was a reminder that Earth is, in the words of Carl Sagan, "a small stage in a vast cosmic arena."

US Science Agencies Squeezed in Final Fiscal Year 2024 Budget

Agencies are bracing for another tight budget year.

BY MITCH AMBROSE

Lofty rhetoric from lawmakers about increasing science spending met the hard reality of budget caps this year, with Congress cutting most science agencies in its final appropriations for fiscal year 2024. The numbers are set through two packages of legislation, the first signed into law on March 9 and the second on March 23.

The U.S. Department of Energy. Credit: JHVEPhoto - stock.adobe.com

Among the hardest hit agencies is the National Science Foundation, whose budget is shrinking 8% to $9.06 billion. The cut reverses much of the 12% increase that Congress provided NSF last year through a special supplementary appropriation.

Congress framed that $1 billion supplement as a down payment on the CHIPS and Science Act of 2022, which proposes rapidly expanding NSF as well as the National Institute of Standards and Technology and the DOE Office of Science. But the supplement ultimately was a maneuver to evade budget limits negotiated for that year, and Congress was unwilling to make the same move this year.

NIST also received one of the largest cuts in percentage terms across science agencies, dropping 8% to $1.16 billion. This rolls back about half of the increase Congress provided NIST for the previous fiscal year, for which its base budget grew 18% to $1.26 billion. (These figures exclude earmarks for projects external to NIST.)

The DOE's Office of Science was one of the few science agencies to escape budget cuts, receiving a 1.7% increase to $8.24 billion that builds on the 8% increase it received last fiscal year. Nevertheless, the amount for this year is unlikely to keep pace with inflation and will still present the agency with hard choices on what programs to prioritize.

Together, these three agencies are now more than $8 billion dollars below the targets the CHIPS and Science Act set for fiscal year 2024.

Though disappointing for science advocates, the outcome is not surprising. Congress routinely does not follow through on the budget targets it sets for itself. The present dynamic echoes the story of the America COMPETES Acts, whose ambitions for growing the same three agencies evaporated after a 2011 showdown over raising the national debt limit led to a decade of budget caps.

The latest outcome has its roots in a similar fight last spring over raising the debt limit. The Republican-controlled House ultimately agreed to raise the limit in exchange for creating new budget caps on discretionary spending. The compromise, implemented through the Fiscal Responsibility Act and a verbal side-agreement, holds total non-defense spending roughly flat for fiscal year 2024 and only permits a 1% increase for fiscal year 2025.

Defense-focused research is not exempt from the belt-tightening. For instance, Congress cut the Defense Department's budget for basic research 10% to $2.63 billion for fiscal year 2024, rolling it back to near the amount it received four years ago. One exception to the trend is that Congress raised the DOE's portfolio of nuclear weapons stewardship research, technology, and evaluation programs by 11% to $3.28 billion.

Science agencies are now bracing for another tight budget year in anticipation that the fiscal year 2025 spending cap will remain in place.

Some science advocates are pinning their hopes on the possibility of Congress boosting science budgets through special legislation. For instance, Senate Majority Leader Chuck Schumer (D-NY) has signaled interest in developing a follow-on to the CHIPS and Science Act, which in theory could include direct appropriations for select technology areas analogous to the original act's $52 billion injection into the semiconductor sector.

However, the overall appetite in Congress for further special measures has been dampened. Congress has already passed a slew of major spending initiatives in recent years beyond the CHIPS Act, namely pandemic recovery legislation, the Infrastructure Investment and Jobs Act, the Inflation Reduction Act, and wartime support for Ukraine.

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

Mohammadi continued from page 1

Mohammadi's children, seated second and third from left, accepted the 2023 Nobel Peace Prize on her behalf in Oslo last fall. Mohammadi's portrait hangs on the wall. Credit: ©Jo Straube / Nobel Prize Outreach

Iranian Revolution, while Mohammadi was a child, the newly formed Islamic republic imprisoned, tortured, and executed members of her extended family. "My childhood dreams were cruelly shattered," she wrote in a message to the Norwegian Nobel Committee in October 2023.

Despite their suffering, her family remained loving and optimistic and supported her studies, Mohammadi told *Time* magazine in a rare interview from prison in November 2023.

Quantum physics fascinated Mohammadi. She studied applied physics as an undergraduate at Imam Khomeini International University and had planned to pursue a physics doctorate, but she felt compelled to support the rights of women and students and report on the injustices plaguing Iran. "Human rights were, for me, as necessary as breathing to stay alive," she told *Time*.

Upon graduation, Mohammadi worked as an engineer and continued speaking out against the oppression of women, vulnerable minorities, and prisoners of conscience; the death penalty; and other human rights abuses, as a journalist and leader in organizations such as the Defenders of Human Rights Center in Iran. As a result, she lost her job and has been arrested 13 times, convicted five times, fined, banned from seeing her children, sentenced to 154 lashes and 31 years in prison, and subjected to solitary confinement.

In 2018, Mohammadi received the APS Andrei Sakharov Prize in recognition of her campaign for peace, justice, and the abolition of the death penalty in Iran, and for promoting human rights and freedoms despite persecution. The citation also acknowledged the forced sacrifice of her scientific pursuit. "I was filled with joy when studying quantum physics at the university as a means to understand the universe," she recalled in an acceptance letter sent from prison.

In her interview with *Time*, Mohammadi reflected on what a life free from persecution may have been like: "I always think that if I had been born in a European or American country and had a different life experience, I could have been an active physicist in a university or laboratory who would also advocate for human rights and peace."

That's exactly what *we* should be doing, said Joel Lebowitz, a Rutgers University physicist and mathematician who survived Auschwitz during the Holocaust.

"We, or most of us at least, are neither imprisoned nor in exile, but are free and live comfortable lives," Lebowitz told the audience in a prerecorded video. "It is our duty not to be silent and forget about those who are suffering, either from the abuse of human rights or more for their struggle for human rights."

In another prerecorded talk, Iranian cosmologist Encieh Erfani highlighted the "dark aspects" of scientific pursuits that often go unaddressed — barriers erected by gender, race, nationality, and religion and, in many places, the impositions of sanctions and restrictions on scientific collaborations, lack of academic freedom, and disregard for ethical considerations in science.

"It is crucial to acknowledge the complex realities that shape our scientific endeavors," Erfani told attendees. "As scientists, we must embrace our collective responsibility to uphold academic freedom, support at-risk scholars, and foster a scientific community that transcends borders and champions inclusively."

She spoke from experience. Erfani was an assistant professor at the Institute for Advanced Studies in Basic Sciences in Iran from 2015 until she resigned in protest in 2022, following the death of Mahsa Amini, a 22-year-old woman who died in custody of the Iranian morality police. Erfani now lives in exile in Germany, her academic future uncertain.

In light of the abuses taking place around the world, Lebowitz urged physicists to support organizations that defend the human rights of scientists and scholars and help those in exile find positions. Even if an organization can only write letters of protest, those letters "are absolutely essential for keeping up the spirits of people like Mohammadi," Lebowitz told attendees.

APS has already sent a letter to Iran's Minister of Justice calling for Mohammadi's release and signifying that its community of 50,000 scientists stands with her, said Slakey.

In her Nobel lecture, smuggled out from Tehran's Evin prison and delivered by her children Kiana and Ali Rahmani in December 2023, Mohammadi wrote, "With hope and eagerness, and alongside the resilient and courageous women and men of Iran, I extend my hand to all forces, movements, and individuals that focus on peace, the global covenant of human rights, and on democracy."

Kendra Redmond is a writer based in Minnesota.

Satellite Sites continued from page 3

has organized a satellite event in Jordan.

Brazil, too, hosted a March Meeting satellite site for the second year in a row. "It brings people together from the community — from São Paulo and greater São Paulo — to come not just to participate in the APS meeting, but also to talk to each other and collaborate," says organizer Nathan Berkovits, professor at the Institute for Theoretical Physics at São Paulo State University and director of ICTP South American Institute for Fundamental Research.

The daylong event, which welcomed around 30 people, featured in-person presentations by students and postdocs and a virtual session where speakers discussed their research on complex systems.

But hosting an event abroad does present challenges. For instance, it's hard to get people who are watching a session online to be engaged and ask questions, Berkovits says. He proposes hosting a joint virtual session where some talks take place at the satellite site and others occur at the main March Meeting site in the U.S.

Attendees listen to a presentation at the satellite meeting in Hong Kong. Credit: Sunny Xin Wang/Physical Society of Hong Kong

The event's hybrid nature also created some difficulties with engagement for the two-day event in Cameroon, says organizer Paul Woafo, professor of physics at the University of Yaoundé I and founder and past president of the Cameroon Physical Society. Still, five physicists from the country presented research on applied nonlinear dynamics at a virtual session, and more than 40 researchers, many of whom were students, attended an in-person component.

Overall, the satellite event organizers say they were excited to collaborate with APS, and Irwin feels the same way. "We have lots of connections and colleagues all around the world," she says. These satellite sites are "something that's very simple where we can work together."

McKenzie Prillaman is a science writer based in Washington, D.C.

The satellite meeting in Yaoundé, Cameroon. Credit: Paul Waofo/Cameroon Physical Society

DESI continued from page 1

DESI is housed at Kitt Peak National Observatory in Arizona. Credit: Marilyn Chung/ Berkeley Lab

far that those ideas may be on the right track. The reported discrepancy with ΛCDM lacks the statistical significance to claim a discovery, so the DESI collaboration remains cautious about its importance until they have more data. But other experts are expecting theorists to immediately begin proposing revisions of ΛCDM.

"I think it's pretty exciting that they see evidence for something beyond standard ΛCDM," says cosmologist Rocky Kolb of the University of Chicago. "We have a standard model that we're very proud of, and everyone wants to break it to see what's behind it, and perhaps this is the first indication of it unraveling."

DESI was designed to measure the properties of dark energy by mapping the cosmos with unprecedented precision. The instrument is installed on a telescope on Kitt Peak, Arizona, and can collect simultaneous images from 5000 robotically positioned optical fibers, which will allow tens of millions of astronomical targets to be observed over five years. The first year's worth of data, which were the basis for the new results, surpassed the quantity and precision of 10 years' worth of data from its predecessors, the BOSS and eBOSS surveys, says one of the spokespeople for the DESI collaboration, Kyle Dawson of the University of Utah.

DESI measures the past 11 billion years of the universe's expansion thanks to a size reference, or "standard ruler," imprinted in the universe as a characteristic scale in the clustering of galaxies. The standard ruler was fixed in the early universe, when sound waves produced regions with higher-than-average matter density that served as seeds for the formation of galaxies, leading to a preferred separation between pairs of galaxies. By measuring galaxy separations at various times throughout cosmic history, researchers can determine how the expansion of the universe stretched the apparent size of the standard ruler. This preferred galaxy separation for distant galaxies is "a very, very faint signal," Dawson says. "And that's why we need so many galaxies to be able to tease it out."

DESI mapped galaxies and quasars with unprecedented detail, creating the largest three-dimensional map of the universe ever made. This effort marks the first measurement of the expansion history for the period of 8-11 billion years ago with a precision of better than 1%, providing a powerful way to study dark energy. With just its first year of data, DESI has surpassed all previous three-dimensional spectroscopic maps combined and has confirmed the basics of the ΛCDM model.

Comparing the evolution of the apparent ruler size with predictions of the ΛCDM model, the DESI team finds agreement. Specifically, the ratio of the density to the pressure of dark energy, called w, comes out to the predicted value of –1. But when the researchers modify the theory to allow w to vary over cosmic history, the DESI data favor this modification, although the error bars still overlap with the constant w theory. When performing a combined analysis of their data with previous measurements of the cosmic microwave background (CMB) — data that are generally consistent with the DESI data — the researchers find that the error bars no longer overlap. The analysis favors a time-dependent w at a statistical significance of 2.6 sigma, which is close to the 3 sigma needed to claim "evidence" for such a result. This significance stays the same or grows to up to 3.9 sigma when the team combines these data with any of three previous supernova-based cosmology data sets.

The collaboration also reported several other cosmological parameters, including the Hubble constant H_0, the current expansion rate of the universe. One of the biggest cosmological mysteries is the disagreement between H_0 values derived from measurements that probe the "early" universe — such as those based on observations of the CMB — and those derived from measurements that probe the "late" universe — such as those based on gauging the distances to supernovae used as "standard candles." The value obtained by the DESI collaboration is between 67 and 68.5 kilometers per second per megaparsec (km/s/Mpc), depending on which assumptions they use, which agrees with results derived from CMB measurements assuming the ΛCDM model. But supernova measurements give values in the range 73-76 km/s/Mpc, so the DESI results confirm this discrepancy.

Kolb says that with the ΛCDM model, cosmologists have been trying to understand the value of the cosmological constant (the unchanging dark energy) — where it comes from and how it relates to other physical constants. "And we haven't been successful understanding that," he says. But if the DESI result holds up, "maybe we're trading a constant that we don't understand for some dynamics that we don't understand.... And as a physicist, dynamics is something that we grow up trying to explain," he says. "I can't wait to think about it."

"This is the most holistic and comprehensive challenge to ΛCDM. We're able to really test what's been assumed for the last 20 years," Dawson says. He says the collaboration finished the data collection for the 3-year data set on March 31 and will be analyzing those data as rapidly as possible. He hopes that the increased precision will bring researchers closer to understanding the discrepancies with the ΛCDM model. "It's really motivating us," he says.

David Ehrenstein is a Senior Editor for APS's Physics Magazine, *from which this is republished.*

BACK PAGE

That's Not Physics

Where do the boundaries of physics begin and end? The debate has persisted for more than a century.

BY ANDREW ZANGWILL

Starlings flock in a so-called murmuration, a collective behavior of interest in biological physics — one of many subfields that did not always "belong" in physics. Credit: Menno Schaefer/Adobe

If you've been in physics long enough, you've probably left a colloquium or seminar and thought to yourself, "That talk was interesting, but it wasn't physics."

If so, you're one of many physicists who muse about the boundaries of their field, perhaps with colleagues over lunch. Usually, it's all in good fun.

But what if the issue comes up when a physics faculty makes decisions about hiring or promoting individuals to build, expand, or even dismantle a research effort? The boundaries of a discipline bear directly on the opportunities departments can offer students. They also influence those students' evolving identities as physicists, and on how they think about their own professional futures and the future of physics.

So, these debates — over physics and "not physics" — are important. But they are also not new. For more than a century, physicists have been drawing and redrawing the borders around the field, embracing and rejecting subfields along the way.

A key moment for "not physics" occurred in 1899 at the second-ever meeting of the American Physical Society. In his keynote address, the APS president Henry Rowland exhorted his colleagues to "cultivate the idea of the dignity" of physics.

"Much of the intellect of the country is still wasted in the pursuit of so-called practical science which ministers to our physical needs," he scolded, "[and] not to investigations in the pure ethereal physics which our Society is formed to cultivate."

Rowland's elitism was not unique — a fact that first-rate physicists working at industrial laboratories discovered at APS meetings, when no one showed interest in the results of their research on optics, acoustics, and polymer science. It should come as no surprise that, between 1915 and 1930, physicists were among the leading organizers of the Optical Society of America (now Optica), the Acoustical Society of America, and the Society of Rheology.

> "Much of the intellect of the country is still wasted in the pursuit of so-called practical science which ministers to our physical needs," Rowland scolded, "[and] not to investigations in the pure ethereal physics which our Society is formed to cultivate."

That acousticians were given a cold shoulder at early APS meetings is particularly odd. At the time, acoustics research was not uncommon in American physics departments. Harvard University, for example, employed five professors who worked extensively in acoustics between 1919 and 1950. World War II motivated the U.S. Navy to sponsor a great deal of acoustics research, and many physics departments responded quickly. In 1948, the University of Texas hired three acousticians as assistant professors of physics. Brown University hired six physicists between 1942 and 1952, creating an acoustics powerhouse that ultimately trained 62 physics doctoral students.

The acoustics landscape at Harvard changed abruptly in 1946, when all teaching and research in the subject moved from the physics department to the newly created department of engineering sciences and applied physics. In the years after, almost all Ph.D. acoustics programs in the country migrated from physics departments to "not physics" departments.

The reason for this was explained by Cornell University professor Robert Fehr at a 1964 conference on acoustics education. Fehr pointed out that engineers like himself exploited the fundamental knowledge of acoustics learned from physicists to alter the environment for specific applications. Consequently, it made sense that research and teaching in acoustics passed from physics to engineering.

It took less than two decades for acoustics to go from being physics to "not physics." But other fields have gone the opposite direction — a prime example being cosmology.

Albert Einstein applied his theory of general relativity to the cosmos in 1917. However, his work generated little interest because there was no empirical data to which it applied. Edwin Hubble's work on extragalactic nebulae appeared in 1929, but for decades, there was little else to constrain mathematical speculations about the physical nature of the universe. The theoretical physicists Freeman Dyson and Steven Weinberg have both used the phrase "not respectable" to describe how cosmology was seen by physicists around 1960. The subject was simply "not physics."

This began to change in 1965 with the discovery of thermal microwave radiation throughout the cosmos — empirical evidence of the nearly 20-year-old Big Bang model. Physicists began to engage with cosmology, and the percentage of U.S. physics departments with at least one professor who published in the field rose from 4% in 1964 to 15% in 1980. In the 1980s, physicists led the satellite mission to study the cosmic microwave radiation, and particle physicists — realizing that the hot early universe was an ideal laboratory to test their theories — became part-time cosmologists. Today, it's hard to find a medium-to-large sized physics department that does not list cosmology as a research specialty.

Not all disciplines have had such clean paths in or out of physics. Consider the case of biophysics, or biological physics — where physicists apply their methods to the study of living systems. Whether or not this field is physics or "not physics" has vexed the community for a century.

In 1920, the physics department at Harvard boldly hired an assistant professor named William Bovie to conduct research and teach courses in biophysics. Bovie did not get tenure, and the Harvard physics department did not hire another assistant professor in this area until 2013.

In 1970, the National Academy of Sciences charged the American physics community with analyzing itself to help the government establish funding priorities. The resulting 2,900-page report devoted only 20 pages to what it called "physics in biology." Tenured appointments for younger people working in biophysics "have been very scarce," it noted. "Among the reasons for this scarcity are the difficulty evaluating their work in a physics department and questions about the appropriateness of such work in a physics department."

This may explain why, in 2000, only 20% of Ph.D.-granting institutions employed at least one physics professor engaged in biophysical research. But also in 2000, six physics departments had biophysics groups with more than three faculty members each, and three of those groups boasted a record of continuous funding and publication beginning before 1965.

Since 2000, the advent of conferences and federal funding devoted to biological physics convinced a growing number of physics departments to accept it as a legitimate and exciting subfield of physics. On the other hand, several prominent U.S. physics departments remain biophysics-free in 2024. It appears that a juror or two must be convinced before a unanimous verdict can be announced.

Perhaps the path of each field — acoustics, cosmology, and biological physics — toward physics or "not physics" seems unique. But all three are archetypes of stories that could be told about virtually every other subfield of physics. To hear the tale of another discipline, simply question its suitability as a part of physics the next time you share a meal with one of its practitioners.

Andrew Zangwill is a professor of physics at the Georgia Institute of Technology.

This article was adapted from a talk the author gave at the 2024 March Meeting in Minneapolis, during a session on APS's 125-year history. The topic is also the subject of a forthcoming book by the author.

Cerium continued from page 3

lems related to neutron capture at the National Institute of Astrophysics in Italy. "There is nothing in the models that should cause such a discrepancy just for one element."

Cerium has another intriguing property — it can form a so-called magic-number nucleus. Most of the universe's cerium (89%) exists as cerium-140, an isotope of the element that contains 58 protons and a magic number of 82 neutrons. Magic-number nuclei are particularly stable and so often exist in higher abundances than other isotopes of the same element or of neighboring elements in the periodic table.

Like other magic-number nuclei, the high stability of cerium-140 arises from its low neutron-capture cross section, which is the probability that a nucleus of the isotope will absorb an incoming neutron. It is also the parameter measured in the new experiments at CERN, which involved bombarding a cerium-oxide sample with a high-energy neutron beam and then measuring the products of that interaction. The capture of a neutron by the cerium-140 in the sample produced cerium-141, an unstable isotope. The subsequent decay of cerium-141 emitted a cascade of gamma rays, which were detected when they interacted with a liquid scintillator. These detections were then used to determine the neutron-capture cross section of the original cerium-140.

Analysis of the data indicates that the neutron-capture cross section is 40% higher than measured in previous experiments, which had lower accuracy. A higher cross section makes it more likely cerium-140 will capture an incoming neutron and less likely that it will stay in its cerium-140 form. That in turn leads to a prediction of a lower abundance of cerium-140 than before, Amaducci says. The higher cross section also has implications for the abundances of the nuclei that form further along in the s-process chain. With cerium-140 being more likely to capture a neutron and form a heavier nucleus, the s process can continue faster, creating a higher abundance of heavier nuclei, Amaducci says.

The mismatch between the cerium-140 abundance predicted by theory and that measured in observations of the low-metallicity stars the team considered suggests that a process other than the s process might also produce this nucleus in those stars. Amaducci, Cristallo, and another of their colleagues, Alberto Mengoni of the Italian National Agency for New Technologies, Energy, and Sustainable Economic Development (ENEA), say that one possibility is that another nucleosynthesis pathway, the so-called i process, is involved in the making of cerium. This proposed neutron-capture process bypasses some stable nuclei involved in the s process, and — if it played a big role — could change the relative abundances of the elements. "It's a possibility," Mengoni says. "But we don't know whether this i process can explain the present situation."

The team is not the only group studying the neutron-capture cross section of cerium-140. In February, using a different technique, Michael Paul of the Hebrew University of Jerusalem and his colleagues found a roughly 15% lower value of the cross section than previously measured with that technique, according to a study published in *Physical Review C* in February. Neither Paul nor Amaducci know the source of the discrepancy between the two new values.

To tease out exactly what is going on, the researchers all agree that more nuclear measurements need to be made. For example, Amaducci notes that there is currently no experimental data for many of the nuclei involved in the i process. "So, the inputs to the model are very uncertain," he says. Many theory and experimental groups are exploring the i process, and Mengoni expects that the results of those studies will lead to some interesting findings. "It may be that current models of nucleosynthesis need to be tuned or new models invented," he says. "Understanding these problems is one of the most active areas in nuclear physics."

Katherine Wright is the Deputy Editor of APS's Physics Magazine, *from which this article is republished.*

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