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# APS NEWS

APS physics

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HONORS

## 2022 APS Medal for Exceptional Achievement in Research Awarded to Elliott Lieb

BY DAVID BARNSTONE

Mathematical physicist Elliott H. Lieb has been selected to receive the 2022 APS Medal for Exceptional Achievement in Research for "major contributions to theoretical physics through obtaining exact solutions to important physical problems, which have impacted condensed matter physics, quantum information, statistical mechanics, and atomic physics."

Awarded annually, the Medal is the highest honor the Society bestows upon researchers across all of physics, recognizing contributions of the highest level that advance our knowledge and understanding of the physical universe in all its facets. The recipient will be recognized for seminal contributions to several fields of physics at a ceremony during the APS Annual Leadership Meeting on January 27.

Lieb is lauded by colleagues and peers for his rigorous mathematical approach to solving fundamental problems in physics. Among his hundreds of scientific publications is one of the most-cited papers in condensed matter physics on the one-dimensional Hubbard model, published in *Physical Review Letters* in 1968.

Lieb is also known for his solution to the "square ice problem," or the number of possible configurations of hydrogen atoms in a lattice of water molecules. This solution started a significant subfield in statistical mechanics. Some other major contributions include the strong subadditivity of quantum entropy, the Thomas-Fermi theory of atoms, the Lieb-Robinson velocity, the AKLT Spin Model, and the Lieb lattice for ferrimagnetism.

"With this prize we recognize Elliott's lifetime of accomplishments that have transformed physics," said APS President Frances Hellman, who chaired the 2022 Selection Committee. "It is a celebration of his dedication to scientific inquiry and pursuit of knowledge."

Elliott H. Lieb

Lieb obtained his bachelor's degree in physics from the Massachusetts Institute of Technology in 1953 and his PhD in mathematical physics from The University of Birmingham

MEDAL CONTINUED ON PAGE 3

LEADERSHIP

## 2022 APS President Frances Hellman

BY DAVID BARNSTONE

Frances Hellman is a condensed matter experimental scientist, a professor in the departments of Physics and Materials Science and Engineering at the University of California, Berkeley, a member of the American Academy of Arts and Sciences, an APS Fellow, and a member of Lawrence Berkeley National Lab and of the LIGO gravitational wave collaboration. She was elected to the APS Presidential Line in 2019 and this year serves as the Society's President. *APS News* spoke with Hellman about her perspectives on the challenges and opportunities facing the physics community in the year ahead. The interview has been edited for length and clarity.

**What are your priorities for your presidential year at APS?**

My role as president is to support and help develop the priorities of the organization. A primary focus of this year is working towards making APS an inclusive home for everybody who thinks of themselves as a physicist. That could mean someone working on foundational, fundamental physics—for which APS is well known—but also those working on applied, use-inspired research, like the half of undergraduate physics majors that go into industry. We

Frances Hellman

HELLMAN CONTINUED ON PAGE 7

LEADERSHIP

## APS Council Approves Revised Statement on Earth's Changing Climate

BY DAVID BARNSTONE

Scientists' understanding of the physical basis of climate change has improved immensely since APS issued its first Statement on Earth's Changing Climate in 2007. While critical gaps in this knowledge remain, one thing is clear: Human activities are the "dominant driver" of global warming.

That is the core message of the Society's 2021 climate statement, which was unanimously approved by the APS Council on November 10. Citing new evidence from recent Intergovernmental Panel on Climate Change reports, the APS statement calls on the physics community to tackle the climate crisis with a renewed sense of urgency.

"This is a wakeup call for the scientific community and society at large," says APS Chief External Affairs Officer Francis Slakey.

"Physicists have been essential to advancing our understanding of the climate system and humanity's impact on it," says APS Past President S. James Gates, Jr. "With this new statement, APS renews its call for sustained research in climate science and actions to reduce greenhouse gas emissions."

APS public policy statements undergo a meticulous process of draft and review, including receiving comments from APS members, before being voted on by the Council. APS Statements are formally revisited by the APS Panel on Public Affairs every five years to determine whether renewal, revision, or retirement is appropriate.

APS has been taking concrete steps to quantify and mitigate the environmental impact of its activities. In 2017, APS became the first US scientific society to

broadly assess and then publish an inventory of its greenhouse gas emissions. APS also considers the carbon footprint in the choice of locations for its scientific meetings. Following the natural experiment of remote work during the pandemic, most APS staff continue to work from their homes and nearby locations, which is expected to reduce emissions from commuting.

APS Government Affairs recently ran a grassroots campaign that helped overturn the Trump Administration's rollback of regulations on emissions of methane—the primary component of natural gas with more than 25 times the heat-trapping potential of carbon dioxide. APS members are also collaborating on a campaign to counter misin-

CLIMATE CONTINUED ON PAGE 5

OBITUARY

## Myriam Sarachik 1933-2021

BY DANIEL GARISTO

Myriam Sarachik, a pioneering low-temperature experimentalist who overcame great personal and professional difficulties to pursue a distinguished physics career, died October 7 in Manhattan at the age of 88.

As one of few women when she entered physics, Sarachik's work was largely overlooked until later in her life, when she was elected to the National Academy of Sciences, shared the 2005 Oliver E. Buckley Prize, and was awarded the 2020 APS Medal for Exceptional Achievement in Research. She was a fellow of APS and, in 2003, served as its president.

"She knew how she wanted to live her life and she followed that passion. That's inspiring—not just to me—but to so many of the other people who were in her orbit," said Jonathan Friedman, a condensed matter physicist at Amherst College and one of Sarachik's graduate students. "She was such a mensch."

Myriam Paula Morgenstein was born in Antwerp, Belgium, to Sarah and Schloimo Morgenstein, in 1933. When the Nazis invaded in 1940, the Jewish family fled to Calais. The family was smuggled across the border to Spain, captured by Nazis, escaped to Vichy, France, sailed to Cuba (where they stayed for five years), and eventually ended up in Brooklyn.

"Wherever we were, Belgium, France, Spain, Cuba, all throughout our travels, Yiddish was the tongue that really bound us together," Sarachik recalled in an oral history.

Myriam Sarachik

She attended the Bronx High School of Science ("full of misfits like me") and went on to Barnard College, where she met her husband Philip Sarachik—later a professor of engineering at New York University. During her PhD at Columbia University, under a mostly-absent Richard Garwin, she found some of the first experimental evidence for the BCS theory of superconductivity.

Finding a job was "real hell," but Sarachik managed to land at Bell Labs, where she was free to pursue her research interests. In particular, she was intrigued by a simple question: how did electrical resistance change as a function of temperature? Measuring iron

SARACHIK CONTINUED ON PAGE 3

MEETINGS

## A Safe and Inclusive Return to In-Person Meetings

BY DAVID BARNSTONE

This fall the APS Divisions of Plasma Physics (DPP) and Fluid Dynamics (DFD) welcomed thousands of attendees to the Society's first in-person meetings in more than two years. The meetings were a success on many fronts: record attendance, stimulating scientific exchange, and ample opportunities to connect with colleagues and friends in real life. Perhaps most importantly, the health and safety measures put in place to mitigate the spread of COVID-19 meant the events were held without incident.

"It was a pleasure to see so many of our members in Pittsburgh and Phoenix," says APS Director of Meetings Hunter Clemens. "The success of the DPP and DFD meetings show that we can safely return to in-person events by following evidence-based, public health guidance."

All attendees were required to be fully vaccinated against COVID-19, obtain a negative test result prior to participating in the meetings, and complete a daily attestation stating that they were not experiencing symptoms. These requirements, as well as the decisions to hold in-person events, were made in consultation with epidemiologists, explains APS Chief Financial Officer Jane Hopkins Gould.

"APS has been working closely with the scientific consulting firm Cardno ChemRisk, carefully planning for these meetings since the summer," says Gould. "Together we have been monitoring federal, state and local guidance and key metrics—case counts, of course, but also the positivity rate and the availability of hospital beds in the local community—and use that information to inform a calculated approach to risk assessment."

The organizers of the Society's most anticipated events of the new year—the Annual Leadership, March, and April Meetings—are now

Attendees at the 74th Annual Meeting of the APS Division of Fluid Dynamics in Pittsburgh, Pennsylvania.

keeping a close eye on the Omicron variant and continuing to collaborate with Cardno ChemRisk. Even as APS returns to in-person meetings, Clemens says he and his team are making sure the many benefits of virtual gatherings aren't lost.

"The APS Council recently approved a recommendation by the Committee on Scientific Meetings that all APS scientific meetings include a virtual component," says Clemens. "This recommendation is consistent with APS's core values of diversity, equity, and inclusion. Hybrid meetings are more accessible to APS members all over the world in varying personal situations, from parents of small children to people with disabilities. All are welcome."

The online component also allows attendees to reduce their personal carbon footprint by foregoing travel without sacrificing their participation in the meeting.

"By easing the pressure to attend meetings in-person and taking other measures to improve the sustainability of our meetings, like reducing printed materials and using energy efficient buildings, we can all do our part to minimize the environmental impact of APS meetings and make it easier for more people to participate, even those who cannot travel," says Clemens.

*The author is APS Head of Public Relations.*



THIS MONTH IN

# Physics History

## January 7, 1939: Marguerite Perey and the Ten Tons of Uranium Ore

BY SOPHIA CHEN

Francium barely exists. Only 30 grams of the element, atomic number 87, reside in the entirety of Earth's crust, as estimates suggest.

It also ranks as perhaps the most deadbeat member of the first column of the periodic table, known as the alkali metals. Aside from francium, the alkali metals are among the most energetic workhorses of applied science. Lithium runs our batteries. Sodium tastes delicious. Potassium ions regulate our bodily functions. Rubidium atoms comprised the first Bose-Einstein condensate ever made. Cesium forms the heart of the atomic clock that standardizes the nation's time.

But francium? It's the indolent sibling that rarely shows up. The Royal Society of Chemistry puts it plainly: "Francium has no uses, having a half-life of only 22 minutes."

Still, the backstory behind the element's short résumé tells an intriguing story of the scientific process. Full of egos, red herrings, and even betrayal, the tale of its discovery also describes the triumph of a female scientist at a time when few women were allowed to enter the fray.

In the early twentieth century, scientists were in hot pursuit of a hypothetical element 87, then known as eka-cesium. The name came from the creator of the periodic table himself, Dmitri Mendeleev, who believed it should exist because of known heavier elements, such as uranium, at atomic number 92. "Eka-cesium", where "eka" was a prefix for "one" derived from Sanskrit, was Mendeleev's way of saying that the element should chemically resemble cesium, right above it in the periodic table.

Following Mendeleev's prediction, a string of scientists began laying claim to the element. In 1925, Soviet chemist Dmitry Dobroserdov said he'd found element 87 in a sample of radioactive potassium. Naming it after his homeland of Russia, he called the substance russium, later found to be potassium-40. In 1932, US physicist Fred Allison claimed to discover six different isotopes of element 87, which he dubbed "virginium" after his home state of Virginia. Researchers later debunked Allison's entire technique, with Nobel laureate Irving Langmuir famously condemning Allison's work as an example of "pathological science." In 1936, the physicist Horia Hulubei found a stable isotope he believed to be element 87. Hulubei named his discovery moldavium after the province of Moldavia in his native Romania. Moldavium would become a point of contention.

Ultimately, a Frenchwoman named Marguerite Perey would be the one to christen the element after her motherland.

Marguerite Perey in 1938 CREDIT: MUSÉE CURIE

In 1938, at 29 years old, Perey had worked at the Institut du Radium in Paris for ten years. She began her career there as Marie Curie's personal assistant, having landed the job because of her standing as the top student at a women's vocational school for chemistry technicians. The youngest of five children, Perey gave up her dreams of attending medical school for this path in response to her father's death, which left her family in financial hardship when she was a child.

Researchers at the institute were studying actinium, a rare earth element discovered nearly four decades before. Scientists still knew little about it. The element presented experimental challenges because of its rarity: technicians at the institute recovered just one or two milligrams of actinium from ten tons of uranium ore. In addition, they had difficulty separating actinium from its chemically similar cousin, lanthanum. One of Perey's routine tasks at the institute was to isolate actinium from ore. She mixed the ore with chemicals to form unwanted compounds, which she would then remove.

Shortly after Christmas in 1938, Perey discovered a curious signal when measuring beta

HISTORY CONTINUED ON PAGE 5

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MEETING

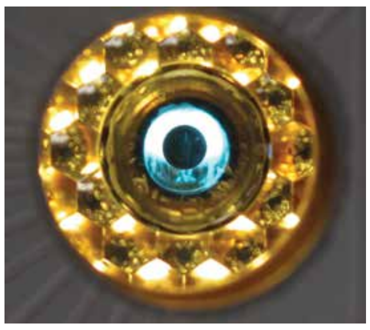
# Ignition First in a Fusion Reaction

BY KATHERINE WRIGHT

*Note: This article is reprinted from Physics Magazine (physics.aps.org).*

If they realize their full potential, nuclear fusion reactors could provide the world with a near limitless amount of clean electricity. That potential is still far from being achieved. But speaking at the recent Annual Meeting of the APS Division of Plasma Physics, Debbie Callahan of Lawrence Livermore National Laboratory (LLNL), California, announced that researchers have, for the first time, triggered "ignition"—a fusion reaction that produces more energy than it receives and can thus burn on its own. The demonstration, which was performed at LLNL's National Ignition Facility (NIF), takes commercial fusion-energy reactors a step closer to reality. It also provides a platform for understanding materials under extreme conditions.

So-called inertial confinement fusion, the type of fusion approach being studied at NIF, involves rapidly imploding a millimeter-sized capsule filled with a thermonuclear fuel mixture of deuterium and tritium (two forms of hydrogen). The capsule is heated with x rays generated by high-power lasers, turning the capsule into a plasma. This plasma accelerates inward, like a collapsing star, compressing the capsule's deuterium-tritium fuel into a tiny sphere with a temperature exceeding 100 million degrees Celsius and a pressure more than 100 billion times greater than that of Earth's atmosphere. Under such conditions, hydrogen atoms in the fuel fuse, releasing energy.



A photo of one of the targets used at the National Ignition Facility. The spherical capsule where thermonuclear fuel is loaded can be seen in the middle. The outer cylinder is the hohlraum, which converts incoming laser light into x rays that bombard the capsule with heat. CREDIT: LAWRENCE LIVERMORE NATIONAL LABORATORY

For a commercial fusion reactor, these fusion reactions need to be self-sustaining, meaning that they need to heat the plasma enough to induce additional fusion reactions. This self-sustaining condition is fundamentally what is meant by ignition, says plasma physicist Jeremy Chittenden from Imperial College London. But "it's really difficult to diagnose directly what's happening inside the fuel," he says. So scientists have adopted more practical definitions of ignition based on the outgoing energy from fusion being greater than the incoming energy from external heating sources.

Until August of this year, no facility had achieved this ignition threshold. That changed on August 8th, with an upgraded experiment

IGNITION CONTINUED ON PAGE 4

MEMBERSHIP UNITS

# APS Membership Unit Profile: The Forum on the History and Philosophy of Physics

BY ABIGAIL DOVE

History and Philosophy of Physics

Physics has a rich, centuries-long history, from Johannes Kepler's description of the laws of planetary motion at the dawn of the Scientific Revolution to contemporary research on quantum computing, sustainable energy development, and physics beyond the standard model. The Forum on the History and Philosophy of Physics (FHPP) provides a home for philosophers and historians of physics, as well as anyone interested in the ways in which physics has shaped technology, education, and culture over time. Established in 1980, the unit includes nearly 3,500 members.

History and philosophy go hand in hand. As FHPP chair-elect Paul Halpern (University of the Sciences) explained, historians trace the development in fundamental physics research over the centuries, while philosophers seek to understand the nuances in interpreting the assumptions set forth in physical theory.

According to Halpern, many FHPP members are particularly interested in the 19th and 20th centuries, which saw revolutions in the understanding of general relativity and quantum theory from giants like Einstein, Bohr, Schrödinger, and Heisenberg. "One of the most amazing advances in physics was Planck's derivation of the black body radiation law in 1900," noted Rudolf Tromp (IBM Watson Research Center), an FHPP member-at-large. "He did not realize exactly what he was doing or what it meant, but he rightly noticed that what he was doing worked. He certainly did not think 'quantum,' but nonetheless set the stage." Understanding the thought processes underlying certain scientific advances points to the importance of philosophy. "We all learn the standard trope that science advances by posing a hypothesis and testing that hypothesis against an experiment. But Planck didn't have a hypothesis. He was just mucking around and hit the jackpot. But mucking around is a good thing – that way we stumble into things that we didn't know about, as long as we are alert enough to see them," Tromp explained.

Teaching the history and philosophy of physics can help students appreciate the context in which science advances. "I find it necessary, in addition to convenient, to introduce a new topic by going over at least some of the history," FHPP secretary/treasurer Ed Neuenschwander (Southern Nazarene University) remarked. "For example, one could logically begin teaching quantum mechanics by starting with the Schrödinger equation, but to begin there would be bewildering – *where did this equation come from?* It has a backstory that brings it to life."

A deeper understanding of the history of physics may even help to counteract burnout and mental stress in academia. "Many students think that they must make a breakthrough discovery if they are to succeed in life, and the result is massive mental health problems in our student body," argued Tromp. "The truth is that breakthrough discoveries come only once or twice in a century, and by far the most progress in science is not made by breakthroughs, but by systematic advances, little by little, over long periods of time. If we can instill this way of understanding science in our professors and our students alike, the academic world will be a much happier place."

To bring greater awareness of physics' fascinating history to APS at large, FHPP sponsors several sessions each year at APS March and April Meetings. "By attending events on the history of physics, APS members can learn about the true processes of insights and innovations that led to famous physics discoveries," said FHPP vice chair Al Martinez (University of Texas at Austin). "They also learn about the fascinating lives and personalities of past physicists, both men and

FHPP CONTINUED ON PAGE 4

MEDAL CONTINUED FROM PAGE 1

in 1956. He has held research and faculty positions at the University of Illinois, Cornell University, IBM, Yeshiva University, and MIT. He has been a professor at Princeton University since 1975.

"I will be delighted to honor Elliott with the APS Medal at our Annual Leadership Meeting in Washington, DC in January," said APS CEO Jonathan Bagger. "His life and career have taken him across physics and around the world, yielding important discoveries at nearly every turn."

"Physics is a big enterprise with many people doing various things, being held together by a common interest in science," said Lieb. "It's important to have scientific institutes like the American Physical Society that bring all this together."

The Medal includes a $50,000 prize, a certificate citing the contribution made by the recipient, and an invited talk at an APS March or April Meeting. The prize is funded by a donation from entrepreneur Jay Jones.

*The author is APS Head of Public Relations.*



SARACHIK CONTINUED FROM PAGE 1

samples, she observed that resistance dipped to a minimum and then rose with temperature—data inconsistent with existing models. Tipped off to her research, Jun Kondo sent her a preprint of a theory he'd been working on, which explained the effect. As the sample temperature dropped, the spin of magnetic impurities would interact more with the spin of conduction electrons, leading to more scattering and thus higher resistivity.

Though the result could reasonably have been dubbed the Sarachik-Kondo effect, her critical paper languished, garnering few citations and no recognition until late in her life. Despite the lack of acknowledgement, Sarachik became a professor at the City College of New York (CCNY) in 1964, where she would remain for the rest of her career.

"She lived inside the physical systems she worked on," said Eugene Chudnovsky, a theoretical physicist at CCNY. "She was moving together with electrons, scattering with them; she was living in the atoms with spin precession. This was her way of thinking."

In 1970, Sarachik's five-year-old daughter Leah was kidnapped and killed by her housekeeper. To cope with the unimaginable tragedy, Sarachik stayed busy, mentoring PhD students and teaching. But, she later wrote, the "curiosity, energy, drive, and excitement that had driven my earlier research were missing."

With the ability to make precision measurements at the milliKelvin level, she began her research in earnest again. Sarachik focused on the metal-insulator transition in semiconductors, trying to figure out the mechanism behind the boundary. Working with Sergey Kravchenko in the 1990s, she also investigated the metal-insulator transition in two dimensions—then thought impossible because the random behavior of electrons would never allow for a metal phase.

"She was really an experimentalist, which means that she respected the data," said Shiqi Li, a professor at MiraCosta College and a former graduate student under Sarachik. When good data didn't fit the theory, Sarachik believed it was often the theory that had to go.

In the late 1990s, Sarachik and her collaborators turned their attention to the problem of macroscopic quantum tunneling of the magnetic moment. A molecule must surmount an energy barrier to flip its magnetic poles. Without that energy, at low temperatures, a molecule can only flip its poles by tunneling through the barrier. By definitively finding evidence for the phenomenon, Sarachik's group effectively began a new subfield of condensed matter, one deeply relevant to quantum technology today.

Sarachik continued research even after she formally retired in 2018.

Beyond her scientific work, Sarachik also served on the board of the Committee of Concerned Scientists, where she helped emigree physicists. She was deeply supportive of women in physics, and made a point of hiring and accommodating mothers in her lab, Li said.

Sarachik's kindness to others came from her own struggles—as a refugee, a mother who lost a daughter, and a woman in physics. In one memorable snub, the 2002 Europhysics Prize went just to Friedman. "I can't think of a case when somebody gets an award for a discovery they made as a graduate student and the advisor doesn't get anything," Friedman said.

"How the community treated her is not acceptable," said Yoko Suzuki, a former graduate student.

But eventually, belatedly, acknowledgements of her research began to pile up, culminating in the 2020 APS Medal. Asked about the honor, Sarachik quipped: "It's very gratifying. I don't want to be an ingrate, but doing it is so much more pleasurable than being lionized for it." And then she laughed.

*The author is a freelance writer based in Bellport, New York.*

FHPP CONTINUED FROM PAGE 3

women, from many countries." Previous topics have included 20th century physics in China, espionage in science, the women in the Manhattan Project, physics in India, philosophies of quantum mechanics, women pioneers in astronomy, the search for gravitational waves, computation in the history of physics, and more.

The forum additionally recognizes outstanding scholarship in the history of physics through the annual Abraham Pais Prize for the History of Physics. The 2022 honoree is distinguished science historian Patricia Fara (University of Cambridge), whose wide-ranging work has focused on under-recognized contributions of women to physical sciences in the 17th through 20th centuries. Previous awardees have included Hasok Chang (University of Cambridge), who focused on historical aspects of the interaction between physics and chemistry (2021), Dieter Hoffman (Max Planck Institute), a specialist in the history of scientific research under totalitarian regimes (2020), and Helge Kragh (University of Copenhagen), who cultivated the history of physical cosmology (2019).

For those not – or not yet – professionally engaged in the history of physics, FHPP sponsors a student essay contest. The winning essay (see Back Page) for the 2021 competition was written by Briley Lewis, a graduate student at UCLA, and details the life and work of Carolyn Shoemaker, pioneering astronomer who discovered a record-setting number of comets and asteroids despite a lack of formal academic training. Essays from past competitions have highlighted the under-recognized work of Lewis Latimer, Thomas Edison's African American collaborator who helped invent the incandescent light bulb (2020), the evolution of the concept of "macroscopic" and "microscopic" worlds over the history of physics (2019), historical misconceptions about Einstein and Bohm (2018), and pioneering figures in fusion research (2017).

Additionally, all APS members can access FHPP's biannual newsletter, *History of Physics*. In circulation since FHPP's founding 40 years ago, the newsletter reviews notable sessions from recent APS meetings, highlights recent publications on the history and philosophy of physics, and provides a platform for physicists who wish to share their perspectives on these topics.

Overall, FHPP stands out as a valuable channel for APS members to gain a wider perspective on physics in the context of its centuries-long history, reminding us that there is much we can learn from the past. More information can be found at the FHPP website.

*The author is a freelance writer in Stockholm, Sweden.*

IGNITION CONTINUED FROM PAGE 3

that yielded 1.3 MJ, which is about 8 times more energy than NIF's previous record. Early reports referred to this breakthrough as the "brink of ignition," because it yielded less than the 1.9 MJ supplied by the facility's 192 laser beams. But many fusion scientists think such a perspective is too conservative. "As far as most people working in the field are concerned, the scientific demonstration of the ignition process has indeed been achieved," Chittenden says.

The argument for ignition is based on an accounting of losses in the energy delivery: Calculations show that only about 230 kJ of the laser energy reaches the fuel capsule. For Callahan, this last energy is the relevant one to consider, as it describes the heat coming in from outside. "We got out almost 6 times as much energy as we put into the capsule," she says. "It's a big accomplishment." She adds that achieving ignition is "what I set out to do" in becoming a fusion scientist, "and we did it."

The question now is, what brought about this big boost in output? The latest experiment trialed several advances in the equipment, fuel, and methods. These advances included creating a fuel-capsule shell with fewer defects and using a significantly narrower tube to place the deuterium-tritium fuel inside the capsule. Callahan says that both changes likely reduced the size of the instabilities that formed within the shell as it turned into a plasma. If those instabilities are too large, they can lead to higher-atomic-number material being injected into the fuel, disrupting fusion.

The NIF scientists also made some other design tweaks that allowed them to increase the speed at which the capsule shell imploded. A faster accelerating shell transfers more energy to the fuel hotspot when the implosion is halted by the internal pressure, Callahan says. She compares it to stopping a car with brakes: The faster the car is moving, the hotter the brakes get. "We wanted to slam the brakes on as hard as possible to transfer as much energy as possible from the shell to the [fuel] hotspot," she says.

So are commercial fusion reactors now just around the corner? Not according to Callahan, who calls this advance a "key step down a long road." To make a viable commercial fusion reactor, the reaction needs to produce significantly more energy than the reactor requires to run. To create the 1.9-MJ-laser input at NIF requires around 400 MJ of electricity. And much of that laser energy is lost before it reaches the hydrogen fuel. One place for significant loss is in a metal cylinder, called a hohlraum, that surrounds the capsule. The hohlraum converts the laser light into x rays that transport the laser energy to the fuel. However, a large fraction of this input energy is lost to heating the hohlraum walls.

Reducing the fraction of energy lost in the hohlraum is on the near-term to-do list for NIF. Nuclear fusion scientists are also exploring new avenues for research opened up by the reaching of a new experimental regime. "It's an extremely exciting time to be working on this topic," Callahan says. "Our field is really in a place that we've never been before."

*The author is a Senior Editor for Physics Magazine.*

GOVERNMENT AFFAIRS

# APS Members Relish Key Legislative Victories in 2021

BY TAWANDA W. JOHNSON

The hard work of APS members and APS Government Affairs (APS GA) paid off handsomely last year after several of the Society's science priorities were included in legislation in both the House and Senate. And in some cases, those priorities were signed into law. APS GA enabled more than 8,200 contacts in 2021 from Society members to federal policymakers and their staff. Members helped advance the Society's science policy priorities through emails to Congress, social media posts, phone calls, an op-ed, and virtual visits to DC and local congressional offices.


Andrea Liu


Jay Mathews


Laura Rios

"As I think about the Society's accomplishments during the past year, I am extremely proud of how APS Government Affairs continued its long tradition of partnering with our members to advocate for policy priorities that are important to keeping our nation's scientific enterprise strong," said APS President Sylvester James Gates, Jr. "I'm eager to see that tradition continue into 2022 and beyond."

Mark Elsesser, Director of Government Affairs, added, "Our members remain dedicated to working with our staff to advocate for physics and amplify their voices for science, even when the pandemic has created additional responsibilities for many. Our combination of grassroots advocacy, meetings by APS leadership, and data-driven policy reports are helping us persuade Congress to take steps to address the physics community's policy priorities."

### APS Congressional Visits Days

The 2021 APS Congressional Visits Day (CVD) held during the APS Annual Leadership Meeting was one for the Society's history books. It was the Society's first virtual CVD, with more than 60 APS members from around the country participating—including some currently living abroad—in more than 80 congressional meetings. Based on members' accounts, their experiences were both positive and productive.

To prepare for the unique, all-virtual, two-day event, APS developed a new website hosting the one-page summaries of APS's science policy priorities, which was accessible by congressional staffers. They also set up a virtual lounge that allowed APS members to communicate with one another and provide feedback to APS GA staff. The APS GA team utilized these new tools again in June when they organized a CVD for about 40 physics department chairs during the APS-AAPT Department Chairs Conference.

During the CVDs, volunteers advocated for action on research funding, combating sexual harassment in STEM, declining international STEM enrollment, climate change, helium, and building research capacity at emerging research institutions to broaden STEM participation.

Callie Pruett, Senior Strategist for Grassroots Advocacy, remarked, "Last year, despite all the challenges presented by COVID-19, our advocates virtually raised their voices on behalf of APS and on behalf of the science community. Looking back, I admire each of them for their courage and commitment to making our world a better place even when the world was a very scary place. They didn't have to step up, but they did."

VICTORIES CONTINUED ON PAGE 6

SIGNAL BOOST

Signal Boost is a monthly email video newsletter alerting APS members to policy issues and identifying opportunities to get involved. Past issues are available at go.aps.org/2nr298D. **Join Our Mailing List: visit the sign-up page at go.aps.org/2nqGtJP.**

FYI: SCIENCE POLICY NEWS FROM AIP

# DOE Eyes Expansive Hunt for Neutrinoless Double Beta Decay

BY WILLIAM THOMAS

The Department of Energy's Nuclear Physics program recently began advocating for a multi-nation search for neutrinoless double beta decay, a theorized phenomenon that, if detected, would offer a long-sought opening into physics beyond the Standard Model.

At a November meeting, program head Tim Hallman asserted, "The potential discovery of a neutrinoless double beta decay would be every bit as much of a game-changer as the discovery of supersymmetry at CERN, and as compelling as any accelerator-based research currently underway."

The existence of the decay would indicate the neutrino is a Majorana fermion, meaning that it is its own antiparticle. That discovery could in turn offer clues about the origins of the neutrino's slight mass as well as the prevalence of matter over antimatter in the universe.

Because the decay would be a low-energy radioactive process, albeit an exceptionally rare one, the search for it would not require a particle accelerator, only a detector large and sensitive enough to find one. Currently, experimenters are focused on building a "ton-scale" experiment to press beyond the limits of prior efforts.

Initiating such a project is among the top priorities identified in a 2015 long-range plan for nuclear science. However, there is also a risk DOE might not be able to undertake the project as it pursues other high priorities such as the Electron-Ion Collider at Brookhaven National Lab. Hallman has previously suggested that finding the needed funding could prove "challenging."

Yet, at the November meeting he made the case that an international coalition could band together to fund up to three such experiments simultaneously.

Because even a ton-scale experiment could only be expected to count about one neutrinoless double beta decay per year, Hallman said it is desirable that any positive result be confirmed. He further noted that a contemporaneous confirmation would "greatly increase the chance of a Nobel Prize."

To scope out a multi-experiment effort, DOE conducted a program review last year of potential ton-scale experiments, focusing on three top contenders: CUPID, nEXO, and LEGEND-1000. Estimates for the overall costs of those experiments were $64 million, $406 million, and $442 million, with DOE covering, respectively, 55%, 85%, and 60% of the total.

Then, at the end of September, potential participants in an international effort convened near Italy's Gran Sasso National Laboratory. Hallman said that the attendees ultimately agreed a multi-experiment effort would provide the best chance of success and that a formalized collaboration should be explored.

Setting the prospective effort in perspective, Hallman said that building all three prioritized exper-

FYI CONTINUED ON PAGE 6

CLIMATE CONTINUED FROM PAGE 1

formation on scientific issues such as climate change.

"These are steps we are taking to address what is arguably the most complex, urgent, and consequential scientific and technological challenge of our time," says APS CEO Jonathan Bagger. "The impact of human activities on the climate system is continuing to grow, and the actions we take over the next few decades will reverberate for centuries."

APS is a signatory on a joint statement with other international physical societies, "*A call to action: the role of physics in delivering the global green economy.*"

*The author is APS Head of Public Relations.*

HISTORY CONTINUED FROM PAGE 2

emission from her samples. The radiation increased in the first 20 minutes or so, indicating that the actinium was decaying into a beta-emitting daughter. Perey suspected the emitter was element 87. She asked for a three-week leave to work on her ideas. Her supervisor, André Debierne—also the discoverer of actinium—initially refused her request. He eventually agreed, while expressing that he thought "the idea was stupid and would end in failure," Perey recalled later.

Perey acted quickly. On January 7, 1939, mixing various chemicals, she found that the substance precipitated with cesium perchlorate. This indicated that the substance was chemically similar to cesium, an alkali metal. Connecting the dots, she concluded that she had found element 87, and that it had a half-life of 21 minutes. Following a naming convention for the decay products of radioactive elements, Perey named it Actinium K.

But the scientific establishment did not embrace her conclusion. Nobel laureate and physicist Jean Perrin, who presented her discovery two days later to the Académie des Sciences, did not stand behind her work. After a journalist reported Perey's discovery, Perrin wrote to the newspaper that Hulubei, who worked in Perrin's laboratory, had discovered element 87, and Perey's Actinium K was merely an isotope of his stable moldavium.

The establishment did not recognize her discovery until 1946. (Researchers debunked moldavium after nuclear studies found that element 87 had no stable isotopes.) The International Committee for Nomenclature invited Perey to name the element. Her first suggestion was "catium," referencing the word "cation," but her superior, Irène Joliot-Curie, said it would evoke the word "cats" to English speakers. Perey chose "francium" instead, making it the second element after gallium to be named after France.

But Perrin's sabotage, which led to years of skepticism from her peers, sullied Perey's feelings of success. Recalling her discovery years later, she said, "Even if the period following my identification of francium brought certain honors, I also went through moments of tears and deceptions caused by vile traits of human character: manifestations of baseness and perfidy."

In 1939, Perey didn't even have the equivalent of a bachelor's degree. Pursuing formal education after her discovery, she received her PhD in 1946 from the University of Paris. She continued to study francium and later became the head of nuclear chemistry at the University of Strasbourg in 1949. In 1962, she became the first woman elected to the French Académie des Sciences.

But Perey's work took a toll: radiation exposure likely caused the bouts of illness she suffered throughout her life. It ultimately caused the bone cancer that took her life in 1975 at age 65.

It's hard to overemphasize Perey's meticulousness to successfully extract and characterize such tiny amounts of francium from ore. "She was brilliant," says Luis Orozco, a University of Maryland physicist who conducts experiments with francium. "But it was not glamorous. It was systematic, rigorous work."

Orozco creates francium synthetically in an accelerator. The isotope he currently works with has a half-life of about three minutes. Because of its ephemerality, his team rehearses their experiments with stabler rubidium atoms first. They work with one to ten million francium atoms at a time. More than that, and they run the risk of violating radiation safety requirements and have to evacuate the lab.

Researchers like Orozco study francium to probe fundamental science. Its heavy nucleus makes it a promising platform to study the weak nuclear force, says Orozco. In particular, he is working to measure electronic transitions in francium enabled by the electron's interaction with the nucleus via the weak force. These transitions are an example of parity non-conservation, where the laws of physics differ between a system and its mirror reflection. He's spent more than twenty years figuring out how to produce, trap, and manipulate the element. Other researchers have also proposed francium molecules as a candidate for studying time reversal symmetry, says Orozco.

After years of evolving monikers, francium may make a new name for itself.

*Sophia Chen is a freelance writer based in Columbus, Ohio.*

**Further reading:**

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J. P. Adloff and G. B. Kaufmann, "Francium (Atomic Number 87), the Last Discovered Natural Element," *The Chemical Educator* (October 1, 2005).

S. S. Preston, "Marguerite Perey (1909–1975): Discoverer of Francium," (ACS Symposium Series, December 14, 2018).

U. Dammalapati et al., "Francium: Tool for Fundamental Symmetry Investigations," (Proceedings of the 12th International Conference on Low Energy Antiproton Physics).

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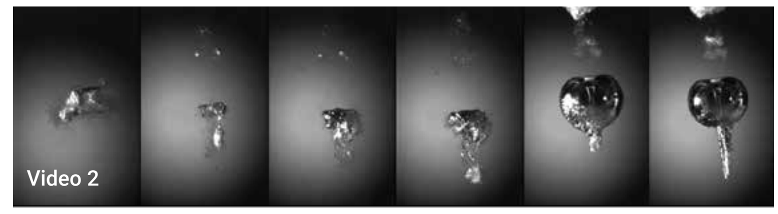
MEETING

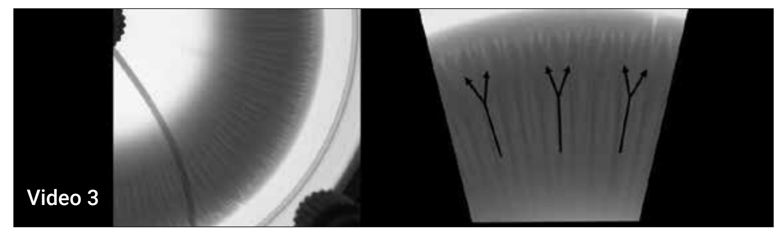
# Complex Droplets and Interacting Bubbles Receive Video Prize

BY DAVID EHRENSTEIN

*Note: This article is reprinted from Physics Magazine (physics.aps.org).*

The APS Division of Fluid Dynamics has announced the 2021 winners of its annual Gallery of Fluid Motion video and poster contest. Below are the video winners of the Milton van Dyke Award, which recognizes the three top videos and the three top posters.


All videos can be viewed at gfm.aps.org

Video 1: A liquid filament containing two different liquids breaks up into droplets in a way that is affected by both components. The video of these breakups is slowed by about 100 times. CREDIT: V. THIEVENAZ/UCSB

Video 2: Researchers produced two bubbles near each other at slightly different times and showed that the interaction between the two produces a jet of vapor when the second bubble collapses. The videos are shown at 15 frames per second (fps), so as indicated by the recording rates given in fps, they are slowed down by about 7000 to 700,000 times. CREDIT: A. MISHRA/INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Video 3: A seemingly 2D flow exhibits complex patterns that imply 3D convective flows. Microgravity experiments confirm that convection is at work, as the patterns disappear without gravity to drive convection. Some of these videos are sped up by as much as 4 times. CREDIT:Y. STERGIOU/HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF

## Oil and Water Team Up (Video 1)

"Droplets are everywhere," says Alban Sauret of the University of California, Santa Barbara (UCSB), from rain to spray paint, to sneezes. Often these droplets emerge from the breakup—or "atomization"—of a large volume of fluid. Understanding this behavior could, for example, help researchers generate the number and size of droplets to efficiently coat a surface with paint or a field with fertilizer. To observe atomization up close, Sauret and UCSB colleague Virgile Thievenaz have developed a technique in which they place a small amount of fluid in the gap between two rods and then rapidly pull the rods apart. A filament of fluid appears and then breaks up into droplets.

Their latest twist on this experiment is to include two different fluids—a small droplet of water inside a larger drop of viscous oil. To the duo's surprise, the water accelerated the breakup of the oily filament and affected the sizes of the final droplets, even with only 1% water in the fluid. Meanwhile, the oil influenced the water by causing it to stretch out much longer than usual before breaking into droplets. "We weren't expecting that there would be such a drastic change with just a very small amount [of water]," Sauret says. He says that pesticide companies, for example, might be able to reduce unwanted drift of their product by embedding a small amount of another fluid that reduces the number droplets with the smallest diameters, the ones most likely to be picked up by wind.

## Interacting Bubbles Create a Jet (Video 2)

Cavitation bubbles often form when a solid object moves rapidly through fluid, as in a rotating ship propeller. Researchers have often studied these clouds of bubbles or looked at individual bubbles, but much less research has focused on the interactions between bubbles, says graduate student Arpit Mishra of the Indian Institute of Technology Kharagpur, India. He worked with Claire Bourquard of the Swiss Federal Institute of Technology (ETH Zurich) to develop a laser-based system for creating two millimeter-sized bubbles in water. The researchers wanted to produce the bubbles at two specific times and positions in order to control their interactions. "The timing was very challenging," says Bourquard, and "we didn't know if it was going to work."

But it did work, and Mishra, Bourquard, and their colleagues observed something unexpected: With the right time and distance between the bubbles, a powerful jet of water vapor shot out of the second bubble as it collapsed. Based on experiments and simulations, the team learned that the jet is produced by a "slingshot" effect. The first bubble collapses and draws part of the second bubble toward it, like an elastic band being stretched. When the second bubble collapses, the outstretched portion comes rebounding back with enough energy to push vapor out the other side of the bubble in a jet.

These bubble-generated microjets could have potential medical applications. Indeed, cavitation bubbles are currently used for dental cleaning and surgical cutting. The team explored the possibility of using microjets to puncture biological tissue without the need for a needle. Their video demonstrates that a bubble-generated microjet can poke through a 5-millimeter-thick layer of agarose, a gel they use as a stand-in for living tissue.

## 2D Fluid Flow Isn't So Simple (Video 3)

One way to dispose of carbon dioxide ($CO_2$) and help fight climate change is to inject $CO_2$-rich liquid

VIDEOS CONTINUED ON PAGE 6

VIDEOS CONTINUED FROM PAGE 5

into calcium-rich soil and create stable calcium carbonate. Anne De Wit of the Free University of Brussels (ULB) and her colleagues modeled this carbon sequestration process theoretically and experimentally a few years ago. Their model assumed a simple 2D geometry in which the $CO_2$-rich liquid is injected into the center of a horizontal disk containing a calcium-rich solution. But "even such a simple situation is very complex," says De Wit.

The complexity that the researchers uncovered involved convection rolls, vertical loops in which heavier fluid sinks and lighter fluid floats. The presence of these flow patterns implied that the 2D assumption was not completely accurate, as buoyancy and gravity forces were acting in the vertical direction. To explore the role of this 3rd dimension, De Wit's colleagues Karin Schwarzenberger and Yorgos Stergiou of the Helmholtz Center in Dresden, Germany, ran experiments aboard an airplane that alternated between microgravity (near zero g) and hypergravity (2g). As shown in their video, the convection rolls disappeared at zero g, proving that these flow features resulted from gravity and buoyancy. The hypergravity phase produced even more complex patterns that the team is still analyzing.

De Wit points out that understanding this type of system, a so-called reaction-diffusion problem with injection, has applications in a wide range of fields beyond carbon sequestration. For example, a COVID-infected person can be thought of as the source of an outward-spreading wave of infection.

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FYI CONTINUED FROM PAGE 4

iments would involve spending $1 billion spread over 10 years. He remarked that it is "not a small amount of money," but neither is it "exceedingly outrageous" if several countries contribute. He also put the figure in context with the much larger sums spent on accelerator-based physics.

Hallman argued that in addition to multiplying efforts and dividing the cost burden, an international effort would help to build an "ecosystem" of institutions and researchers around the neutrinoless double beta decay search. That, in turn, could pave the way toward a subsequent generation of experimentation if it turns out to be needed.

He remarked, "If this really is a campaign, if the next round of experiments is not going to be decisive, because nature is not kind, then you need sort of an ecosystem to carry this through to conclusion. And it's not going to be a two-decade outlook, it's more like a four-decade outlook, and you want that ecosystem to be able to carry through."

*The author is a Senior Science Policy Analyst for FYI.*



VICTORIES CONTINUED FROM PAGE 4

### Domestic STEM Workforce & Science and Innovation Legislation

Last year, APS GA partnered with multiple science societies to advocate for major pieces of legislation addressing science and innovation. A primary one was the NSF for the Future Act, which aims to accelerate American innovation by expanding the agency's use-inspired research and strengthening the agency's curiosity-driven fundamental research programs. The reauthorization bill also includes provisions to address a number of APS's policy priorities, including broadening participation to bolster the domestic STEM workforce. APS GA underscored the importance of that provision in its report, "Building America's STEM Workforce: Eliminating Barriers and Unlocking Advantages. Additionally, APS President Sylvester James Gates, Jr. and Gerald C. Blazey, Vice President for Innovation and Partnerships at Northern Illinois University, partnered to write an op-ed about broadening research opportunities in *The Hill*, one of Capitol Hill's main media outlets.

To support the NSF for the Future Act, APS launched a community sign-on letter, gathering more than 1,650 signatures of members of the scientific community. The House Science Committee posted the letter to its support page for the bill and shared it with the Speaker of the House's legislative team.

After the NSF for the Future Act and the Department of Energy (DOE) Science for the Future Act successfully passed the US House of Representatives with strong bipartisan support, nearly 600 APS members wrote letters to their representatives to say "thank you." The bipartisan DOE Science for the Future Act will give comprehensive policy guidance and funding authorization for the major research programs housed in DOE's Office of Science.

Additionally, several pieces of legislation addressing some of APS's policy priorities passed out of the House in May, including the Supporting Early-Career Researchers Act, the STEM Opportunities Act, the MSI STEM Achievement Act, and the Combating Sexual Harassment in Science Act, a bill that has long been a priority for APS GA. In support of these bills, APS members contacted Congress more than 800 times through email, calls, and social media in early 2021. Some of these bills also are included in Sen. Majority Leader Chuck Schumer's (D-NY) US Innovation & Competition Act (USICA), which passed the Senate with bipartisan support in June. In November, Congress agreed to merge some of the House bills, including NSF for the Future, with USICA, as the next step to having Congress pass a final bill for President Biden to consider signing.

### Visas and Immigration

In 2020, the Trump Administration sought to eliminate the current "duration of status" guidelines that allow international students who study in the US on certain visas—such as F and J visas—to remain in the country for as long as they maintain compliance with their terms of admission. In response, about 1,600 APS members submitted personal comments opposing the proposed rule change, and the Society's members were responsible for approximately 1 in every 20 comments submitted concerning the proposed rule. On July 6, 2021, the Department of Homeland Security withdrew the notice of proposed rulemaking.

In other visa and immigration news last year, APS GA continued to advocate for Congress to authorize international students pursuing advanced STEM degrees to express their intent to stay in the US and pursue their careers post-graduation; and to provide any international student who earns an advanced degree in a STEM discipline a clear path to a green card by exempting them from any green card caps. The APS-endorsed Keep STEM Talent Act and the US Citizenship Act both include similar legislative provisions.

### Climate Change

The APS Council approved a revision of the Society's climate change statement in November, clearly implicating human activities as the "dominant driver" of climate change. In a move aimed to help address climate change, Senator Martin Heinrich (D-NM) and Representative Diana DeGette (1st-D-CO) introduced joint resolutions of disapproval in the House and Senate in March, using the Congressional Review Act to reverse the rollback of regulations for methane emissions from the oil and gas industry during the Trump Administration. APS members contacted Congress nearly 2,300 times in support of the joint resolutions via email, phone calls, and social media. The Senate passed the bill on April 28, and the House did the same on June 25. President Joe Biden signed the legislation into law on June 30, restoring Obama-era methane regulations.

### Research Security

Since the release of an APS Board Statement in February 2020, the Society has advocated for the federal government to take a balanced approach to address its concerns regarding research security and foreign influence. The Society has engaged policymakers on this issue through letters from the APS President, meetings with APS leadership, APS GA reports and more than 600 letters from APS members to Congress. These efforts began paying off late last year.

In a letter addressed to Biden Administration officials, APS President Sylvester James Gates, Jr. outlined a series of recommendations for adjusting the China Initiative—a targeted effort that is sowing fear among some APS members, restricting legitimate international scientific collaboration, and hindering the US in the race for global talent. Furthermore, during a meeting with the FBI, agency staff described plans for a research security "pivot," which involves a rebalancing of investigations where the FBI focuses on intentional, malign activity and other federal agencies together with professional societies handle non-disclosure cases that are administrative or inadvertent in nature.

In addition, Secretary of State Antony Blinken signed a delegation of authority on August 25, 2021, stating that Chinese students could obtain a visa to study and conduct research in the United States if their entry is deemed "in the national interest." The delegation of authority gives the US consulates abroad who provide visas the ability to make exceptions to Presidential Proclamation 10043, which bars Chinese students and scholars who allegedly have ties to China's "military-civil fusion strategy" from studying and conducting research in the United States. The Trump Administration issued the proclamation, which remains the current policy.

APS members raised their voices on this issue through more than 600 letters to Congress.

### Helium

At a time when Congress was confronting many unprecedented issues, US Rep. Joe Neguse (CO-D-2nd) kept another important matter—access to affordable helium—on its radar by re-introducing the "Securing Helium for Science Act" during the 117th congressional session. Neguse originally introduced the bill in December 2020. If passed into law, the legislation would provide researchers supported by federal grants the ability to continue to purchase helium from the Federal Helium Reserve at a discounted rate for eight years after its sale, which is scheduled to be completed in September 2022. APS GA has also advocated for funding for key federal science agencies to support robust helium recycling programs for principal investigators. Helium recycling provisions were included in both the National Science Foundation (NSF) for the Future Act and the Department of Energy (DOE) Science for the Future.

### Nuclear Weapons

In 2021, the APS-supported Physicists Coalition for Nuclear Threat Reduction sponsored 53 colloquia, virtually and in-person, at universities and a few national laboratories across the country. Given by a team of 13 experts, the talks highlighted the physics, history, and risks of nuclear weapons as well as potential policy opportunities to reduce their dangers. After each colloquium, interested attendees were invited to stay to learn more about the coalition, which grew to about 600 members in 2021. Launched in 2020 to inform, engage, and mobilize the US physics community around the danger posed by the world's nuclear weapons, the coalition is supported by the APS Innovation Fund. APS GA guides coalition leaders on advocacy topics and in other pertinent areas. One of the coalition's first advocacy activities was to push for a five-year extension of the New Strategic Arms Reduction Treaty (New START), with advocates sending more than 175 letters. In early 2021, the Biden Administration extended New START through 2026, maintaining the current arms control regime and providing both governments time to negotiate a future agreement.

*The author is APS Senior Public Relations Manager. Members of the APS GA team also contributed to this article.*

HELLMAN CONTINUED FROM PAGE 1

also need to figure out how to better support our members internationally, whether they live and work outside the United States, come here from other countries, or are engaged in international collaborations, and how to better engage with the international scientific community. We're called the American Physical Society, but APS is a global organization.

The lack of diversity in physics is an ongoing challenge that we need to address. It's not enough to be personally not racist and not sexist. Defining yourself by what you're not is abdicating responsibility. We need to dismantle the barriers that prevent people from participating in physics. I look forward to working with the Ethics Committee and to continuing [APS Past President] Jim Gates's important work on the DELTA-PHY initiative, which aims to change the culture of physics by engaging in open conversations about these issues.

Other major priorities include modernizing the structure of our publishing operation, developing strong and productive relationships with other scientific societies, building on the success of our education and outreach programs, and helping to make philanthropy an important part of the Society's financial picture.

**COVID-19 has created many challenges, as well as opportunities, for physics. How do you see APS emerging from the pandemic?**

Hybrid meetings are the obvious example of an approach that needs development. We're all tired of Zoom - it's an efficient but only moderately effective interaction tool. Conferences, poster sessions, talks, they're all a very different experience done remotely. But there are plusses, too. The April Meeting usually attracts some 1,500 people and last year there were 7,000 people who attended online. Think of people with small children, a sick parent, or have a disability. Increased access was an important thing enabled by the pandemic.

**The APS Council recently adopted a revised Statement on Earth's Changing Climate. What is the significance of this new statement?**

APS is now clearly stating that humans are the dominant driver of global warming, because the evidence has become increasingly clear and the support of the physics community for this statement has gone way up. We are now in a strong position to advocate for necessary change. There's a lot we don't understand, but the fact that we don't have all the answers doesn't mean that we should not act. Years ago, when I was on [the Panel on Public Affairs] working on the previous statement, and there were a lot of people saying that physicists should not be weighing in on this, this is not our purview. There are still those saying that, but very few.

**The *Physical Review* journals are essential to the Society's mission to advance and diffuse the knowledge of physics. How will APS journals maintain their preeminence in the face of increasing competition, open access mandates, and disruptive information technologies?**

The journals are our jewels, completely essential to our mission. But our preeminence is getting chipped away at and it's in part because we have an obsolete structure that dates back a hundred years. There are proposed changes to the governance of APS publishing that are under consideration right now. There will be a greatly re-energized publishing committee and stronger oversight by the Editor in Chief, who will become a member of the Board Executive Committee, responsible for the quality and relevance of our journals . We're attempting to modernize the structure in a way that will leave us more nimble and better able to publish the preeminent journals in the world.

**How did you get started in physics? What drew you to APS and prompted you to become a member?**

I had an amazing high school physics teacher. She taught us in an utterly non-mathematical way. So I learned none of the traditional intro physics stuff. We spent all our time learning about general relativity, how the universe began, black holes. I loved it! It was fascinating. She encouraged us to think and to be creative.

When I got to Dartmouth, I knew I wanted to major in physics and I was also deeply involved in ski racing. The standard introductory physics class started in the winter, but there was an advanced class that started in the fall. So I took a placement test and the professor, who was later my advisor, called me in and said "I don't quite know what to do with this. It's clear you haven't had any introductory physics. But I see a lot of really good insight and I think you're going to make a great physicist." He gave me the opportunity to try the class.

I was fortunate to have great advisors all along. In the end I do have a knack for physics. It's something I love and do well. I joined APS back when I was a graduate student and I probably made the world's best financial investment when I signed up to be a life member when I was about 28.

**How is APS progressing on the actions laid out in the 2019 Strategic Plan?**

The Strategic Plan is a remarkable document and underlies everything we do. Its mission and vision statements, as well as its plans and calls for action, are powerful and inspiring. I'm struck by its opening lines about increasing the participation of the next generation of physicists, increasing public appreciation of the power of physics to transform our world, advocating for a robust research enterprise, and strengthening our publications enterprise. I am committed to helping APS, its staff, and its members achieve these goals.

**What message would you send to APS members in these turbulent times?**

This is a challenging time for everybody. We're not through this yet, and there's a lot of ramifications that we don't even understand. So my message is this: Be kind to yourself and others. When you feel frustrated, go for a walk. This is a shared experience that we'll get through together. And, we're lucky to do physics as a career!

*The author is APS Head of Public Relations.*



SHOEMAKER CONTINUED FROM PAGE 8

studies of impact craters and planet-crossing asteroids. "Carolyn's legacy is as part of the Shoemaker team," explains Dave Jewitt, UCLA Professor of Astronomy and famous dwarf planet discoverer. "It takes two or more people to operate [the telescope] and develop the plates, so Carolyn was essential and she was obviously totally invested."[11]

Among other honors, she was awarded an honorary doctorate from Northern Arizona University in 1990, finally earning a degree to match her experience and contributions. There is even an asteroid named in her honor, 4446 Carolyn.[12]

### Conclusion

"Without the human relationships we cherish, knowledge would count for naught; both are to be nourished," said Shoemaker. "Henceforth, I'll continue my scientific exploration, knowing that I must not neglect the other side of living."[1]

Carolyn Shoemaker engaged in astronomy with her whole self—her identity and experience as a woman, a mother, a wife, a friend, a curious learner, and a scientist. Her story illustrates how becoming a successful scientist depends not only on the work you do, but who you do it with and who teaches you along the way. "Successful careers—such as Carolyn's—depend on the individual and on their luck in being influenced by other people," explained Mary G. Chapman, senior scientist at the Planetary Science Institute.[2] Throughout her career, a repeated theme in Shoemaker's comments is how her collaborators made all the work she did possible, worthwhile, and enjoyable.

Shoemaker also reminds us that the value of science often lies in how it relates to our communities, to the livelihoods of the unique life forms here on Earth. Asteroids are not simply distant rocks in space, and astronomy is not an impractical endeavor. Instead, she asserted that "impact cratering is a process that affects all life, which means to me that science and society cannot help but be intertwined...as one progresses, so does the other. Pure science, the search for knowledge without knowing where it will lead, is part and parcel of what will make the world a better place for all mankind."[3]

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The author would like to acknowledge that this essay was completed on Gabrielino/Tongva land, once known as Tovaangar until its colonization. Many indigenous people still live in this region today. Also, thank you to Julia Zeh for proofreading this work.

***About the Author***

*Briley Lewis is a fourth-year graduate student and NSF Fellow at the University of California, Los Angeles studying Astronomy & Astrophysics. Her research focuses on how we can apply techniques from direct imaging of exoplanets to other planetary science questions. She is a member of the Astrobites collaboration, contributing author for Massive Science, and former organizer for ComSciCon-Los Angeles. She also teaches writing at UCLA in her course for first year undergraduates, "Astrobiology in Science Journalism." Follow her on Twitter @briles_34 or visit her website www.briley-lewis.com.*

*Reprint of the winning essay from the 2021 APS Forum on the History and Philosophy of Physics Essay Contest.*

# THE BACK PAGE

## An Unusual Orbit: The Life and Discoveries of Carolyn Shoemaker

BY BRILEY LEWIS

Not everything in our solar system follows a tidy, near-circular orbit, and not every scientist follows a typical, traditional path. Carolyn Shoemaker was unexpectedly pulled into science at nearly age 50, and despite her lack of scientific background, she went on to change our understanding of the solar system by discovering over 800 asteroids and comets, including the famous Shoemaker-Levy 9.[1,2] Along with her husband and scientific partner, Gene, she held a particular interest in asteroids with strange planet-crossing orbits, since their impacts have huge implications for life on Earth.[1] Shoemaker recently passed away at the age of 92 in August 2021, leaving behind a legacy of science built on community and collaboration.[12]

### Shoemaker's First Education

Carolyn Shoemaker never meant to be a scientist. Neither of her parents were scientists, and her science classes bored her.[1,2] Attending college right after the end of World War II, her goal was purely pragmatic: to get out as quickly as she could and get on with her life. At her hometown college of California State University, Chico, she earned a master's in history, a master's in political science, and a high school teaching credential.[1]

Her first degrees weren't totally unrelated to her later pursuits, though. Shoemaker explained, "These fields are basically historical sciences—astronomy is like a time machine that tells us about the creation of our solar system and our universe, geology reveals the nature of our world in the past and helps us to understand Earth and its neighboring planets today."[3]

After graduation, Shoemaker planned to teach 7th grade in Petaluma, California.[1] Until she met Gene, that is.

### A Nourishing Partnership

As Shoemaker herself says, it's hard to talk about her career in science without talking about her beloved husband, Eugene (Gene) Shoemaker.[3] Married in 1951, Gene was a geologist working for the US Geological Survey (USGS) with an infectious love of science. He brought Carolyn along on mapping expeditions, without any reservations about the lack of women in field work at the time, and enthusiastically taught her about rock structures and sedimentary layers. She soon became pregnant with their first child, and although she couldn't join for the strenuous field work, she kept camp and learned from all the fireside stories told by the scientists.[1]

The launch of Sputnik in 1957 changed their course, though—Gene's dream of science on the Moon felt suddenly within reach. He began to lobby for an astrogeology branch of the USGS, travelling all across the country for work. Carolyn stayed at home in California to care for their young kids, eagerly awaiting updates from Gene when he returned home.

Eventually, the family settled at Caltech in Pasadena for Gene to work on the Apollo and Voyager missions. Gene soon started the first search for asteroids that cross Earth's path, known as Near Earth Objects (NEOs), at Palomar Observatory near San Diego. An enthusiastic supporter of women working in astronomy, he worked with Eleanor (Glo) Helin, a female trailblazer in asteroid science. Although science classes never caught Carolyn's attention, the electric enjoyment of science by Gene's colleagues did. Caltech really amazed her—this was where she "fell in love with planetary science, the skies, our solar system, and the universe."[1]

Carolyn had years of experience listening to cutting edge research, immersed in the community with her husband. When her kids left home in the 1970s, science was a natural choice for what she should do next and Gene offered for her to work with him on his asteroid research. Other astronomers helped train her, and she began searching through data for new asteroids and helping with observations at Palomar.[1,3]

Fellow planetary scientist Mary Chapman commented on this partnership that "the two mutually supported each other throughout their symbiotic marriage. Without Gene, Carolyn would never have become a famous astronomer. Without Carolyn's help, Gene would never have progressed very far with his asteroid statistics program, found comet Shoemaker-Levy 9, and probably would never have mapped impact craters in Australia. Without each other, they would not have been successful companions and working partners, had their children, or home life."[2]

### Identifying Minor Planets (on Film)

The Shoemakers' 1980s asteroid searches, like the Palomar Asteroid and Comet Survey they started together, used film for their telescope observations. Film was a tricky medium—it had to be kept in the dark, hypersensitized to shorten exposures, and cut to make round pieces. In order to find moving small solar system bodies, they used spectrographic film and placed it within a stereomicroscope, which made the moving bodies appear to float, distinguishing them from background stars.[1] This work could be quite tedious and grueling, with a typical night of work lasting 13 hours with no rest, quickly changing out and developing films at the telescope.[1,3] It took a keen eye, great patience, and attention to detail to do this kind of work, all of which Carolyn had.[3]

Carolyn Shoemaker CREDIT: USGS ASTROGEOLOGY[2]

Gene's method of science was to collect as much data as possible, and deal with the analysis later.[5,6] They spent a week each month, when the Moon was dark, collecting around 100 films per night on the 18 inch Schmidt telescope, Palomar's oldest and smallest.[1,6] They were able to cover a whopping 60 square degrees of sky—around 300 times the angular size of the Moon—on a 6 inch film.

A true team effort, they recorded over 2,000 new asteroids. As Carolyn recalled, "The excitement of a special discovery was a reward for the whole team, because it took each of us working together to make those discoveries. Throughout the years we never ceased to be intrigued and elated when we found an unusual object."

> "To work in planetary science is to work in an area that takes us both back to the origin of our solar system and beyond it into the future."[1]

In true Gene Shoemaker fashion, only around 270 of those have official number designations, and thousands still need further observations to determine their orbits. The Shoemakers used their observations to estimate the number of Earth-crossing asteroids larger than 20 kilometers in diameter (around 1500), and to estimate that Earth will see two impact craters larger than 20 kilometers every million years. 60 percent of these asteroids also crossed Venus's orbit, meaning that Venus should have a cratering rate fairly similar to Earth's, another similarity between these sister planets.[6]

They also found almost 200 asteroids with high inclination orbits, many comets, and the first Trojan asteroid, trailing Jupiter in its orbit. They appropriately named it Paris, for the Greek mythological antagonist of the Trojan war.[6] Asteroids and comets, the leftover junk of our solar system's formation, hold so many clues to how our planets came to be. Gene and Carolyn did the hard, tedious work of discovering and cataloguing these asteroids, giving us the first glimpse into exactly what is out there tumbling around near our planet. By far their most well known discovery, though, was a happy accident at Palomar, taken on a night where they almost gave up.[8]

### Comet Shoemaker-Levy 9

Observing the night sky requires some cooperation on the part of the sky. Wind, clouds, and a number of other natural factors can ruin a night's time on a telescope. One night during their survey at Palomar, there were terrible winds, patchy clouds obscuring the stars, and to make it worse, someone had ruined a large cache of the photographic films. Usually, the team would have quit to avoid wasting expensive film, but instead they continued and used some of the slightly damaged film since it was already a loss. With Gene holding the telescope's shutters open against the wind, they took the first images of the famous Shoemaker-Levy 9 (SL-9) comet that night.[6,8,10]

"I don't know what this is, but it looks like a squashed comet," Carolyn said, as she noticed SL-9 on the films.[10] Further research showed that this unique comet was actually a series of 21 broken up pieces, all in orbit around and on a collision course with Jupiter. [9,10] These fragments were expected to hit only a year later in summer 1994, crashing into Jupiter with an energy equivalent to two million of the largest nuclear bomb ever dropped (the 50 megaton Russian Tsar Bomba).[9]

SL-9 was the first comet to be seen in orbit around a planet, the first comet to be seen completely disrupted, and the first large object to be seen impacting a planet. Astronomers were eager to observe the impact—would the atmosphere swallow the comet whole, or would it disrupt the atmosphere, maybe even leaving a lasting impression?[10] Carolyn called it "everyone's comet" due to the incredible interest from professional and amateur astronomers, as well as the general public.[3] It's clear that she saw the value of this comet's discovery in not only the scientific knowledge that it would provide, but also the public excitement around science and the increased cooperation between various people and institutions it generated.[3]

The first Hubble Space Telescope images of the collision were soon revealed, and everyone was thrilled by the results. Plumes from SL-9's impact were clearly visible, rising 3000 kilometers above the surface of Jupiter.[8] For reference, the International Space Station is only around 400 kilometers from Earth's surface. Impact scars lasted for years, with dark marks from the comet's material propagating across the atmosphere, allowing researchers to trace Jupiter's wind patterns.[6]

Carolyn connected this once-in-a-lifetime event with her research on impacts on our own planet, explaining that we were lucky it was Jupiter being hit and not Earth. On our own planet, an impact of that size would have cometary material throughout our sky, blotting out the sunlight—similar to the event that killed the dinosaurs.[6]

### Craters Across the World

In addition to their work on otherworldly impactors, the Shoemakers recorded detailed maps of impacts here on Earth, particularly in Australia. Australia is well-suited for crater studies, with its flat, dry terrain. Gene and Carolyn visited over 20 different impact structures, fastidiously mapping these craters and investigating their structures. They traveled alone, with no GPS or satellite, finding new features to add to the Australian impact record. This record, Gene hoped, would help determine the flux of impacting asteroids on the ancient Earth.[5] This work illustrated that planetary science isn't just an endeavor for space missions; craters here on Earth are ready for investigation, excellent sites to see the science of impacts up close.[5]

Gene and Carolyn also took opportunities to engage with the local community, finding craters by word of mouth and local legends, even occasionally following an Aboriginal guide. At Liverpool crater, Carolyn and their guide Johnny Maurirundjul exchanged stories about the crater's origin, which in Aboriginal culture is the nest of a giant catfish.[5]

Australia, however, is where the Shoemaker's partnership came to an abrupt end. Gene was killed in a car crash in 1997 on one of their excursions, leaving Carolyn injured and much of this data unanalyzed and unpublished.[1]

### Legacy and Lasting Impacts

Carolyn Shoemaker spent the later years of her life studying Near-Earth Objects and watching the field of planetary science grow and thrive. [12] Even after her husband's death, she remained engaged in astronomy, striving to finish some of the work they had started together.

Astronomy relies on the hard work of cataloguing the sky, and the Shoemakers' work essentially founded the scientific

SHOEMAKER CONTINUED ON PAGE 7

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