Radiations

FALL 2022

The official publication of Sigma Pi Sigma

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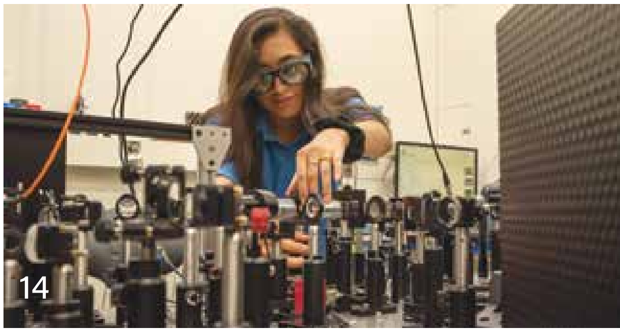

ON THE COVER

A space image captured by the Webb telescope, called the "Tarantula", contains fluffy, tan-colored nebula clouds, with rust-colored highlights, surrounding a black central area. Within that area, the focal point of the image is one large yellow star with eight long thin points. Multiple arms appear to spiral out of a cloudy tan knob, resembling a spider or a squid structure. Other blue and yellow eight-pointed stars, as well as distant galaxies, are dotted throughout the image.

Image credit: NASA, ESA, CSA, STScI, Webb ERO Production Team.

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EDITOR
Kendra Redmond

MANAGING EDITOR
Andrew Zeidell

CONTRIBUTING EDITORS
Brad R. Conrad
Kayla Stephens
Korena Di Roma Howley
Mikayla Cleaver

COPY EDITOR
Cynthia Freeman

ART DIRECTOR
Aaron Hansen

LAYOUT DESIGNER
Hyun-Joo Kim

SIGMA PI SIGMA PRESIDENT
Blane Baker,
William Jewell College

SPS PRESIDENT
Kiril Streletzky,
Cleveland State University

SIGMA PI SIGMA/SPS DIRECTOR
Brad R. Conrad

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Sigma Pi Sigma is an organization of the American Institute of Physics. It was founded at Davidson College, Davidson, NC, December 11, 1921. Member, Association of College Honor Societies. Contact us at sigmapisigma@aip.org; telephone: (301) 209-3007; fax: (301) 209-3082.

Letter from Sigma Pi Sigma President

Building Community through Service

by Blane Baker, Sigma Pi Sigma President and Professor of Physics, William Jewell College

Blane Baker. Photo by SPS.

As your incoming president, one of the common themes that I have heard recently is that campuses have become less active and more disengaged since March 2020—mainly due to the effects of the COVID-19 pandemic. As an educator for more than 25 years, I agree. While the shutdowns and limited interactions were necessary, I missed face-to-face communication with students and casual conversations with colleagues. I also missed talking in person with groups of schoolkids and local organizations. I, along with you, have felt the loss of personal interactions. Now, with the lifting of many restrictions, campus culture is beginning to return—but we have much work to do. How do we reengage our departments, campuses, and commuities?

Service is one of the most natural ways to develop camaraderie and build community. There are many reasons to serve. We engage with others because we are passionate about physics and astronomy, and we want to share that excitement and enthusiasm. We enjoy interacting with others and sharing our knowledge (and learning new things in the process). We have a desire to encourage the next generation of students and aspiring scientists. Alumni, students, and faculty are vital in building relationships and promoting service in physics and astronomy departments.

If you are in a department that has not done service recently, start small. Take a few minutes each week to gather those in your department and discuss a physics or astronomy topic and enjoy snacks together. Once you have some momentum, you might host a tutoring session for students in introductory courses. These are great ways to engage first-year students and to build fellowship between new and

Get Support for Inductions and Chapter Activities

Sigma Pi Sigma Chapter Project Awards of up to $500 are awarded to Sigma Pi Sigma chapters to support inductions or other engaging activities that include alums or promote Sigma Pi Sigma on campus or to the public. Learn more at **www.sigmapisigma.org/sigmapisigma/awards/chapter-project**.

advanced students. Participants will see that your department is committed to helping them thrive.

Additional activities might include a journal club where folks read articles and discuss them over lunch, or talks by guest speakers. Inviting students to talk about their research promotes local scholarship. Using resources like *GradSchool Shopper* magazine, the Careers Toolbox, and panels to discuss graduate school or career options provides opportunities for students to consider their future. Social events like game nights with pizza are always fun and stress relieving, too.

In addition to departmental service, service to the community is crucial. That's how we communicate science, and how we do science, to broader audiences. There are many ways to interact with your community—hosting large demo shows, visiting classrooms or after-school programs with hands-on activities, or giving campus tours—all of which can have lasting impact.

Not in a department? Contribute by interacting with local departments and your alma mater. Offer to participate in or host events. Connect departments, chapters, and students to local businesses and organizations. Mentor students. Donate equipment or other items for use in demo shows and after-school programs. Financial gifts are always welcome for purchasing supplies and small equipment, too.

If you can, invite others to visit your campus or place of work. Organize a demo show and encourage widespread participation. Invite local schools and youth organizations, and volunteer to interact with them in the future. So often young students have a genuine interest in science that, if not nurtured, can fade away by high school or university. Your service can help build their enthusiasm, motivation, confidence, and knowledge.

As a society, Sigma Pi Sigma has emphasized service since its inception at Davidson College in 1921. The original founders of Sigma Pi Sigma wanted a student group that honored outstanding scholarship, encouraged interest in physics at all levels, promoted service among fellow students, colleagues, and the public, and cultivated fellowship among students interested in physics and astronomy. By promoting these same values, we follow in their footsteps.

As you begin this academic year, I encourage each chapter to begin planning a Sigma Pi Sigma induction event. While these ceremonies recognize outstanding students as part of a national honor society, I encourage you to host other activities in conjunction. You might recognize student research, host a guest speaker, or introduce first-year students to the larger physics and astronomy community. Your department could host an open house and invite alumni. With planning, your induction ceremony can honor students who have achieved in physics and astronomy while engaging others who share the values of the society.

I challenge each of us to become advocates for our disciplines of physics and astronomy and to embrace service as part of who we are and what we do. ●

Be a Resource for SPS Chapters

Join the SPS and Sigma Pi Sigma Alumni Engagement Program—a database of participants willing to be speakers, panelists, tour guides, and mentors for SPS chapters. Learn more at **www.spsnational.org/programs/alumni-engagement**.

AIP

The American Institute of Physics is a federation of scientific societies in the physical sciences, representing scientists, engineers, educators, and students. AIP offers authoritative information, services, and expertise in physics education and student programs, science communication, government relations, career services, statistical research in physics employment and education, industrial outreach, and history of the physical sciences. AIP publishes *Physics Today,* the most closely followed magazine of the physical sciences community, and is also home to the Society of Physics Students and the Niels Bohr Library & Archives. AIP owns AIP Publishing LLC, a scholarly publisher in the physical and related sciences. www.aip.org

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Acoustical Society of America

American Association of Physicists in Medicine

American Association of Physics Teachers

American Astronomical Society

ACA: The Structural Science Society

American Physical Society

AVS Science and Technology of Materials, Interfaces, and Processing

Optica (formerly OSA)

The Society of Rheology

Other Member Organizations

Sigma Pi Sigma

Society of Physics Students

Connect with Sigma Pi Sigma

LinkedIn
https://www.linkedin.com/groups/142619/

Instagram
www.instagram.com/spsnational

AIP Foundation
foundation.aip.org

2022 Individual SPS Award and Scholarship Recipients

These awards and scholarships are made possible by the generous donations of ΣΠΣ members and friends of SPS. To join them in supporting student programs, please visit foundation.aip.org/student-programs.html.

SCHOLARSHIPS

Scholarships range from $2,500 to $6,000 and are awarded to individuals demonstrating excellence in academics and SPS participation, among other criteria. Learn more at www.spsnational.org/awards/ scholarships.

SPS Outstanding Leadership Scholarship

Sylphrena Kleinsasser
Lycoming College

NEW! Jack Hehn SPS Leadership Scholarships

Dan Fauni
University of the Sciences (merged with Saint Joseph's University)

Aidan Keaveney
Appalachian State University

SPS Leadership Scholarships

Mackenzie Gibbs
Rhodes College

Ameya Kunder
University of California Berkeley

Cielo Medina
Central Michigan University

Jaelyn Roth
Denison University

Annika Stare
Juniata College

LLNL-AIP Leadership Scholarships - Sponsored by Lawrence Livermore National Laboratory

Marta Celebic
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Allison Helferty
Juniata College

Olivia Kaufmann
Rhodes College

Natalie Lam
University of California San Diego

SPS Future Teacher Scholarship

Ian Carter
University of Wisconsin - River Falls

Peggy Dixon Two-Year Scholarship

Patrick Herron
Cleveland State University

Herbert Levy Memorial Scholarship

Priktish Rao Suntoo
Lycoming College

AWIS Kirsten R. Lorentzen Award

Kate Pletcher
University of Denver

Aysen Tunca Memorial Scholarship

Kayla Dickert
University of the Sciences (merged with Saint Joseph's University)

Science Systems and Applications, Inc. (SSAI) Academic Scholarship

Ronan Hix
University of Maryland, College Park

Science Systems and Applications, Inc. (SSAI) Underrepresented Student Scholarship

Alexander Pantoja
Texas Lutheran University

SPS AWARD FOR OUTSTANDING UNDERGRADUATE RESEARCH

Winners receive $1,800 in travel support to present their research at an AIP Member Society meeting, $500 for themselves, and $500 for their SPS chapter. Learn more at spsnational.org/awards/outstanding-undergraduate-research.

Winners

Ameya Kunder
University of California Berkeley

Hurum Tohfa
Bryn Mawr College

THE SPS SUMMER INTERNS

The SPS summer internship program offers 10-week positions for undergraduate physics students in science research, education, outreach, and policy with organizations in the greater Washington, DC, area. Students are placed in organizations that use the interns' energy and viewpoints to engage with the community and promote the advancement of physics and astronomy. The 2022 interns were able to be in-person this session, making for an extra eventful summer! Learn more at spsnational.org/programs/internships.

Justin Andre Avendaño
Stevens Institute of Technology
Society of Rheology/Soft Matter Kitchen Intern

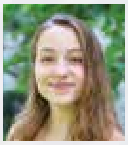
Divyansh Chamria
Colgate University
NIST Research Intern

Taylor Colaizzi
Washington and Lee University
NIST Research Intern

Lucy Corthell
Juniata College
APS Education & Diversity Intern

Gizem Doğan
Bowdoin College
Physics Today Science Writing Intern

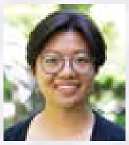
Katie Futrowsky
University of Maryland, College Park
AIP Mather Public Policy Intern



Emma Goulet
Saint Anselm College
AIP Center for History of Physics/Niels Bohr Library & Archives Intern

Benjamin Johnson
University of Virginia
Potomac LLC Machine Learning Intern

Aidan Keaveney
Appalachian State University
AIP Mather Public Policy Intern



Nicole Leung
Wellesley College
NASA Goddard Space Center Intern

Matangi Melpakkam
Bryn Mawr College
AIP FYI Science Policy Communications Intern

Anthony Olguin
University of Maryland, College Park
Space Telescope Science Institute Intern

Taylor Overcast
Union University
AAPT Teacher Professional Development Intern

Saksham Prajapati
University of Missouri - St. Louis
APS Public Engagement Intern

Janessa Slone
Embry-Riddle Aeronautical University, Prescott
SPS Science Outreach Catalyst Kit (SOCK) Intern

Valeria Viteri-Pflucker
Illinois Wesleyan University
NIST Research Intern

TEAM-UP TOGETHER SCHOLARSHIP

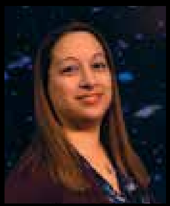
NEW!

The TEAM-UP Together Scholarship Program (TUTSP), developed by the TEAM-UP Together Lead Partners and administered by SPS, supports African American students in the pursuit and attainment of a bachelor's degree in physics or astronomy. These awards of up to $10,000 per year aim to reduce the financial barriers that prevent Black students from completing their undergraduate degree programs in physics and astronomy. For eligibility requirements and deadline information, please visit spsnational.org/scholarships/teamup.

Sigma Pi Sigma Members Help Capture and Study JWST Observations

The world's most ambitious space telescope, the James Webb Space Telescope (JWST), rocketed into space on December 25, 2021, less than one year ago. But already it's given us stunning images and a rich source of new data to explore. Here are three of the Sigma Pi Sigma members who've had a hand in making it happen.

Knicole Colón



Knicole Colón. Photo courtesy of Colón.

Deputy Project Scientist for Exoplanet Science, NASA's Goddard Space Flight Center

My passion for science fiction was a driving factor for me to become an astrophysicist and an expert in the discovery and characterization of exoplanets. I've been working at NASA's Goddard Space Flight Center since 2017. Before that, I worked at NASA's Ames Research Center on the Kepler mission. I also held postdoctoral positions at the University of Hawai'i and Lehigh University after earning my PhD from the University of Florida. I became a Sigma Pi Sigma member when I was an undergraduate at The College of New Jersey in 2007. It was the first professional society I ever joined, and it gave me such a feeling of pride!

These days, I'm part of the Transiting Exoplanet Survey Satellite (TESS) mission and the JWST project team. I've been part of TESS since shortly after its launch in 2018. My roles on the mission include facilitating communications between different mission partners and supporting the community in obtaining and using TESS data for all types of astrophysics projects. I joined the James Webb Space Telescope project team in 2019. In this role I support ground operations for the collection and analysis of exoplanet observations and also interface with the scientific and public community to present JWST's exoplanet capabilities.

I also enjoy studying extreme exoplanets—disintegrating planets, super puffy (low-density) planets, and planets on highly eccentric orbits. I want to learn more about how they formed and evolved and why the planets in our solar system are so different!

Kimberly Ward-Duong

Kimberly Ward-Duong. Photo courtesy of Ward-Duong.

Assistant Professor, Department of Astronomy, Smith College

As a child fascinated by the stars and growing up enchanted by stunning Hubble Space Telescope (HST) images in the 1990s, I had no idea I would someday use space telescopes for my own research. Today, I feel very fortunate to work with some of the first-ever data from JWST, NASA's flagship successor to the HST, which has exceeded the community's best expectations in its first few months of operation.

As an undergraduate at Northern Arizona University, I knew I wanted to study physics, mathematics, and astronomy, but I was unable to decide which area of physics to pursue. Becoming an enthusiastic member of the Astronomy Club and president of the Society of Physics Students helped kickstart my path into research, which at the time involved using the campus telescope to indirectly search for planets orbiting other stars (exoplanets) and their moons.

After completing an astrophysics PhD at Arizona State University and a postdoc in the Five College Astronomy Department at Amherst College, I began another postdoc fellowship at the Space Telescope Science Institute, headquarters of HST and JWST. My career has come full circle, as my current scientific research also involves searching for exoplanets—now using a method that takes direct images of the planet alongside its star. I am a member of the JWST Telescope Scientist and Early Release Science teams, and my involvement includes simulating realistic datasets, helping devise ways to remove starlight from our images to measure faint planet light, and measuring the atmospheric and orbital properties of distant worlds.

Christopher Stark

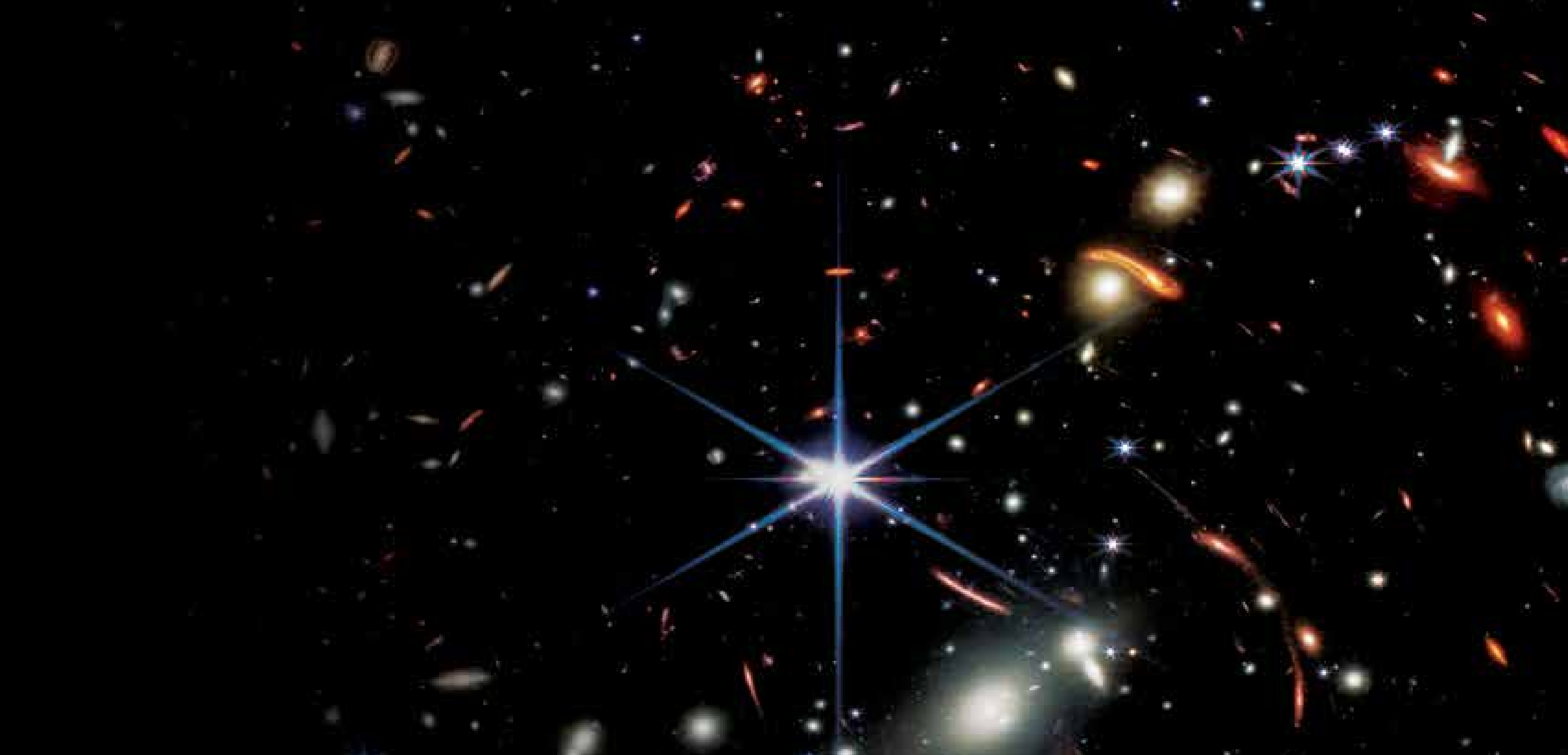
Christopher Stark. Photo courtesy of Stark.

Deputy Observatory Project Scientist, NASA's Goddard Space Flight Center

I found my calling as an astrophysicist while attending undergraduate physics classes at the University of Northern Iowa. It was there that I first heard about the field of exoplanets and immediately knew what I wanted to do with my life. I went on to study exoplanets and circumstellar disks at NASA Goddard while earning my Ph.D. in Physics from the University of Maryland. After graduating, I spent five years at the Space Telescope Science Institute as part of the Wavefront Team, helping to prepare the alignment of JWST's hexagonal mirror segments.

In my current role at NASA, I participated in the six-month commissioning phase of JWST to prepare the telescope for science observations. I now track JWST's performance and its ability to directly image exoplanets, as well as interface with the broader community as the mission goes forward. My research focuses on circumstellar belts of debris generated by asteroids and comets orbiting other nearby stars, and I'm excited to see what JWST will reveal when we image these other planetary systems.

When I'm not working on JWST, I'm helping to define NASA's future missions that aim to directly image potentially Earth-like planets. I evaluate the exoplanet science yield from future missions to guide and optimize their design and ensure that they can address major scientific questions for decades to come.



Known as Webb's First Deep Field, this image of galaxy cluster SMACS 0723 is overflowing with detail and includes the faintest objects ever observed in the infrared. Image credit: NASA, ESA, CSA, and STScI.

Embracing the Twists and Turns

by Lauren Balliet, Physics Graduate Student, Michigan State University

I never would have envisioned the path my career has followed thus far, but I wouldn't change any of it. It has shaped me into the person I am today.

Going into my senior year of high school, I knew I wanted to study astrophysics and eventually become a professor. As a first-generation college student, I relied heavily on what "experts" said was the appropriate educational path for my goals: Attend a four-year institution for a bachelor's degree, enroll in a graduate program for five to six years to earn a PhD, then get a job as a professor. At the time, the journey seemed arduous but straightforward.

I attended Clarion University of Pennsylvania, where I majored in physics with an astrophysics concentration and a minor in mathematics. It was a small program with few research opportunities, but I attended a Research Experiences for Undergraduates (REU) program at the University of Colorado Boulder. During the fall of my senior year, I started working on my graduate school applications.

Fast-forward to the following spring. My educational path took its first turn when I wasn't accepted by any graduate programs. I had quickly shifted to applying for jobs when my professors told me that Texas A&M University-Commerce (TAMUC) had an opening in their physics master's program. I researched the program, submitted my application, and was accepted within the week! I had one month to move from Pennsylvania to Texas.

Though it wasn't part of my plan, the people I met and the opportunities I had at TAMUC were pivotal to my career path. I got involved in a very active SPS chapter and was inducted into Sigma Pi Sigma. I learned about new pedagogical methods in teaching physics and practiced them as a graduate teaching assistant. My advisor, Dr. Will Newton, encouraged my research group to present at conferences from Texas to Lyon, France. That research led to my first professional publication.

Having built a strong CV at TAMUC, I felt confident applying to physics PhD programs a second time. But my applications were again unsuccessful. A friend sent me a job posting from Lycoming College, a small liberal arts college in Williamsport, Pennsylvania. The college was seeking an astronomy and physics laboratory manager and planetarium director. Looking over the job description, I felt as though I were reading my own CV! I applied, excited at the thought of moving close to home and pursuing my passions for teaching physics and physics outreach.

Lycoming became the second pivotal experience in my career path. I quickly became involved with the SPS chapter there and became advisor in the spring of 2020. I helped the chapter enter a new age, taking more students to conferences to explore networking opportunities. Our chapter focused on providing a welcoming environment and fostering a sense of community in our department. I feel very fortunate to have worked with so many amazing students.

During the fall 2020 semester I was an interim instructor in the department. Despite having no prior experience creating an entire course, I developed three courses simultaneously with a week's notice and navigated in-person instruction during a global pandemic. It was by far the most challenging experience I've had, both professionally and personally.

Balliet speaks with students during a planetarium presentation. Photo by Max Wilhelm, Lycoming College institutional videographer and photographer.

Lauren Balliet. Photo by Amber Elinsky, Lycoming SPS.

Unbeknownst to me, my students nominated me for a Sigma Pi Sigma service award, which I received in November 2021. It was truly an honor to be recognized nationally by Sigma Pi Sigma and SPS—especially because my students nominated me. In spring 2022, our chapter was awarded Organization of the Year at Lycoming College.

Through all of this, I promised myself that I would apply to PhD programs one more time, and my third round of applications led to three acceptances! I believe the roles I had and connections I made at Lycoming were key to my successful applications. I also now recognize that the previous rejections weren't a reflection of my ability in physics. Instead, my applications had neglected to convey who I am, my capabilities, and my contributions as a physicist.

I am now a graduate research assistant studying nuclear astrophysics at Michigan State University, the number one program in the country for nuclear physics. My path here has been anything but traditional, but I hope my story will inspire others to persist in their goals and welcome the twists and turns. If not for the unplanned chapters in my life, I would not have ended up where I am today—happily attending my top-choice physics PhD program. ●

Share news or a note with us at **www.sigmapisigma.org/sigmapisigma/radiations/member-news**.

SHARON GLOTZER

PROBING THE WHAT-IFS WITH STATISTICAL MECHANICS

by Kendra Redmond, Editor

Sharon Glotzer. Photo courtesy of Glotzer.

If you find quantum mysteries and astrophysical wonders far more captivating than statistical mechanics, spend a few minutes talking to Sharon Glotzer. You might change your mind.

"Statistical mechanics is incredibly powerful," Glotzer says. "If you tell me that you have a beaker of water containing a bunch of gold nanoparticles, without knowing too much about it I can predict whether the nanoparticles are likely to stay in the water, precipitate out, or self-assemble into some ordered structure."

But to understand a system in classical or quantum mechanics, you need all the details. In classical mechanics, she explains, you need to solve Newton's equations of motion, track what every single object is doing at every moment, and know what forces are acting on every object and how that affects all the other objects. Things get "really complicated really fast," she says.

In statistical mechanics, it doesn't even matter if the objects are atoms, nanoparticles, granular particles, tiny robots, self-propelled bacteria, or even birds. If a system is ergodic—meaning that it can, in principle, explore all available configurations (or microstates)—you can predict its collective behavior with statistical mechanics, Glotzer explains. Studying systems this way often reveals universalities or commonalities across different systems, scales, and phenomena.

The practical applications of statistical mechanics research are central to industries ranging from cosmetics to semiconductors, but Glotzer is most intrigued by the what-ifs. They're the focus of her research group at the University of Michigan, where she's chair of the chemical engineering department.

Using computer models, Glotzer's group looks at systems governed by statistical mechanics and then changes the rules or creates entirely new systems that don't exist yet, but could someday, to see what happens. It's kind of like playing God, she says. "You can say, 'These are my objects, and these are the rules by which they will interact with one another—show me what happens under this condition.'" If the code doesn't exist to do the desired simulation, her group writes it—and then makes it available for others to explore.

Researchers in her group can do millions of computer experiments in a fraction of the time it would take to do one of them in a lab. It's a way of scoping out research areas, guiding collaborators and the experimental community to where they might find the most exciting, intriguing, or useful results.

In June of 2022, Glotzer was awarded a Vannevar Bush Faculty Fellowship from the US Department of Defense, her second. These high-profile, single-investigator awards of up to $3 million support blue-sky research—research that doesn't map immediately to a real-world application but is likely to have transformative potential down the road.

Glotzer's fellowship research explores the notion that entropy sometimes acts like a chemical bond. That might sound a little strange. Entropy is a system quantity, as Glotzer freely admits. It doesn't make sense to talk about the entropy at a specific point in space, as you might a chemical bond. But it's sometimes useful to consider the effects of entropy at a local level, she says.

Glotzer gives the following example. Many nanoparticles are actually nanocrystals, shaped like multifaceted gemstones. These nanoparticles can self-assemble into even larger crystals. Her group discovered that in the absence of any interactions between these nanoparticles and with just one constraint—they can't overlap—a surprisingly diverse set of complicated crystals can emerge. "And it turns out that in those systems, when you have no explicit interaction energy, the only driving force is entropy," she says.

To explain how these particles organize locally, Glotzer and her team formulated a theory of entropic bonding. And they're using the Bush fellowship to explore what that theory reveals about how entropy works, why atoms and nanoparticles can both form crystals of such great complexity, and all the ways you can potentially mix and match atoms or nanoparticles to get crystal structures. "We're hoping that the theory of entropic bonding can even help us understand what happens when you have lots of forces between atoms or molecules," Glotzer says. The exploration could potentially change the way people think about—and teach—basic chemistry.

Although she's chair of the chemical engineering department, Glotzer is a proud physicist. She was inducted into Sigma Pi Sigma as an undergraduate physics major at the University of California, Los Angeles, and earned a PhD in physics at Boston University. After graduating, she worked at the National Institute of Standards and Technology (NIST) in Maryland, eventually cofounding and directing the NIST Center for Theoretical and Computational Materials Science before moving to the University of Michigan as a professor.

"I work with PhD students who come from chemical engineering, chemistry, physics, material science, macromolecular science and engineering, computer science, and mechanical engineering—all of these different disciplines," Glotzer says. "Physics underlies all of it." If she had to go back in time, she'd still major in physics. That's because of the subject matter and because "physicists learn how to see past all the tiny details that make different systems different, and see instead how they are the same."

Glotzer receives so many invitations to give lectures and seminars that she can't possibly accept them all. But she always says yes to those that come from graduate students. It brings back the excitement of being a student and meeting the authors of papers who inspired her own curiosity and research trajectory, she says. "I'm still having so much fun doing science, just like when I was a student." ●

To hear what sparked Sharon Glotzer's interest in science and learn more about her research, check out her 2021 interview with *Quanta* magazine in their podcast, *The Joy of X*. **www.quantamagazine.org/sharon-glotzers-deep-curiosity-about-order-from-chaos-20210322**

Is there a Sigma Pi Sigma member you'd like to see featured in a Member Spotlight? Let us know at **sps@aip.org**.

Rolke prepares to board SOFIA. Photo by Coral Clark, SETI Institute.

LESSONS FROM THE STRATOSPHERE:

AN AIRBORNE ASTRONOMY AMBASSADOR SOARS ABOVE EARTH ABOARD SOFIA

by Korena Di Roma Howley, Contributing Editor

"It was the darkest sky I have ever seen." Educator Susan Rolke was more than 38,000 feet above the Earth, looking out at the world from the cockpit of the flying observatory known as SOFIA. The view of the black Pacific Ocean below and the stars and Milky Way above, she says, will always stay with her.

For Rolke, who grew up in the small town of Keene, New Hampshire, the sight of the Milky Way in the dark night skies first sparked her interest in astronomy. Though she avidly read everything she could on the subject, she only signed up for a physics class in her senior year of high school to follow the lead of fellow college-bound students. She assumed it would be like other science classes. It wasn't.

"Up until that point, science was a lot of memorization," she says. "But with physics you really had to think, and it wasn't necessarily intuitive … I enjoyed the challenge that it presented. I enjoy pondering the what-ifs and what-could-bes. Physics was really looking at how the natural world worked via the big picture. I fell in love with it."

Rolke received an academic scholarship to Keene State College, where she studied math and physics and was inducted into Sigma Pi Sigma in 1992. Today Rolke teaches physics and chemistry at a small rural high school, where she enjoys bringing the excitement of science—and especially physics—to her students through the use of cooperative learning, hands-on labs, and whiteboard sessions. "Teaching them is exhilarating," she says. "I'm always striving to make the class relevant to their lives and to ignite their interest in science."

In 2020, Rolke was selected to take part in the SETI Institute's NASA Airborne Astronomy Ambassadors (AAA) program, created to provide professional development to middle school, high school, and community college science instructors. Following the program, instructors communicate current, NASA-enabled research to their students using a science curriculum model created by AAA program staff at the SETI Institute. The goal is to engage students in STEM and inspire pursuit of science-related careers.

Those selected for the highly competitive program receive astrophysics and planetary science training through a two-week curriculum and participate in a one-week immersive experience. For Rolke, that experience was flying aboard the Stratospheric Observatory for Infrared Astronomy (SOFIA), which soars above Earth's infrared-blocking atmosphere to study cosmic magnetic fields, the origin of cosmic rays, and other phenomena with a 2.7-meter (106-inch) reflecting telescope and other instruments.

After learning about SOFIA and infrared astronomy, Rolke was scheduled to attend a summer workshop and fly on the aircraft in June 2020. The COVID-19 pandemic, however, put the plan on hold. With the aircraft grounded, SETI worked to provide other opportunities for the program's participants. Rolke submitted the winning art for a mission patch design competition, attended a one-day virtual workshop, and met with SOFIA's flight crew via Zoom.

When she taught the SETI program in the fall, Rolke wasn't able to include firsthand information about SOFIA as planned. Still, she enjoyed sharing the program with her students. "They were among the lessons my students remembered most, despite the fact that our school went remote halfway through the two-week curriculum."

In June 2021, Rolke learned that she would finally fly on SOFIA. Flight week took place at Armstrong Flight Research Center in Palmdale, California, where she attended preflight mission briefings before each of her two overnight flights. During the official crew briefing, the group went over anticipated weather conditions at different altitudes, the flight plan, and the objects that would be observed. Rolke and her fellow AAAs then made their way to the aircraft and took their seats at the educators' console, which has a series of computer screens showing increasing magnification and detailed information about the telescope, altitude, and temperature.

"Each overnight flight was spectacular in its own way," Rolke says. The first flight was over the Pacific and lasted eight and a half hours. The second flight, over the US, lasted nine and a half hours.

Shortly after takeoff, Rolke was invited to sit with the telescope operator, who walked her through the telescope operation. Once the telescope door was open, she assisted in the systems check, then input the coordinates for the first object of the night and updated them periodically. "It was really interesting to see the telescope move when we encountered a little turbulence," she says. "However, in reality it was the plane that was moving around the telescope."

She later learned that she was the first AAA to operate the telescope. Later in the flight, she spent time with the researchers, who explained the instrument panels at their stations and the data they were collecting using FORCAST, Cornell University's faint object infrared camera for the SOFIA telescope.

Rolke also spent time in the cockpit with the flight crew, where she learned about the engineering controls and flight path and got her unforgettable glimpse of the night sky above the Pacific Ocean.

For the second flight, Rolke sat in the cockpit during takeoff. "None of my prior flying experiences compared to this," Rolke says. "The view was amazing, with the sun setting as we flew over Edwards Air Force Base and saw where the space shuttles had landed. Later, Las Vegas was visible as a small, brilliant dot in the desert."

In addition to the flights, the AAAs met with members of the flight crew over dinner to hear their stories and toured the instrument lab to learn about SOFIA's instruments.

Rolke's winning mission patch design. Photo courtesy of Susan Rolke.

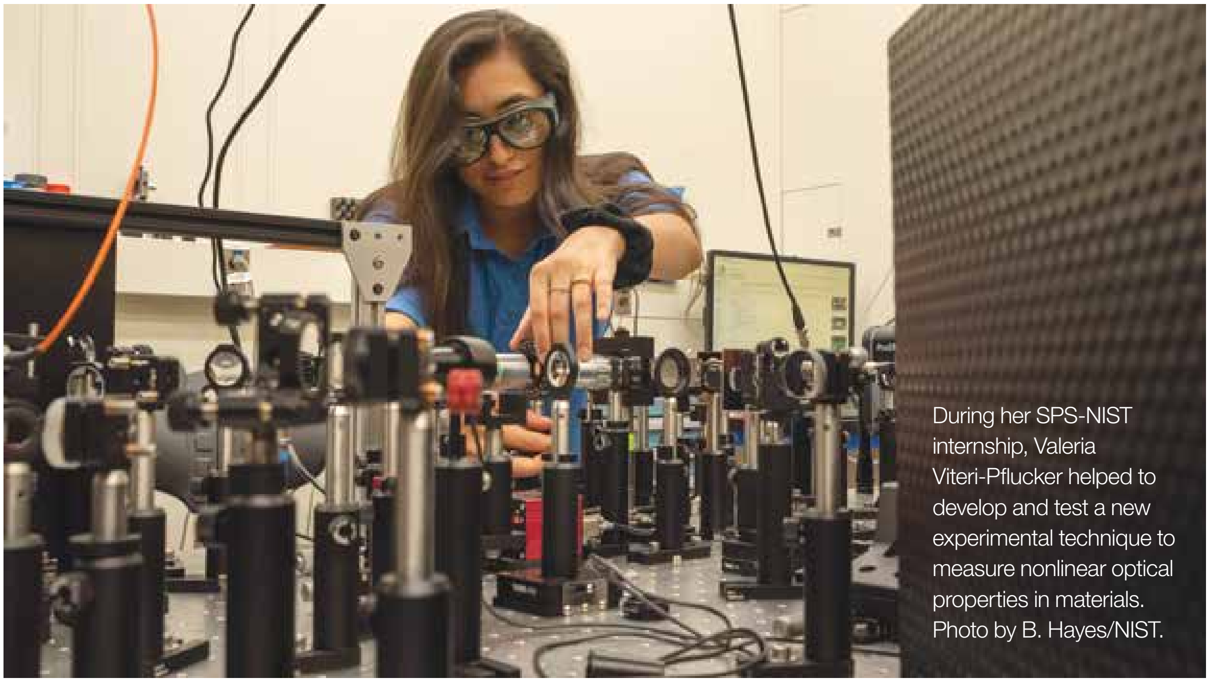
Rolke sits in the mission director's chair. Photo by Coral Clark, SETI Institute.

"My time at NASA learning about SOFIA was an incredible experience," Rolke says. "I gained so much knowledge to share with my students. I only wish I had more time there to learn."

In addition to her AAA experience, Rolke has participated in other professional development programs. In 2009 she attended a weeklong field class in Makoshika State Park through Montana State University (MSU) in Bozeman. The class is known as Dino Camp to students in the science education master's program. In 2011 she spent a week in Glacier National Park through another program at MSU, and in 2015 she attended a three-day teacher workshop at McDonald Observatory in Fort Davis, Texas, for which she took part in workshops and night observations.

Rolke feels fortunate to have been able to pursue her interests and bring back what she's learned.

"These professional development opportunities have allowed me to develop a more cohesive, big-picture understanding of the world around us and the ability to draw on examples from my experiences when in the classroom," she says. "I confess that I get really excited whenever I have the opportunity to share my experience on SOFIA. That enthusiasm and excitement is contagious. Being able to speak firsthand about the current research being conducted by SOFIA makes science interesting and real to my students." ●



During her SPS-NIST internship, Valeria Viteri-Pflucker helped to develop and test a new experimental technique to measure nonlinear optical properties in materials. Photo by B. Hayes/NIST.

WHAT'S A PHYSICIST?

MY SUMMER AS A STUDENT INTERN AT NIST

by Valeria Viteri-Pflucker, 2022 SPS-NIST Summer Intern and Graduate Student, University of Rochester

Valeria Viteri-Pflucker. Photo by SPS.

At the age of 13, I had firmly decided that I wanted to be a particle physicist, whatever that meant. All I knew is that I wanted to play with subatomic particles and was particularly fascinated by the idea of antimatter. Whenever I'd tell my parents or friends this goal, they'd inevitably ask what a particle physicist does, since they'd never met one. Amusingly enough, I didn't really know either, but that didn't matter.

Fast-forward to where I am now. I earned a bachelor's degree in physics from Illinois Wesleyan University in May, and this fall, I am beginning my graduate journey with a PhD program in optics at the University of Rochester. During the summer, I was one of 16 students participating in the SPS internship program in the Washington, DC, area, and I was one of three stationed at NIST. For many years now I have been trying to answer the question of what a physicist *does*. This summer fundamentally shaped my answer to this question.

Doing Physics

For my internship project, I worked with Jared Wahlstrand in NIST's Nanoscale Spectroscopy Group, helping to develop and test a new experimental technique to measure nonlinear optical properties in materials. By optical properties, I am talking about how the material slows down and absorbs light of different colors. By *nonlinear* optical properties, I mean how this slowing and absorbing depends on the intensity of the light. The experiment I helped develop and test uses a form of holography, a technique that records light waves and later reconstructs them to measure small changes in a light pulse's properties. It should yield higher precision than other current methods, extract information on a wide range of colors in a single measurement, and work on very small pieces of material.

When I think of optics, I usually envision lasers, mirrors, and lenses scattered atop an optical table (that's a table holding lots of optical equipment while minimizing vibrations that would disturb the experiment). Nowadays, researchers are interested in placing all those optical components onto a tiny chip, an approach known as integrated optics.

The ultimate goal is to create miniature optical circuits like the miniature electrical circuits that revolutionized electronics by making possible laptop computers and pocket smartphones. Using photons instead of electrons as a medium of communication opens doors for even faster processing, greater bandwidth, and lower amounts of signal loss.

Optical circuits contain important components known as wave guides through which light travels. Engineers want to select the best-performing material to use as the wave guides. A material's nonlinear optical properties can enhance the functionality of the circuit but can also be detrimental to its operation. To choose the best material for the job and to model these systems well, these nonlinear properties need to be well measured. During the summer, we were working on making those precise measurements.

As a first material, Wahlstrand asked me to measure the optical properties of gallium phosphide, an orange/gray semiconductor that shows promise in integrated optics. Its nonlinear absorption properties have not been measured at many wavelengths of light.

Our measurement is based on what is called a pump-probe spectral interferometry experiment. In a pump-probe experiment, a short laser pulse excites a material and we "probe" it with a white light pulse (which is actually a lot of colors of light together) to see what the energized material did with the different colors of light. This technique allows us to measure how much of each color of light was absorbed and how much each color is delayed by the excited material.

After a lot of work, we got the experiment up and running! In gallium phosphide we observed nonlinear absorption at the wavelengths we expected, and the technique was sensitive enough to measure very small effects. We also saw nonlinear refraction, in which light pulses experienced an extra delay due to the actions of the pump pulse. The amount of delay depends on the pulse's color in a way that doesn't seem to match a simple theory, suggesting a newly observed optical effect or an unforeseen problem with the measurement scheme.

Building confidence in the technique will require doing measurements on other materials whose nonlinear properties are well known. Overall, the initial results are promising. If the technique proves itself, it will be used on other materials, particularly ones where large samples are hard to make.

During the summer, I needed a lot of help understanding how to use various laboratory equipment and how such equipment works on the inside, so I received one-on-one mentoring in the lab to help me develop experimental skills. That was what I really wanted for my summer, and I had a great time in that regard. I also got to learn about what some physicists do. I knew physicists had to be fantastic problem-solvers, but I hadn't truly witnessed that in action. In the process of setting up and testing the technique we developed, there were many obstacles. The breadth of problems experienced was rivaled only by the breadth of solutions tried, and something went wrong every day—sometimes every hour.

It wasn't only optics and physics equipment. Virtually everything in the lab interfaces with a computer in some way. Wahlstrand had written code to have computers control other computers, which in turn controlled a lot of our lab equipment. Everyone in the lab must be a little bit engineer, a little bit computer scientist.

Meeting Physicists

Of all the internship programs I've participated in, applied to, or read about, the SPS program is unique. The diversity of physics and astronomy shines through. Each intern does something completely different from everyone else, and each works at a different place. Despite that, we all live in the same dorm and share our experiences. Collectively, we worked in science policy, physics outreach and diversity, science writing, the history of physics, physics and astrophysics research, and machine learning.

What I witnessed from this group is that doing physics means more than doing research. I'm very happy with the work I did in the lab, but I'm also glad I had the experience of thinking about the education side of physics and the science communication side of physics. It seems physicists wear many hats.

The 2022 SPS interns pose with SPS staff at the American Center for Physics. Photo by SPS.

What *Doesn't* a Physicist Do?

I think the confusion expressed by my friends and family, and especially myself, about what physicists do is much more justified than I would have expected. Research scientists work on a wide array of incredibly specific problems throughout the course of their careers, and all of them have developed their own unique toolboxes to field the problems they have.

In addition, there aren't that many physicists. Each year in the US around 9,000 people earn an undergraduate degree in physics. From there roughly half go to graduate school, and half go to the workforce. A lot of graduates go to the private sector for engineering or computer software. Not surprisingly, we do a lot of different things.

I'm very happy that this internship reaffirmed that I really enjoy the research process. I've been curious about nonlinear optics for a long time, and this was the first time I got to interact with it directly. I'm excited for the next chapter in my life after NIST and am grateful for the experiences it has afforded me. ●

This piece is adapted from a blog post of the same name published on *Taking Measure*, the official blog of the National Institute of Standards and Technology (NIST). Reprinted with permission.

The SPS Summer Internship Program

The SPS internship program offers 10-week, paid positions for undergraduate physics and astronomy students in science research, education, outreach, and policy. The program is made possible in part by the generous contributions of Sigma Pi Sigma members and friends.

Learn more and give at **foundation.aip.org/student-programs.html**.

Get details and apply at **www.spsnational.org/programs/internships**.

About NIST

Part of the US Department of Commerce, NIST's mission is to promote US innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. Learn more at **www.nist.gov**.

FEATURE

CELEBRATING GLASS

by Brittney Hauke, PhD Candidate in Materials Science and Engineering, Penn State

It's the International Year of Glass (IYoG)! The year 2022 was designated as such by the United Nations to promote and celebrate the rich history of glass, its value to humanity, and the possibilities it holds for the future.

Glass has played an important role in human history for millennia. Glass beads dating back more than 4,000 years have been found in what was then Mesopotamia, and glass vessels seem to have emerged in Egypt at around 1,500 BCE. Glass has been and continues to be vital to the advancement of science and technology and the betterment of life for humanity.

Through glass windows we can view the outside world while staying safe from the elements and predators. Glass bottles preserve our food and beverages. Without the development of glass lenses, many readers wouldn't be able to make out the letters in this article. And humankind would know little about the universe at its largest and smallest scales without the views provided by microscopes and telescopes. Glass has made lasting impacts on society through its use in art and religion as well, in forms such as glass blowing, bead making, stained glass, and glazes.

Glass plays such a critical role in life today that it's often overlooked. But then why celebrate glass now, in 2022?

"This year's worldwide celebration of the United Nations–declared International Year of Glass—the only material in UN history so honored—gives exceptional credence to recent proclamations that we have entered the Age of Glass and that glass is the quintessential nanotech material," says L. David Pye, emeritus dean and professor of glass science at Alfred University and an organizer of the IYoG.

Some scientists have dubbed the present era the Glass Age because we're harnessing the unique properties of glass to tackle some of the world's most imminent problems. Cutting-edge areas of glass research include containing nuclear waste, making safer batteries, biomedical applications ranging from soft tissue regeneration to implants and bone regrowth, electronic and ionically conductive glasses, and more durable glasses and glass ceramics. Glass even helped slow the COVID-19 pandemic: vaccine storage vials couldn't withstand the storage temperatures required for COVID-19 vaccines, so novel glass ones were created.

Celebrations marking the IYoG have been happening all year across the world. The opening ceremony at the Palace of Nations in Geneva, Switzerland, in February 2022 included presentations by glass historians, scientists, artists, and engineers. In the United States, the largest celebration was the National Day of Glass Conference, hosted in Washington, DC, in April. The conference featured talks by experts in the North American glass industry, the art community, government agencies, and educational systems.

Although 2022 is coming to a close, it's not too late to celebrate! Take a class or watch a demonstration of glass blowing or another glass art form; visit a museum to see the colorful history and evolution of glass; or browse the resource list and check out the latest on glass science. ●

A sodium aluminosilicate glass sample Hauke synthesized. Photo courtesy of the author.

Glass Science Resources

- Physics World (June 2022), https://physicsworld.com/a/celebrating-the-international-year-of-glass-the-june-2022-issue-of-physics-world/.
- ACerS Bulletin (2022), https://ceramics.org/publications-resources/the-bulletin-of-the-american-ceramic-society.
- Glass: Then and Now—historical journal articles published by the American Ceramic Society, https://ceramics.org/gtan.
- IYoG opening ceremony, https://media.un.org (search "International Year of Glass 2022").
- National Day of Glass, https://ceramics.org/event/national-day-of-glass.
- GEEX Talks 2022–2023: Expanded Glass Histories, https://geex.glass/programming/geextalks/.

Brittney Hauke. Photo by SPS.

My Glass Research

Glass is a noncrystalline and nonequilibrium material. "Noncrystalline" means that it has a long-range disordered structure, while "nonequilibrium" means that although it appears solid on a short time scale, glass continuously relaxes toward its supercooled liquid state. I study this relaxation because it can change the structure of a glass, and thus its properties.

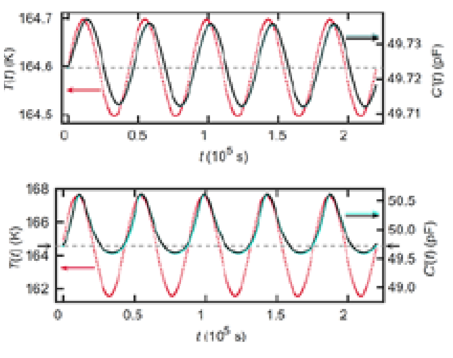
My research focuses on relaxation in glasses that are used for industrial applications. We're trying to better understand relaxation via experiments and tie our findings back to current theories.

GLASS AGES IN MATERIAL TIME

by Christine Middleton, Physics Today

Follow a tour guide around a European city and you're likely to hear the tale that old cathedral windowpanes appear uneven because over hundreds of years, the glass has slowly flowed toward the bottom of the pane. That story is just a myth; such flow in silica would require at least geologic time scales. But glassy materials, molecular and otherwise, do slowly evolve toward elusive equilibrium states—a process known as aging. And because they're out of equilibrium, the process is nonlinear and history dependent, making the aging system's behavior hard to model or predict.

Like many physical processes, however, a glassy material's response can be linear when it's subjected to sufficiently small perturbations. In the 1970s, researchers proposed that such a material's linear response—which can be described by existing theoretical frameworks—could also be used to understand its hard-to-capture nonlinear behavior. By their reasoning, if the same thermal rearrangements were behind the system's evolution in both regimes, then the same response function should describe both. But in the nonlinear regime, the dynamics are slowed down and the laboratory time must be replaced by a so-called material time that proceeds at a rate that reflects the state of the sample.



Credit: B. Riechers et al., ***Sci. Adv.*** 8 (2022).

Subsequent theories have relied on the material-time framework to connect linear and nonlinear glass aging, even though the existence of such a time has never been directly validated by experiments. Now Birte Riechers and coworkers at Roskilde University in Denmark have made that connection in a glass-forming molecular liquid.[1] After performing a series of careful measurements to determine the material's response to small changes in temperature, they were able to accurately, and with no fit parameters, predict its behavior after larger temperature jumps.

In their first set of experiments, the researchers subjected a thin layer of the liquid to temperature jumps and tracked its evolution after each one. They measured the sample's capacitance at 10 kHz as a proxy for its configurational evolution. The experiments were time consuming because the sample could take days or even weeks to equilibrate after a jump. They were also precise: a Peltier element kept temperature fluctuations to less than a millikelvin, and an ultraprecise capacitance bridge enabled resolution at the level of a hundredth of a picofarad.

The researchers determined the sample's linear-response function by observing its evolution after small temperature jumps of less than 1 K and as small as 10 mK. Then they put the function to the test. The top graph in the figure confirms that the researchers were indeed observing the linear regime—the change in the temperature (red) produces a proportional change in the measured capacitance (green)—and demonstrates that the response function (black) could predict the sample's behavior. The bottom graph shows the prediction of the response function after incorporating the material time. The larger-amplitude temperature oscillation brought the sample outside the linear regime, but the prediction and data still closely agree.

Deviations between the data and predictions began to appear when temperature jumps reached about 2.5 K. Based on that behavior, the researchers believe the material likely has two nonlinear aging regimes: an intermediate one, in which the same relaxation mechanisms are at play as in the linear regime, and a more extreme one, in which other processes contribute to the material's response. ●

For a more in-depth discussion of this research, see the Physics Today *article of the same name that appeared in the May 2022 issue,* ***https://doi.org/10.1063/PT.3.4995***.

Reference

1. B. Riechers et al., "Predicting Nonlinear Physical Aging of Glasses from Equilibrium Relaxation via the Material Time," *Sci. Adv.* 8 (2022), DOI: 10.1126/sciadv.abl9809.

In honor of the International Year of Glass, *Radiations* is pleased to share this *Physics Today* article from March 29, 2022.

Ancient NANOTECHNOLOGY

by Brittney Hauke

The Lycurgus Cup is a fourth-century Roman glass chalice that depicts a scene involving King Lycurgus of Thrace. The cup changes colors depending on how it's viewed: It appears jade green in bright, direct light and when lit from the front. When lit from the inside or back, most of the cup appears blood red, with the king's body taking on a slightly different shade. This is an example of dichroic glass and was created by adding nanoparticles of silver and gold. Did the Romans know exactly what they were doing, or is the effect due to accidental contamination? Unfortunately, that answer seems to have been lost to time.


The colors of the Lycurgus Cup depend on how it's viewed. Photographs ©The Trustees of the British Museum.

FEATURE

TEAMING UP FOR CHANGE

by Kendra Redmond, Editor

It's been two years since *Radiations* highlighted the work of TEAM-UP, a task force convened by the American Institute of Physics (AIP) to study why African Americans are dramatically and persistently underrepresented in physics and astronomy.[1] In 2020, TEAM-UP published "The Time is Now," a report identifying two overarching reasons for the disparity—historical injustices and unsupportive environments—and calling on the community to at least double the number of physics and astronomy bachelor's degrees awarded annually to African Americans by 2030.[2]

Now, through a collective initiative called TEAM-UP Together, SPS and other national physics and astronomy organizations are pooling their resources and expertise to advance this goal. Currently, the lead partners in TEAM-UP Together are AIP, SPS, the American Association of Physics Teachers, the American Astronomical Society, and the American Physical Society. They are also engaging important and especially relevant organizations, such as the National Society of Black Physicists in this work.

"We want to leverage the resources, tools, expertise, and experience that all of these organizations bring to the community," says Arlene Modeste Knowles, the TEAM-UP Diversity Task Force project manager. The organizations have worked independently on many different projects to increase diversity in physics and astronomy; TEAM-UP Together aims to harness their efforts for collective impact, says Modeste Knowles.

The initiative has two main components: game-changing scholarships for African American undergraduates majoring in physics or astronomy and funding for departmental efforts that yield successful outcomes for African American undergraduates in those fields. In April 2022, the Simons Foundation and Simons Foundation International awarded a $12.5 million five-year grant to the AIP Foundation to implement this plan. Much of that money will go directly to supporting students.

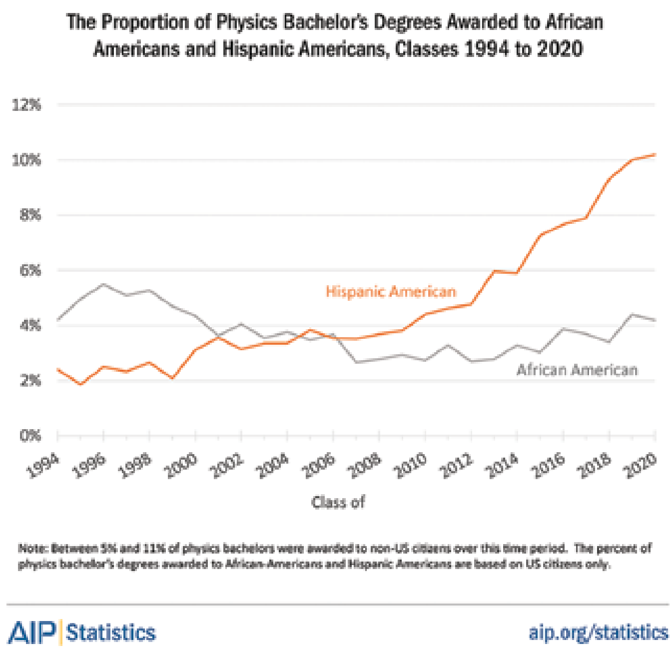
One of the key TEAM-UP findings is that "financial stress is particularly high for many African American students given the documented enormous racial wealth disparities in the US." TEAM-UP Together hopes to directly impact retention with $10,000 scholarships for African American/Black students majoring in physics or astronomy at accredited higher education institutions. The scholarships are for one academic year, and awardees can reapply each year they're an undergraduate for up to five years.

Scholarship applications are being accepted on a rolling basis for 2022, and TEAM-UP Together will support up to 37 scholars this academic year. The scholarships aim to ease the unjust burden on African American physics and astronomy majors to balance demanding coursework, time-consuming and often low-paying jobs, and other obligations, says Modeste Knowles.

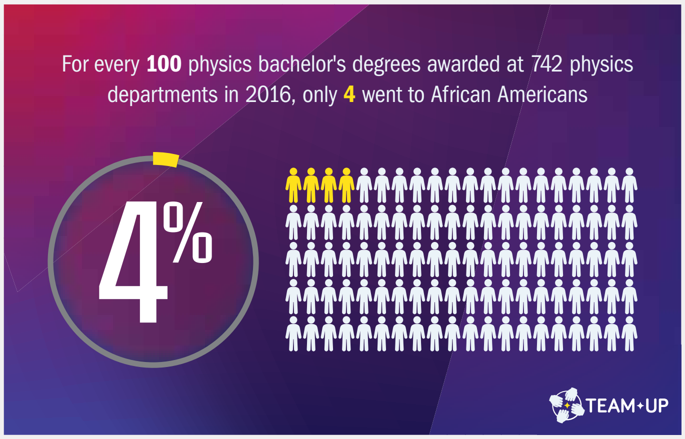
Another key TEAM-UP finding is that physics and astronomy departments are often unsupportive environments for African American students. TEAM-UP found that fostering a sense of belonging and physics identity among African American students is vital to keeping them in the major, as is effective teaching and use of a strengths-based (rather than deficit-based) approach to academic support.

Since releasing its findings in 2020, TEAM-UP has been educating departments on how to better support African American students. Teams from nearly 50 US physics and astronomy departments have committed to creating more supportive environments for African American students, attending TEAM-UP implementation workshops, and developing strategic action plans to improve outcomes for African American students in their departments. TEAM-UP Together will build on this work and offer financial support for effective departmental efforts and programs. The lead partners are currently inventorying their resources and formulating a cooperative approach to supporting programs that improve outcomes for African American students. More details on their efforts will be forthcoming.

The underrepresentation of African American students in physics and astronomy is "not a matter of their capability, it's



An increasing percentage of African American students are earning earning bachelor's degrees in the US, but the percentage earning physics and astronomy bachelor's degrees has remained persistently and inexcusably low. Credit: The AIP Statistical Research Center.



a matter of resources and encountering people and environments that are barriers to participation," says Modeste Knowles. She says that some students are discounted from these fields in introductory classes because they don't come in with a strong math and science background—but that's no fault of their own, it's often a result of structural inequality and racism. The academic community needs to change its mindset to one of nurturing the curiosity and potential of interested students and making it a priority for them to succeed in the majors. "But until we change hearts and minds, we need to start changing policies, procedures, and practices," says Modeste Knowles.

References

1. K. Redmond, "A Problem with Physics," *Radiations*, Fall 2020, 11, www.sigmapisigma.org/sigmapisigma/radiations/fall/2020/problem-physics.
2. TEAM-UP, *The Time is Now: Systemic Changes to Increase African Americans with Physics Bachelor's Degrees in Physics and Astronomy* (College Park, MD: American Institute of Physics, 2020), www.aip.org/diversity-initiatives/team-up-task-force.

TEAM-UP Together Scholarships for African American/Black Undergraduates

Applications for $10,000 TEAM-UP Together scholarships are being accepted for the 2023–24 academic year.

Application deadline: March 15, 2023.

- Awards are for current African American/Black undergraduate students who are physics or astronomy majors or prospective majors at accredited US colleges and universities.
- Scholarships will be awarded based on need and commitment to pursuing a bachelor's degree in physics or astronomy.
- Students are welcome to reapply each year they are eligible.
- Funds are for tuition, fees, books, supplies, and equipment necessary for pursuing a bachelor's degree.

For details and to apply, visit **www.spsnational.org/scholarships/teamup**.

Team up with TEAM-UP

You can help make physics and astronomy more supportive of Black students, even if you're not currently in a department. Below are some ideas—if none of them resonate with you, draw on that problem-solving nature to come up with more!

Educate yourself

Read the TEAM-UP report and watch archived TEAM-UP webinars that dig into its findings. Both are available at **www.aip.org/diversity-initiatives/team-up-task-force**.

Educate others

Share the TEAM-UP report with others in the community who might benefit from its findings and recommendations.

Promote the TEAM-UP Together scholarship

Share TEAM-UP Together scholarship information with your alma mater, local departments, undergraduate interns at your workplace, and local high school physics teachers. Encourage eligible students you know to apply at **www.spsnational.org/scholarships/teamup**.

Support your colleagues of color

Suggest colleagues of color for Member Spotlight and Hidden Physicist features in *Radiations* by emailing **sps@aip.org** and for other recognition opportunities.

Check in with physics and astronomy departments

While sharing information on the TEAM-UP Together scholarship, ask questions: Do you have any faculty of color? Do you have any students of color? What efforts are underway to improve the department culture and recruiting efforts to this end? What help do you need?

Reach out to historically Black colleges and universities (HBCUs) and predominantly Black institutions (PBIs)

Do you have relevant internships or job opportunities? An interesting career story or research finding? A cool lab? Expertise in Python, machine learning, spectroscopy, or another skill or tool? Contact physics and astronomy departments and offer to give a talk, host a workshop, or lead a lab tour, in person or virtually.

Voice your support for TEAM-UP Together

If you belong to a TEAM-UP Together lead partner organization (SPS, AAPT, AAS, or APS), send them a note of support and ask how you can help, or send a letter to the editor of one of their publications to show your support more publicly.

Look at your own spaces

Look around, whether you're a department chair, business owner, principal investigator, community group leader, board member, or teacher. Are there people of color in your spaces? Are your communities supportive of them and considering the impact of institutionalized racism? If the view is homogenous, evaluate why and initiate change. Reading the TEAM-UP report is a good place to start.

Welcome to the Newest Sigma Pi Sigma Chapters!

Kalamazoo College (MI)

Chapter #585, founded May 19, 2022
Founding members: Jonah Beurkens, Linh H. Dao, Eli Edlefson, Joseph Dongwon Jung, Arman Khan, Claire Kvande, Matthew Nelson, Kate Roberts, Carter E. Wade, and Elias Wennen.

Photo courtesy of Brad Conrad.

University of Alabama at Birmingham

Chapter #586, founded April 8, 2022
Founding members: Isaiah Joel Coley, Rachel Day, Tharon Holdsworth, Anthony Knighton, Fahad Nadeem, Claudia Nardone, Syed Raza, Keston Smith, Sarah G. Van Winkle, and Hannah York.

Photo courtesy of Brad Conrad.

Saint Mary's College - Notre Dame (IN)

Chapter #587, founded May 13, 2022
Founding members: Claire Alonzo, Kerrie Anne Koller, Lea Bin Markowski, Kyra Obert, and Sarah Palmer.

Photo courtesy of Brad Conrad.

Purdue University Northwest (IN)

Chapter #588, founded April 29, 2022
Founding members: William Feithen, Brandt Fraser, Raúl Garrido García, Kristin Swartz-Schult, and Brittney Vroom.

Photo courtesy of Brad Conrad.

Florida Polytechnic University

Chapter #589, founded May 3, 2022
Founding members: Addam J. Ben-Abdallah, Louis Ferreira, Alexander Gage, Brennan Halsey, Nicoleta Hickman, Daniil Ivannikov, Matthew Knitter, Tyler Matos, Ethan Montero, Joseph Pusateri, Manimegalai Ramamourty, Antonio Ruotolo, Sima Saeidi, Sebastian Sage, and Sesha Srinivasan.

Photo courtesy of Sesha Srinivasan.

THE ENVIRONMENTAL HEALTH ENGINEER

by Tom Jenckes, Research and Development Department,
Pacific Gas & Electric Co., and Associate Professor of Business, Argosy University (Retired)

Tom Jenckes. Photo courtesy of Jenckes.

In high school I avoided the "hard" sciences, but I enlisted in the US Navy nuclear submarine program in 1960. It required three years of college-level sciences, and for that I was sent to Nuclear Power Training School in New London, Connecticut, where I learned that I could do physics, chemistry, and higher math. Then it was on to a nuclear power submarine training facility in Windsor Locks, Connecticut. While stationed there I went to night school at the University of Hartford and majored in electrical engineering. After two years I was sent to the submarine USS *Skate* (SSN-578). Within six months the *Skate* entered the Norfolk Naval Shipyard for refueling. While there, I continued my education at Old Dominion College and signed up for a prerequisite Physics 101 course.

My professor had just completed his physics doctorate at the College of William & Mary. Boy, did he ever open my eyes to all the wonderful facets of physics! He instilled in me an excitement for physics that changed my path. When I was discharged from the Navy, I went to the University of Rhode Island (URI) to complete my bachelor's degree, which I did in two years.

At URI I served as president of the Society of Physics Students. While in this role, I arranged field trips for the group. One trip took us to the US Food and Drug Administration (FDA) lab in Natick, Massachusetts, where we observed techniques for irradiating food to prolong shelf life. That's where I learned of a master's program in health physics at Temple University. I applied and began the program, which was sponsored by the US Public Health Service, in September 1969. Opportunities opened up, and I was able to garner fellowships to continue my studies at Temple. That field trip to the FDA lab opened up a career for me.

Once I completed my doctorate in environmental health, I worked at Metropolitan Edison in Reading, Pennsylvania. In 1978 I became a supervisor in the radiation safety and environmental engineering group at the Pacific Gas & Electric Company (PG&E). There were four of us initially. Our main responsibility was to procure an environmental technical specifications license for PG&E from the Nuclear Regulatory Commission (NRC). We were excited to have such an important role and hired top-notch consultants to ascertain the environmental impacts of our unit. My physics training prepared me to take on this huge endeavor, and a year later our company received an environmental operating license from the NRC! People from other power companies came to see how we accomplished such a big job in such a short time.

The culmination of my career was designing the research and development program at PG&E, which I was able to develop thanks to the physics skills I learned. My advice to physics students: Think big! Physics trains you to have broad horizons. ●

THE ECONOMICS PROFESSOR

by Hannah Gabriel, Assistant Professor of Economics, California State University, Sacramento

Hannah Gabriel. Photo courtesy of Gabriel.

I was cruising along as a physics major in college, thinking I'd eventually get a PhD in physics, when I decided to add an economics minor. Then I started really liking my economics classes. A lot. I remember thinking, This is something that I'm very good at and that comes very naturally to me. What do I do now?

Physics and economics have a lot in common. Both use rigorous mathematics to study real-world problems, and both use logic and model building to explain complex phenomena. Both explore broad, abstract concepts.

Ultimately, I decided to pursue a PhD in economics, in part because I liked the social science aspect of studying human behavior. I'm not the only one to travel this path. Other physicists have transitioned to economics (although it's much less common to go in the other direction!). In economics, someone with a physics background is recognized for being familiar with rigorous mathematics and thinking broadly about the world.

I took a gap year before graduate school to take some additional math and economics classes and then started working toward my PhD. The first year of economics grad programs focuses on foundational math. It's far removed from typical economics research and extremely challenging, but I was just as well prepared as everyone else. One of the fun, unique things about economics is that you don't necessarily need a bachelor's degree in economics to get a PhD, but you need to have a strong math background.

I'm an applied economist specializing in international economics and how economies change. I look at globalization: the rise of multinational firms, the differences between multinational firms and domestic firms, and multinational banks and international banking. For example, I have a paper that examines how an international bank becoming a domestic bank impacts the firms that are borrowing money from that bank[1]

The paper focuses on a banking turnover that happened in Hungary and examines how that event affected Hungarian firms. Economists call this a natural experiment—an event that is not controlled by researchers but can still be studied academically. Natural experiments are different from experiments in the physical sciences, where researchers often carefully control the setup and execution. I can't control who's buying and selling banks in Central Europe, but I can follow along with current events and say, "I have historical data that might reveal the downstream effects of this." We can abstract from our studies of specific events to provide policy recommendations, cautionary tales, or other takeaways for today's decision-makers.

Applied economists don't usually collect their own data. Some conduct surveys, but good survey design is its own skill. We primarily use public data sets or anonymized administrative data from banks, firms, states, countries, or other entities. We might partner with an entity or reach out in hopes that one is interested in being studied and will send us its data. Finding data is half the battle in economics. If there's something you want to study, you can only move forward if the data exist and the data steward is willing to share them with you.

I became an economics professor in fall 2020, so my first semester of teaching was completely online and in the middle of the pandemic. Teaching classes has a steep learning curve, but I've found that it gets easier with time. The experience is rewarding, especially when you see students grasp a complicated subject. I love hearing from students who have taken one of my classes about what they're up to now and the cool internship opportunities or job interviews they've had.

While I conduct research year-round, I do a lot of research during the summer or during January term, when I'm not teaching. I love the flexibility and freedom to study whatever problems I'm interested in from anywhere. Unless we have a large data set that needs high-powered computing, economists can work anywhere with a Wi-Fi connection. Most of us don't need labs and, for the most part, are less reliant on grant funding than physics researchers.

To the physics students out there, my advice is to stick with the degree. A bachelor's degree in physics is one of the most versatile degrees out there. It signals that you're a smart and quantitative problem solver, which is useful in *any* job. If you don't want to be a traditional physics professor, you can cast a very wide net in your job search. You're more qualified than you think you are.

If you like physics research but are interested in studying the human aspects of current events, consider going into economics or other social sciences. It's not all about finance. You can study the economics of education, labor, industrial organization, and so much more. It's a very engaging discipline.

I was inducted into Sigma Pi Sigma as a physics major at Lawrence University. I learned last week that you still get to call yourself a physicist even if you pivot careers. It's nice to have reassurance that being a physicist never goes away. ●

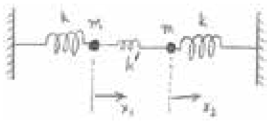
References

1. "Multinational Activity and Banking: The Effects of Ownership Status on Exporters" is available at **sites.google.com/a/msu.edu/hannahcgabriel/research**.

Coupled Oscillations in Diverse Phenomena

Part 2: The ammonia molecule as a quantum two-state system

by Dwight E. Neuenschwander, Southern Nazarene University



Part I of this article appeared in the Spring 2022 issue of Radiations *and is available at [www.sigmapisigma.org/sigmapisigma/radiations/issues/spring-2022.](www.sigmapisigma.org/sigmapisigma/radiations/issues/spring-2022) Numbering in Part II continues from Part I.*

In the *Feynman Lectures on Physics*, Richard Feynman elegantly takes the reader through a set of quantum-mechanical two-state systems. One of them models the location of the nitrogen atom in the ammonia molecule NH_3 [5]. It's an important example, because those two states are at the heart of the ammonia maser, the 1953 precursor of the laser. The point to be made here emphasizes that this quantum two-state system (and Feynman's other two-state examples) is mathematically similar to the coupled mechanical oscillator problem. Let's examine the ammonia molecule problem along the lines of Feynman's approach. We keep in mind that a quantum state $|\psi\rangle$ contains complex numbers, so to get positive-definite probabilities, its square is $\psi^*\psi = |\psi|^2 = \langle\psi|\psi\rangle$, where ψ^* denotes the complex conjugate of ψ.

The architecture of the ammonia molecule features the three hydrogen atoms lying in a plane, with the nitrogen atom found on either side of the hydrogen-atom plane, as in Fig. 4.

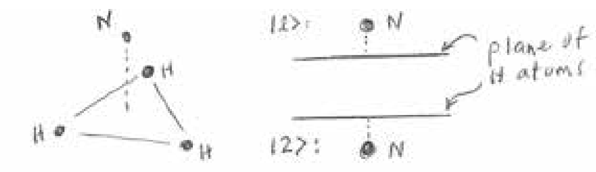


Figure 4. The structure of the ammonia molecule. The N atom can be on either side of the plane of hydrogen atoms. All figures by the author.

Let state $|1\rangle$ denote the molecule's state when the nitrogen atom is "above" the plane, and let $|2\rangle$ denote the state when the nitrogen lies "below" the plane. States $|1\rangle$ and $|2\rangle$ can be given the matrix representations of Eqs. (23a) and (23b), respectively. As a complete set of orthonormal vectors, $|1\rangle$ and $|2\rangle$ form a basis of any arbitrary state $|\psi\rangle$ that describes the location of the nitrogen atom relative to the plane of three hydrogens, so that

$$|\psi\rangle = \psi_1|1\rangle + \psi_2|2\rangle. \tag{27}$$

The nitrogen molecule can jump across the plane of hydrogen atoms, from state $|1\rangle$ to state $|2\rangle$ or the reverse, or if in state $|1\rangle$ or $|2\rangle$ it may stay there. Let H be the Hamiltonian for the nitrogen atom to either make a transition or remain in place. The probability amplitude for making the transition from state $|1\rangle$ to state $|2\rangle$ will be $\langle 2|H|1\rangle \equiv \beta$, where by symmetry $\langle 1|H|2\rangle = \beta$ as well; and let the probability amplitude for the nitrogen atom staying on one side of the plane of hydrogen atoms be $\langle 2|H|2\rangle = \langle 1|H|1\rangle \equiv \alpha$. The evolution of the nitrogen atom's behavior is described by the Schrödinger equation,

$$H|\psi\rangle = -\frac{\hbar}{i}\frac{\partial|\psi\rangle}{\partial t}, \tag{28a}$$

or, with the matrices written out explicitly,

$$\begin{pmatrix} \alpha & \beta \\ \beta & \alpha \end{pmatrix}\begin{pmatrix} \psi_1 \\ \psi_2 \end{pmatrix} = -\frac{\hbar}{i}\begin{pmatrix} \partial\,\psi_1/\partial t \\ \partial\psi_2/\partial t \end{pmatrix} \tag{28b}$$

[compare to Eq. (10)], which splits into a pair of coupled equations:

$$\alpha\psi_1 + \beta\psi_2 = -\frac{\hbar}{i}\frac{\partial\psi_1}{\partial t} \tag{28c}$$

and

$$\beta\psi_1 + \alpha\psi_2 = -\frac{\hbar}{i}\frac{\partial\psi_2}{\partial t}. \tag{28d}$$

Other than the names of the variables and the order of the time derivative, Eqs. (28c) and (28d) describe *essentially the same system as the coupled oscillators of Eqs. (2).* Therefore, in following the same procedure (forming the sums and differences of ψ_1 and ψ_2, solving the problem for those combinations, and then inverting) and with the initial condition $\psi_1(0) = 1$ and $\psi_2(0) = 0$, we find

$$\psi_1(t) = e^{-i\alpha t/\hbar}cos\left(\frac{\beta t}{\hbar}\right) \tag{29a}$$

$$\psi_2(t) = ie^{-i\alpha\,/\hbar}sin\left(\frac{\beta t}{\hbar}\right). \tag{29b}$$

Consequently, the probabilities P_1 and P_2 of the nitrogen atom being in state $|1\rangle$ and state $|2\rangle$, respectively, are

$$P_1 = |\psi_1|^2 = cos^2\left(\frac{\beta t}{\hbar}\right) \quad (30a)$$

$$P_2 = |\psi_2|^2 = sin^2\left(\frac{\beta t}{\hbar}\right). \quad (30b)$$

Notice that $P_1 + P_2 = 1$ at all times, as required if the nitrogen atom is to remain part of the ammonia molecule. But it will be observed from Eqs. (30) that P_1 and P_2 are time dependent—ψ_1 and ψ_2 are not "stationary states." Figure 5 shows plots of $P_1(t)$ and $P_2(t)$ as functions of time. The probabilities oscillate with a period $T = \frac{\pi\hbar}{\beta}$.

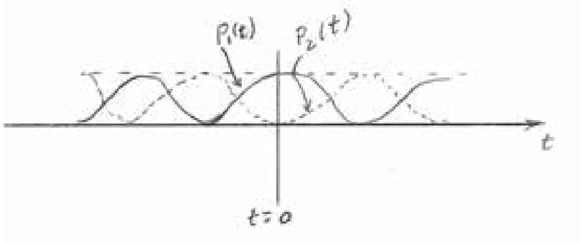


Figure 5. Illustration of the $P_1(t)$ and $P_2(t)$ states.

Figure 6 shows the same information in another way: "clouds" or "balloons" that contain the probabilities for the nitrogen atom being in state $|1\rangle$ or state $|2\rangle$ at different times.

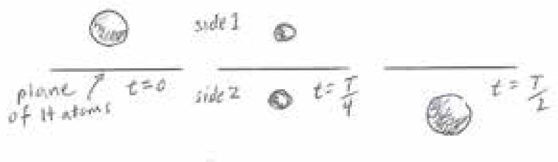


Figure 6. Illustration of how the probability of the nitrogen atom being above or below the plane of hydrogen atoms varies in time through one period. The shaded regions indicate a relatively high probability of locating the N atom.

At the risk of being repetitive, because the probability oscillates, the states ψ_1 and ψ_2 are not stationary states—i.e., not eigenstates, not normal modes of the nitrogen atom's motion in the NH_3 molecule. Let's find those eigenstates!

To find the eigenstates $|\psi_\omega\rangle$ of the nitrogen molecule in this system, we seek states with harmonic time dependence,

$$|\psi_\omega\rangle = \begin{pmatrix} A_1 \\ A_2 \end{pmatrix} e^{-i\omega t} \equiv |A\rangle e^{-\frac{iEt}{\hbar}} \quad (31)$$

(compare to Eq. (14), where

$$E = \hbar\omega, \quad (32)$$

and $|A\rangle$ is time independent; therefore $|\langle\psi_\omega|\psi_\omega\rangle|^2$ is time independent. The probability distributions for these states remain constant in time—analogous to how the normal-mode oscillations of the coupled oscillator remain steady in time, or how a single standing wave mode in musical acoustics does not change.

To proceed, insert the *ansatz* of Eq. (31) into the Schrödinger equation, Eq. (28a), to obtain

$$\begin{pmatrix} \alpha & \beta \\ \beta & \alpha \end{pmatrix} |A\rangle = E|A\rangle \quad (33a)$$

or

$$\begin{pmatrix} \alpha - E & \beta \\ \beta & \alpha - E \end{pmatrix} |A\rangle = |0\rangle. \quad (33b)$$

To obtain nontrivial solutions, set the determinant of the square matrix equal to zero, which gives

$$E = \alpha \pm \beta \equiv E_\pm . \quad (33c)$$

A radiative transition between these two eigenstates, with their energy difference $E_+ - E_- = 2\beta \sim 10^{-4}\, eV$, produces photons in the microwave portion of the electromagnetic spectrum [5]. This energy gap is responsible for the population inversion in the ammonia maser.

Having found the eigenvalues, we turn to the eigenstates. We start with $E_+ = \alpha + \beta$. Upon inserting this into Eq. (33a), we find for its corresponding normalized eigenstate,

$$|\psi_+\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \end{pmatrix} e^{-i(\alpha+\beta)t/\hbar}. \quad (34a)$$

Similarly, for the eigenvalue $E_- = \alpha - \beta$, we find for its eigenstate

$$|\psi_-\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix} -1 \\ 1 \end{pmatrix} e^{-i(\alpha-\beta)t/\hbar}. \quad (34b)$$

You can easily verify that these eigenstates are orthonormal and satisfy the completeness relation for all t:

$$|\psi_+\rangle\langle\psi_+| + |\psi_-\rangle\langle\psi_-| = \tilde{1}. \quad (35)$$

Notice (and this was the point of finding eigenstates) that the respective probabilities of finding the nitrogen atom in $|\psi_+\rangle$ or state $|\psi_-\rangle$ are constant in time:

$$P_+ = [\langle\psi_+|\psi_+\rangle]^2 = ½ \text{ and } P_- = [\langle\psi_-|\psi_-\rangle]^2 = ½.$$

(The fact that P_+ and P_- happen to be the same merely reflects the symmetry of the nitrogen atom's placement above or below the plane of hydrogen atoms.) Thus the "clouds of probability" remain the same for the eigenstates for all times (Fig. 7); they are analogous to the electron orbitals in the hydrogen atom.

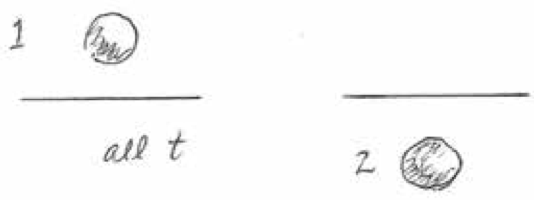


Figure 7. Shapes that enclose the probability of the nitrogen atom's whereabouts when it's in a stationary state.

Since the original $|1\rangle$, $|2\rangle$ vectors form a complete set, the eigenstates can be expressed as a superposition of them:

$$|\psi_+\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\1\end{pmatrix} e^{-i(\alpha+\beta)t/\hbar}$$

$$= \tfrac{1}{\sqrt{2}}(|1\rangle + |2\rangle)e^{-i(\alpha+\beta)t/\hbar}, \qquad (36a)$$

and

$$|\psi_-\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix}-1\\1\end{pmatrix} e^{-i(\alpha+\beta)t/\hbar}$$

$$= \tfrac{1}{\sqrt{2}}(-|1\rangle + |2\rangle)e^{-i(\alpha-\beta)t/\hbar}. \qquad (36b)$$

If we think of $|1\rangle$ as the *x*-axis $\hat{\boldsymbol{\imath}}$ and $|2\rangle$ as the *y*-axis $\hat{\boldsymbol{\jmath}}$ basis vectors in a two-dimensional abstract "state space," then by Eqs. (36) the transformation from the $\{|1\rangle, |2\rangle\}$ basis to the $\{|\psi_+\rangle, |\psi_-\rangle\}$ basis corresponds to a clockwise rotation through 45° (Fig. 8).

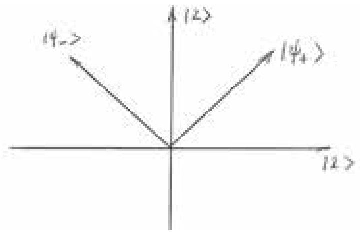


Figure 8. A change of basis as a rotation of axes.

The Hamiltonian matrix in the $\{|1\rangle, |2\rangle\}$ basis had nonzero off-diagonal terms. If we rewrite the Hamiltonian matrix in the eigenvector $\{|\psi_+\rangle, |\psi_-\rangle\}$ basis, then *H* becomes diagonal and the diagonal elements are the eigenvalues. Let's see how this feature emerges.

Any set $\{|n\rangle\}$ of orthonormal basis vectors (eigenvectors or otherwise) respects the completeness relation, for which

$$\tilde{1} = \sum_n |n\rangle\langle n|. \qquad (37)$$

Any vector $|\psi\rangle$ in the space can be expressed as a superposition of basis vectors. To carry this out, multiply the completeness relation from the right by $|\psi\rangle$:

$$|\psi\rangle = \sum_n |n\rangle\langle n|\psi\rangle$$

$$= \sum_n c_n|n\rangle \qquad (38)$$

where

$$c_n \equiv \langle n|\psi\rangle. \qquad (39)$$

The state vector $|\psi\rangle$ has now been projected onto the $\{|n\rangle\}$ basis set. Such a projection can also be done with the Hamiltonian matrix, as in Feynman's ammonia molecule problem. First, recall that in the notation for a matrix element such as H_{rc}, the first index *r* identifies the row and the second index *c* identifies the column in which the matrix element stands. Notice from the Hamiltonian matrix of Eq. (28b), expressed in the context of a $|1\rangle, |2\rangle$ basis, that

$$\langle 1|H|1\rangle = \begin{pmatrix}1 & 0\end{pmatrix}\begin{pmatrix}\alpha & \beta\\ \beta & \alpha\end{pmatrix}\begin{pmatrix}1\\0\end{pmatrix} = \alpha = H_{11} \qquad (40a)$$

$$\langle 1|H|2\rangle = \begin{pmatrix}1 & 0\end{pmatrix}\begin{pmatrix}\alpha & \beta\\ \beta & \alpha\end{pmatrix}\begin{pmatrix}0\\1\end{pmatrix} = \beta = H_{12} \qquad (40b)$$

and so on. More generally, for any basis vectors $|n\rangle$ and $|n'\rangle$ that belong to the same complete set,

$$H_{nn'} = \langle n|H|n'\rangle. \qquad (41)$$

So the matrix representation of the Hamiltonian in the $\{|\psi_+\rangle, |\psi_-\rangle\}$ basis is

$$\begin{pmatrix}\langle\psi_+|H|\psi_+\rangle & \langle\psi_+|H|\psi_-\rangle\\ \langle\psi_-|H|\psi_+\rangle & \langle\psi_-|H|\psi_-\rangle\end{pmatrix} \equiv \begin{pmatrix}H_{++} & H_{+-}\\ H_{-+} & H_{--}\end{pmatrix}. \qquad (42a)$$

Working out the four matrix elements gives a diagonal representation with the eigenvalues on the diagonal:

$$\begin{pmatrix}H_{++} & H_{+-}\\ H_{-+} & H_{--}\end{pmatrix} = \begin{pmatrix}\alpha+\beta & 0\\ 0 & \alpha-\beta\end{pmatrix}. \qquad (42b)$$

In general, the transformation from a representation of a matrix *M* in one basis set $\{|n\rangle\}$ to its representation *M'* in another basis set $\{|\gamma\rangle\}$ is a "similarity transformation," which can be efficiently developed by inserting the unit matrix twice, in the form of the completeness relation:

$$M'_{\gamma\gamma'} = \langle\gamma|M|\gamma'\rangle$$

$$= \langle\gamma|\tilde{1}\, M\, \tilde{1}\,|\gamma'\rangle$$

$$= \langle\gamma|\sum_n |n\rangle\langle n|\, M \sum_{n'} |n'\rangle\langle n'|\gamma'\rangle$$

$$= \sum_{n,n'} \langle\gamma|n\rangle\, M_{nn'}\, \langle n'|\gamma'\rangle, \qquad (43a)$$

or, more succinctly, for the matrices themselves,

$$M' = \Lambda^{\dagger} M \Lambda\,, \qquad (43b)$$

where Λ denotes the matrix of transformation coefficients, $\Lambda_{n\gamma} = \langle n|\gamma\rangle$, and $\Lambda^{\dagger}$ denotes its Hermitian conjugate, the "adjoint" (the transpose and complex conjugate of Λ).

References

[5] Richard Feynman, Robert Leighton, and Matthew Sands, *The Feynman Lectures on Physics*, vol. III, chap. 9 (Reading, MA: Addison-Wesley, 1965).

Editor's note: This article was updated on Feb. 6, 2023, to correct formatting errors.

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