APS News

A Publication of the American Physical Society | aps.org/apsnews | June 2024 | Volume 33 | Number 6

At the APS April Meeting, Scientists Debate the Latest Data from the James Webb Space Telescope

From far out in space, the JWST has sparked rigorous discussion here on Earth.

BY SOPHIA CHEN

Supernova remnant Cassiopeia A, as captured by NASA's James Webb Space Telescope's NIRCam (Near-Infrared Camera), at left, and MIRI (Mid-Infrared Instrument). Credit: NASA, ESA, CSA, STScI, D. Milisavljevic (Purdue University), T. Temim (Princeton University), I. De Looze (University of Gent)

Nearly two years after it began its scientific operations in July 2022, the James Webb Space Telescope has been churning out data with exciting new implications for astronomy and cosmology. At the 2024 APS April Meeting in Sacramento, California, scientists gathered to present and debate the telescope's latest observations.

"The most exciting sentence in physics is not 'Eureka!' but 'That's funny,'" says astrophysicist Tommaso Treu of the University of California, Los Angeles, quoting Isaac Asimov. "I think that's what we're finding — something surprising."

Situated 1.5 million kilometers from Earth and fitted with the largest mirror ever launched into space, the telescope is helping scientists study the early universe, the life cycle of stars, and exoplanets. JWST's four instruments detect wavelengths spanning 600 nanometers (the visible red) to 28.5 microns (the mid-infrared).

The telescope's sensitivity to infrared light lets it see through dust to the stars beyond, allowing researchers to glimpse distant objects and galaxies formed in the early universe. These older stars, born soon after the Big Bang, emitted a lot of visible and ultraviolet light, but those wavelengths stretch as the universe expands.

"Light that starts in the UV arrives at us in the infrared," says Treu, who studies the earliest galaxies and who attended the April Meeting.

JWST's recent data has added new fuel to an ongoing debate over how fast the universe is expanding. The heart of the issue: Different groups of researchers have for years measured different values for the

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To Hunt for Dark Energy, Swipe Left or Swipe Right

A citizen science initiative called Dark Energy Explorers has recruited 17,000 people to identify galaxies in telescope images.

BY SOPHIA CHEN

Dark Energy Explorers was founded by Lindsay House, a graduate student in astrophysics at UT-Austin. Credit: UT-Austin College of Natural Sciences

Physics is awash in large collaborations. The gravitational wave hunters in the LIGO Scientific Collaboration include 1,200 members in 18 countries. The ATLAS particle physics collaboration encompasses 6,000 members from 42 countries. But the size of Lindsay House's team is an entirely different magnitude. Since 2021, House, a graduate student in astrophysics at the University of Texas at Austin, has recruited 17,000 people from 85 different countries to contribute to her dark energy research.

House's 17,000 collaborators are "citizen scientists" — volunteers who have signed up for an online program she created called Dark Energy Explorers. "I definitely didn't expect there to be this much inter-

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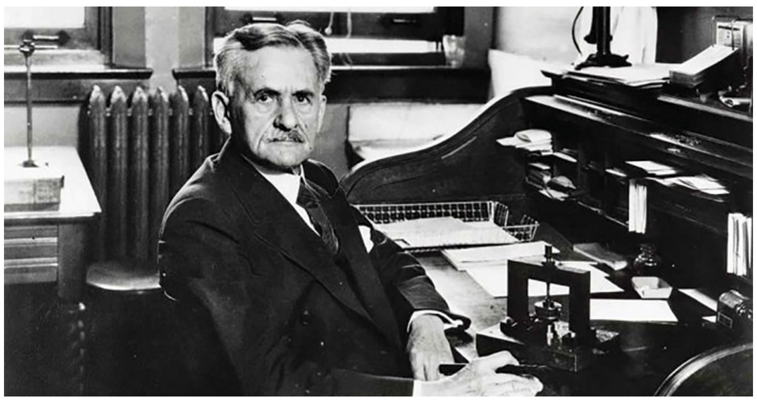
Where Albert Michelson Measured the Speed of Light 145 Years Ago

APS honors a historic site in physics — the United States Naval Academy.

BY KENDRA REDMOND



Albert Michelson in his office at the University of Chicago around 1927. On his desk is a revolving mirror used in a velocity of light experiment. Credit: U.S. Naval Academy

For more than 175 years, the United States Naval Academy has educated future officers along the scenic shores of Maryland's Severn River, just before it converges with the Chesapeake Bay. In the late 1870s, a young physics teacher, Albert A. Michelson, meticulously aligned optical equipment against that backdrop.

There, on the school's seawall, he measured the speed of light far more accurately than anyone had before.

That seawall is gone now; as the Academy grew, it filled in much of the shoreline to make room for new buildings. Today, the original path of Michelson's experiment is marked by round aluminum disks set into the terrace between Michelson Hall and Chauvenet Hall (named for mathematician William Chauvenet, who helped found the Naval Academy). Michelson Hall houses the school's science wing.

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The Path to Making Batteries Green

For Shirley Meng, the biggest barrier to achieving sustainable batteries is sociological, not technological, requiring a change in mindset about how we consume and dispose of batteries.

BY KATHERINE WRIGHT

When it comes to batteries, "green" is all the rage. To get green credentials, a battery must contain only materials obtained using sustainable methods. The manufacturing processes used to make the battery should also have minimal environmental impacts and the device should be fully recyclable. Scientists are making advances in all these areas, but obstacles remain. So, when will green batteries become the norm? To find out, *Physics Magazine* spoke with Shirley Meng, a molecular engineer at the University of Chicago who works on materials discovery for green batteries. Meng is also the chief scientist at the Argonne Collaborative Center for Energy Storage Science, Illinois, where scientists and engineers from different fields work together to solve modern energy-storage problems.

"I try to keep the big picture in mind, even though I am only focused on a small part of the problem," says molecular engineer Shirley Meng. Credit: S. Meng/University of Chicago

When it comes to batteries, what does green mean to you?

A green battery is first a battery that stores "green" electrons, those generated by renewable sources such as wind or solar. But a battery itself is not renewable. Batteries contain minerals that are mined from Earth's crust, which, like fossil fuels, are not naturally replenished. For a battery to be green, the other factors in its lifecycle, therefore, need to be sustainable. Those factors include not only how the minerals are mined but also the mine locations relative to manufacturing plants or end users — the closer mines and factories are to one another, for example, the less energy goes into transportation of raw materials.

We must also think about what happens to the battery when it no longer works. To be sustainable the minerals in a battery should be 100% recyclable, and industries should be able to turn materials from an old battery into a new one an infinite number of times. Only with this circularity can we have a truly green battery that helps us transition away from fossil fuels to more sustainable energy sources.

That's a lot of factors. Is there one that is proving harder to achieve than the others?

The biggest obstacle in making a green battery isn't technological. It's changing the mindsets of companies and consumers who until now have largely treated batteries as disposable commodities that they just throw into the dustbin after they're done using them.

Companies and laboratories are actively developing battery-recycling technologies, but they are still nascent — the techniques might work for a few tens of kilograms of materials, but to be commercially viable, they need to work for hundreds of tons of material. Achieving that goal is key, yet it won't matter if no one recycles their batteries — we can see that for plastics. So, for me, it's changing this mindset that is the big challenge.

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Quantum “Torch” Begins Its Relay

A quantum light source is touring European labs in preparation for the 2025 International Year of Quantum Science and Technology.

BY MICHAEL SCHIRBER

Like the flame that started its journey from ancient Olympia to the 2024 Olympic Games in Paris, a “quantum torch” has begun its tour of Europe to mark the coming International Year of Quantum Science and Technology in 2025. The kickoff ceremony of this QuanTour project occurred in Berlin on April 14, World Quantum Day. The quantum torch — a microscopic device in the shape of a dartboard — emits light one photon at a time, exemplifying the precise control at the core of quantum technologies. “We want to get everyone excited about quantum physics,” says QuanTour organizer Doris Reiter of the Technical University of Dortmund, Germany.

> Heindel described QuanTour’s quantum torch device as “a nanophotonic dartboard” with a quantum-dot emitter sitting at the bullseye.

The quantum torch, which was fabricated by Tobias Heindel and his group at the Technical University of Berlin, is scheduled to visit 12 different labs in 12 different countries during the next 12 months. At each stop, there will be events tied to the International Year of Quantum Science and Technology — a global initiative highlighting the contribution of quantum physics to our daily lives. QuanTour organizers are planning public demonstrations of quantum mechanics concepts and “behind the scenes” visits of quantum physics labs. Videos will also be aired of scientists explaining their work to science communicator and QuanTour organizer Pranoti Kshirsagar.

The launch ceremony included talks on the importance of quantum science and technology in our daily lives. Claus Lämmerzahl, a theoretical physicist from the University of Bremen, Germany, and the spokesperson for the German Physical Society (DPG), provided motivation for the upcoming Year of Quantum. He says that 2025 was chosen because it commemorates the 100-year anniversary of Werner Heisenberg’s theoretical breakthrough in formulating the mathematics of quantum mechanics. “Quantum theory is one of the fundamental findings of humankind,” Lämmerzahl says.

Next year also marks the 125th anniversary of Max Planck’s introduction of the concept of “quanta” — packets of energy that could explain the spectra of light from thermal sources, such as a flaming torch. Cornelia Denz, the president of the German National Metrology Institute (PTB), recounted the efforts at the end of the 19th century that led to that development and to single-photon quantum light sources, such as the quantum torch. “The quantum emitter is so important for quantum technology,” Denz says.

One key use of the single-photon emitter is in communication. “Quantum physics can provide enhanced security and functionality to our communication networks,” Heindel says. That enhanced security relies on single-photon emitters, he says, as these devices can provide a steady stream of photons that are highly sensitive to any type of eavesdropping.

Heindel, whose research focuses on quantum communication, described QuanTour’s quantum torch device as “a nanophotonic dartboard” with a quantum-dot emitter sitting at the bullseye. The 4-µm-wide device is etched into a thin slab of gallium arsenide, a

Quantum Torch continued on page 4

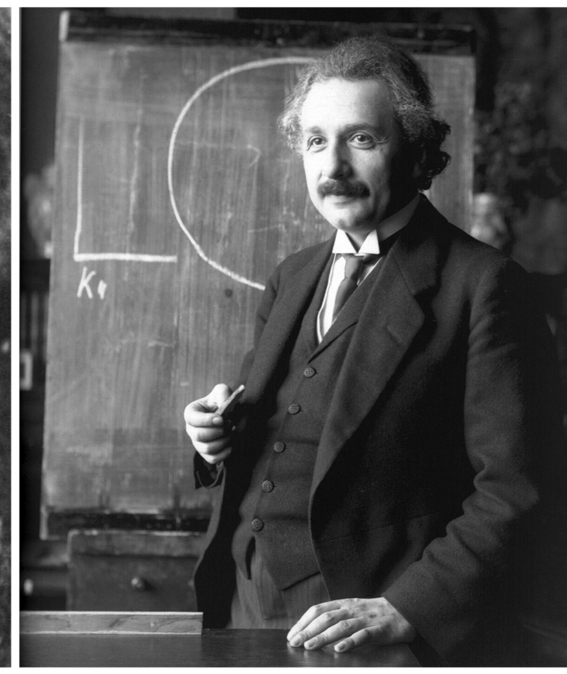
A quantum light source will tour several labs this year in preparation for the International Year of Quantum Science and Technology. At a kickoff ceremony in Berlin, the organizers of the QuanTour project placed stickers on the suitcase carrying the emitter. Credit: A. Böttcher/DPG

THIS MONTH IN PHYSICS HISTORY

May/June 1922: Alexander Friedmann Proposes That the Universe Could Expand or Contract, to Einstein’s Chagrin

Friedmann used Einstein’s general theory of relativity to predict a changing universe — what would become the foundation of the Big Bang theory.

BY TESS JOOSSE



Alexander Friedmann (left), a Russian mathematician and meteorologist, took a keen interest in Albert Einstein’s 1917 paper applying the general theory of relativity to cosmology. Credit: Friedmann: Leningrad Physico-Technical Institute, courtesy AIP Emilio Segrè Visual Archives (1925). Einstein: Ferdinand Schmutzer (1921).

In May 1922, a relatively unknown Russian mathematician and meteorologist sent a casual note to a friend outlining ideas that would rearrange our understanding of the universe.

Along with the letter, Alexander Friedmann typed up a manuscript detailing how Albert Einstein’s general theory of relativity showed that the universe could expand or shrink. He sent the manuscript and note to his friend, the Austrian physicist Paul Ehrenfest.

“I’m sending you a brief note regarding the question about the possible shape of the universe more general than the cylindrical world of Einstein, and the spherical world of de Sitter,” the correspondence reads, referring also to another solution proposed by Dutch astronomer Willem de Sitter. “Aside from these two cases there appears also a world, the space of which possesses a curvature radius varying with time.”

In other words, Friedmann thought the universe might not be static after all — that it could expand or contract at a calculable rate. Several years before Georges Lemaître theorized an expanding universe and Edwin Hubble measured it, Friedmann had unearthed the foundations of what would become the Big Bang theory.

Einstein first derived the general theory of relativity in 1915, publishing equations that describe how mass curves spacetime as gravity. Then, in a 1917 paper titled “Cosmological Considerations in the General Theory of Relativity,” he applied his field equations to the whole universe.

But a mathematical problem had emerged. The accepted paradigm of the time was that the universe was static, and Einstein thought that any alternative was impossible — but his field equations, he and later de Sitter realized, would allow for a universe that could change.

“From the standpoint of astronomy ... I have erected but a lofty castle in the air,” Einstein, then in Berlin, wrote in a letter to de Sitter, who was also coming up with cosmological solutions to the general relativity equations. “For me, though, it was a burning question whether the relativity concept can be followed through to the finish, or whether it leads to contradictions.”

He devised a parameter for the equations called the cosmological constant that he thought would keep the universe closed and static. The constant was merely a “hypothetical term,” he admitted. Still, “I am satisfied now that I was able to think the idea through to completion without encountering contradictions,” he wrote in a letter to de Sitter.

Along came Friedmann to provide contradictions aplenty. Born in St. Petersburg in 1888, Alexander Friedmann studied math and physics at university and applied these studies to aeronautics and meteorology research. He flew in missions for the Russian Imperial Army in World War I and spent down time modeling the trajectory of dropped bombs, which he verified during flights over the Austrian front.

By 1922, Friedmann was back in St. Petersburg, then called Petrograd. There, while he worked as a professor, he began to tackle Einstein’s 1917 paper in earnest. In what would later be dubbed the Friedmann equations, he showed that by varying a few assumptions, including the value of the cosmological constant, Einstein’s equations could describe a universe that expands over time, contracts over time, or contracts and then expands again.

> “The results concerning the non-stationary world ... appear to me suspicious,” Einstein wrote. “In reality it turns out that the solution given in it does not satisfy the field equations.”

Friedmann wrote up his conclusions in a paper, “On the Curvature of Space,” which was accepted for publication by the respected German journal *Zeitschrift für Physik* on June 29, 1922.

Einstein swiftly wrote to the journal with a refutation. “The results concerning the non-stationary world ... appear to me suspicious,” he wrote. “In reality it turns out that the solution given in it does not satisfy the field equations.”

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APSNews

Series II, Vol. 33, No. 6
June 2024

APS News is published 10 times per year by the American Physical Society, One Physics Ellipse, College Park, MD 20740-3844, (301) 209-3200. It contains news of the Society’s units, events, initiatives, and people; opinions; and related information.

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Coden: ANWSEN ISSN: 1058-8132

Allis Prize Highlights the Importance of Ionized Gases to Modern Life

Although plasmas are used throughout electronics research and manufacturing today, it took decades for their industrial potential to be realized.

BY LIZ BOATMAN

Across the universe, plasma — a gas so energetic that its electrons have been stripped from atomic nuclei — is the most common state of matter. But on Earth, plasma only occurs naturally in a few instances, like in auroras near our planet's magnetic poles or in bolts of lightning.

Even so, a century ago, scientists weren't quite sure what plasma was, much less whether it could have useful applications if harnessed.

Today, industrial applications of partially and completely ionized gases, like plasma, have touched many parts of our world: in the fabrication of computer chips, the purification of drinking water, the adhesion of the surface of films, and even in spacecraft thrusters.

APS recognizes advances in plasma science with the Will Allis Prize for the Study of Ionized Gases. Allis, an American theoretical physicist, "made seminal contributions to the science of ionized gases," establishing "basic concepts that describe how these systems behave," says Rick Gottscho, a chemist and the executive vice president of Lam Research, which specializes in advanced technologies for semiconductor manufacturing.

Plasmas — like those found in plasma cutters — are used across industries.

After becoming an APS Fellow in 1936, Allis explored the feasibility of building a nuclear fusion engine, eventually co-founding the APS Gaseous Electronics Conference, which still runs today.

Chemical engineer David B. Graves, the 2014 Allis Prize recipient and a professor at Princeton University, says Allis' work motivated his own early research on particle-in-cell and fluid simulations of plasma. Allis' 20th-century contributions to physicists' understanding of electron kinetics — how

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"When I was a kid coming to the Academy with my dad, I would walk that path," says Naval Academy Provost Samara Firebaugh. Years later, as an electrical engineering professor, she would take her students there, and today, she still points out the markers to visitors and shares Michelson's story.

The site now has newfound fame: In a ceremony on April 12, APS President Young-Kee Kim and CEO Jon Bagger formally recognized it as an APS Historic Site, an honor given to a select number of places each year where important events in physics history took place. The Naval Academy was chosen because of Michelson's enduring contribution to physics.

The U.S. Naval Academy was recognized as an APS Historic Site during a ceremony in April. The round disks set into the terrace mark the original path of Michelson's historic experiment measuring the speed of light. Credit: U.S. Naval Academy / Stacy Godfrey

Michelson's family immigrated to the United States from Prussia in 1856, opening a dry goods store in a California mining town, and later in Nevada. His parents sent him to school in San Francisco, where he excelled in science and became fascinated with optics.

"Albert's brothers and sisters were swept into the drama of Western life," wrote Michelson's daughter Dorothy Michelson Livingston in *The Master of Light: A Biography of Albert A. Michelson*, but Albert "had acquired a different set of values."

Michelson sought to continue his science education after high school. He saw his chance when the paper announced a statewide competition for a coveted spot at the U.S. Naval Academy, which had a strong optics program. Michelson tied for first place, but the appointment went to a co-winner.

With the support of his U.S. representative, Michelson appealed to President Ulysses S. Grant for a special appointment to the Academy. President Grant initially declined, having already made the 10 appointments he was allotted, but later reconsidered and awarded Michelson an 11th appointment.

At the Naval Academy, Michelson led his class in optics and thermodynamics but lagged in seamanship. Around his graduation, the Naval Academy's superintendent, Rear Admiral John Lorimer Worden, told Michelson, "If in the future you'd give less attention to those scientific things and more to your naval gunnery, there might come a time when you would know enough to be of some service to your country," according to a 1931 *New York Times* article.

After a two-year tour, Michelson returned to the Academy as a chemistry and physics teacher. In the fall of 1877, his supervisor suggested Michelson start an advanced physics class by demonstrating Léon Foucault's 1862 speed of light measurement. Michelson reluctantly agreed — demonstrations were a new teaching method at the Academy — and studied the original experiment.

To find the speed of light, Foucault had measured how much a rapidly rotating mirror displaced a reflected beam of light, and then he had correlated the displacement to the mirror's angular velocity. The result was solid, but Michelson saw room for improvement.

"The objection to Foucault's method is that the displacement, a quantity which enters directly in the formula, is very small, and therefore difficult to measure accurately," Michelson wrote in a paper published in *The Scientific Monthly*. By increasing the displacement, Michelson realized he could measure it more precisely. That meant he could more accurately determine the speed of light — a fundamental measurement for navigation at sea and for science broadly.

With a few months and scavenged parts, Michelson built a proof-of-concept apparatus. He spent the next year refining a large-scale design that, in 1879, yielded a 115 mm displacement (Foucault's was less than 1 mm) and a value of 299,940 km/s for the speed of light. The most accurate value of its time, Michelson's measurement was within 0.05% of the currently accepted speed of light.

This work kicked off his groundbreaking career in optics, during which Michelson experimentally challenged the existence of ether, invented the interferometer bearing his name, and, in 1907, received the Nobel Prize in Physics, becoming the first American laureate in science. He resigned from the Navy in 1881 to pursue physics but always stayed connected. "Father's devotion to the Navy took second place only in relation to his romantic feeling about light," wrote Dorothy Michelson Livingston in an article for the U.S. Naval Institute Proceedings.

Each year, the Naval Academy honors Michelson by inviting a distinguished researcher to share their expertise with midshipmen during the Michelson Memorial Lecture. The event is a campus-wide reminder that although technology landscapes and seawalls may shift, clever instrument design and careful measurement have lasting impact.

Kendra Redmond is a writer based in Minnesota.

Any APS Member Can Now Be Nominated For the APS Board

APS is pleased to announce an important governance change. Effective immediately, all APS members are eligible for nomination to the APS Board of Directors.

Previously, Board candidacy was reserved for members who have served for a year on the APS Council of Representatives. Now, all APS members, especially those deeply engaged in APS activities and possessing leadership experience, can be nominated.

This change strengthens the Board — which is responsible for the governance and affairs of the Society — by harnessing the diverse expertise and perspectives of APS membership.

To nominate yourself to the APS Board via a secure APS portal, visit go.aps.org/nominateboard. To nominate someone else, send an email with the nominee's name to governance@aps.org.

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Hubble constant, the universe's current rate of expansion.

Researchers take two main approaches to measure the constant. In one method, they plug data on the cosmic microwave background, the oldest observable light in the universe, into the standard model of cosmology. Results vary, but researchers have found the Hubble constant to be around 68.3 kilometers per second per megaparsec, with 1 percent uncertainty.

In the other method, researchers estimate the distance from Earth of certain supernovae by using objects of known brightness, collectively known as "standard candles." They also measure how quickly the supernovae are moving away from Earth, and thus calculate the Hubble constant. Different teams have gotten slightly different values using this method.

But the bigger problem is that the two approaches yield very different constants. The Supernova H0 for the Equation of State (SH0ES) team's measurement of the supernovae offers the largest discrepancy — five standard deviations — from that of the cosmic microwave background method, at 73.3 with 2 percent uncertainty.

Many think the divergence between the two sets of results could signal that cosmology's standard model is incomplete. In her talk at the April Meeting, Wendy Freedman of the University of Chicago presented new approaches to resolving the discrepancies.

In particular, observations using JWST could help researchers measure the distance to supernovae more accurately, Freedman noted. Before JWST's launch, she and her colleagues developed a new method known as the "tip of the red-giant branch" method, which uses the luminosity of the brightest red stars in a galaxy to estimate supernovae distance. They found a Hubble constant value of 69.8 with an uncertainty of about 3 percent. Their new measurement is "consistent" with the results of the cosmic microwave background method, says Freedman.

Considering that value alone, "it doesn't appear that we need fundamental new physics to incorporate into the standard model," she says. But they're refining that measurement further using JWST's new observations of "tip of the red-giant branch" stars.

To further validate these methods, the team is working to measure the supernovae distances using a brand-new method that makes use of JWST's observations of another star category, known as the J-region Asymptotic Giant Branch stars. They will also use JWST to refine an old method using pulsating stars known as Cepheids, a project Freedman has been working toward for decades.

Beyond the puzzle around the universe's rate of expansion, JWST's observations have raised questions about the early universe. Treu's team at UCLA is one of several using the telescope's data to study the earliest galaxies, formed when the universe was only about 500 million years old.

These galaxies are far more compact than younger galaxies — a hundred to a thousand times smaller in diameter, and a million to a billion times smaller in volume, than the Milky Way. These ancient galaxies also have a different chemical composition, containing less oxygen and other elements heavier than helium.

Using JWST, Treu's team found ten to twenty more galaxies than expected. The galaxies were also brighter than anticipated, indicating they had formed stars quickly. "Galaxies seem to be forming earlier than we thought, and they form stars more rapidly and efficiently than we thought," says Treu.

The next step is to use JWST to take higher resolution spectra of these objects to "really get into the details," he says. "We don't understand how the universe formed stars from pristine gas well enough."

Meanwhile, Tea Temim of Princeton University is using JWST to study closer objects: supernovae in the Milky Way and nearby galaxies. At the meeting, she presented analyses of JWST observations of supernova remnants, the high-speed, leftover material from stellar explosions.

JWST's infrared camera allows researchers to see deeper into the layers of ejected material from a star. From these images, Temim and her colleagues aim to perform forensics — to understand how the supernova occurred, and how it interacts with the material surrounding it. "We're still trying to understand what types of systems produced the supernova explosions we observed," says Temim.

In one study, they analyzed Cassiopeia A, located in our own galaxy. The images reveal details like a web-like network of material, as well as the supernova's outermost shell colliding with circumstellar material. "It's the first time that we've seen the resolved interior of supernova-ejected material," she says. One challenge, she notes, is determining which structures in the image represent material ejected during the explosion rather than material the star lost prior to the explosion.

Temim also discussed JWST's observations of the remnants of Supernova 1987a, an explosion that occurred 37 years ago about 170,000 light-years away. It's the closest supernova ever studied, says Temim. "We've been able to follow its evolution from the explosion until now," she says. Studying the spectra of ejected material, they saw indirect evidence of a compact object inside, such as a neutron star or a pulsar wind nebula. In the future, Temim and her colleagues plan to use additional observations to better understand the explosion mechanisms.

Sophia Chen is a writer based in Columbus, Ohio.

Letter to the Editor: Publishing for Part-Time and Retired Faculty

Responding to "The Steep Price of Free Science Access," by Robert Rosner, April 2024:

The evolution of publishing toward open access models described in Robert Rosner's April 2024 Back Page threatens to further disenfranchise two groups within our community who have historically tended to suffer from limited access to grant or institutional funding: part-time and retired faculty. Part-timers who are seeking full-time positions will be looking to publish in reputable journals to bolster their credentials, while retirees often wish to remain active and can have much to contribute based on their years of experience.

At present, options for hybrid/subscription-based publication help to address this disparity, but I anticipate that financial considerations will inevitably drive the trend to an exclusively pay-to-play environment. That APS is helping to subsidize publishing costs for scientists in less privileged countries is worthy and laudable, but let us not forget that many in first-world settings are by no means competing on a level field.

— Cameron Reed (Nova Scotia)

Green Batteries continued on page 1

Any ideas on how to get everyone on board with recycling?

It won't be easy — just as it isn't for plastics. But we can't just live in the mess.

I would love for companies to have more responsibility on that front and to lead by example. They currently have an economic incentive to recycle in that the cost of battery materials is so high. But if the cost of making batteries goes down, that incentive for companies could disappear. That is where we, as consumers, have power.

We need to push battery companies to report how much carbon dioxide was emitted during a battery's fabrication, what mining practices were used, where the materials were sourced from, and how long the battery will last, for example. And then we need to buy only those devices containing batteries that are sustainable, long-lasting, and recyclable.

How do these issues play into your own research projects on developing new battery technologies?

> "[Recycling batteries] won't be easy — just as it isn't for plastics. But we can't just live in the mess." — Shirley Meng

I try to keep the big picture in mind, even though I am only focused on a small part of the problem.

My personal passion is finding an alternative to lithium, which is used in all sorts of batteries that power everything from wireless headphones to electric vehicles. Most of Earth's lithium is concentrated in Chile and Australia and then gets shipped to China for refining and manufacturing. Using sodium instead of lithium could allow countries to source minerals locally, which would substantially reduce transportation energy costs. So that is a material we work with a lot in my lab.

We also study other battery-design changes, such as replacing the commonly used liquid electrolyte with a solid material. Solid-state batteries would potentially be denser, safer, and longer lasting than current batteries.

When do you think the world will see its first truly green battery?

Soon. There are still challenges to overcome, but I believe that all the promised scientific advances in batteries will be achieved in the near future. The bigger barrier is the trend of companies and countries to consider green batteries as a zero-sum game. Everyone needs to work together to create local ecosystems for generating and storing renewable energy. That is the only way we can transit to a new energy regime.

Katherine Wright is the Deputy Editor of Physics Magazine, *from which this article is reprinted.*

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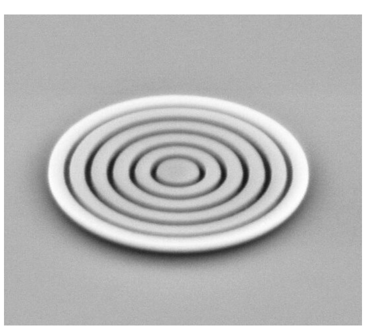

A scanning electron microscope image of the quantum torch. The dartboard-shaped device is roughly 4 μm across. Credit: L. Rickert/Technical University of Berlin

semiconductor material, and consists of concentric rings around the central dot. The rings enhance the rate at which single photons are produced, and they orient the emission of the photons in the direction perpendicular to the dartboard's plane.

Users can test the quantum nature of the torch by performing a so-called Hanbury-Brown-Twiss (HBT) experiment. In such a demonstration, the light from a device is sent into a beam splitter that has a detector at each of its two outputs. A time delay is introduced to one of the detectors, and the number of coincident photon detections are counted as the time delay is varied.

If the source of the light is classical (as is the case for a light bulb or a burning flame), then the measurements should show a large peak at zero-time delay. For a single quantum emitter, users should see a dip, as the single-photon source produces no coincident counts for zero-time delay. Scientists will perform this HBT experiment at each of the 12 labs and then present the data to the public.

The kickoff ceremony ended with a skit that featured a pair of guards wearing "Quantum Security" uniforms escorting in a suitcase carried by Technical University of Berlin graduate student Lucas Rickert. The suitcase was opened, and viewers were offered a peak at the quantum torch packed inside. The QuanTour organizers then closed the suitcase and slapped on to it travel "stickers" from the DPG and other supporting institutions. The quantum torch was ready for its first trip to Linz, Austria.

Michael Schirber is a Corresponding Editor for Physics Magazine, *from which this article is reprinted.*

Science Policy Highlights

The cost of open access, next-gen gravitational wave detectors, and more.

BY THE FYI TEAM

The LIGO detector in Livingston, Louisiana. A recent NSF report advises the U.S. to aggressively pursue the construction of a new gravitational wave observatory and then phase out existing LIGO facilities. Credit: Caltech/MIT/LIGO Lab

Congress orders cost estimate of open access publishing requirement from White House

Congress is pressing the White House to produce an in-depth cost estimate of its plans to remove paywalls from federally funded research. The White House issued a policy in 2022 mandating that research papers funded by federal agencies must be freely available upon publication — a major shift from the prior approach of allowing publishers to keep content behind paywalls for up to a year. With that requirement due to take effect in 2026, lawmakers concerned about the policy added a provision in recent legislation that directs the White House to provide the cost estimate by this June. If that deadline is not met, the provision directs the White House to put the policy on hold until the estimate is provided to Congress. The House Appropriations Committee had pushed to prohibit the White House from implementing the policy entirely, calling it an "unfunded mandate" without a "serious financial analysis." However, Congress removed that prohibition and replaced it with the cost-estimate requirement.

Aggressive timeline proposed for next-gen gravitational wave detectors

The U.S. should aggressively pursue the construction of a new gravitational wave observatory to remain competitive in the field, according to a March report commissioned by the National Science Foundation. NSF asked an advisory panel to chart a path to a ten-fold improvement in sensitivity over the Laser Interferometer Gravitational-Wave Observatory (LIGO), particularly given that Europe might build a much more sensitive detector called the Einstein Telescope. After soliciting detector concepts, the panel concluded that the ideal approach is the "Cosmic Explorer" plan, which involves constructing a 40-km-long, L-shaped detector and possibly a second 20-km long detector if the Einstein telescope is not built. The panel also concluded that maintaining current-generation LIGO facilities "does not significantly contribute" to the science goals of this future network, with the potential exception of a LIGO variant currently under construction in India. As a result, the panel recommends phasing out the U.S. LIGO facilities when the Cosmic Explorer observatory comes online between 2035 and 2040. The 40 km Cosmic Explorer observatory is estimated to cost around $1 billion and the 20 km observatory around $0.7 billion.

PCAST backs use of AI to accelerate scientific research

The President's Council of Advisors on Science and Technology published a report in April that emphasizes the potential for artificial intelligence to accelerate scientific research and help tackle major societal challenges. The report recommends that federal agencies should encourage grantees to integrate AI into their workflows and consider requiring them to detail how they will responsibly use AI tools, noting such a requirement could be aligned with the White House's Blueprint for an AI Bill of Rights and the AI Risk Management Framework developed by the National Institute of Standards and Technology. In light of the huge amount of computing power required to make the most of AI, the report also recommends fully funding the National Science Foundation's National AI Research Resource, which aims to democratize access to supercomputers needed for AI research.

NIH advocate becomes top House appropriator as FY25 cycle heats up

The U.S. budget cycle for fiscal year 2025 is ramping up with new leadership atop the House Appropriations Committee. Rep. Tom Cole (R-OK) became chair of the committee in April after Rep. Kay Granger (R-TX) stepped down from the role ahead of her planned retirement. Cole is a long-time advocate for biomedical research, having supported sustained budget increases for the National Institutes of Health during his time as the top Republican on the appropriations subcommittee for NIH. In the Senate, leadership of key science appropriations panels is unchanged. Notably, Sen. Patty Murray (D-WA) is remaining as chair of both the full Appropriations Committee and the subcommittee that oversees the Department of Energy, the latter of which she filled on an interim basis after the death of Sen. Dianne Feinstein (D-CA) last year. Murray's interest in the subcommittee stems in part from her state being home to the Hanford Site, which formerly produced plutonium and now receives billions of dollars from DOE each year for environmental remediation efforts.

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Dark Energy continued from page 1

The night sky above the McDonald Observatory's Hobby-Eberly Telescope in western Texas. Since 2021, citizen scientists have searched for galaxies in the telescope's images. *Credit: Ethan Tweedie Photography*

est," says House, who is in the fourth year of her program.

The volunteers contribute to the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX), a collaboration that researches the nature of dark energy, a hypothesized form of energy causing the universe's expansion to accelerate. To that end, they are using the eponymous telescope, located 450 miles west of Austin at the McDonald Observatory, to create a 3D map of a projected 1.2 million galaxies, ranging from 9 to 11 billion years old. "We're mapping the large-scale structure of the universe," says House. By analyzing the spatial distribution of the galaxies, they can determine the universe's expansion rate at different points in time. Many competing hypotheses about dark energy imply certain expansion rates, so these measurements will help them rule out incorrect theories.

The citizen scientists contribute to the research by sorting through telescope images paired with spectral data. After reading a brief tutorial, they classify which sets of images contain a galaxy and which do not. Images containing galaxies resemble black dots in a sea of gray noise and come with a telltale spike in their spectra at the right wavelength.

On a smartphone, Dark Energy Explorers' design appears to borrow from online dating apps like Tinder: Swipe right if you think the given images contain a galaxy; swipe left if the images just look like noise. Unlike a dating app, the interface reminds you to take it easy. "Do not stress yourself on thinking you have misidentified the images," the instructions read. "Each classification is distributed to ~10 users and averaged by HETDEX astronomers before analyzing their data."

The HETDEX team then uses the classifications to aid their analysis. "It's really helpful," says House. "They are classifying these galaxies and artifacts so well that we can use it in our science."

In particular, the researchers pair the human classifications with machine learning to remove false detections that arise from instrument or calibration issues. According to a study published in *The Astrophysical Journal* in 2023, House and her collaborators found that the citizen scientists helped them remove 7,781 false detections. As astronomy collaborations rely on ever larger data sets, citizen science projects like House's have made data processing much more efficient, she says.

To find volunteers, House's team wrote press releases, which led to some podcast appearances and some coverage in local news. They also relied on the publicity engine of Zooniverse, the citizen science platform that hosts Dark Energy Explorers, which has an existing online presence and which enables volunteers to communicate with each other on message boards. The team has also partnered with public libraries and museums to reach wider audiences.

To stay connected with this far-flung community, House herself has played an active role in organizing events. She has put on a live meet-and-greet on YouTube, where HETDEX scientists chat with volunteers about the research, as well as a virtual tour of the telescope facility they use. She has presented her work through the APS Joint Network for Informal Physics Education and Research (JNIPER), and participated in school visits over Zoom to teach about the project.

Because of overwhelming interest from schools, House's team has put together a suite of materials, including videos and worksheets, for teachers to use in their classrooms. Her team also organized a logo design competition among their citizen scientists, and eventually printed the winning design on stickers.

However, sustained publicity and engagement over multiple years has been a challenge because the team is so small, says House. She manages Dark Energy Explorers largely by herself, with support from team members. For researchers interested in starting their own citizen science projects, "some sort of longevity plan for driving traffic to the project would be really valuable," she says. Many citizen scientists in her project are enthusiastic, which is "cool and exciting," she says, but it can be hard to keep up with the demand.

With the volunteers' help, HETDEX has identified 200,000 galaxies, about a sixth of what they expect to find by the project's end. HETDEX will stop taking data this summer, but it will still take a while to sort through all of it. "We'll still have plenty of data for Dark Energy Explorers," says House.

House feels motivated to do this work because she believes everyone should have a personal relationship with the cosmos. She grew up in the mountains near Asheville, North Carolina, and remembers having access to dark night skies and watching the moon with her family. "It should be an educational right for people to actually reflect and understand their own place in the universe," she says.

Sophia Chen is a writer based in Columbus, Ohio.

Ionized Gases continued from page 3

electrons move in different environments — proved foundational for industrial applications of plasma, Graves says.

But Graves also notes the impact of another American physicist: Irving Langmuir, whose work predates Allis'. After contributing to the development of atomic structure theory, Langmuir discovered atomic hydrogen and applied it in a new welding process, and invented the gas-filled incandescent lamp. Langmuir was the first to call the state of matter "plasma," which reminded him of blood plasma. His contributions are recognized today, in part, by physicists' reliance on the Langmuir probe for characterizing electrons in plasma, says Graves.

"This gives all sorts of special properties in low temperature plasmas," he says, "and these can be leveraged in multiple applications" — even cancer therapies and the treatment of wounds.

This potential has inspired far-reaching collaborations. Beyond his basic research, Graves works with private sector companies, like Lam, to better understand the utility of plasmas in their industrial processes, including the development of electronic materials.

Collaboration like this is also what led to the creation of the Allis Prize in 1989. Gottscho played a key role in establishing the prize while he was still at Bell Labs. Another founding supporter of the prize was General Electric, the company where Langmuir first enclosed a light-emitting resistive filament in a glass tube filled with gas, to prolong the filament's lifetime. Langmuir's invention was the precursor to the modern incandescent light bulb.

> "As chip technology becomes even smaller and more precise, the challenges we face become greater and more complex," says Gottscho.

Although Langmuir studied plasma through the 1920s, it took decades for widespread interest in its industrial applications to emerge. "The biggest single change in the 20th century was the growth of the semiconductor industry in the 1970s," Graves says.

Following the invention of the transistor and the integrated circuit, both in the 1950s, NASA's demands during the space race and the "calculator wars" of the 1960s and 1970s — fierce competition between companies like Texas Instruments and Hewlett-Packard — sparked rapid advances in semiconductor technology.

Today, semiconductors are ubiquitous components of modern electronics, forming the basis of modern computer chips. "As chip technology becomes even smaller and more precise, the challenges we face become greater and more complex," says Gottscho.

Ionized gases play a key role in many steps of semiconductor manufacturing, he says — from photon production for lithography to the etching of fine-scale circuit patterns on thin films, and even treatments for smoothing surfaces.

The plasma used in semiconductor manufacturing is not like the plasma in the sun. While the temperature of solar plasma can reach 15 million degrees Celsius, the plasmas used in semiconductor manufacturing can be much closer to room temperature. For this reason, they're known as cold or low-temperature plasmas.

This type of plasma "has different energies for the different components," says Graves. "Electrons especially are very hot, on the order of tens of thousands of degrees, whereas neutral species and ions are close to room temperature."

Recent gifts from Micron Technology, Intel Corporation, and Lam Research have helped APS expand the Allis Prize from a biannual award to an annual one, offering each recipient $10,000.

Graves says there's another good reason for these companies to support the prize: Many physics, chemistry, and engineering students ultimately pursue careers at them. Nineteen of Graves' own former grad students or postdocs have worked for Lam Research at one point or another in their careers.

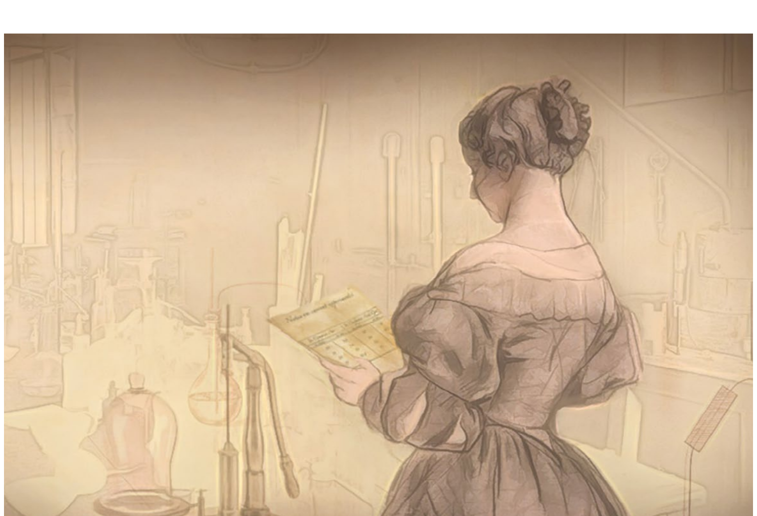
Graves says he sees a lot of opportunities for young physicists in industry, especially those who can stretch beyond their own disciplines. "Physics students need to realize that applications [of technologies] always involve many factors, not just physics," he says. "Although physics is the essential foundational field, people must be willing to dive deeply into a new field and learn things that are not necessarily in their formal educational field."

This can sometimes differ from a research career in a physics department, so students must set the right expectations for a job in industry.

Good things can come to those who do. "[It's an] extraordinarily rich field, both intellectually and practically," Graves says. "Plasma physicists can have an enormous impact on society."

Liz Boatman is a science writer based in Minnesota.

APS Fundraises For New Award in Climate Physics



Artist's depiction of Eunice Newton Foote, after whom the new award is named. *Credit: Carlyn Iverson / NOAA Climate.gov*

APS is pleased to announce the Eunice Newton Foote Award, which will recognize impactful research by a female scientist in climate physics. When fully funded, the prize will be the first APS-level prize honoring research in climate physics, and the second recognizing women, discounting early-career awards.

The award is named after Eunice Newton Foote, an American woman whose experiments in August 1856 led her to conclude that carbon dioxide could warm the atmosphere, a discovery that presaged what we now call the greenhouse effect.

APS is seeking donations to fund the award. To learn how you can help, visit go.aps.org/Foote.

Physicists Have Long Written Op-Eds. You Can Too.

Scientists have used their expertise and unique perspectives to shape public opinion and policy for decades. The tradition must go on.

BY AARA'L YARBER

We live in an era defined by a strange paradox. On one hand, information has never been more abundant, available instantly from all corners of the internet. On the other hand, truth, drowned out by misinformation, appears more elusive to a greater number of people than ever before.

The timing probably seems grim. Trust in public institutions is waning. The free press is shrinking. Crises like climate change loom.

But the timing is also right for us scientists to speak up. As both a scientist and a journalist, I believe scientists can and should seek out opportunities to share their views and their research, and writing op-eds and serving as sources for journalists is one place to start.

The decline of traditional newsrooms has been playing out for decades, but the rise of the internet and social media have accelerated this decline in recent years. *The Washington Post*, *The Los Angeles Times*, *The Atlantic*, *The Wall Street Journal*, *ABC News*, *NPR*, and countless more outlets have all cleaved journalists from their ranks in the last few years.

Science news sources have been hit, too. Last year alone, *National Geographic* laid off all its staff reporters, and *Popular Science* ended its 151-year-old magazine. As an atmospheric scientist who interned at *The Washington Post*, I've seen many science stories fall by the wayside because a small handful of staff writers were overloaded with assignments.

Or consider more recent examples, like nuclear physicist Frank von Hippel's *New York Times* op-ed highlighting the need for improved nuclear power safety and U.S. regulatory reform. You could read, too, the op-eds by geophysicist and climatologist Michael E. Mann, who has written in national outlets, like *The Washington Post* and *The Los Angeles Times*, on the science and impact of climate change.

Scientists also have much to say on the broader science enterprise, including its people and communities. Astrophysicist Jedidah Isler argued in *The New York Times* in 2011 that Black students should not have to justify their presence in academic settings, including physics classrooms. Atmospheric scientist Gregory Jenkins argued in *Newsweek* in 2023 that tackling climate change requires a deep commitment to understanding and prioritizing global climate injustice. Last year, physicist Jacinta Conrad, with the help of APS staff, argued in the *Houston Chronicle* for the importance of legislation supporting international students and scientists.

Physicists have long been keen observers of and advocates for science funding, too. In the last few months, for example, APS members — with the Society's support — have published at least seven op-eds in local newspapers across the country, from Maine to Montana, arguing for robust funding for federal science agencies.

In the same way that none of these individuals were born scientists, none were born writers. They merely worked hard to excel at this kind of storytelling, and I think more scientists can and should do the same. By writing op-eds for national and local news outlets, scientists can help bridge the gap between the scientific community and the public by demystifying scientific topics, shaping public opinion, and informing policy decisions.

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Cuts to science journalism are felt especially deeply at local newspapers. One study projected that, by the end of this year, the U.S. will have lost a third of the newspapers it had in 2005. This will leave more than half of American counties with only one or no local news sources at all, dramatically diminishing local science reporting.

This is bad news for everyone because independent journalism is a salve against misinformation about science. And on the issue of climate change, this is especially bad news for communities of color, which suffer disproportionately from its impacts.

While they cannot replace independent journalists, scientists do have a unique ability to provide accurate, timely, and relevant perspectives that can fill in the gaps.

One way is by contributing opinion pieces, which scientists have been doing for decades. Consider the 1955 Russell-Einstein manifesto, a public plea about the dangers of nuclear bombs, which was written and signed by leading scientists amid the Cold War. "Many warnings [about hydrogen bomb warfare] have been uttered by eminent men of science and by authorities in military strategy," it read. "We have found that the men who know most are the most gloomy."

For many scientists, writing op-eds seems daunting, but there are plenty of resources to help get started. The first and most important task of this work is identifying and honing your story. You can start by asking yourself a few questions: What do you know, why does it matter, and why are you the right person to talk about it? Think carefully about how your scientific background can add insight or a unique perspective to a timely (and timely is key!) societal issue. Focus on developing a story that will resonate with a wide audience, not just those in the scientific community.

In drafting an op-ed, understanding the basics of "pitching" — that is, suggesting your article idea to a news outlet — is also crucial. Media outlets, like newspapers, usually get many pitches, so sticking with best practices will help you get noticed.

This requires shifting some of the communication standards we're trained with in science. Every field has its jargon, and it takes practice to recognize and strip out jargon while retaining precision and accuracy. It also takes practice to find examples and analogies that translate complex facts into digestible takeaways.

At the same time, facts alone will rarely persuade a skeptical audience, a common shortcoming of traditional scientific communication. Instead, personal storytelling is essential in making scientific issues tangible to the public. This is often a challenge for scientists, who are frequently taught to stay impersonal and objective — to take the "I" out of it. But in writing op-eds, who you are informs the reader why your opinion counts, so talking about yourself, as a scientist *and* human being, is vital.

Op-eds, which have inherent bias, cannot replace excellent independent journalism. But op-eds aside, scientists play another indispensable role by serving as sources for science journalists. If you're not ready to dive into writing op-eds, you can still be a resource for a journalist.

Of course, journalists will not always tell a story the way we want it told. Their job is to get all the facts, and our job is to share the facts we have. But it is both a responsibility and a privilege to contribute in this way to such a vital institution, and in such precarious times.

So, whether you're summarizing research to a seasoned journalist or penning your own op-ed, just start the process! Read the resources available to you (starting with the sources below), and reach out for advice. Then pick up your pencil and get writing.

Scientists can speak directly to the public by penning op-eds, and by acting as sources for journalists. Credit: Lawrey - stock.adobe.com

Aara'L Yarber received her doctorate in meteorology and atmospheric science in 2024 from Pennsylvania State University and is starting her postdoc at Howard University. She was a 2023 AAAS Mass Media Fellow for The Washington Post*; her fellowship was sponsored by APS.*

If you're looking for tips and tricks to work with journalists and you work at a research institution — whether a university, national laboratory, or company — your institution's media relations or press office is the best place to start.

To share and get feedback on an op-ed idea you have that might be suited for the APS News *opinion column or another venue, contact the* APS News *Editor at letters@aps.org.*

Additional resources:

The OpEd Project: theopedproject.org

The SciCommers Network: sites.bu.edu/scicommers

SciLine for Scientists: sciline.org/scientists

Friedmann continued from page 2

Friedmann, undaunted, responded to Einstein with his precise calculations. And, Friedmann asked, if the esteemed physicist verified independently that they were indeed correct, could he please inform the editors of *Zeitschrift für Physik* and amend his earlier criticisms?

Einstein did eventually retract his statement after meeting with a colleague of Friedmann's in May 1923. "My criticism … was based on an error in my calculations. I consider that Mr. Friedmann's results are correct and shed new light," he wrote in a letter to *Zeitschrift für Physik*. (Einstein would later call the cosmological constant his "greatest blunder.")

New light was an understatement. In 1923, Friedman published a book, *The World as Space and Time*, elaborating on his findings and considering how his equations might actually map to the physical world. He published a second paper in 1924, outlining more possibilities for an infinite static or non-static universe.

He was aware that no observational evidence existed. "All these scenarios must be considered as curiosities which cannot be presently supported by solid astronomical experimental data," he wrote.

Early data arrived that very same decade. In 1929, Edwin Hubble observed that the redshift of a galaxy was directly proportional to the galaxy's distance from Earth. This implied that the further the galaxy, the faster it was moving away — proof of Friedmann's theoretical work on a changing universe. In the 1960s, the discovery of the cosmic microwave background provided yet more evidence of the universe's expansion, and by the 1970s, the term "Big Bang" had caught on to describe what was by then the reigning cosmological theory.

Tragically, Friedmann did not live to see any of this evidence. He contracted typhoid and died in August 1925, four years before Hubble's observational evidence of the universe's expansion. He was just 37 years old. For many years, both during his life and after his death, his contributions were largely overlooked.

Nevertheless, his work represents an important piece of physics history. A 1993 biography of Friedmann describes his contributions succinctly: "As Copernicus made the Earth go round the Sun, so Friedmann made the Universe expand."

Tess Joosse is a science writer based in the Midwest.