RESOURCES

New Results from MICROSCOPE Mission Tighten Constraints for Key Principle of General Relativity

The satellite’s free-fall experiments yielded the most precise confirmation yet of weak equivalence.

BY ABIGAIL EISENSTADT

The MICROSCOPE mission satellite was decommissioned in 2018, but its final findings were published this week. CREDIT: JULIET 2012, ILLUS. D. DUCROS / CNES 2015

In a grumpy NASA video from 1973, the astronaut David Scott, donning a spacesuit and standing on the dusty lunar surface, holds up a feather and a hammer. “A gentleman named Galileo,” he says, “made a rather significant discovery about falling objects in gravity fields.” Scott says. “Where would be a better place to confirm his findings than on the moon?” He drops the feather and hammer. In defiance of the law of Earth-bound viewers who see falling objects drift slowly, both objects hit the ground at the same time. “How about that?” he muses.

The stunt introduced many to the weak equivalence principle (WEP), central to the theory of general relativity, but it wasn’t a formal experiment. Now, new and final data from MICROSCOPE—a tiny satellite that, between 2010 to 2018, orbited more than 40 miles above Earth—has added to physics the most precise test yet of the WEP.

The WEP dictates that two objects in the same gravitational field should accelerate in free-fall at the same rate, regardless of their configuration or mass, so long as there are no other forces (like air resistance, which slows a falling feather on Earth but not on the airless Moon). The MICROSCOPE results, published in the journal Physical Review Letters on September 14, reveal the tightest constraints for the WEP ever established in the journal Physical Review Letters on September 14, reveal the tightest constraints for the WEP.

MICROSCOPE CONTINUED ON PAGE 5

PROFILES IN VERSATILITY

Physicist Receives Grant to Test Nanoparticle-and-Laser Cancer Treatment in Humans

After losing her aunt to cancer, Dr. Hadilyah–Nicole Green dedicated her career to physics-based therapies.

BY ALAINA G. LEVINE

When Hadilyah–Nicole Green crossed the stage at her college graduation, she felt sure about what would come next. She’d start a career in optics—a good option for someone with a bachelor’s degree in physics—and that would be that.

Life, though, had other plans. The day after she graduated from Alabama A&M University, she learned that her aunt, Ora Lee Smith, had cancer. Smith and her husband had raised Green since she was four years old, after the death of Green’s mother and then grandparents.

Her aunt “said she’d rather die than experience the side effects of chemo or radiation,” Green says, now a medical physicist and founder and CEO of the Ora Lee Smith Cancer Research Foundation.

“At statistical physics, in particular, is used to explain the properties of a large collective from the properties of its parts. This is most often applied to different forms of matter, but in studies of large populations of people, the same principles might be relevant,” statistical physics is a very powerful tool to study large quantities,” says Hyge Piaget M. Melo, a senior researcher at the Enrico Fermi Research Center in Italy, who spoke at CCP22. “You can almost see the behavior of these systems as a collective action of particles.”

In 1999, researchers published a paper in Physical Review E that analyzed the results of a survey of federal election outcomes in Brazil. When the candidates were ordered by the number of votes they received, the researchers found that a small fraction of candidates received the vast majority of votes; all the other candidates got very few. When graphed, this data closely followed a power law, a well-known mathematical relationship.

Statistical physicists also use the power law to study the underlying mechanisms. “There was an avalanche of papers trying to explain this,” Melo said.

In 2011, Brazil passed a law requiring candidates to publish detailed information about their campaign finances. Melo and his collaborators took advantage, investigating the relationship between campaign spending and number of votes in the 2014 and 2018 elections for federal deputies in Brazil. Could the data shed light on the power law seen across elections?

The researchers modeled the votes as particles in a gas and the candidates as energy states the particles could occupy, maximizing the entropy of the system, and watched what happened with the distribution. They found that the correlation was not linear: doubling the amount of money spent in a campaign did not double the number of votes a candidate received. Even so, the distribution of wealth matched the power law distribution of votes.
**For Women and Gender Minorities in Physics, Community Builds Confidence**

Lessons from the 2022 Advancing Graduate Leadership Conference

BY LIZ BOATMAN

B y third grade, Erica Snider knew, resolutely, that she wanted to be a physicist. But that doesn’t mean it was always smooth sailing. Snider, who has worked as a high-energy physicist at Fermilab for more than two decades, says that, early in her career, “I declared some goals—purely because I didn’t have the confidence to get up in front of people.”

That lack of confidence, she says, stemmed from her environment. Confidence is “massively affected by the people around us,” the culture that we’re in—and for women and gender minorities, who make up about one-fifth of physics graduate students, finding a supportive community can be a challenge.

To help students overcome this challenge and build community, with funding from the Heising-Simons Foundation—hosted a multi-day conference for women and gender minorities. The Advancing Graduate Leadership (AGL) Conference, which took place in August in Washington, DC, sponsored nearly 100 attendees from 13 states. Sessions focused on professional development, and topics ranged from coping with mental health challenges to cultivating inclusive leadership skills.

Snider, drawing on lessons from her own career, facilitated a session called “Developing Confidence and Presence.” She opened by asking attendees if they ever struggled with confidence in their physics careers. “Almost everybody in the room said that they felt as though [their confidence] interfered with their job, or that it affected their decision-making in ways that might affect their career,” she says.

“That was certainly the case with me,” she adds. “There was a point in time where I thought confidence was an immutable personality trait.”

At the AGL conference, she sought to break down that myth. Confidence, she told attendees, is something you can shape “through your attitudes or your approach, the way you react. And presence is a skill—you can just learn it.”

Xuan Chen, a postdoctoral researcher in high-energy physics at Cornell University who attended the conference, is concerned about the confidence gap she sees in many of her peers. “If you talk to female students or students from minority groups,” she says, “you will realize that they often do not feel confident, regardless of how much they have achieved in their field.”

Chen plans to pursue an academic path after her postdoc. In preparation, she’s focused on finding ways to promote a more inclusive culture in physics and academia as a whole, which is why she attended the AGL Conference.

Sam Kaufman-Martin, a PhD student researching the turbulence of wind energy kites at UC-Santa Barbara, flew from the west coast to participate in the event. Kaufman-Martin originally saw the conference on a physics job search program and thought she might be able to connect with other women in the field.

“Having a community is really important for me because it’s the only other community that I have,” she says. “It’s really energizing to talk to people who have a similar point of view.”

Conversely, Shuang Wu’s experiment suggested Lee and Yang’s theory was correct. In a second, frantic note, Paul wrote: “Sehr aufregend. Wir wissen jetzt die Nichtschirme!” (Very exciting. How sure is this news?).

Lee and Yang’s “Question of Parity Conservation in Weak Interactions,” published October 1, 1956, took the physics community by storm. Their ideas provoked a frenzy of debate and experimentation, which just a year later landed the pair two Nobel medals.

At the time, physicists were perplexed by a problem known as the “theta-tau puzzle.” Two particles—now called kaons—seemed to have the same masses and lifetimes, but, somehow, different decay modes: theta into two pions, tau into three pions.

Hypotheses proliferated. Some physicists proposed that the particles weren’t identical after all—that tau was a smidge heavier than theta—or that high spin numbers might explain the strange decay. Ironically, Lee and Yang pitched an idea: Tau and theta might point to a new symmetry (ironic, given that their later, Nobel-winning paper argued for a violation of symmetry). Experiments quickly proved all these models wrong.

At a conference in April 1956, Yang discussed the theta-tau puzzle, prompting a debate. At one point, Richard Feynman asked a question of Martin Block: “Could it be that parity is not conserved…does nature have a way of defining right or left-handness uniquely?” Yang replied that he and Lee had investigated the question but not reached a conclusion.

After the conference, Lee had a breakthrough while speaking with Jack Steinberger, which he recalled during a 2001 talk: “If parity is not conserved in strange particle decay, there could be an asymmetry between events… This is the missing key!” The conversation led Steinberger and his colleagues to search for parity violation in hyperon decay, but with too little data—just 48 detected particles—their results were inconclusive.

Meanwhile, Lee and Yang began to pore over existing data. “At that time, everyone believed, to a certain degree that at least as far as we knew—that parity was conserved in the strong and electromagnetic interactions,” says Allan Franklin, a physics historian at the University of Colorado, Boulder.

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**Women in Physics Grant Information**

Applying for funding to build your on-campus scientific community

Deadline: November 11, 2022

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**Physicists Chen Ning Yang (left) and Tsung-Dao Lee, whose 1956 paper on parity violation earned them the Nobel Prize in Physics at the University of Chicago Photographic Archive (APF1-03706); Hanna Holborn Gray Special Collections Research Center.**

**O n a hazy January day in Zurich 65 years ago, Wolfgang Pauli was composing a letter in untidy scrawl to his colleague Victor Weisskopf. He was dubious about a recent proposal, from Tsung-Dao Lee and Chen-Ning Yang. A few months earlier, that parity—the basic symmetry between left and right in physical laws—might have been violated. Pauli captured his skepticism in an immortal quip: “Ich glaube aber nicht, daß der Herrgott ein schwacher Linkshänder ist.”** (I do not believe that the Lord is a weak left-hander.)

He wasn’t alone. At the time, physicists believed all the known fundamental forces—electromagnetism, gravity, the strong force, and the weak force—obeyed parity symmetry. Why shouldn’t the universe look the same in a mirror?

But two days later, the elegant mirror of parity was shattered. Initial data from Chien-Shiung Wu’s experiment suggested Lee and Yang’s theory was correct. In a second, frantic note, Paul wrote: “Sehr aufregend. Wir wissen jetzt die Nichtschirme!” (Very exciting. How sure is this news?).

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Meanwhile, Lee and Yang began to pore over existing data. “At that time, everyone believed, to a certain degree that at least as far as we knew—that parity was conserved in the strong and electromagnetic interactions,” says Allan Franklin, a physics historian at the University of Colorado, Boulder.
When a mosquito harboring a malaria parasite bites you, the parasite attacks your red blood cells, changing the cell’s membrane, which makes them more rigid. The sick cells stick to the inside of blood vessels, causing most of the symptoms, like fever and vomiting.

Malaria isn’t the only disease that changes a cell’s physical properties. Cancer and sickle-cell anemia can, too. So being able to quickly, effectively separate sick, stiff cells from healthy, squishy cells could help scientists detect and study disease.

The study published August 8 in Physical Review Fluids details a proof-of-concept experiment to use soft cell’s tendency to deform—that is, squish and change shape—to sort them on microfluidic devices, small instruments etched with tiny channels in which scientists can control and study fluid. The research could support the development of therapeutic or diagnostic microfluidic methods for separating complex mixtures of cells with different properties, like sick and healthy cells.

“This is the first time the experimental work has been done to show [that] actuation—like change of shape of soft particles, like a red blood cell, can move them forward,” says Chaoshu Minbash of Grenoble Alps University in France, who was not involved with the paper.

In March this year, researchers at the University of Bayreuth in Germany published a hypothesis on this potential phenomenon in Physical Review Fluids. When soft particles deform in a flowing fluid, the drag on them changes. By pushing a mix of particles in a fluid forward and backward through a microchannel at different rates, it might be possible to push soft particles forward and leave the rigid ones behind, the researchers suggested.

A separate team at the University of Bayreuth decided to test this theory with red blood cells, which are particularly well suited for the experiment, says Pierre-Yves Gires, a co-author of the most recent paper. “They don’t have a nucleus,” he explains. “They can be deformable, as they have to fit through very thin capillaries” in the body.

To test it, Gires and his colleagues Sebastien Krauss and Matthias Wotas ran a mixture of red blood cells and hard plastic beads that wouldn’t deform through the channels of a micro device, which they designed and printed themselves. They ratcheted the particles in one direction for an interval of time, then reduced the flow rate and drove the particles backward for ever longer. The soft cells would remain behind.

The researchers modeled the votes as particles in a gas and the candidates as energy states the particles could occupy. The key result is that after the phase change, the energy state of the electoral system leads to the development of “negative representation,” where a small move in the electorate in one direction could lead to an elected candidate that tends toward the opposite direction. This may be a consequence of the two-party system, where each election is a choice between two candidates: for example, if the choice is between a center-left and far-right candidate, and the prevailing opinions move left, far-left voters may stay home if the center-left candidate’s views are too far from their ideal.

Modeling voters as gas or magnetic particles in a gas demonstrates oversimplified—it is, say Melo and Siegenfeld—and there’s plenty of debate about the limits of these tools. But Melo’s and Siegenfeld’s results speak to the potential of physics to help us understand our world.

“Humans aren’t particles,” says Siegenfeld, but the field might help answer a more fundamental question: “What are the conceptual approaches behind physics that have made the study of physics so successful, and can we apply those more broadly?”

Meredith Fore is a science writer for the Chicago Quantum Exchange.
Scientists Create 3D-Printed Model to Study How Particles Move Through Blood

The research could improve embolization, a procedure to stop bleeding and fight tumors.

BY MARGARET OSBORNE

Dr. Alaina G. Levine is a professional speaker, writer, and STEM career coach, and the author of the book Networking for Nerds (Wiley, 2008). Dr. Levine received a $1.1 million grant from the US Department of Veterans Affairs (VA) for her research, and, in April, joined the Morehouse School of Medicine as an assistant professor.

In 2016, Green was named one of the 100 Most Influential African Americans in the United States by Ebony and the Root magazines, and in 2020, she was named one of the Top 10 Women of the Century for Alabama, in a USA Today list that included Coretta Scott King and Rosa Parks.

Green is focused on moving her research from mice to humans—albeit at a slow pace. Her earliest hopes as a medical student were dashed when Dr. Green rerouted her career trajectory. She recalls thinking, “If a satellite could change the way I look at physics and biology go hand in hand. My own experience with cancer just at the site of the tumor, we so won’t have all of these side effects.”

For Green, cancer research and physics go hand in hand. “My initial approach to physics is, what is the application? How can it help people?” she says. “The work I’m doing now gives me a hopeful and purposeful outlet for applied physics, but it hasn’t changed the way I look at physics fundamentally.”

Physicist has shaped her outlook, too. “It has made me very solution-oriented in everything I do,” she says. “It gives me a greater sense of confidence.” She attributes part of this to her doctorate advisor, Dr. Sergey Mirov. Under his guidance, “I had to slow down, pick the material apart, understand everything, and be patient with myself and with the process,” she says. “The practice of getting something wrong—the iterations and revisions and noodling through ‘what steps did I miss’ and going back to the drawing board—is part of the process.”

That life lesson has helped me so much with building my team and nonprofit,” she adds. Her effort and impact have not gone unnoticed: Green has been named one of the 100 Most Influential African Americans in the US by Ebony and the Root magazines, and in 2020, she was named one of the Top 10 Women of the Century for Alabama, in a USA Today list that included Coretta Scott King and Rosa Parks.

Green’s interest in cancer research started as early as high school. "I was diagnosed with cancer soon after. Green’s uncle survived with chemotherapy, but the process took an almost unimaginably cruel twist, a traumatic toll: He lost 150 pounds and was left with disfigured skin and chronic diarrhea.

During her uncle’s treatment in 2003, Green experienced what she refers to as a “divine download”—an electric jolt that inspired her to apply to programs at the University of Alabama at Birmingham—the second Black woman to do so—and dove into cancer treatment research, with physics as her guide. In 2009, she developed a treatment that uses nanoparticles and lasers in tandem: Specially designed nanoparticles are injected into a solid tumor, and, when the tumor is hit with near infrared light, the nanoparticles heat up, killing the cancer cells. In a related animal study published in 2016, Green tested the treatment on mice, whose tumors were eliminated with no observable side effects.

2016 was a big year for Green: She received a $1.1 million grant from the US Department of Veterans Affairs (VA) for her research, and, in April, joined the Morehouse School of Medicine as an assistant professor. Also that year, she founded the Ora Lee Smith Cancer Research Foundation, named after her aunt, Ora Lee Smith. Green founded the Ora Lee Smith Cancer Research Foundation in honor of Smith, who died of cancer. CREDIT: HADILYN-MICHELLE GREEN

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o fight tumors, doctors sometimes use a procedure that starves tumors of blood. To “embolize” a tough-to-remove tumor, they inject in it very tiny particles, such as gelatin sponges or beads, into a specific blood vessel, block it. Without oxygen—blood, tumors can shrink and the process is less invasive than surgical removal.

But embolization has its limitations, and the ability to predict how these particles move in vessels could improve the accuracy and efficacy of the procedure. In a new paper published in Physical Review Fluids, researchers report on a 3-D model they built to examine how various concentrations of particles affect their speed, accuracy and tendency to block a branching system, like a blood vessel.

“Embolization is not only for tumors,” says Omid Amili, a professor of mechanical engineering at the University of Toledo and a co-author of the study. “It has multiple applications.” Embolization is used to stop bleeding after injuries, for example, and even treat pain. It’s also used in conjunction with chemotherapy drugs in the treatment of tumors.

Serious complications from embolization are rare, but every so often, the particles—usually no bigger than grains of sand—can block the wrong vessel and deprive healthy tissue of blood, or fail to block blood flow as intended. Predicting particle behavior, then, can improve the procedure’s success.

Previous studies have looked at different factors affecting particle dynamics in the body, but “not many people have studied the importance—or the effect—the of the particle concentration,” says Yinghui Li, the lead author and a fluid dynamics researcher at ETH Zurich.

The team designed an idealized, symmetrical model of a blood vessel, which was 3D-printed out of clear resin by a collaborator at the University of Zurich. The model starts as one tube but then forks, like branches on a tree. By 2016, Green says, she was awarded a $2.1 million VA grant to launch a pilot study on her treatment, and veterans, research that’s set to begin in October at the Atlanta VA Medical Center. “It’s a small project but a huge step for my research and the technology and my career,” she says. “This is 20 years in the making. I get emotion in my eyes thinking about it.”

For Green, cancer research and physics go hand in hand. “My initial approach to physics is, what is the application? How can it help people?” she says. “The work I’m doing now gives me a hopeful and purposeful outlet for applied physics, but it hasn’t changed the way I look at physics fundamentally.”

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Now, Green focused on moving her research from mice to humans—an uphill battle, as fundraising for large-scale clinical trials is fiercely competitive, especially for early-stage research. The most recent VA grant is a start. For her, the stakes are high. “There is a segment of the community who feel like they are forgotten when it comes to cancer—the people who chemotheraphy and radiation don’t save,” she says. “This gets to me. So the work must go on.”

The CHIPS Act is “the most significant science legislation in more than a decade.”

The CHIPS Act will funnel $52.7 billion into US semiconductor research, manufacturing, and workforce development.

The law offers several mechanisms to broaden participation in research and STEM, Blazey said, including at smaller institutions. In support of this effort, the law establishes a new category of academic institutions, the Emerging Research Institutions (ERI), and creates a pilot program for partnerships between flagship research institutions and ERIs.

The law will also help the scientific community manage disruptions to the nation’s helium supply. “It’s a life saver for so many—in chemistry, physics, and engineering—all of us who use helium for cooling, for lifting applications, and in other specialized processes,” said Sophia Hayes, Vice Dean of Graduate Education and Professor of Chemistry at Washington University in St. Louis. She advocated for the CHIPS Act program to help universities and two House congressional committees.

Programs that encourage helium recycling and reuse, and the infrastructure and equipment that support it, “will help sustain the US research enterprise” for decades to come, Hayes added.

The law also seeks to protect STEM workers from hostile work environments. According to a 2018 National Academies study, nearly three in four undergraduate women reported experiencing sexual harassment, which can deter them from STEM professions. To change this, the law created a working group that will develop uniform sexual and gender harassment policies and metrics for federal research agencies.

Mark Elsesser, Director of APS Government Affairs, noted that the law “—the most significant science legislation in more than a decade”—was the culmination of years of effort, which were vital to ensuring that it included three of APS’s science policy priorities. “It would not have been possible without the hard work of APS members, leadership, and staff.”

For the MICROSCOPE mission, Métris and his colleagues designed an experiment to measure the acceleration of hollow alloy cylinders. A nested pair of balls included three in one of two sensor units in the satellite. If the masses” acceleration varied by more than one part in 10^15, this would signal a violation of the WEP. To measure any variations, the researchers could wait for the satellite to pick up changes in the electrostatic forces that keep the masses in unison.

After the satellite’s launch in 2016, the team faced challenges. Equipment had to be adjusted for temperature sensitivity, power consumption, and circuitry issues. “Before it launches, you’re not sure that the launch will be a success,” said Métris. “You are not sure that the instruments will work, because they cannot be tested on the ground for how they will behave in space. There are so many possible sources of problems that really make you doubt the scientists had to scrub data of random glitches caused by cracks in the satellite’s insulation.

But, he added, “the experiment still worked well.” The team noted there were no issues in their 2017 findings, but methodically resolved them in their new paper.

While the analysis does not reveal a WEP violation, the findings are significant. The study places the narrowest constraints yet on the scale at which any WEP violation could occur. It also recommends improvements, like equipment upgrades, for future experiments.

According to the researchers, these improvements could one day lead to a precision of one part in 10^17. Perhaps a WEP violation lurks there, ready to throw limits around general relativity and make way for new theories.

“It’s a kind of game. You have to bet to win, by doing this experiment,” said Métris. “This time we didn’t. If one day we could see something, then it would be revolutionary.”

Abigail Eisenstadt is a science writer at the American Association for the Advancement of Science.

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The MICROSCOPE mission, with its goals of precise measurements and exploration of quantum physics, is emblematic of the enduring curiosity and dedication found within the scientific community. The journey from concept to reality is a testament to the combined efforts of scientists, engineers, technicians, and support staff, who work tirelessly to bring these grand ideas to life.

In a world where technological advancements are increasingly critical to national security and economic competitiveness, the CHIPS Act represents a strategic investment in America’s future. By strengthening our research capabilities and fostering an environment that encourages diversity and inclusion, this legislation sets the stage for continued innovation and leadership in the global arena.

The MICROSCOPE experiment is a prime example of the kind of groundbreaking research that could emerge from these investments. By seeking to measure deviations from the equivalence principle, the researchers are not only testing the foundations of our physical theories but are also pushing the boundaries of what we understand about the universe. The possibility of a WEP violation, while challenging, is also an invitation to refine our understanding of the laws that govern nature.

As we continue to explore the cosmos and probe the deepest realms of physics, the quest for knowledge remains a driving force. Whether through programs that encourage diversity in STEM or through experiments that test the fundamental laws of physics, the scientific community is committed to advancing our collective understanding and preparing us for the challenges of the future.
more young kids see themselves as liking science or being good at science. The organization will start releasing results in November and plans to have a complete report available in early 2022. Now that the lab kits have been disseminated, WS2 is working to put the instructions—which include teacher and student manuals and surveys—online, where they’ll be available for free use by instructors around the world. They’re also working on translating the documents into other languages, such as Swahili and Portuguese.

Meanwhile, the teams that conceived the initial kits are already beginning to envision future experiments that could focus on topics like computer science or artificial intelligence. And longer-term, WS2 leaders hope that the international relationships the organization is building will lead to future initiatives and even research exchanges with African researchers like Rolance and Elisadiki. “There’s different things that can arise from creating an international initiative that really tries to create these personal connections,” said Wendorot. “The problems that we’re facing… impact people that are not just in your local community, but really are in your global community. Finding ways that we can be collaborators across borders is really important.”

Jesse Kathan is a science journalist based in Berkeley, California.

Of the students the lab kits have reached, 70% are girls. CREDIT: WS2

So far, seven types of lab kits have been distributed to eight partner schools across Uganda, Kenya, Tanzania, Rwanda, and Ethiopia, reaching 1,400 students—about 70% of them girls.

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the conference advertised in an APS newsletter and thought it sounded like a great opportunity. “We’re working with non-binary or transgender scientists with similar career interests.” From Kaufman-Martin’s perspective, limiting attendees to women and gender minorities created a more welcoming environment. “Being in a physics conference where I was not only recognized and included, but people were actually saying ‘we want you here, as a non-binary person,’ was really exciting,” they say.

The conference also made Kaufman-Martin think a lot about the experiences of many women in physics. “Hearing some of the stories was pretty sobering,” they say. “It’s really hard to stay confident if everyone is telling you that you’re not good enough.” As Snider indicated, some environments are better than others at supporting young physicists through the standard frustrations of earning a graduate degree, like an experiment failing. For Kaufman-Martin, it’s vital to have a community “that can help you maintain confidence in the face of setbacks.”

“These people—friends and family and colleagues—still value you and reflect that to you,” Kaufman-Martin says. “It’s not about your performance.” That type of strong support, according to Snider, can also help normalize the challenges of graduate students’ and early career scientists’ experiences in physics. When people feel that their experiences and struggles are common and shared, “they’re likely to feel better—and this, in turn, can give them the confidence boost they need.”

Liz Borosan is a staff writer for APS News.
first woman to hold the position. As director, Merminga oversees nearly 2,000 people working on cutting-edge experiments, ranging from the Muon G-2 experiment, whose 2021 measurement of the muon’s magnetic moment may point to physics beyond the Standard Model, to the Long-Baseline Neutrino Facility currently under construction, designed to study properties of neutrinos that could help explain why the amount of matter in the universe was not zero— and why the universe exists at all.

Under her leadership, Merminga hopes to solidify FermiLab’s standing as a world leader in particle physics for decades to come. “We will do the definitive neutrino experiments here,” she says.

Merminga spoke to APS News about her life, career, and views on the future of particle physics. This interview has been edited for length and clarity.

**SC:** You’re originally from Greece. Can you talk about your early years? 

**Merminga:** I was born in and grew up in Chalandri, in a suburb of Athens. I can still remember many friends living in the area. I grew up playing in the street in front of my house with other kids. We would play tennis, football, and a game like hopscotch. I walked everywhere—to school, to the bakery, to the farmer’s market. Then I moved to a different school, and we were split into girls and boys. The girls would go to school in the morning Monday through Wednesday, and the boys would go in the afternoon. Then the next week, the schedule would swap.

**How did you decide to become a physicist?**

In Greece, at age 15, you have to decide whether to study the humanities or the sciences. By then, I knew that I loved physics and math. I enjoyed describing a physical phenomenon. So I really enjoyed describing a physical phenomenon with the language of math. I found that this was the ultimate form of elegance. I also liked that physics and math problems had a true answer that was not subjective.

My first exposure to science was through stories from my mother and grandmother about my uncle (George Dousmanis), who had a PhD in physics from Columbia University. He was legendary in my family, but he died very young, at age 37 (from a heart attack). I met him once when he visited from the US when I was two years old, but I have no memory of it. Later on, when I became a graduate student, I got to read some of his physics papers. I appreciated how excep- tional he was, and how unfortunate his untimely death was.

Also, at age 13, one of my middle school friends gave me a biography of Marie Curie written by her daughter Eva Curie. I just absorbed that book. Then, in high school, I read about居里夫人的女儿艾娃·居里. That set the stage, and I was drawn to physics through the language of math.

**What kind of high school did you go to?**

When I became a graduate student, I knew that I loved physics... This was the ultimate form of elegance. I also enjoyed describing a physical phenomenon with the language of math. So I really enjoyed describing a physical phenomenon with the language of math.

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**What are the big challenges right now in developing future accelerators?**

We’ve pushed accelerator performance in terms of higher energy, intensity, and efficiency. A grand challenge today is reaching higher energies using more compact machines. The ultimate breakthrough of our field would be to make plasma-driven accelerators (a method that would significantly reduce facility size).

A more near-term goal is to produce more efficient technology to create accelerators that use less energy and allow more progress on sustainable accelerators. Without upgraded technology, future colliders would consume enough power for a small town. What are some strategies people are working on to make sustainable accelerators?

People are starting to make more energy-efficient components, such as superconducting and radio frequency (RF) power sources. The design for the European Spallation Source (a neutron source under construction in Sweden) also collects the waste heat produced by the accelerators and then uses it to heat nearby buildings.

Future proposed colliders include a 100 TeV circular collider, linear electron-proton colliders like the ILC, and muon colliders. What’s your opinion on what the particle physics community should invest in?

For the health of our field, it is incumbent to pursue these design studies of all of these different types. But we still need to resolve significant technical and physics questions for each of these approaches. Fortunately, these approaches require similar research and development. For example, several of them require high field magnets and highly efficient superconducting RF technology. CERN has chosen already to pursue a 300 TeV future circular collider.

**By six o’clock in the morning, we were able to call people and tell them that the laws of particle violate mirror symmetry.**

Feynman bet against it $50-to-$1, and Felix Bloch told his Stanford colleagues he’d bet his hat.

“By six o’clock in the morning, we were able to call people and tell them that the laws of particle violate mirror symmetry.” Feynman later recalled. The universe, by a margin of roughly 1 in 10,000, really did prefer left to right.

In a landmark experiment, Chen-Shiung Wu showed that physics sometimes violated parity, proving Lee and Yang’s theory. Despite her instrumental role, Wu never received the Nobel Prize for her work—though Lee and Yang did. 

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Scientists Don’t Succeed in a Vacuum. Why Expect This Of Graduate Students?

Graduate student isolation existed long before the pandemic, thanks to go-it-alone culture in physics programs. Then as now, peer support groups can help.

BY ANDREA WELSH

I imagine you’re in a subway car, packed shoulder-to-shoulder with other riders. Do you feel isolated? If you are able to look around the people around you, you probably do. That’s because isolation isn’t solved by the presence of others; it’s solved by authentic connection with others. A crowded subway car makes you feel less alone.

It’s no different in PhD programs. For graduate students, isolation is a major symptom of an always-on, go-it-alone culture in physics programs. It promotes a sense of distance from work and leaves very little room for community. This culture, and the isolation it fosters, preceded the COVID-19 pandemic—but peer support groups can help reverse it.

Many Graduate Students in Physics Have Long Coped with Isolation

In the cultures of many graduate programs, students have learned to go-it-alone as a means of success. They work very long days, into evenings and on weekends, and when they’re not working, they’re still reachable by email, sometimes at all hours of the night. When I was a graduate student, I once received an email on December 24, when I was visiting family. When I didn’t respond right away, I received one on December 26, asking if I had seen the previous email.

Students also worried that asking for breaks, days off, by traditional metrics of success. Any deviation from the goals of marginalized backgrounds often feel isolation more acutely, in background and experience, but also identity. Those from students at US institutions, 34% had moderate or higher diagnosis of post-traumatic stress disorder. A full two-thirds students.

In a summer 2020 survey of nearly 3,500 graduate students at US institutions, 34% had moderate or higher diagnosis of post-traumatic stress disorder. A full two-thirds students. In a summer 2020 survey of nearly 3,500 graduate students at US institutions, 34% had moderate or higher diagnosis of post-traumatic stress disorder. A full two-thirds students.

Students' Sake

Support groups can also help students discuss and resolve interpersonal issues with faculty advisors, relationships that can be stressful and isolating for students. Research has shown that PI mentorship styles correlate strongly with graduate student mental health, and laissez-faire leadership is associated with significantly increased levels of psychological distress. In support groups, students can share experiences and advice—how one student has broached this type of peer support can transform the experiences of graduate student isolation existed long before the pandemic, thanks to go-it-alone culture in physics programs. Then as now, peer support groups can help reverse it.

Support Groups Can Protect Students from Isolation

There is no single type of support group—that’s a strength—but all good support groups aim to create a community for folks with similar perspectives, identities, goals, or needs. For example, many schools have a society for women in STEM, and many have LGBTQ groups, campus spiritual groups, and groups for students of a certain ethnicity. Graduate physics organizations can serve this purpose, too.

Over my own seven years as a graduate student, I belonged to multiple types of groups and even founded a few, including the Georgia Tech Society of Women in Physics, when I found support lacking. Support groups are powerful tools because students need time and space to connect with peers non-academically, in an environment where they’re valued as authentic, multi-faced human beings, rather than just by their research or identities. These spaces offer, first and foremost, the chance to find reprieve from work alongside peers who understand the stresses of an academic career. In these spaces, students can freely discuss things they’re feeling—and realize they’re not alone in them.

The types of challenges that support groups can address are diverse. For example, a student facing microaggressions may connect with others who face similar (unacceptable) challenges. An international student might feel a sense of comradery with other international students; a transgender student might discover a community of supportive peers in an LGBTQ group that extends across programs. For me, finding others with invisible illnesses, often exacerbated by the stresses of graduate school, helped me understand that I wasn’t the only one dealing with them.

Support groups can also help students discuss and resolve interpersonal issues with faculty advisors, relationships that can be stressful and isolating for students. Research has shown that PI mentorship styles correlate strongly with graduate student mental health, and laissez-faire leadership is associated with significantly increased levels of psychological distress. In support groups, students can share experiences and advice—how one student has broached difficult conversations with advisors, for example, or how another student has done career planning despite an advisor’s unrealistic expectations, and that, importantly, she’s not alone in her experience.

Even though a support group can serve first and foremost as a resource for comradery and community, they can also provide vital support for career-building. Many people in support groups are in similar stages of their professional career. This allows them to gain and share crucial feedback on job-finding that advisors—often older, and further from the job-search process—might be unable to share.

For students who plan to stay in academia, support group peers often navigate the same processes around the same time—applying for grants and fellowships, searching for faculty positions, or negotiating salaries—which can give students avenues of support for years to come. For a student seeking non-academic careers, support group peers can help one another market their skills effectively, share networking at the symposium, and prepare for a transition into a different work culture.

Faculty Must Proactively Back Support Groups—For Students’ Sake

Many faculty are deeply supportive of their students’ involvement in peer groups. But some faculty are not, which I’ve learned from students across schools. I’ve met students whose PIs took support groups as “time away from work” or a “waste of time” with both quotes—including personal time spent at events from moments over dinner to lunches. Once I organized a coffee discussion for the Society of Women in Physics, which was advertised clearly on the door of the department lounge. A professor, walking in to grab his coffee, loudly interrupted to ask, “Why are you all sitting around?”

We explained, but the damage was done. Multiple students had even been silenced for attempting to organize something about being away from the office too long and needing to go back. I didn’t see them at the next events.

Worse still, students facing this kind of hostility may have limited room for recourse. They may feel that they can’t bring up these issues with other department faculty, for fear of retaliation. After all, for students, years of effort are on the line—or even whether they’ll ultimately earn their PhD.

For students’ sake, departments and faculty in physics, and those in graduate programs more broadly, must do more to proactively back the creation and upkeep of student support groups. Students must be free to join and participate in groups that exist already, and—where networks have yet to be established—they must be empowered to create groups of their own that address their specific needs. Alongside access to high-quality mental health services, this type of peer support can transform the experiences of graduate students in physics.

It isn’t enough that some PIs choose to do the right thing; doing the right thing must be expected of everyone in a position of power in graduate programs. And neither is it enough that a group of students drifts around in the same PhD program. To feel connected, students must feel like part of a community.

After all, standing in a crowd of strangers probably won’t make you feel less alone—but having friends by your side just might.

Dr. Andrea Welsh is a postdoctoral researcher in mathematical physics at the University of Pittsburgh. She received her PhD in physics from the Georgia Institute of Technology in 2019. In August 2022, she co-facilitated a panel on mental health at the APS Advancing Graduate Leadership Conference.