INTERACTIONS

THE DEPARTMENT OF **PHYSICS** AND **ASTRONOMY** 2023 - 2024

MESSAGE from the HEAD

Hello Boilermakers!

We have had an amazing year in Physics and Astronomy. The Department continues to ascend in our sciences and work as a collaborative unit. We continue to produce outstanding science and attract significant funding resources. Our astronomers continue to use cutting edge technological tools such as the James Webb Space Telescope to expand our understanding of the universe. We've had notable discoveries that expose various flavors of anyons, prove that antimatter does not fall up, track mercury in the mammalian brains and so much more. Our outreach program continues to impress and went all the way to Colombia this past year to spread our love of astrophysics to children around the world. We celebrate the many awards granted to our faculty including awards from the W. M. Keck Foundation grant for attosecond scientific discovery, the Microsoft Quantum Purdue, the DOE funded Quantum Science Center, the Center for Quantum Technologies, the Pacific Northwest National Laboratory and Department of Energy for geomechanics, as well as Department of Energy funded upgrades for the CMS Experiment at CERN.

With our highs also came sorrow this year as we said goodbye to faculty who have passed such as my predecessor, Prof. John Finley. Although he has passed, we will always feel his presence in our classrooms, halls and labs.

In this edition of Interactions, we present you with this snapshot of our departmental, but there is so much happening it is difficult to contain in one newsletter. Our faculty members are constantly devising new ways to keep the public informed. Whether it is publishing a new book about interference, starting an astrophysics podcast, creating a website and videos for quantum physics, or working with media to help lay audiences understand what we are doing here at Purdue, our faculty hope to deliver the next giant leap in science to the public.

As head, I am proud of our alumni, faculty, staff and students and honored to watch as they progress. I see every day one Boilermaker after another helping the next generation of Boilermakers ready themselves for their own successful careers. This is the way we collectively and boldly move our sciences forward. I want to say thank you to the alumni who continue to show up, mentor our students and help them reach their own academic and career successes. If you are an alumnus who'd like to become more involved, please do give me a call or email, I look forward to our conversation.

As always, to all current faculty, staff and students, thank you for all that you are doing to elevate our program.

Gabor Csathy
Department Head and Professor of Physics and Astronomy

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PURDUE UNIVERSITY®

Department of Physics and Astronomy

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FACULTY AWARDS AND HONORS

Chris Greene
- The Ruth and Joel Spira Award for Outstanding Graduate Teaching

Sanjay Rebello
- Excellence in Graduate Advising

Laura Pyrak-Nolte
- Dean's Award for Achievement, University at Buffalo

Ken Ritchie
- Spira Award for Outstanding Undergraduate Teaching

Birgit Kaufmann
- Purdue Insights Forum Fellow

Maxim Lyutikov
- 2023 American Physical Society Fellow

Nat Lifton
- 2023 Kirk Bryan Award – Geological Society of America

Niranjan Shivaram
- W. M. Keck Foundation Grant

COLLEGE OF SCIENCE FACULTY AND STAFF AWARDS

David Sederberg
Outreach Coordinator
- Staff Engagement Award

Austin Beidelman
Demonstration Assistant
- Customer Service Award

Jeffrey Gerber
Lecturer
- Outstanding Service Award

Lan Luo
Laboratory Chemist
- Leadership Award

Robin Sipes
Associate Administrative Assistant
- Customer Service Award

Robert Austin
Lecturer
- Outstanding Service Award

Lindsey Eggold
Senior Graduate Coordinator
- Customer Service Award

Sonia Hill
Administrative Assistant
- Customer Service Award

Brian Mason
Tandem Accelerator Laboratory Engineer
- Professional Achievement Award

Laura Urba
Lecturer
- Outstanding Service Award

FACULTY PROMOTIONS/PROFESSORSHIPS

Xingshan Cui
- Promoted to Associate Professor

Danny Milisavljevic
- Promoted to Associate Professor

Tongcang Li
- Promoted to Full Professor

FACULTY/STAFF YEARS OF SERVICE AWARDS

Aaron Mull
Maintenance Mechanic
- 10 years

David Huckleberry
Coordinator of Digital Instruction
- 10 years

Steven Plunkett
Machinist, PRIME Lab
- 15 years

Irena Ratkiene
Demonstration Assistant
- 20 years

MEMORIALS

It is with great sadness that we announce those who we have lost over the past year. These Boilermakers influenced our lives in so many ways. They were scientists, leaders, educators, helpers, problem solvers, and family. The imprint they leave on our department is immeasurable. Our halls are forever changed due to their presence.

- **Dr. Virendra V.K. Saxena**
- **Professor Paul Simms**
- **Nancy Schnepp**
- **Professor John P. Finley**
- **Professor Jorge Rodriguez**
- **Patricia Metcalf**
- **Bruce Poer**

Colombia

K-12 OUTREACH:

SEDERBERG LEADS PURDUE SCIENCE STUDENTS IN OPPORTUNITIES FOR LEARNING AND SERVICE IN COLOMBIA

While other students were visiting beaches or popular night spots, several Purdue College of Science students spent their spring break accompanied by Dr. David Sederberg for a service project in Medellín, Colombia where they engaged 35 students from three different schools in lessons in astronomy, astrophysics, and related topics in AstroCamp 2023.

Recently awarded a Staff Engagement Award for collaborating in sustained synergistic partnerships with his community, Sederberg has led the K-12 Outreach efforts of the Purdue Department of Physics and Astronomy for more than a decade. His mission is to create and enhance science enrichment opportunities for K-12 students and their teachers in central Indiana and beyond, with the trip to Colombia representing the most recent study abroad experience through his program.

In the months of preparation prior to traveling to Colombia to host the program, the Purdue students learned principles of instructional design, pedagogy and assessment as part of their commitment to the Physics and Astronomy Service Learning course in which they enrolled.

"They worked together as a finely oiled machine," Sederberg commented. "Writing, testing, revising, and, in some cases, going back to the drawing board and redesigning their lessons and experiments with predetermined learning goals and cultural objectives for our middle and high school audience."

An essential part of the instructional design process is learning about target audiences. As the study abroad students began designing their experiments and lessons, they initiated frequent Zoom calls with their Colombian colleagues, in addition to email exchanges, recording explanatory videos and learning about the availability of materials and common items, which might be taken for granted in the U.S., but less common in Colombia.

"AstroCamp 2023 in Colombia was a unique and amazing experience," says Alan Wright, first year grad student in Physics Education. "As an aspiring educator, I loved having the opportunity to work with the students from Medellín and both share my interest in astronomy and learn about their way of education."

Even with all that preparation, there were still bound to be some surprises, but in AstroCamp 2023 those surprises were often pleasant inspiring ones. One example involved a design experiment in which students were given the charge of creating a physical planetary surface which they would in turn use sonar detectors to create a three-dimensional model. Students dove right in, exceeding all expectations.

Danielle Dickinson, third year grad student studying astrophysics, explained, "In the practice runs of this activity at Purdue prior to the trip, we set up simple box configurations in a grid pattern on the floor. In Colombia, students cut up the boxes, placed fabric over openings, and used additional materials. They created mountain ranges, craters, lakes, and other features that more accurately represent a planetary surface. Not only was the strategy more engaging for students, but the model also extended far beyond what we rehearsed with. The students' resulting terrains facilitated a study of how the instrumentation could handle subtle changes in elevation, different geometries, and tested the resolution of the sensor, all of which are important diagnostics in developing the instruments used for mapping Mars."

An important aspect of the study abroad experience is for potential student travelers to stop, stand back, think and contemplate ways in which cultures and traditions have values that are often different from their own. That means thinking about what to say (and when not to say something), what to wear, ways to move, how to talk, and ways in which travelers might come across as inappropriate and how we could be perceived by others. The key is to be respectful and appreciate the people, surroundings, and culture that study abroad students can witness in their travels.

"Leaving Medellín, Colombia, I was completely amazed by this new world I was able to live in for a few days, and I will always be grateful for that," says Mariana Aguilar, undergrad senior in Planetary Science. "I greatly appreciate all the teachers that participated in the activities and I'm also thankful for the curiosity and passion present in each student. In the future, I hope to be able to return and continue growing the relationship between Colombia and Purdue. The trip inspires me to push myself outside of my comfort zone and take advantage of all opportunities to travel and teach young students."

The primary goals of Service Learning Study Abroad for students are to:

Apply grade level and culturally appropriate pedagogical strategies and science content knowledge to create and present STEM lessons to students of another culture.

Demonstrate intercultural knowledge and effectiveness to successfully communicate, understand, and interact among people with ethnic and cultural differences.

Demonstrate and evaluate personal growth in cultural worldview and self-awareness to confidently address challenges in a particular situation.

The Physics and Astronomy Service Learning and Study Abroad experiences are open to all majors. The service learning courses (PHYS 295 and PHYS 595) are offered every semester and are occasionally related to study abroad experiences. Interested students may enroll for 1-3 credits and participate in any of the outreach events available that semester. Both courses are repeatable for credit.

This article originally published with the Purdue University College of Science.

Prof. Tongcang Li
Professor of Physics and Astronomy and Professor of Electrical and Computer Engineering

Prof. Tongcang Li:

Pushing the limits of quantum technology with spin qubits and levitated particles

By Cheryl Pierce

Shattering world records and proving the seemly impossible to be possible isn't an occasional happenstance with Tongcang Li, professor at Purdue University; it's part of his daily routine. Over a century ago, Albert Einstein said it would never be possible to observe the instantaneous velocity of particles undergoing Brownian motion due to collisions with surrounding molecules. Over a decade ago, Li helped prove Einstein wrong about that. In 2018, Li's research team shattered the records for the fastest spinning object when his team created the fastest nanorotor in the world with an optically levitated nano-dumbbell. Science that could easily be confused with magic is daily practice in Li's lab where levitation, qubits, and spintronics enable him to delve into fundamental physics and to advance quantum technology for a wide range of applications.

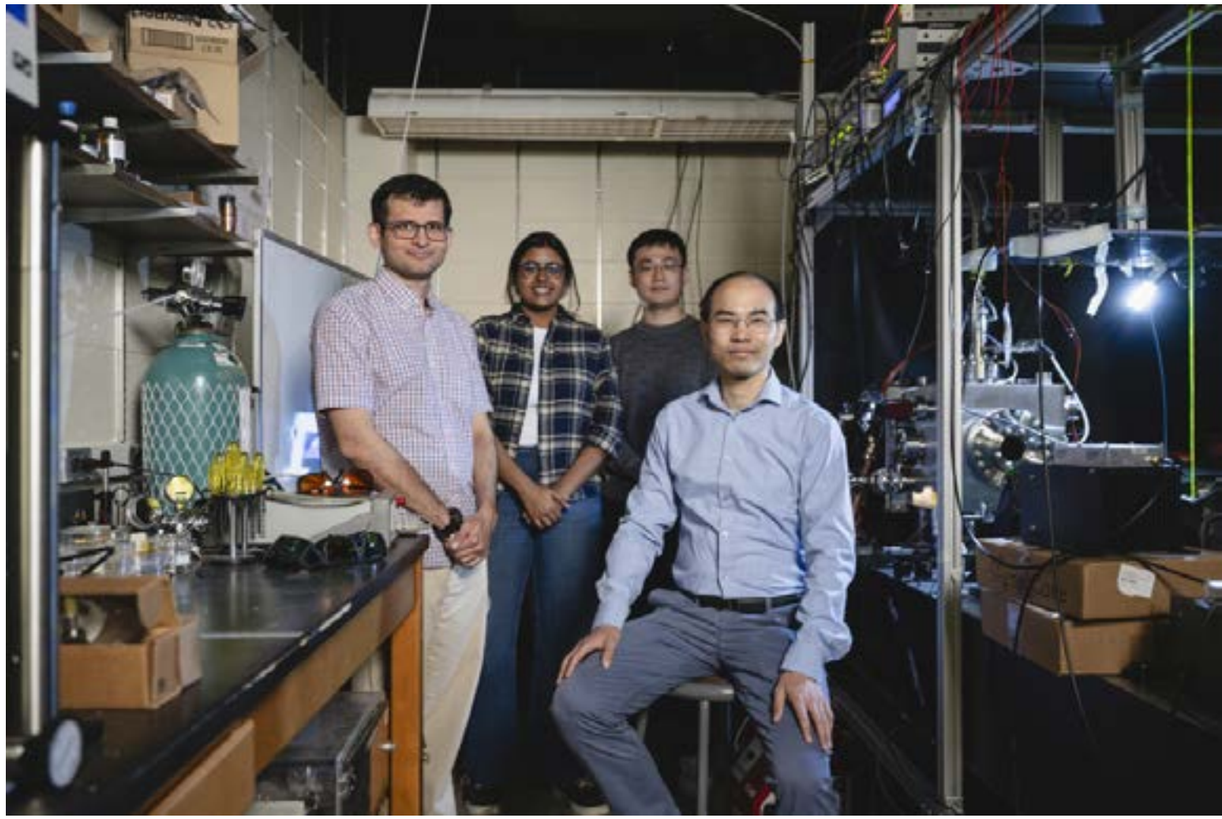
Li, a professor in both the Department of Physics and Astronomy and Elmore Family School of Electrical and Computer Engineering, has his roots in many aspects of physics and engineering. This ability to wade into multiple scientific areas allows his research to canvas a growing scientific territory.

Li has been recognized by multiple awards, including the Experimental Physics Investigator Award from the Gordon and Betty Moore Foundation in 2023 and the CAREER award from the U.S. National Science Foundation in 2016. In addition, his work has been featured in Highlights of the Year of 2018 by the American Physical Society and Optics in 2022 by the Optics & Photonics News.

"My group studies the quantum interaction between light and matter at atomic and nanoscales for quantum sensing and quantum information processing," says Li. "For example, we are exploring spin qubits in 2D materials, levitated optomechanics, quantum biological and chemical sensing, and quantum vacuum fluctuations."

Quantum technology relies on the qubit which is the quantum counterpart of a classical computer bit. In electron or nuclear spin qubits, the classical binary states "0" and "1" are represented by spin, a characteristic akin to magnetic polarity, making it sensitive to electromagnetic fields. This allows spin qubits to act as sensors, capable of probing structures like proteins or measuring temperature with nanoscale precision.

"Recently, we have established an interface between photons and nuclear spins in ultrathin hexagonal boron nitrides. We are also using spin qubits in 2D materials to study biological molecules," he explains. "In another study, we utilized light to levitate nanoparticles in a vacuum. In 2018, we successfully levitated and driven a nano-dumbbell to rotate at over 60 billion rpm, setting a world record for the fastest human-made rotor at that time. By employing a levitated nanoparticle, we also developed the world's most sensitive torque detector. More recently, we levitated a nano-dumbbell near a surface to investigate particle-surface interactions. This ultrasensitive device holds the potential to explore quantum



Toncang Li (right) with students he advises (from left to right) Sumukh Vaidya, Saakshi Dikshit, and Xingyu Gao. This photo and cover photo by Charles Jischke.

vacuum fluctuations and gravity at the nanoscale."

Li's research has several offshoots heading into seemingly unrelated branches of physics and engineering. Because he has explored many of these branches in his educational path, he is able to bring them together seamlessly.

"As a high school student, I was inspired by my science teachers and renowned scientists like Isaac Newton and Albert Einstein to pursue a career in physics. When I became an undergraduate student, I realized that there are now many different branches in physics," he says. "I specialized in condensed matter physics during my undergraduate studies before transitioning to atomic, molecular, and optical physics (AMO) for my graduate research. After earning my PhD, I joined a research group in the Mechanical Engineering department at UC Berkeley. Now at Purdue University, I am dedicated to exploring new frontiers in physics and pushing the boundaries of knowledge. It's especially thrilling when we set world records or discover new phenomena."

Setting records is a skill that Li is especially adept at mastering. He shows zero signs of stopping when it comes to setting records and has his eye on smashing even more of them with his students at Purdue.

"My proudest work so far is measuring the instantaneous velocity of the Brownian motion of a suspended particle for the first time, a task deemed impossible by Albert Einstein over one hundred years ago," he says. "This work was published in Science magazine in 2010. At Purdue University, we created the fastest rotor in the world in 2018 with an optically levitated nano-dumbbell. This work was featured as one of the ten Highlights of the Year in 2018 by the American Physical Society. We are hopeful that our students at Purdue will generate more important results in the future."

Li's lab, the Quantum Sensing and Quantum Optomechanics Laboratory, is located in the Physics Building at Purdue's West Lafayette campus. Because he works in both physics and engineering, he has collaborated with many fellow faculty members, including Yong Chen (Physics), Francis Robicheaux (Physics), Yulia Pushkar (Physics), Zubin Jacob (ECE), Sunil A. Bhave (ECE), Pramey Upadhyaya (ECE), and Vladimir M. Shalaev (ECE).

"Purdue University is famous for world-class research. I am thankful to our colleagues who are so supportive. Our research involves both fundamental physics and engineering applications," says Li. "During our research, we aim to understand the physical principles underlying the phenomena we observed and apply them to practical uses. For example, when studying spin qubits in 2D materials, we want to understand the atomic structures of spin defects, which involves physics, and use spin defects to build quantum sensors for broader applications, which involves engineering. Our research group includes students from both Physics and ECE. They work closely and have produced many high-impact results through collaborations."

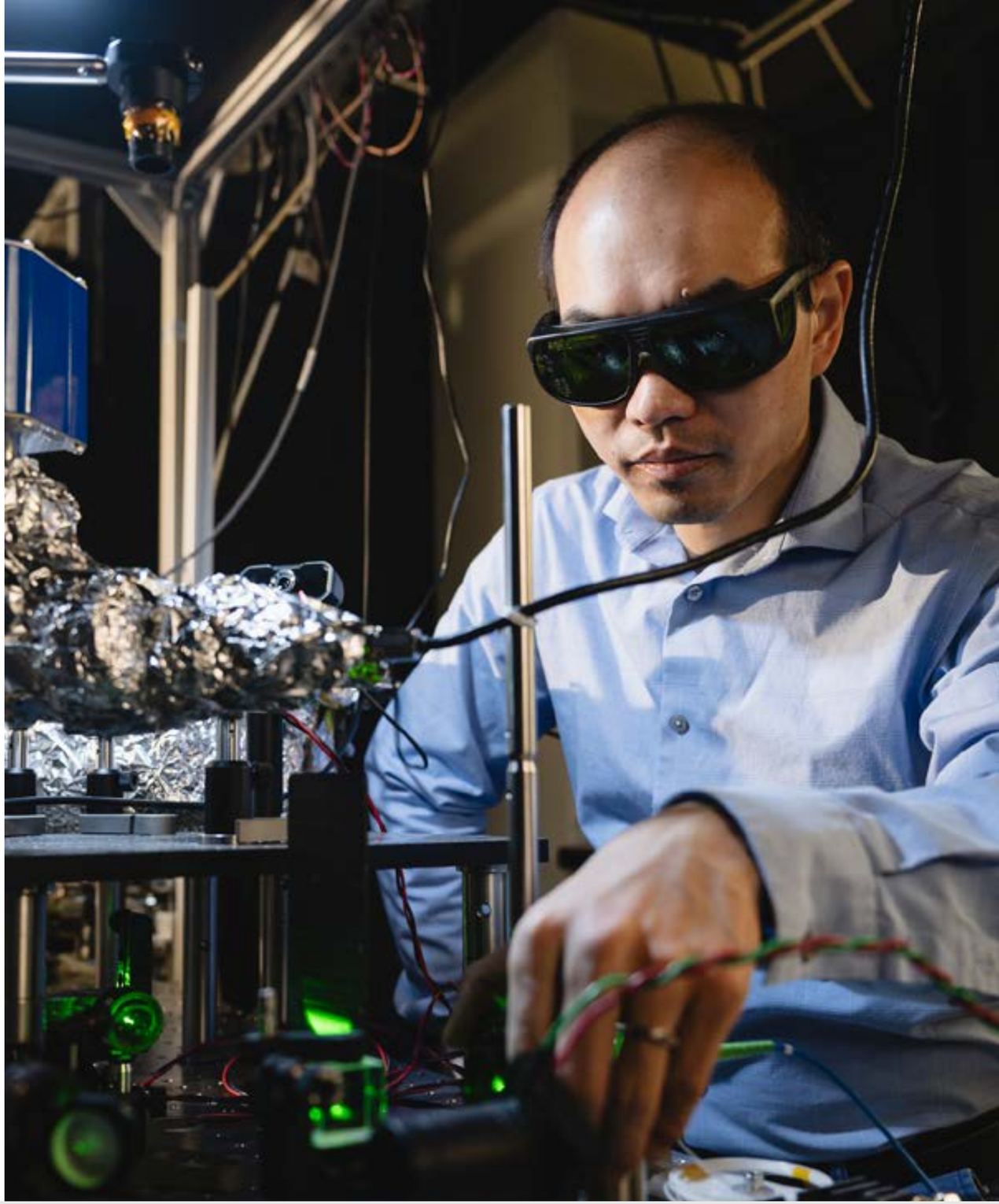
As important as research is to Li, teaching is also something he holds as equal in value. Because Purdue is a Land Grant university, research and teaching are fundamentally tied together.

"One of the most rewarding aspects of being a professor is witnessing the growth of my students. I take great pride in their achievements, as evidenced by the numerous awards they have received," he says. "Notably, one of my PhD students, Zhujing Xu, was awarded the Harvard Quantum Initiative Postdoctoral Fellowship from Harvard University. Additionally, she was selected as one of only seven trailblazing young researchers to present at the Trailblazers Symposium at the California Institute of Technology in 2023, highlighting her exceptional contributions to the field."

Li has advised about ten graduate students and ten undergraduate students. He encourages students who might be interested in his research to contact him by email or visit his lab's website. He hopes that students who are passionate about research will reach out.

Li's path to record-setting research started in a small village in China where he grew up. He received his bachelor's degree from the University of Science and Technology of China and subsequently his PhD degree from the University of Texas at Austin. He then pursued his post-doctoral research at the University of California, Berkeley. Then in 2014, he joined the faculty at Purdue University.

"I have experienced several dramatic changes in my life. When I was a small kid over 30 years ago, our house and the neighborhood did not have electricity for most of time. So, we had to use oil lamps and candles for illumination during the nights," says Li. "Now my group is using advanced lasers and single photon emitters to perform state-of-the-art research. I am grateful to so many people who have helped me and would like to help my students to be successful."



For the latest news in research at the Purdue University Department of Physics and Astronomy, visit physics.purdue.edu/news

The men behind the mechanisms

Austin Beidelman and Gary Hudson puppet master the experiments demonstrated in Physics classrooms and labs

By Cheryl Pierce

When alumni are asked what they remember from classes, often it is an experiment they watched in full dazzling display. These demonstrations create a sense of wonder that can be experienced with all five senses. What people often do not realize is that these experiments are carried out with safety and precision in mind, so the Department of Physics and Astronomy has assigned these demonstrations to two highly trained specialists: Austin Beidelman and Gary Hudson.

Students in the large lecture halls of Physics are facing two doors at the front of the classroom. These doors lead to the "office" of Beidelman and Hudson. This space is as long as the instructional spaces combined and hide treasures that can produce extraordinary phenomena. With these instruments, the two can conduct physics in a hands-on, visual way for students who might be struggling with the concept as it is written in the textbooks.

Both demonstration specialists have a background in physics education at Purdue University. Beidelman studied Physics at Purdue University and obtained his B.S. in Physics Teaching in 2013 then taught Physics 1 and the physics half of Integrated Chemistry Physics at area high school Lafayette Jefferson High School. He taught there eight and a half years before joining Purdue Physics and Astronomy and has been here for two years. Hudson is starting his twelfth year with the department. He earned his B.S. in Physics and started his career as a secondary educator teaching physical science in 1974. He then spent 38 years teaching physics and all levels of mathematics at the secondary level, and even taught both subjects as a continuing lecturer at Ivy Tech for five years.

"My role model as a child was my uncle, Bill Golden who was a science/math teacher and baseball coach," says Hudson. "He lived next door to us, so I grew up enjoying his company and developing an admiration for him as well as his work. Uncle Bill would include and encourage me to assist him from time to time in his teaching/coaching activities. These early experiences made an impact on me, so much so that I wanted to pursue a career similar to his."

Austin Beidelman (center) and Gary Hudson (right) work together demonstrate the specific heat experiment for Saran Nern, Outreach Coordinator for Purdue Chemistry and co-creator of the Superheroes of Science YouTube channel. Beidelman is a frequent and popular guest on the channel. Photo by Steven Smith.

Changing course from education to demonstration was a natural career progression according to both demonstration specialists. And coming back to Purdue was like icing on the cake.

"I fell in love with Physics in high school where it jumped out to me as a way of applying the math that I was good at to the real world and understanding how and why things happened," says Beidelman. "While I was in college I realized that I loved explaining Physics and wanted to help people understand the subject and get excited about it the same way that I did in high school, which led me to pursue teaching in that setting. When I heard about the chance to come back to Purdue and be involved with the department here, especially setting up some of the same demonstrations that I remembered from undergrad, I jumped at the opportunity."

The duo primarily services the two lecture halls in the Physics building, but their services are available to all physics classes and they often volunteer for K-12 outreach events. The schedule keeps them hopping. This semester alone, they have eleven courses meeting 42 times a week in the two halls. How many demonstrations they take part in depends on how many professors request.

"It is a wonderful experience to be a part of the outreach events, especially when younger children are the audience," says Hudson. "You begin by showing them phenomena that they have given little thought about. Performing the demonstration and asking questions draws wonder and amazement from them. With a simple explanation and posing more questions, you continue to

amplify their amazement and wonder. As a teacher, that moment of enlightenment in learning is what you live for. When compared to older audiences, they are more experienced and knowledgeable, so the sense of amazement is not as dramatic but you always see signs of wonderment. As a former teacher, I enjoy the reactions of all as they are learning something new."

When good experiments go wrong

In a perfect world, every experiment would work out perfectly every time. However, sometimes, outside forces can cause an experiment to fail in front of a lecture hall full of participants. Hudson and Beidelman have learned to go with the flow when good experiments go wrong. Both have fond memories of experiments that ran adrift.

"We have a demonstration where we hold a paper cup of water over a Bunsen burner and show that it can't catch fire until the water boils out of the cup since the water will boil at a lower temperature than the paper cup will catch on fire," says Beidelman. The first time I set that demonstration up, I was rushing around grabbing things early in the morning and I grabbed a Styrofoam cup. Since the Styrofoam is an insulator, it wasn't transferring the heat as well into the water and the cup melted before the water boiled, spilling water all over the demonstration table during the lecture. It was after that class that I found our large box of paper cups that I should have been using for that demonstration."

For Hudson, the expectation of a notoriously tricky experiment ended up being the answer the students of the class were hoping for. The demonstration is called "Tangential Velocity from a Radial Motion."

"This demo is notorious for not working as expected, however, a professor requested it for his lecture knowing it failed a majority of the time," says Hudson. "When it came time to use the demonstration in his lecture, he explained what should happen and prefaced the class that this demonstration seldom works correctly. He was so confident of its tendency to fail that he offered an A to every student in class if it did work. Well, to his surprise and the student's joy it did work! The shocked professor did not want to renegotiate his promise so he gave everyone an A for the day (not for the course). After class, he inquired why the demonstration worked successfully. It was discovered by the staff that the knife used to cut the string of three whirling balls was dull, so the demonstration crew had sharpened the knife."

Favorite demonstration

As with any profession, there are some moments that stand out and simply make for a more fun work day. When your daily routine is science experiments, there are bound to be some that are downright fun. For Hudson, the small gyroscopes make for a delightful day of science.

"My favorite is Small Gyroscopes," he says. "By spinning a gyroscope, it will demonstrate stability. It can exhibit this stability in different orientations and supported by different figures. The gyroscope can stand on end or on a vertical extension. It will precess or rotate continuously in a horizontal plane. The gyroscope will also stand on a stretched string."

And or Beidelman, the experiment that is his favorite to demonstrate is, well, just plain weird.

"I really like the shoot the monkey demonstration because of how ridiculous it seems to me," he says. "We have a stuffed monkey hanging from an electromagnet on the ceiling, which is just something you can't just do any place. You have to have the proper setup ready with the equipment in place in the classroom. It's the type of demonstration you might never get to see somewhere else."

Sometimes it isn't the demonstration that stands out. It's the reaction. Hudson says the Superconductivity Demonstration is a crowd favorite and always draws the proper amount of oooos and awwwws.

"This is a demonstration where we place a small cubed neodymium magnet (about 8 mm on a side) on a superconductor, which is about the size of a quarter," he says. "We pour liquid nitrogen on the demonstration and wait for the superconductor to reach critical temperature. When it does, the magnet will rise and levitate above the superconductor. We can then take a pair of plastic tweezers and strike a corner of the magnet causing it to rotate at a high rate. Because of the small size, we use a remote camera to project this demonstration on the viewing screens of the lecture hall. After class, many of the students will come to the front to better observe and video the spinning magnet."

Taking the experiments where the students are

If Beidelman seems familiar to you and you can't quite figure out why, it's because he conducts these experiments for College of Science k-12 outreach via social media for the Superheroes of Science YouTube channel ran by outreach coordinators Sarah Nern and Steven Smith. Some YouTube videos that feature his demonstrations have racked up millions of views!

"I love filming the video because it winds up being just time with Sarah and Steve where I get to show off all the department's cool toys and explain the science behind them, which was always one of my favorite parts of teaching. When I'm filming, it helps me to just pretend I'm explaining it to the people in the room with me and talk about how the demonstration works like I'm explaining it to a friend instead of worrying about it being recorded. But seeing positive responses to some of the videos and realizing that I still get a chance to help people learn about the world around me has been really encouraging since I was missing that impact a bit when I stepped out of the classroom and moved into a behind the scenes role."

To view a couple of his favorites, check out the Hoot Tubes or the Tibetan singing bowl. "The Hoot Tubes demo has always been one of my favorite to get out and set up, particularly because it was a demonstration that I'd never seen before I got to Purdue," he explains.

Secret ingredient: teamwork

The old adage of "it doesn't happen in a vacuum" mostly applies with this duo and the team of professors they work with. Ok, ok, yes of course science works sometimes in a vacuum, we've all seen the egg in the bottle by now. But when it comes to the key to any successful demonstrations, it takes a team to educate the next generation of Boilermakers.

"I want to mention how impressed I am with all of our professors and lecturers in the Physics department," says Beidelman. "I have the easy job of maintaining the equipment and setting it up for them, but they're the ones who will actually use the equipment to make a point in their lectures and plan out lessons around the demonstrations that they request. I love getting to be a part of them teaching the next wave of physics students and knowing that I can do the prep work to make a meaningful addition to the lectures that they've put together and present to our students."

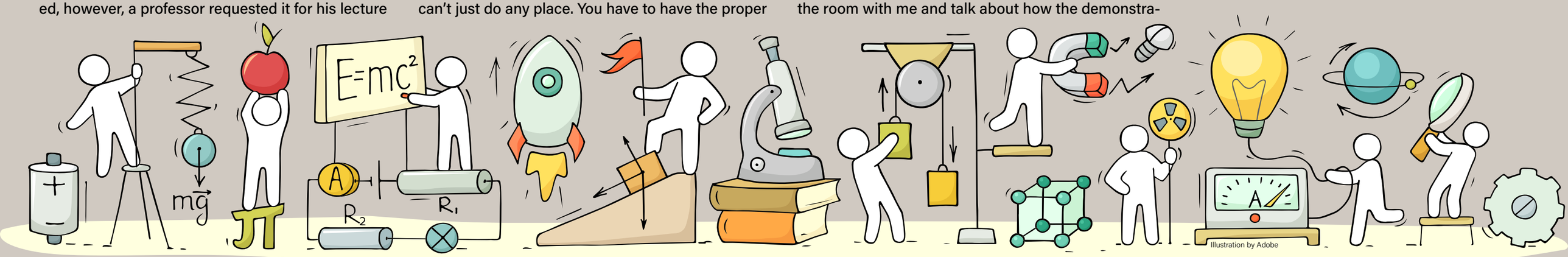


Illustration by Adobe

Danielle Dickinson presented her research at the 2024 American Astronomical Society convention. She was awarded the Chambliss Astronomy Award for her presentation. This award is granted to the top one percent of submissions. Photo provided by Danny Milisavljevic.

Student Spotlight: Danielle Dickinson

Years of core collapse supernovae research results in stellar autopsy of ASASSN-15ua

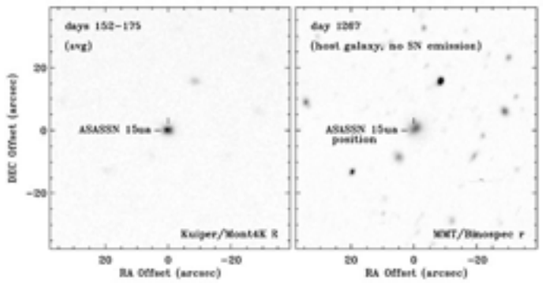
By Cheryl Pierce

It's been a stellar year for PhD student Danielle Dickinson. She was awarded the Chambliss Astronomy Award for a presentation at the American Astronomical Society convention this past December. This award is only granted to the top one percent of students who present. She also spent time in Colombia with Physics and Astronomy K-12 Outreach for the Saturday Morning Astrophysics program. In addition to all this, she published her premiere first-author paper for a supernova she has been researching since she was an undergrad.

Dickinson specializes in core collapse supernovae. These supernovae begin as giant stars that explode into collapse into the code. As molecules fuse inside the star, eventually the star cannot support its own weight and gravity forces the star to collapse into itself. Her publication appeared in the Monthly Notices of the Royal Astronomical Society and focuses on ASASSN-15ua which she has studied since she was an undergrad at Arizona State.

According to Dickinson, the star that exploded as ASASSN-15ua spent the last 12 years of its life losing mass. Some eruptive mechanism caused gas to come off of the star at a rate of one solar mass per year! When the supernova happened, the explosion ran into this "circumstellar material" around the star.

"My paper serves as a sort of stellar autopsy," she says. "I use spectroscopy to understand how fast the circumstellar material is moving, and I make estimates of how and when that mass was lost. We don't know why massive stars undergo these crazy mass loss events so close to the time of stellar death. It's like the star knows it's going to die. There are several well-studied examples, and the wind speeds and strengths vary considerably. Since they are all over the place, it's hard to pin down exactly what is causing it. My study contributed another of these objects to the sample, and I found that this object fell in the middle of the observed parameter space. This suggests a continuum of behavior, ie: one thing is causing a large diversity of behavior. I discuss many possible mechanisms for the mass loss, but I think binary interaction between massive stars is very important in this mass loss process."



Above is a visual of the ASASSN supernovae which appeared as the first image in Dickinson's recently released publication. She says it may appear like a dot among a fuzzy host galaxy, but the image is very beautiful to her. Photo provided by Dickinson.

Dickinson has a passion for outreach. Last year, she joined with Physics and Astronomy's K-12 Outreach for AstroCamp to help ignite a passion for science in the students of Medellín, Colombia. Photo provided by David Sederberg.

ASASSN stands for the All-Sky Automated Survey for Supernovae, and it's run by The Ohio State University. This object exploded in 2015, and it was given the extension "ua" because ASASSN found a lot of objects before it. ASASSN-15a would be the first object found in 2015. ASASSN-15b is the second, ASASSN-15aa is the 27th, etcetera.

"I think the star that made ASASSN-15ua was a luminous blue variable (LBV). These are the monsters of the universe," explains Dickinson. "They can be upwards of 100 times the mass of our sun. These stars burn so bright and so hot that they are very puffy and hardly bound together. We see in the literature that these stars are born less massive, but they feed off a companion star or completely merge with it, creating a rejuvenated star. Astronomers during Halloween like to call them vampires, but this is actually a very fair comparison. They are much older than they look. Because they are loosely bound, extremely hot, and in multiple-star systems, there are many reasons why mass would be eruptively lost from them. They are really, really awesome!"

Data for this publication was gathered using the SuperLOTIS Telescope, Kuiper 61" Telescope, the Large Binocular Telescope, the MMT Observatory, and the Bok 2.3-meter Telescope. All of these facilities are run by the University of Arizona. Dickinson initially became interested in astronomy and these facilities while an undergrad at the University of Arizona. They even featured her and her research in a video while she was there.

"I also have data from PANSTARRS," she says. "The SuperLOTIS data and PANSTARRS are open source, so anyone can access them. There are also light curves from ASASSN and the Catalina Sky Survey's Transient Survey (CRTS) out there that are publicly available, although I do not present that data in my paper."

Her publication was supported in part by the Rolf Scharenburg Graduate Fellowship and her advisor, also a co-author on the paper, Danny Milisavljevic. The Rolf Scharenberg Graduate Fellowship was established in 2017 through the generosity of Wendell and Nancy Lutz in memory of emeritus professor Scharenberg. The fellowships allow first- or second-year graduate students to work with a research advisor for a summer prior to joining a research group permanently. Dickinson worked on the research for this publication during the summer of 2022 in relation to the fellowship.

"Danielle's passion ignites discovery, her intellect forges new paths, and her dedication inspires excellence in us all," says Milisavljevic.

CONTINUED ON NEXT PAGE

As an undergrad at Arizona State, Dickinson was able to work with the Very Large Array Telescope on Kitt Peak, AZ. Photo provided by Danielle Dickinson.

She describes her research with ASASSN-ua as in "good but rough shape" when she arrived at Purdue. She considers herself lucky to be working with Milisavljevic and given the resources at Purdue to continue the research she began elsewhere. She also credits Katie Weil (postdoc), Paul Duffell, and Bhagya Subrayan for helping get this publication ready.

"They gave me a lot of support and advice to get this thing off the ground. It was a big Purdue effort, but I also received a lot of support from my coauthors, namely Nathan Smith and Jen Andrews," she says. "I'm really happy this paper is out, and I am very proud of the academic arc that it represents. I started this project in August 2018, and it was published Dec 13, 2023. I have grown a lot as a person and as an astronomer and everyone on the paper, coauthors and those in the acknowledgements, were part of that!"

Although this is her first first-author paper, the sky is the limit for Dickinson. One should expect many more to come as she perfects her next giant leaps in supernovae research.

"I study astronomy because it is breathtaking. Especially with the images from JWST, astronomy is beautiful, big, and exciting," she says. "I learned about Pulsar Timing Arrays in high school and found that they are a probe for gravitational waves! I was fascinated by the fact that mass could literally bend time and space. Like, wow! There is a Pulsar really far away, and I am being stretched by it! Once I took my first observational astronomy course my freshman year of undergrad, I was locked in. Light spends tens to thousands to millions of years to travel from a star to my eyes. It is a beautifully humbling history lesson. I love studying supernovae because they are element factories. I am thankful for the white dwarf that exploded billions of years ago for the Iron in my blood, and I am thankful for the massive star that exploded and made the gold in my earrings! I continue to be bewildered by nature, and I plan on continuing to study astronomy in academia."

THE DEPARTMENT OF PHYSICS AND ASTRONOMY WELCOMES NEW FACULTY

Dr. Jing Liu

Fall 2023 new faculty member

Liu's research focuses on the development of cutting-edge imaging methods and biophysical analysis tools to quantitatively interpret the complexity of molecules in a human cell. He was an assistant professor of Physics at the Indiana University - Purdue University Indianapolis (IUPUI).

"The utilization of physical sciences in cell biology is highly underestimated," says Liu. "Classical biology research is mostly based on the experimental observations; in the past decade, the newly emerged technologies and computational power have made the biological experiments quantitatively interpretable. I am especially interested in the spatiotemporal dynamics of the DNA and RNA that are the building blocks of life. Understanding these fundamental physical properties in the human cell will facilitate the diagnosis, treatment, and prevention of cancers, diabetes, and Alzheimer's Disease. My further research will integrate quantum optics techniques that would enable further advances in these fields."

Liu, an Associate Professor, will be teaching general physics, advanced laboratory, biophysics, and optics/advanced optics. While being at IUPUI, he has established his teaching philosophy by using the "Just In Time" method of teaching.

"I have integrated student active learning, group activities, and hands-on experience into my courses," explains Liu. "I intentionally create a collaborative learning environment, in which I act as a facilitator of learning and a resource to help in the students' own learning. Students are encouraged and expected to be actively involved in the learning process. In my classes, I have attempted to provide students with both theoretical perspectives and immediate practical applications necessary for their mastery of the course material. In addition, I also help students develop their presentation and writing skills through projects and presentations."

When not teaching or conducting research, Liu enjoys running. "I usually run 10k several times per week," he says. "This is the time that belongs to myself and I can focus on thinking about/brainstorming one specific thing over a long time."

Liu is no stranger to the West Lafayette campus; he received his Ph.D. at Purdue in 2015 in biological engineering from the Departments of Agriculture and Biological Engineering. Prior to this, he received his B.S. in physics at Nanjing University and his M.S. in optics at the Chinese Academy of Sciences (both located in China). After receiving his degree at Purdue, he immediately started an independent lab at the South Dakota School of Mines and Technology, then relocated to IUPUI in 2017. He is also affiliated with the Indiana University School of Medicine as a member of the Simon Comprehensive Cancer Center, Indiana Center of Diabetes and Metabolic Diseases, and Center for Computational Biology and Bioinformatics.

"The reason I chose to come to Purdue is the fantastic group of peers and excellent students in the physics department, College of Science, and across the entire west Lafayette campus," he says. "I appreciate the aggression on the research advances and emphasis on the engineering and physical science in biomedicine. At Purdue, I wish to establish a multidisciplinary biophysics program by connecting the strong physics and engineering research in West Lafayette with the unmet need in biomedicine in Indianapolis."

BOILER UP!

Dr. Ian Arnold

Fall 2023 new faculty member

Prior to this appointment, Prof. Arnold held several teaching positions at the collegiate level, including Lecturer at Purdue University, adjunct faculty at Indiana University Purdue University Indianapolis, and adjunct faculty at Ivy Tech Community College.

Prof. Arnold has taught multiple subjects in physics and mathematics, including general physics, physics for life sciences, electric and magnetic interactions, optics lab, physical mechanics, general calculus, and multivariate calculus.

"It's really important to me as a physics teacher to make this great subject less scary for all students, especially those who are intimidated by its complexity," says Arnold. "I am a physicist because I love exploring the structure and beautiful logic of the models that we use to describe nature. I also truly value the opportunity to communicate these ideas to the incredible students I get to teach here at Purdue."

Prof. Arnold earned his doctorate from Purdue in 2019 in theoretical condensed matter physics and a master's degree from Purdue in 2013 in experimental condensed matter physics. He graduated cum laude with a Bachelor of Arts degree in physics from Princeton University in 2011.

On his teaching career to date, Arnold noted, "I have called the Department of Physics and Astronomy my home for the last twelve years as a graduate student and lecturer, and I'm thrilled to be joining the amazing faculty who have taught me so much through the years!"

Part of Arnold's teaching philosophy includes assisting students beyond the classroom. He notes, "Students come with varying levels of exposure to mathematical sciences and physics. My familiarity with both theoretical and experimental research also aids in conversations with students who are applying to graduate school in scientific research fields. I strive to make myself available to students to shore up understanding in the fundamentals needed to approach more complex topics. I also feel it is important to help students prepare for their pre-professional exams, including medical, dental, and optometry school admissions tests. I have frequently heard from students in person and in reviews that they were surprised to see how approachable physics can be, which is of paramount importance when working with such a technical subject."

Prof. Arnold has been recognized with several awards during his career, including the 2023 Purdue College of Science service award, and the Purdue 2016 Akeley-Mandler Award for teaching excellence.

Prof. Arnold will teach multiple classes and administer learning and engagement initiatives for the Department of Physics and Astronomy. This fall his course offerings include PHYS 214 – The Nature of Physics, PHYS 233 – Physics for Life Sciences I and PHYS 234 – Physics for Life Sciences II.

Written by: Andrew Robison, Assistant Department Head of Purdue Physics and Astronomy

THE DEPARTMENT OF PHYSICS AND ASTRONOMY WELCOMES NEW FACULTY

Dr. Valentin Walther

Fall 2023 new faculty member

Walther is an assistant professor of both Physical Chemistry and Physics and Astronomy. He uses his extensive knowledge of quantum physics to teach advanced Quantum Mechanics and Quantum Optics, graduate level courses, at Purdue University.

"My research focuses on the science of light, called quantum optics," explains Walther. "A long-term dream is to manipulate individual particles of light or photons. To make this happen, we investigate how we can interface light in novel ways with atoms and semiconductors. We devise schemes for how we can create correlations between photons and how photons form quantum mechanical superposition states with atoms and semiconductor excitations, called polaritons. We also develop theoretical tools to describe the interaction of light and matter on the level of a few and many photons, and what we can learn about matter when we look at light that it emits."

Walther is originally from central Germany. He completed his BS in Frankfurt, Germany before moving to Stony Brook University for a year on a Fulbright grant. He received his PhD in theoretical physics at the Max-Planck-Institute for the Physics of Complex Systems in Dresden and also the University of Aarhus, Denmark. He then spent three years as a postdoctoral fellow at the Institute for Theoretical Atomic, Molecular and Optical Physics (ITAMP) at Harvard University. He says that his new home at the Purdue University West Lafayette campus stands out as the first smaller-town or rural environment he has lived in.

"I'm excited about the vibrant research in quantum science at Purdue," he says. "I really like the strong collaborative atmosphere among senior colleagues and the many starting research groups. The active participation of faculty and graduate students at the AMO seminars is a great example of this. My work is in AMO Theory, which is a traditional physics domain but it has more recently developed exciting overlap with Chemistry. I collaborate with chemistry colleagues on organic molecules that emit light, on semiconductors and giant Rydberg molecules."

When he's not teaching or conducting research, he enjoys the great outdoors. "I love being outdoors and I can be seen riding my bike to campus, almost every day. I've already explored some of the local places to hike but am currently expanding my horizon," he says.

Walther welcomes students, graduate and undergraduate, to reach out to him by email and join his weekly group meetings. They can learn more about him at his research website.

BOILER UP!

Dr. Tiancong Zhu

Spring 2024 new faculty member

Zhu is an assistant professor and began setting up his research program in the 2024 spring semester. He brings with him expertise in condensed matter physics and materials science, where he designs 2D quantum materials and heterostructures with novel properties and investigates their underlying physics at the atomic scale. He also explores the applications of these materials for both spintronics and quantum information science. He is currently setting up his lab in the Birck Nanotechnology Center with a state-of-the-art scanning tunneling microscope and a molecular beam epitaxy system. He is also setting up another lab in the physics building for van der Waals material assembly, hoping to provide more research opportunities to undergraduate students. In addition, he plans to develop a class on scanning probe microscopy and thin film deposition in the future to share his knowledge to the students who are interested in these topics.

"I am thrilled to join the Department of Physics and Astronomy at Purdue University, eager to embark on this new venture in physics," says Zhu. "I look forward to collaborating with exceptional colleagues and inspiring students, exploring new frontiers in physics during this exciting quantum era."

Zhu is an experimentalist who designs and investigate new materials with state-of-the-art technologies at atomic precision.

"My research delves into understanding how electrons behave within the atomic lattice of materials, and how that leads to intriguing quantum phenomena like magnetism, topological properties, and superconductivity," explains Zhu. "I meticulously design new materials with atomic precision using molecular beam epitaxy and van der Waals stacking. Employing scanning tunneling microscopy, I explore the properties of materials at the atomic scale, hoping to bridge the gap between macroscopic quantum phenomena and microscopic intricacies and explore their usage in quantum technology and information science."

Zhu is originally from Anhui, China. He earned his bachelor's degree in physics from Peking University in China. He spent six years in Columbus, OH, working on his Ph.D. at the Ohio State University. While there, he worked with Prof. Roland Kawakami, focusing on spin and magnetism in 2D materials. As a postdoctoral researcher at the University of California, Berkeley, he collaborated with Prof. Michael Crommie studying correlated and topological properties in 2D materials with scanning tunneling microscopy. He says the Midwest, including West Lafayette, feels like a second home.

"I love the people here, who are always warm-hearted and down-to-earth," he says. "I was attracted to Purdue for its stellar academic reputation, highly collaborative research environment, and visionary approach to quantum materials and quantum information science. During my visit last year, I was impressed by the innovative research directions and ideas, vast research opportunities, and world-leading research facilities at both the Department of Physics and Astronomy and the Birck Nanotechnology Center. I feel that my expertise will fit very well with the existing research agenda at Purdue, and Purdue will also provide a perfect platform to advance my research goals."

When not conducting research and teaching physics, Zhu can be found outside enjoying the great outdoors. He is an outdoor enthusiast and avid cyclist.

"Cycling, for me, is not just a sport but a way to enjoy nature and engage in conversations with friends," he says. "During my postdoc at UC Berkeley, I organized cycling trips, forming lasting connections with lab mates and friends outside of work. I am hoping to establish something similar here at Purdue."

UNDERGRADUATE STUDENT AWARDS

Ramdas Award
Colton Griffin
The Ramdas Award award was establish in 2018 by Anant K. Ramdas, the Lark-Horovitz Distinguished Professor of Physics and his wife, Vasanti Ramdas. The purpose of the Ramdas Award is to recognize an exceptional senior who has completed a unique project in the Department of Physics and Astronomy.

Judith Peters Humnicky Award
Olivia G. Scherrer, Raymond Glowner, John (Jay) Frandina, Suhani Sunder, Eliot D. Hilton
Judith Peters Humnicky was relentless in pursuit of her goals and this award honors her memory by recognizing the persistence, diligence, and hard work necessary to obtain an undergraduate degree in physics and enhances the gender diversity of among the Department's undergraduates. This award is made possible due to the generosity of Mr. Michael Humnicky (BS1970).

Spira Undergraduate Summer Research Award
Jack Rodgers
This award supports one or more students working on a research project under the supervision of a faculty member in the Department of Physics and Astronomy and/or the Department of Mathematics. The Spira Summer Research Award is made possible thanks to the generosity of Dr. Joel S. (BS1948) and Mrs. Ruth R. Spira.

Lijuan Wang Memorial Award
Marygrace M Fagan
The Lijuan Wang Memorial award is given annually to one or more outstanding undergraduate physics majors who promote the gender diversity of the department through participation in Women in Physics. Lijuan Wang was a graduate student in the department from 1989 until her untimely death in 1992.

Ralph Lefler Memorial Award
Ethan Pinarski
This award recognizes outstanding undergraduate students in the Department of Physics and Astronomy who have demonstrated interest or commitment in teaching K-12 programs after graduation. The award also recognizes students who significantly contribute to Physics and Astronomy outreach programs offered to K-12 students. Professor Ralph Lefler was a pioneer of physics education at Purdue and the Ralph Lefler Memorial Award is made possible due to the generosity of a group of his former students.

Frederik J. Belinfante Scholarship in Physics
William Messman
This scholarship recognizes outstanding physics upperclassmen. The scholarship is possible due to the generosity of Dr. Robert Newcomb (BS 1955).

Shalim and Paula Sargis Memorial Scholarship
Santiago Lopez and Gabriel Skowronek
The Sargis Scholarship recognizes a physics upperclassman from outside the state of Indiana who also graduated from a U.S. high school. This scholarship is made possible due to the generosity of Dr. James Sargis (BS 1958).

David G. Seiler Physics Scholarship
Amelia R. Binau
The Seiler Scholarship recognizes an outstanding physics upperclassman who is involved in Women in Science or Women in Physics programs. This scholarship is possible due to the generosity of Dr. David G. Seiler (PhD 1969).

Arthur N. Pozner Memorial Scholarship
Rana Yuvraj
This scholarship recognizes outstanding physics upperclassmen. The scholarship is possible due to the generosity of the Arthur N. Pozner Trust.

Kenneth S. and Paula D. Krane Physics Scholarship
Marygrace Fagan and Darin Tsai
The Krane Scholarship recognizes outstanding physics upperclassmen. The scholarship is possible due to the generosity of Dr. Kenneth S. (PhD 1970) and Mrs. Paula D. Krane.

Robert L. Mieher Physics Scholarship
Mason Giacchetti
The Mieher Scholarship recognizes outstanding physics upperclassmen and is made possible through the generosity of Dr. Edward B. and Dr. Barbara A. Hale.

Margie and Don Bottorff Undergraduate Physics Scholarship
Arianna Meenakshi McNamara and Melody Shimba
The Bottorff Scholarship is made possible by a gift from Ms. Celeste Bottorff (MS 1975). The scholarship is a 1-year award made to outstanding physics upperclassmen.

COLLEGE OF SCIENCE AND EXTERNAL AWARDS

AWM Schafer Prize Winner
Arianna Meenakshi McNamara
(external - 2024)

NSF Graduate Research Fellowship
Colton Griffin (external)

College of Science Outstanding Student
Spencer J. Walsh - Freshman
Marygrace Fagan - Sophomore
Gabriel Goodwin - Junior
Grace Francis - Senior

College of Science Ambassadors Graduating Seniors
Colton Griffin

College of Science Championing Diversity Award
Melody Shimba

Undergraduate Merit Scholarship
Jack Rodgers, Ashley Ortiz, Ian Holda, Allison Loper, Joshua Friedman

Science Physics Scholarships
Ashley Ortiz, Arianna Meenakshi McNamara, Allison Loper, Joshua Friedman, Santiago Lopez, Gabriel Skowronek, Leland Bednarz, Gabriel Goodwin, Jaiveer Dutta, Emanuel Borror

John Martinson Honors College Pillar Award for Outstanding Senior
Bianca Caminada

Purdue Mortar Board Class of 2023 Graduate Support Award
Bianca Caminada

Purdue University Bruce Helfert Memorial Award
Arianna Meenakshi McNamara

CONGRATS!

GRADUATE STUDENT AWARDS

Ramdas Prize in Honor of Professor CV Raman
Dr. Keiichiro Furuya
(Nominated by Nima Lashkari)
The Raman Prize recognizes a Ph.D. student or recent alumni for their outstanding dissertation. The award was made possible through the generosity of Anant K. Ramdas, the Lark-Horovitz Distinguished Professor of Physics and Astronomy (emeritus), and his wife Vasanti Ramdas.

Karl Lark-Horovitz Award
Xingyu Gao (nominated by Tongcang Li)
Our Department's most prestigious graduate student honor, the Lark-Horovitz Award recognizes outstanding research accomplishments. The award is possible through the generosity of the faculty as well as the family, friends, and associates of Prof. Lark-Horovitz in memory of his great contribution to the growth and development of the Department of Physics and Astronomy.

Gabriele F. Giuliani Award
Danielle Dickinson (nominated by Anderzej Lewicki)
Established in 2013 in memory of Prof. Gabriele F. Giuliani, this award honors excellence in teaching by first- or second-year graduate students. These graduate students show dedication and dependability, and, like Professor Giuliani, demonstrate a passion for physics that contributes to a rich learning environment.

George W. Tautfest Award
Juehang Qin (nominated by Rafael Lang)
Zachary Davis (nominated by Dimitrios Giannios)
This award honors outstanding physics graduate students in high energy particle physics, high energy nuclear physics, or astrophysics. Prof. Tautfest was the leader of the Purdue High Energy Physics group until his death in 1967 at age 41. The award was established in 1969 by his colleagues and the Purdue Alumni Foundation.

H. Y. Fan Award
Xinchao Zhou (nominated by Chen-Lung Hung)
The Fan Award recognizes outstanding graduate research in condensed matter physics, biological physics, or AMO physics. The award was established in recognition of Prof. Fan's many contributions to condensed matter physics, particularly in the area of infrared studies of semiconductors, and to the Department of Physics and Astronomy.

Charlotte Ida Litman Tubis Award
Keiichiro Furuya and Juehang Qin
The Charlotte Ida Litman Tubis Award was established in her memory by her husband, Prof. Emeritus Arnold Tubis, to promote clear and concise communication of scientific ideas beyond the physics and astronomy community.

Dr. Warner Black Award
Xingyu Gao (nominated by Tongcang Li)
The Black Award recognizes graduate students whose research has the potential to bring physics to the people and to help them improve their lives by using a deep knowledge of fundamental and applied physics to make practical and useful inventions that have a real and lasting impact.

Edward S. Akeley Award
Guangjie Li (nominated by Jukka Vayrynen)
This award recognizes outstanding physics graduate students in theoretical physicists. The Akeley Award is made possible through the generosity of Instructor Emeritus Anna M. Akeley.

Akeley-Mandler Award for Teaching Excellence
Robert Orlando (nominated by Andrezej Lewicki)
The Akeley-Mandler Award recognizes exceptional graduate student teaching assistants who excel beyond the mere requirements of the job, investing their effort to ensure that they provide the best education possible to their students. This award is made possible thanks to a gift made by Instructor Emeritus Anna Akeley in memory of her husband, Prof. Edward S. Akeley, and brother, Kurt Mandler.

Lijuan Wang Memorial Awards
Riya Riya (nominated by Rafael Lang)
Jijun Chen (nominated by David Koltick)
Bhagya Subrayan (nominated by Danny Milisavljevic)
The Lijuan Wang Memorial award is given annually to one or more outstanding graduate student majors who promote the gender diversity of the department through participation in Women in Physics. Lijuan Wang was a graduate student in the department from 1989 until her untimely death in 1992.

Rolf Scharenberg Graduate Summer Research Fellowship
Abigail Wesolek, Rongjie Li, and Kevin Barrow
This Fellowship was established in 2017 through the generosity of Wendell and Nancy Lutz and allows 1st- or 2nd-year graduate students to work with a research advisor for a summer prior to joining a research group permanently.

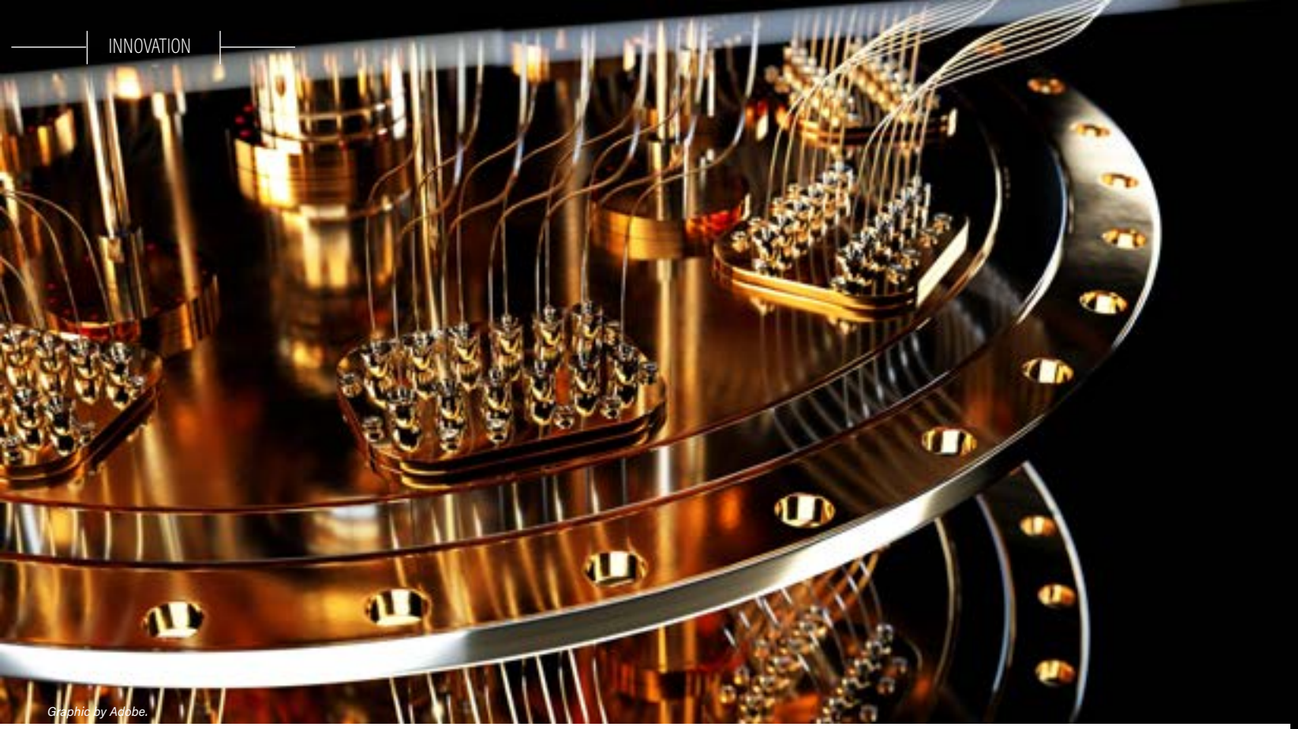
Teaching Academy Graduate Teaching Award for Physics and Astronomy
Ravishankar Subramaniam and Razan (Rosie) Hamed
This award honors graduate students with teaching responsibilities from across campus for their dedication to Purdue students and their outstanding teaching contributions.

Award for Most Contribution to Our Graduate Community
Ranadeep Dastidar
Given in Honor of Sandy Formica former Physics and Astronomy graduate advisor who retired last year. Given for For greatest contribution to the graduate community in the department of physics & astronomy.

Fellow into the Purdue University Teaching Academy
Ravishankar Subramaniam

Chambliss Astronomy Achievement Student Award (external award)
Danielle Dickinson

Bilsland Dissertation Fellowship
The Bilsland Dissertation Fellowship provides support to outstanding Ph.D. candidates in their final year of writing.
Xingyu Gao (2022-23) and Kunaal Joshi (2022-23)



Graphic by Adobe.

BOILERMAKERS GRANTED RARE OPPORTUNITY FOR HANDS-ON EXPERIENCE WITH A QUANTUM COMPUTER

By Cheryl Pierce

Quantum computing is expected to be the next giant leap in computer technology. These high-tech computers draw from physics and mathematics to use the properties of quantum physics to perform computations with amazing speed. These computers exist, but so far, very few people have been able to use or interact with them. They are so new that only a few even exist.

Thanks to a grant from the US Department of Defense, Purdue University students are now listed among the few people who will have hands-on experience with a quantum computer. The grant established the Innovation in Quantum Pedagogy, Application and its Relation to Culture (IQ-PARC) project, which not only gave funding, but awarded time on a quantum computer.

IQ-PARC seeks to address the gap in quantum education and workforce development. It not only develops educational materials accessible to learners with different backgrounds and levels but also provide free access to a diverse set of quantum hardware for learners to interact with through Azure Quantum.

Prof. Erica Carlson, 150th Anniversary Professor of Physics and Astronomy at Purdue University and host of The Quantum Age, is a co-founder of IQ-PARC. She is giving sophomore Physics majors this hands-on experience in Introduction to Quantum Science (PHYS 344).

"The day that I announced to the students that their last homework set would be programming on actual quantum computers, I also said I would need some beta testers, because I needed to be sure the signup instructions I gave the class were clear and correct before I deployed it to the entire class of 83 students," says Carlson. "Several hands shot up immediately. 'Okay, the first 5 people to email me will be our quantum computing beta testers.' Several students emailed right away. A few students approached me after class to ask when they would be given access to the quantum computers - could it be as early as tomorrow? (This was a Friday.)"

One of the eager Boilermakers is undergraduate Casey Ward. They are a second-year physics and mathematics major. As a budding physics theoretician, they are especially interested in what role quantum mechanics would play in gravitational theory.

"My experience working with quantum algorithms in comparison to classical ones was quite interesting," says Ward. "Computer science has a lot of mathematics tied into its foundations so to be able to work with a branch of computing where you are constantly seeing linear algebra and how it impacts how you write logic for different programs is fascinating. Linear algebra is such a far-reaching field in mathematics and is one of the foundations of what we do in non-quantum physics and becomes even more important in quantum mechanics. From Dr. Carlson's class we learned how the power of quantum mechanical effects can truly cause a drastic change in how we look at everyday processes. From how atomic clocks can help with more precise GPS signals to how quantum mechanics' stochastic nature can result in the ability to write algorithms that can solve problems much quicker than classical computers, such as prime number factorization (finding two prime numbers that multiply together to make a different number), through the use of quantum superposition of different possible outcome states of the problem."

How exactly does it work out that students can use a quantum computer? There isn't one physically at Purdue, so students are able to essentially remote in. Carlson recommended that students train using Microsoft's Azure Quantum's copilot. Carlson says that the students view a split screen with the quantum computing equivalent of "Hello World" on the left, and the Azure Quantum Copilot on the right.

"Think of it like ChatGPT for quantum computing, only they've been careful to train it really well," she explains. "I found it to be an excellent resource for anyone wanting to learn how to get started coding quantum computers. You can ask the copilot what the code example means, and you can even ask it to write new code for you. It can convert the code into standard quantum circuit language... Being a physicist, I was keen to ask it to translate Q# code into Pauli matrix language, and to my delight, it does this very well!"

Mahdi Hosseini, professor at Northwestern University, is the director of IQ-PARC. He says that the team tapped a student organization, the Quantum Game Club, which IQ-PARC helped launch, along with Microsoft to curate assignments compatible with cloud-based quantum processors on Microsoft Azure.

"By furnishing students with pre-written code and comprehensive instructions, we significantly reduced the barrier for engaging with quantum processors," he explains. "As a result, students could execute algorithms, experiment with the code, and articulate their findings effectively. Our students accessed cutting-edge quantum hardware at no cost via the Azure platform, courtesy of DoD-NDEP support (grant #HQ0034-21-1-0014). This initiative facilitated hands-on exploration and learning opportunities in quantum computing."

Students really understood the gravity of what they were able to do in this class. They understood that this is a rare opportunity and were excited to be able to use the newest technological breakthrough in computing.

"It was very exciting to be able to have the opportunity to work with something that at the time, I had only heard about in physics media," says Ward. "It was so much fun being able to play around and see what would happen when I did different things within the program."

Another student eager book time on the quantum computer is Rhea Pahuja. She is a Physics major minoring in Computer Science and is working toward an Applications of Data Science certificate. She was surprised to learn how much math and linear-algebra was involved in this process.

"The idea that we're playing with qubits and using these mathematical 'gates' to manipulate them is so cool," she says. "The fact that the entire computer functions on the properties of some electrons and these impossible probabilities that only exist in quantum mechanics, and we're using these complicated computers and coding on them blows my mind.

As a Purdue Data Mine student, she had similar experiences using Jupyter notebook to access a supercomputer. She found the processes similar and using the quantum computer felt familiar.

"Because of this detached way of coding, I don't think I ever really realized the full magnitude of what we were doing- we were coding on a quantum computer," she says. "In movies and media, the quantum is just one of those words they throw around to make something sound more 'science-y' and 'high-tech,' so understanding the fact that we are even learning quantum mechanics blew my mind. Even in the science world, quantum was always described as an exception- when discussing classical mechanics, sometimes a teacher or professor would say something like 'this is always true- except for in quantum mechanics but you'll learn about that later.' It is now that later, which is so crazy."

Pahuja came to this project hoping to figure out what is possible on quantum computers and what skills she would need to learn in order to understand the basics of usage. She sought to find similarities to other coding languages and logic.

"The huge calculation and power potential that quantum computers have, that they can even brute-force previously uncrackable encryptions... Even though at the beginning, quantum computers will only be available to governments and the rich, the potential of quantum computing is exciting and scary," she says. "Similar to AI- you want to be in that field and see where it goes, but everyone also thinks of the ramifications of this technology growing, both good and bad. The quantum computer itself is so incomprehensible to me- quantum mechanics I still don't fully get, and the fact that we're using it somehow to create these powerful computers that rely on two states kind of existing at the same time when we can't even really see or measure when they exist in that superposition state is a development I can't believe we're actually able to reach."

Carlson credits Dongyang Li, graduate research assistant with Purdue University's School of Electrical and Computer Engineering, for helping students gain access to the quantum computer.

"He is an administrator for our account on the quantum computers, and it was the heroic efforts of Dongyang that got all 83 of my students added into the quantum computing environment," she says. "Dongyang even came to our class to help students who were having trouble with the sign-in process."

Students taking PHYS 344 with Prof. Erica Carlson were able to use a quantum computer last fall. Carlson is able to bring this technology, which very few people have been able to access, to sophomores in her Introduction to Quantum Science class thanks to a Department of Defense Grant funding Purdue's IQ-PARC project. Pictured left to right: Akshith Karri, Thomas Slamecka, Prof. Erica Carlson, Casey Ward, and Esha Varkekar.

Student stargazers:
PURDUE ASTRONOMY CLUB AIMS TO BRING THE UNIVERSE TO FELLOW BOILERMAKERS

Bringing the community to the universe is a specialty of the Purdue Astronomy Club. This student club gets involved with community outreach events, such as the "Night Under the Stars" which they helped host last year in Zionsville, IN. Pictured in grey shirts from left to right are: Prof. Danny Milisavljevic, Outreach Coordinator David Sederberg, Dylan Caudill, Amelia Binau (front), Jack Mrachek, Aiden Dillard and Ethan Pinarski. Photo provided by Amelia Binau.

By Cheryl Pierce

On an icy cold morning at 5 a.m. November 8, 2022, Dylan Caudill ventured out into the frigid air with friends he'd met at Purdue University. He became interested in astronomy while at Purdue and joined the Purdue Astronomy Club (PAC). Going out into the crisp darkness, he and members of the student club witnessed a spectacular view of a lunar eclipse. He says it was this moment that really drove home for him the "why" in "why do we do what we do?"

Caudill, a senior undergrad studying Applied Physics specializing in Astronomy, is the current president of PAC. He has his sights set sky high at Purdue by getting involved in astronomy related research. He currently works with Jeffrey Gerber, continuing lecturer, conducting stellar astronomy research - characterizing flare rates of M-dwarf stars that were simultaneously observed by space telescopes. His love of astronomy is newly formed as it wasn't until he reached Purdue that he developed an interest in the science of the sky.

"I became interested in astronomy during my time at Purdue. Taking my first course hooked me into the field and set me on the path to pursuing it for the rest of my academic career," he says. "I became involved with the club through the invitation of a great friend that I made in those early astronomy classes."

The club seeks to involve undergrads in all things astronomy. It currently has 632 members, many of which attend the various events hosted by the club. It is a completely free, totally accessible, no pressure club that allows students from any major to take part. The faculty advisor for the club is Dr. David Sederberg, outreach coordinator for Purdue's Department of Physics and Astronomy. Students seeking to join the club can find information on its boilerlink page. There that they will meet PACs team members and be offered a link to the club's Discord channel. This allows students to keep in touch with upcoming sky-watching events and meet-ups.

PAC seeks to be a club that invites all students to gaze at the sky through telescopes and strives to pass their love of the sky to others. Ethan Pinarski, also a senior undergrad seeking an Applied Physics major, is the club's Outreach Coordinator. He also served as the Vice President of the club for two years previous. He studies astronomy and astrophysics with his main focus of study involving tracing the large-scale structure of the Universe using Lyman-alpha emitting galaxies and also studies supernova remnants in another research group.

"I have always had an interest in astronomy, but what really pushed me into studying it was my high school's astronomy club and the outreach events I went to at a local observatory," says Pinarski. "I got my first telescope shortly thereafter, and the rest is history. I got involved with PAC through the B-involved fair during my freshman year. I went to the stargazing events and eventually ran for office."

Ethan Pinarski enjoys his astrophysics with a side of nightscape photography (using the night sky as a backdrop to a nearby subject). Above is a photo he took on Purdue's West Lafayette campus. Below is a photo he took of the Orion Nebula which he was able to take with his phone. Photos provided by Ethan Pinarski.

Caudill credits the club's latest successes to Amelia Binau who started her presidential run of the club back in 2021. He said the club is what it is today because she helped revive a club that went somewhat dormant at the time she joined. She is the current Vice President of PAC and was President for two years. She is also a senior undergrad studying Applied Physics. She credits the movie Interstellar for propelling her love of astronomy but says that the basic principles of science drew her to the complexities of the sky.

"I'm a person who is very grounded in the outdoors, nature, and the natural world/environment and my entire life, I've had a tendency to analyze anything in the natural world I could get my hands on," says Binau. "I'd collect rocks, leaves, and insects and organize them, quantify their qualities, and classify them accordingly... this is something I still do as a hobby. This is the same research process astronomers use to understand astronomical objects, so my interests in astronomy followed naturally from this."

Binau says PAC is socially-oriented, laid-back, due-free, and open to all. The goal is to allow everyone, regardless of experience or background, to experience astronomy first-hand. If students would like to become more involved, she encourages them to email herself or Caudill.

"Our main goal is to give everyone the chance to look through a telescope and help them discover an appreciation for the universe," says Pinarski. "We cater to complete beginners, all the way up to astronomy minors and long-time astrophotographers. I think my favorite memory of this club might be when we helped run the 'Explore the Universe' event during the 2023 Boiler Gold Rush. I was astonished to see hundreds of students from all backgrounds coming to gaze upon the night sky through telescopes. We saw nebulae, star clusters, star clouds, and much more that night. The people who stopped by had great questions, and we were all happy to answer."

One of Binau's favorite memories of PAC involved helping students see the stars who were never before able to see them clearly due to living in an urban area.

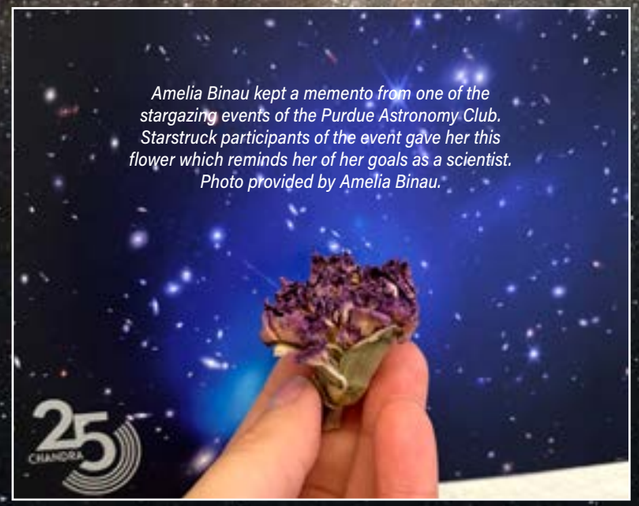
"During one stargazing event about a year ago, a group of girls gave me a carnation," she says. "They explained that in the city they grew up in, they could never see the sky in such detail as they could here due to light pollution, and thanked PAC for the experience. I keep the flower as a reminder that my goal as a scientist is to help others through the creation of knowledge, inspiration, and understanding." (would love a photo of the flower in your hands if that is at all possible.

Amelia Binau kept a memento from one of the stargazing events of the Purdue Astronomy Club. Starstruck participants of the event gave her this flower which reminds her of her goals as a scientist. Photo provided by Amelia Binau.

Due to the fact that all three students are in their final year as an undergraduate at Purdue, they are thinking ahead in hopes of preserving the club for the next generations of Boilermakers. They currently have three telescopes but two have fallen into disrepair due to use. They have applied for grants to help maintain these telescopes or to purchase more.

"We have been working through the SOGA grant system to attempt to gain new equipment for specific events during the various cycles. So far, our events have been unsuccessful, however we remain encouraged to keep trying to provide the best experience for our members," explains Caudill. "The reality is that much of our equipment is worn down from years of usage and cannot sustain major events which causes us to frequently rely on contributions from our members. Once these students move on from Purdue, we worry about the sustainability of the club given the status of what we have. We are doing the best that we can to make the most efficient use out of our time here and spread the wonders of astronomy to the student body. This is the major reason why we host free events, but this is getting increasingly difficult to do as time goes on and the current bank of funding decreases. For the sake of our members, we hope that we can continue to provide an amazing, free experience to our members, but without support from grants and members, this may not be possible in the years to come."

Ethan Pinarski enjoys his astrophysics with a side of nightscape photography (using the night sky as a backdrop to a nearby subject). Above is a photo he took on Purdue's West Lafayette campus. Below is a photo he took of the Orion Nebula which he was able to take with his phone. Photos provided by Ethan Pinarski.



Amelia Binau kept a memento from one of the stargazing events of the Purdue Astronomy Club. Starstruck participants of the event gave her this flower which reminds her of her goals as a scientist. Photo provided by Amelia Binau.

Alumnus Spotlight: Bruce Sherwood

The next giant leap relies on a matter of interaction

Alumnus Bruce Sherwood literally wrote the book that has educated boilermakers for decades

By Cheryl Pierce

For nearly 25 years, boilermakers taking engineering and physics classes have stood on the shoulders of alumnus Bruce Sherwood. With his spouse Ruth Chabay they literally wrote the book that thousands of students per year have used to take their next giants leaps in physics and engineering.

The books, "Matter & Interactions" (Wiley 4th edition 2015), are a two volume set that are a crucial stepping stone to both Engineering and Physics and are used by two of the largest groups of students at Purdue. In a given academic year, roughly 4,000 students will interact and learn from their books in PHYS 172H and 272H. The two-volume set has been used in courses taught by many faculty over the past two decades, including Gabor Csathy, department head, who taught from Matter & Interactions for well over ten years. According to Sherwood, these books take a contemporary view of physics, and they exploit novel educational approaches that make the physics much more accessible to students.

"Matter & Interaction takes a contemporary perspective emphasizing that there is only a small number of fundamental physics principles, a small number of types of interactions (gravitational, electromagnetic, the strong interaction, and the weak interaction), and a small number of fundamental particles," he explains. "The atomic nature of matter plays a major role. It includes a serious introduction to computational modeling of physical systems (thanks to the VPython programming environment we have developed) something that is central to all of STEM but completely missing from the other introductory physics textbooks."

Sherwood's list of accomplishments runs deep. He is a Professor Emeritus of North Carolina State University, fellow of the American Physics Society, fellow of the American Association of Physics Teachers, and fellow of the American Association for the Advancement of Science. He is fluent in Esperanto, Italian, and Spanish, and he reads French and Portuguese. And he's from just down the street, a West Lafayette High School graduate (1956) who received his B.S. in Engineering Science at Purdue University in 1960. He received a Fulbright in physics where he was able to study in Padua, Italy in 1961. He then received his PhD in experimental particle physics at the University of Chicago in 1966.

He is also the lead developer of VPython; and his writing partner has also contributed to its development. This background in programming language helped the pair set their textbooks apart from what was once the standards in education. They added a computational element to the books at a key time when computer science was taking hold in education. The team knew that instructors needed and wanted a radically different approach to teaching mechanics.

"In 1997 we started teaching a radically different mechanics semester," says Sherwood. "A key insight was made by Ruth, who pointed out that the utter centrality of computation to all of STEM meant that we could not teach authentic physics if we did not include a serious introduction to computational modeling. Her 1997 insight is striking; only very recently has computation begun to be seen essential in undergraduate physics, and our textbook 'Matter & Interactions' is still the only calculus-based physics textbook that includes computation!"

The decision to change course in textbooks was born out of a request presented by physics students. In 1997, Andrew Hirsch, professor emeritus of physics and astronomy, was the department head and entered into discussions with the undergraduate curriculum committee.

"The feedback we got back from our physics majors was that the mechanics education was the same mechanics that they received in high school, there was nothing really new," says Hirsch. "The problems were harder, but there was nothing modern included. We undertook a search for replacement books. Prof. Mark Haugan suggested we take a serious look at 'Matter & Interactions.' We looked at this two-volume set and realized it is a radically different approach. A key element in the development of these books was to incorporate computing. Up until then, our labs were very traditional. After incorporating this set, we made use of the computational component which used VPython, where you could do sophisticated simulations and visualize them in 3D. What we found is that students would make use of the programing aspects as they moved up through the physics curriculum."

Life at Purdue

"Ruth and I have visited Purdue several times, and it is a thrill for me, a West Lafayette kid, to see how our work is used in the giant Purdue course," says Bruce. "My Purdue experience had a huge impact on my work and life."

Two ways that Sherwood credits Purdue for influencing his work are purely academic. He took two courses that shaped his future. "One of the engineering courses I took was in Aero, taught by Paul S. Lykoudis [professor emeritus], who introduced the concept of making macro-micro connections, which is something we've done a lot of in our textbook," he explains. "Another was an engineering course on strength of materials made Young's modulus loom large, and it plays a major role in our textbook. Neither of these ideas plays a role in the traditional intro physics textbooks."

Even though he graduated with a 5.93 out of the then 6-point scale, life at Purdue wasn't strictly academic for Sherwood. He sang in the Glee Club in his early years at Purdue. He met his mentor, Pete Palfrey, who he credits for pointing him in just the right direction both in academics and his career. He met his then spouse when they attended West Lafayette High School and the two were chosen to represent Purdue on the nationally televised GE College Bowl contest.

Purdue College Bowl

"We were the first married couple to appear on the program; I was the captain," says Sherwood. "Purdue was nervous about participating, for fear that the breadth of students at liberal arts colleges would enable them to clobber us. However, we beat William & Mary, Case Western-Reserve, Reed, and Smith. What seems to have been the case is that there were so many students at Purdue, there would surely be some with broad interests, plus we were on average stronger in technical matters than our liberal-arts opponents. Upon our 4th appearance, which was the first time any team had won 4 times, it was announced that win or lose, the next Sunday would be our last appearance. By that time, we were all pretty exhausted, and we lost to Cornell."

Post Purdue

Sherwood was granted a Fulbright which took him to Italy. From there, he decided to apply for graduate school at the University of Chicago. Both these choices were encouraged by his mentor Palfrey.

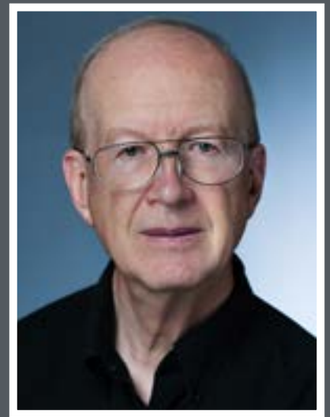
"I earned a PhD with one of the first online' experiments, on the energy spectrum of the electrons in muon decay, in the Telegdi group," says Sherwood. "While at Chicago I realized that Spanish was becoming ever more important, and I learned to speak Spanish based on my experience with Esperanto and Italian. This opened many interesting doors."

He took the expertise he gained and earned a position in an experimental particle group at Caltech.

"My teaching assignment was in the intro physics course, and the textbook was The Feynman Lectures on Physics. This experience had such a huge impact on me that I switched from particle physics to physics education, including the possible use of computers," he says. "While visiting family in West Lafayette at Christmas 1968, Palfrey urged me to go visit UIUC, where he believed there was an interesting project to use computers in education. I told him I was reluctant to go, because I hadn't heard of anything important there, but he made a strong case that if I was going to choose that field it made sense just to see what they were doing. So I reluctantly made an appointment to visit the PLATO project at UIUC."

As many do, Sherwood didn't account for the time change when going to Urbana-Champaign so he had an hour to kill upon arrival. A secretary gave him some internal reports to read, and it was at this point, Sherwood knew he had found his match with the PLATO project. Before he left for the day, he had a new position with the PLATO project with a joint appointment in physics. His strong knowledge of how to teach intro physics helped push the PLATO projects to new heights. But it wasn't just PLATO that Sherwood matched with at UIUC. He also made time to work with another passion: linguistics.w

"While working on speech synthesis in the PLATO context I took advantage of a splendid



Bruce Sherwood

Author of "Matter & Interactions" (Wiley 4th edition 2015)

B.S. in Engineering Science at Purdue University in 1960

PhD in experimental particle physics at the University of Chicago in 1966

Lead Developer of VPython

Professor Emeritus of North Carolina State University

Fellow of the American Physics Society

Fellow of the American Association of Physics Teachers

Fellow of the American Association for the Advancement of Science

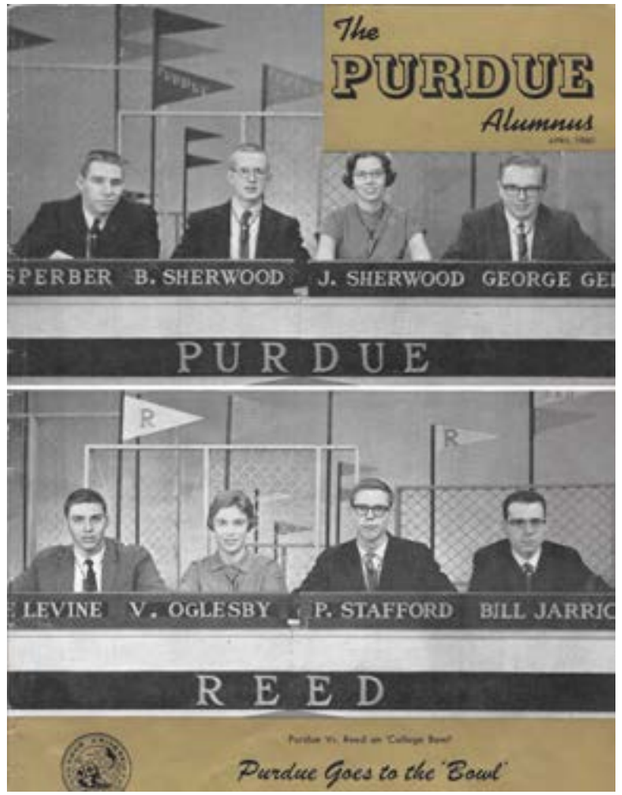
UIUC option to take an internal sabbatical year in a different department, to pick up tools that would be useful in my PLATO work," he says. "I spent a year in the renowned UIUC linguistics department, auditing graduate courses and co-teaching a course on international communications. At the end of the year I was awarded a courtesy appointment in linguistics." Yet another Purdue connection: the Purdue physicist Frederick Bellinfante introduced Sherwood to Esperanto, which was an enabler for learning other languages.

At a certain point, Sherwood realized there was nothing new that he could learn in the PLATO context, and he had a passion for learning. Again, it was time to move on and he embarked on a new path at the Center for Design of Educational Computing at Carnegie Mellon with a joint appointment in physics. It was here that he and Ruth realized that the textbooks for the calculus-based intro physics course were seriously lacking.

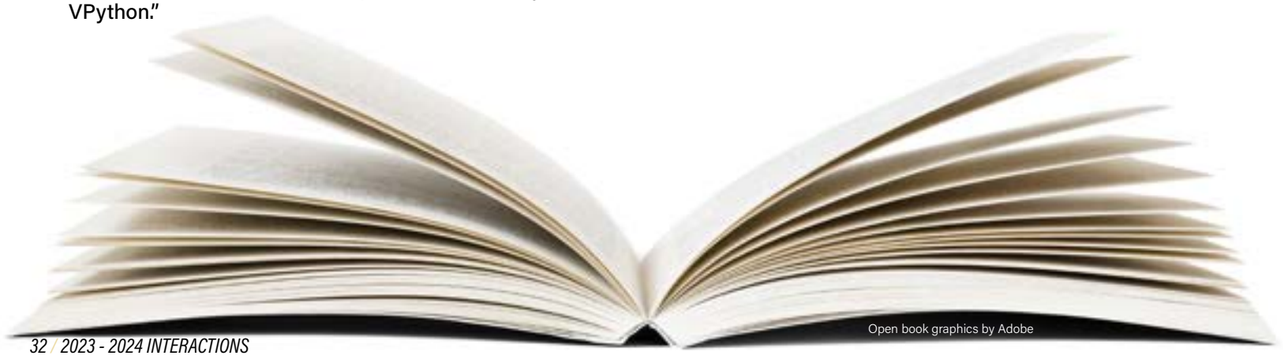
"We saw that at that time almost all PER (Physics Education Research) focused on the first-semester (mechanics) course," he says. "We decided to study the second-semester course on electrodynamics. When we began to study the traditional textbooks we were appalled by the sequencing of topics (e.g. charge, field, and Gauss's Law in the first week), and by the fact that arcane/abstract approaches were made to phenomena that no student had ever actually experienced. To take a simple example, students may have had experience with static cling but have never experienced electric repulsion. Ruth proposed some radical changes in the course, including moving Gauss's Law to late in the semester and moving magnetism much earlier in the semester (to firm up the field concept by showing students more than one kind of field). We also treat electrostatics and DC circuits as one coherent topic rather than two utterly separate topics. Wiley published our E&M textbook in 1995."

In 1999, after completing the mechanics volume, they reached out to all US physics departments to talk about their unique approach to teaching mechanics and E&M. This is where the full-circle moment came in with Purdue physics being early adopters to the exciting new chapter in physics and engineering education. In 2002, the couple moved to North Carolina State University.

"We learned how to make our curriculum, which had been developed with unusually well-prepared students at CMU, work with less well-prepared students, and we did succeed," says Sherwood. "In 2008 I retired from teaching, but I remain active professionally with Matter & Interactions and with VPython. Ruth, who is also a Fellow of APS and AAPT, retired from teaching in 2021. We now live in Portland Oregon and remain professionally active, including work on a 5th edition of our textbook, continued development of VPython."



Bruce and Judy Sherwood were chosen to represent Purdue on the nationally televised GE College Bowl contest. They were the first married couple to appear on the contest. The Purdue team went on to be the first team with four straight wins. Proto provided by Purdue Alumnus Magazine.



Open book graphics by Adobe

Purdue For Life:

Meet Erica Stickler, Senior Director of Development

Hello Boilermaker,

My name is Erica Stickler and I'm a Senior Director of Development with the College of Science. I'm honored to be able to serve as a liaison for the Department of Physics and Astronomy. I've already enjoyed getting to meet many of you!

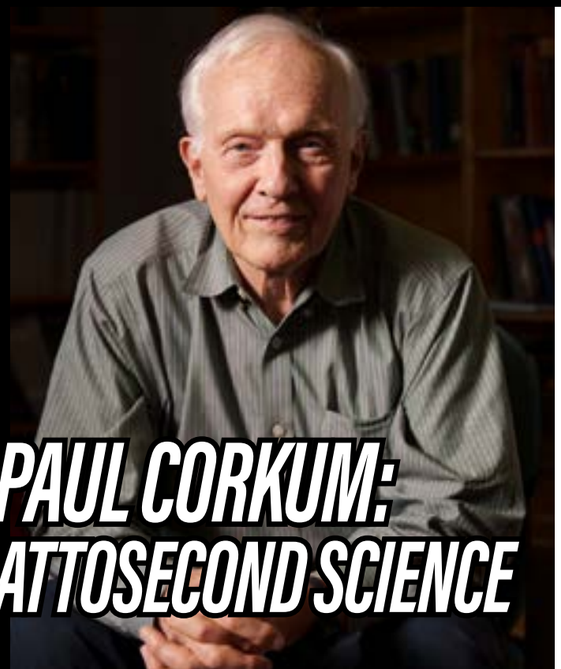
My educational experience is in nonprofit management and philanthropy. It has been such a gratifying experience getting to work with Purdue alumni and their families since joining the Purdue For Life team more than 3 years ago.

My favorite part of this job is hearing your Purdue stories and learning how your time on campus influenced who you are today. If you're interested in learning how you can make an impact in Physics and Astronomy, or simply want to learn more about the department, please feel free to email me at epstickler@purdueforlife.org.

Boiler Up!

Erica Stickler
Senior Director of Development | College of Science

PURDUE PHYSICS AND ASTRONOMY HUBERT JAMES LECTURE SERIES



THANK YOU TO PAUL CORKUM FOR DELIVERING THE HUBERT JAMES LECTURE THIS YEAR!

Paul Corkum, of the University of Ottawa and National Research Council Canada, spoke with faculty and students about his amazing research in attosecond science on March 28, 2024.

The Hubert M. James Lecture Series brings distinguished physicists to Purdue University to highlight fundamental aspects of physics for a broad university audience. The Department of Physics and Astronomy established the Hubert James Lecture in 1990 thanks to the generosity of the James family and in recognition of Prof. James's outstanding service to Purdue University from 1936 to 1974.

Hubert James Lecture Committee:

Chris Greene, David Nolte, Martin Kruczenski, Norbert Neumeister, Yong Chen, David Koltick

Stellar forensics: Clearest ever look at Cassiopeia A sheds light into the heart of an exploding star

JWST image and data give researchers insight into the nature of explosions, Cassiopeia A's progenitor star and the difficult-to-study interstellar medium

Story by Brittany Steff, Purdue University Science Writer
This story originally published on Purdue News, January 2024

WEST LAFAYETTE, Ind. — Images of stars released to the public, like the new image of Cassiopeia A, fire the public's imagination and kindle wonder in the breadth and beauty of the universe. But those images are more than just awe-inspiring art — they are treasure troves of priceless scientific information.

By taking photos of the stellar remnant using a range of tools and filters on the James Webb Space Telescope (JWST), astronomers are getting their clearest look ever at Cassiopeia A. Astronomer and star expert Danny Milisavljevic (pronounced mili-sahv-la-vich), an associate professor of physics and astronomy in Purdue University's College of Science, led an enormous international team of researchers on a JWST Year 1 project to study the supernova remnant.

Scientists are getting their best look ever at Cassiopeia A. The new image of that dead star has a starring role in First Lady Jill Biden's digital Advent calendar this year. Milisavljevic leads the project team whose data contributed to the staggeringly detailed new image. Photo by JWST/NASA.

"Previous images of Cassiopeia A, one of the most well-studied and important supernova remnants, were beautiful and staggering, but they only scratched the surface," Milisavljevic said. "They showed the brightest emissions. We are interested more in the gas that's closest to where the explosion originally took place, and what it can tell us."

False colors, true insights

When a supernova explodes, it sends out a powerful shock wave into the environment, gas and dust that was shed by the star before it exploded. The gas is cool — not just cool as in amazing and fascinating, though it is, but also cool in temperature compared to the bright emissions. The dust and other material Milisavljevic and his team are focusing on are incredibly complex, the result of an array of conflicting forces that scientists still do not completely understand.

The newest image of supernova remnant Cassiopeia A uses different colors to designate different wavelengths of energy.

"With some clever manipulation of the filters, we are able to look closely at the gas inside Cas A," Milisavljevic said. "We've never had this kind of look at an exploded star before. This weblike network of gas, these patterns and insights, these are all new discoveries. We are trying to figure out what is going on in the center of Cas A, the heart of the explosion."

The flashy part of Cassiopeia A is like a firework explosion — bright, eye-catching and dynamic. But the dust clouds and their movement, like the smoke left behind by a firework, are complex and communicate new information about the original star, its fatal explosion and the environment that surrounded the supernova. Using the new tools and abilities of JWST, the team can mask out the brightly shining parts of the star and focus more on the dust.

"The bright ring that draws your eye on images of Cassiopeia A, that's the result of shocks, like when a rock drops into water," Milisavljevic said. "That shocked material is very bright in ultraviolet and X-ray light, and it shines photons inside the cloud of gas that hasn't yet been shocked. That's why we can see it in the infrared — because of this rain of X-ray and UV photons shining and illuminating all this gas that has been hidden from view."

Astronomers have spent decades trying to figure out what kind of star existed before it turned into supernova Cassiopeia A. To do that, they needed new, stronger tools and the ability to peer into the heart of the explosion.

Danny Milisavljevic's Year 1 research on the James Webb Space Telescope led to his new detailed image of stellar remnant Cassiopeia A in which infrared light is translated into visible-light wavelengths. Photo by Purdue University.

Stronger, closer, better

When Galileo first looked closely at the planet Saturn in 1610, he famously described it as having ears. Decades later, with advances to telescopes, Huygens was able to resolve the ears into rings around the planet. And much, much later, in 1856, Scottish physicist James Maxwell deduced that the rings weren't solid at all but were composed of innumerable shards of rock and ice.

That same advancing of knowledge, along with technical telescope improvements, is echoed in JWST's discoveries.

"We have had glimpses of the heart of the explosion before," Milisavljevic said. "It was shown faintly in images from Spitzer, and HST (Hubble Space Telescope) shows it a little bit. Additional information came from Chandra and NuSTAR telescopes sensitive to X-ray light. I wrote a paper about modeling it in 3D years ago. But Webb has this spectacular ability to tease out all the gas that is there. For the first time, we'll be able to connect the relatively bright gas located along the periphery of the remnant with the faint gas inside the explosion that only Webb can see."

For instance, an enigmatic structure dubbed the "Green Monster" for its resemblance to the eponymous green wall in Fenway Park baseball stadium puzzled and dazzled the world since NASA's first image release in April 2023. However, careful analysis by Milisavljevic's team, supported by observations made by Chandra, demonstrated that this Green Monster was actually gas in the foreground, located far away from the explosion center. Like a rogue photobomber in a vacation photo, the Green Monster grabbed attention but was not the intended target. Using special filtering techniques, scientists were able to digitally remove the Green Monster and successfully examine the extremely faint light emanating from deepest layers of the exploded star, as they had originally set out to do.

Understanding the nature of the explosion will help astronomers answer long-held questions about how stars live and how they die. How the core of the star collapsed physically, and why it did, will answer important questions about the composition of stars and how they change and evolve.

Time machines and light echoes

What astronomers really want, of course, is faster-than-light travel, time machines, and endless time and resources to personally inspect the stars. Absent those, however, JWST is a pretty good substitute. The laws of physics themselves, in fact, have acted as a sort of time machine to show astronomers what the supernova remnant looked like earlier in its history.

In the corner of the image of Cassiopeia A, something that looks like a smaller version of the supernova remnant itself appears. Dubbed "Baby Cas A," it is actually a light echo located about 170 light-years behind Cassiopeia A. Located about 11,000 light-years away, Cassiopeia A exploded 340 years ago from Earth's point of view. Baby Cas A formed as the light from the explosion hit dust about 170 years behind Cas A and then bounced forward again to hit JWST's mirrors.

Watching how the star explodes and how light and matter move outward gives astronomers insight into the very nature of space itself between the stars. As hard as it is to study balls of gas burning billions of miles away, at least they're lit up and visible against the darkness of space. Studying that dark space, the space between the stars, is exponentially more difficult, but as vitally important to understanding how the universe, and humanity's planet within it, developed and evolve.

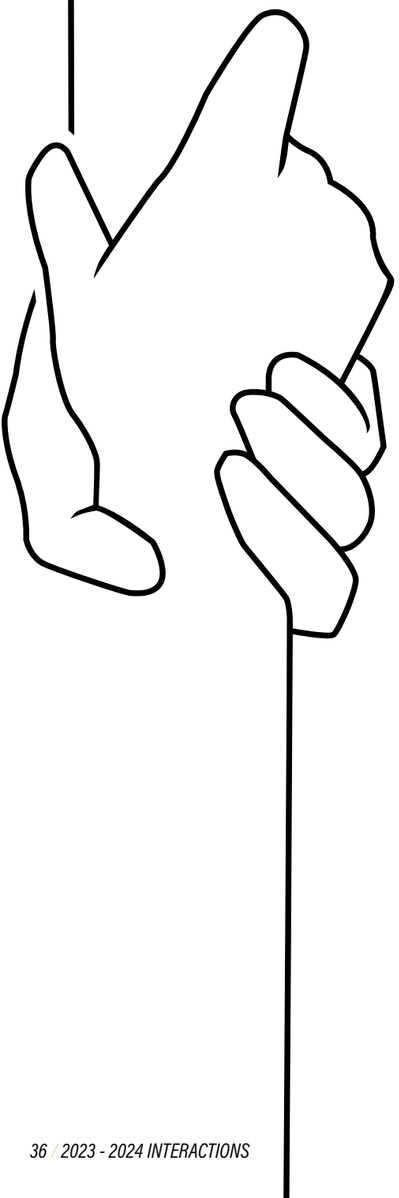
"This round of papers, this round of discoveries, are incredibly exciting," Milisavljevic said. "We are highlighting what we see as some of the most exciting initial results, the kind that immediately pop out of the dataset. It is the first reconnaissance. I anticipate many exciting scientific discoveries still to come from these data over the next several years."

The Professor Ralph Lefler Memorial Scholarship Endowment:

Scholarship honoring professor, created by students to help students

JWST image and data give researchers insight into the nature of explosions, Cassiopeia A's progenitor star and the difficult-to-study interstellar medium

Professor Ralph W. Lefler



Story by Cheryl Pierce

Once you've reached a higher step, you reach back and help the next person up. That's the Boilermaker way. One shining example of this is the legacy of Professor Ralph W. Lefler and the endowment created in his honor by his students that began helping current Boilermakers two years ago.

Professor Ralph W. Lefler's education began in a one room eight-grade schoolhouse in rural Indiana. Through his tenacity, he elevated his own education which enabled him to be a Professor of Physics at Purdue University. He described the teachers he encountered in his early education as good, earnest people and noted that his interest in physics grew out of a science class in his high school.

His passion for education educators allowed him to take charge of a National Science Foundation (NSF) program that ran through 1974 called the Master's Degree Physics Summer Program. Lefler ran this program through 1971 and his input benefited roughly 200 Physics Alumni. The summer program recognized that high school science teachers needed more education and resources with specific regard to physics. Lefler retired in August of 1971 and passed away in June of 1995, but his immeasurable impact lives on through his students. And now, that impact is being passed to the next generation of Boilermakers.

A group of students from the Master's Degree Physics Summer Program wanted to honor their mentor and friend so they started the Professor Ralph Lefler Memorial Scholarship Endowment so that Lefler's legacy would be impacting students at Purdue in perpetuity. This endowment allows for scholarships to be given to students in the department of Physics and Astronomy who have an interest in and focus on teaching physics.

The endowment began giving scholarships in Fall of 2022 and so far has been given four times to Boilermakers that aspire to bring their love of physics to the next generation. Alan Wright (Fall 2022 and Spring 2023), Benjamin D. Simon (Fall 2022), and Ethan Pinarski (Fall 2023).

Pinarski is a current senior undergraduate studying Applied Physics. He will earn his Bachelor of Science this year. In addition to his studies, he is active in the Purdue Society of Physics Students, Purdue Astronomy Club, and can often be found working with Physics and Astronomy outreach to help K-12 students foster their own love of science.

"Receiving the Lefler award really solidified that the work I am doing is having an impact," says Pinarski. "When I got the award in 2023, I had been doing outreach with the Physics and Astronomy Department's Outreach Coordinator, Dr. Sederberg, for two years in a multitude of programs and projects he has been running. This award, and my time as an outreach volunteer, have helped me understand the importance of outreach on all levels, from kids to adults. While I one day aspire to be a professor, my immediate teaching goals after Purdue will remain in outreach. I love giving these learning opportunities to students, and I will continue to do so wherever I end up."

Alan Wright has received this scholarship and is currently student teaching at an area high school. He earned his Bachelor's degree in 2022 and is pursuing his Master's Degree at Purdue in Science Education with an expected graduation date of 2024.

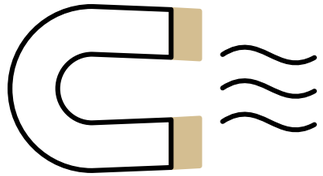
"I didn't decide to be a K-12 educator until my junior year, but as an undergraduate I had several great teaching experiences that helped me make that decision," says Wright. "I loved working as a teaching assistant for PHYS 172 and 272 and also helping Dave Sederberg with physics outreach like Saturday Morning Astrophysics at Purdue. For me, the Lefler Award stood for this involvement in the department and was validation from my mentors and colleagues that I was on the right path. I'm currently finishing up my student teaching at Jefferson High School in Lafayette. It has been a wonderful experience, and I hope to have a high school physics teaching position of my own in the fall."

Another student who has benefited from the award is Benjamin Simon, currently a first year physics PhD student at Purdue who is working as a graduate research assistant under Dr. Miaoyuan Liu. He was one of the first students to receive the award.

"I'm very passionate about teaching and connecting with students, so receiving the Lefler scholarship felt extremely rewarding," says Simon. "The award renewed and reinvigorated my commitment to giving my current and future students the best education I can provide. My long-term career goal is to be a physics professor so that I can continue working with students while I pursue research. Receiving the Lefler scholarship definitely made me feel like I'm on the right track. After I received my bachelor's degree and began my PhD program, I had the opportunity to be a teaching assistant for PHYS172H, the introductory mechanics course for 1st-year physics majors. I had an incredible time getting to know these students, guiding them through the course material, and giving them advice on how to navigate undergrad. Now as a research assistant, I continue to work with undergraduate students on various projects, and I hope I continue to have the privilege to work with students in my future positions."

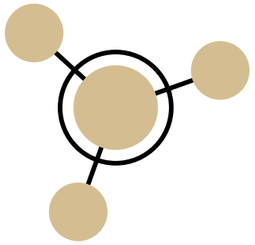
One of Lefler's students, James Jennings, credits Lefler for changing the course of his professional life. He says that Lefler continued to aid his professional career even after Jennings graduated from the summer program. It was for this reason, Jennings and other students of Lefler came together to honor him with this scholarship endowment. These students said each of their lives were forever changed for the better because of the education they received at Purdue and due to Lefler's impact. This endowment is open for additional donations. Friends and alumni who would like to add to the endowment and help the next generation of Boilermakers become better teachers, can do so here.

Benjamin D. Simon, is a first year physics PhD student at Purdue who was one of the first students to receive the Lefler scholarship. He spoke about the impact it made in his life on his LinkedIn profile.
Lineart hands image by Adobe.



KEEP UP WITH WHAT'S HAPPENING AT PURDUE PHYSICS AND ASTRONOMY!

The Department of Physics and Astronomy is constantly pushing the limits of the world's collective knowledge of our physical world. We persistently pursue the next giant leap in our sciences and explore avenues of outreach. Below is a sampling of the ways you can keep up with what is happening in the department. Boiler up!



Website: physics.purdue.edu

Departmental Social Media:

Twitter/X: @PurduePhysAstro
Threads: @purduephysastro
Instagram: @purduephysastro
Facebook: Purdue Physics and Astronomy
LinkedIn: Purdue Physics and Astronomy

Galileo Unbound:

galileo-unbound.blog

This blog is an ongoing series by Professor David Nolte, the Edward M. Purcell Distinguished Professor of Physics and Astronomy. He discusses all things physics and takes you on a roller coaster ride into the history of our sciences. You can also keep up with Galileo Unbound on the YouTube page.

The Astrophysics Podcast:

rss.com/podcasts/astrophysics

Once a month, Purdue University's Professor Paul Duffell discusses astronomy and astrophysics with experts from around the world on The Astrophysics Podcast. Duffell and guests discuss supernovae, galaxies, planet formation, black holes, and the nature of space and time.

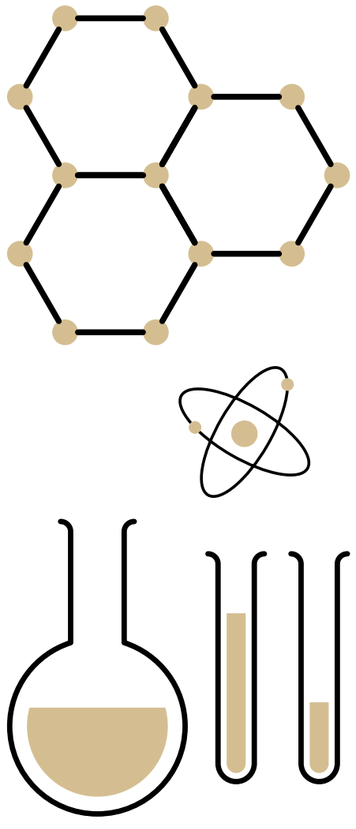
The Quantum Age:

thequantumage.com

As host of The Quantum Age, Professor Erica Carlson takes you through the ins, outs, ups and downs of the quantum world. Using everyday objects and creative analogies, she makes quantum materials exciting and easy to understand. In addition to her stunning website, you may find The Quantum Age on Dr. Carlson's YouTube page.

Purdue Physics and Astronomy K-12 Outreach: physics.purdue.edu/outreach

Physics and Astronomy Outreach is ran by Dr. David Sederberg. It has many programs but also makes Classroom Calls, providing resources and expertise for the K-12 classroom teachers. Whether we provide a "Scientist on Site" for a classroom talk and demonstration, support for lesson design and implementation, or work with teachers to provide a novel learning experience, Physics and Astronomy Outreach is eager to spread our enthusiasm for learning science. Keep up with the latest on K-12 outreach on the outreach website, their YouTube page, or on Twitter/X.



DEGREE RECIPIENTS

SPRING 2023

William F. Alford, Bachelor of Science
Zackary T. Balbo, Bachelor of Science
Bianca C. Caminada, Bachelor of Science
Benjamin F. Coate, Bachelor of Science
George J. Economou, Bachelor of Science
Margaret C. Erichsen, Bachelor of Science
Grace C. Francis, Bachelor of Science
Aubrey L. Fuhrman, Bachelor of Science
Thomas M. Gallagher, Bachelor of Science
Zachary M. Garcia, Bachelor of Science
Manuel A. Gil, Bachelor of Science
Colton M. Griffin, Bachelor of Science
Preston R. Hardcastle, Bachelor of Science
Kyler A. Harrison, Bachelor of Science
Benjamin H. Hayward, Bachelor of Science
Marco A. Iacobucci, Bachelor of Science
Zain Z. Khurshid, Bachelor of Science
Danny H. Kim, Bachelor of Science
Nolan C. Kruger, Bachelor of Science
Michael C. Kuske, Bachelor of Science
Nicolas W. Lamb, Bachelor of Science
Alex Leung, Bachelor of Science
Qingyang Li, Bachelor of Science
Japneet K. Mavi, Bachelor of Science
Joseph J. McGuire, Bachelor of Science
Ankita Mishra, Bachelor of Science
Chandler Pilipis, Bachelor of Science
Amit Rohan Rajapurohita, Bachelor of Science
Caleb T. Remocaldo, Bachelor of Science
Peter Salisbury, Bachelor of Science
Dominic A. Seidita, Bachelor of Science
Cameron A. Shane, Bachelor of Science
Erin E. Smith, Bachelor of Science
Madelyn E. Sumner, Bachelor of Science
Keller M. Swartzentruber, Bachelor of Science
Zheng Yuan Tan, Bachelor of Science
Xinghan Wang, Bachelor of Science
Michael M. Wasem, Bachelor of Science
Daniel G. Woodruff, Bachelor of Science
Ivan Yang, Bachelor of Science
Jacob DeLange, Master of Science
Haichuan Cao, PhD, doctor of Philosophy
Michael Higgins, PhD, doctor of Philosophy
Akhil Jaisingh Sheoran, PhD, doctor of Philosophy
Forrest Simmons, PhD, doctor of Philosophy
Jason Thieman, PhD, doctor of Philosophy
Yuchen Wang, PhD, doctor of Philosophy
Saeed Yazdani, PhD, doctor of Philosophy
Hao Zhang, PhD, doctor of Philosophy

SUMMER 2023

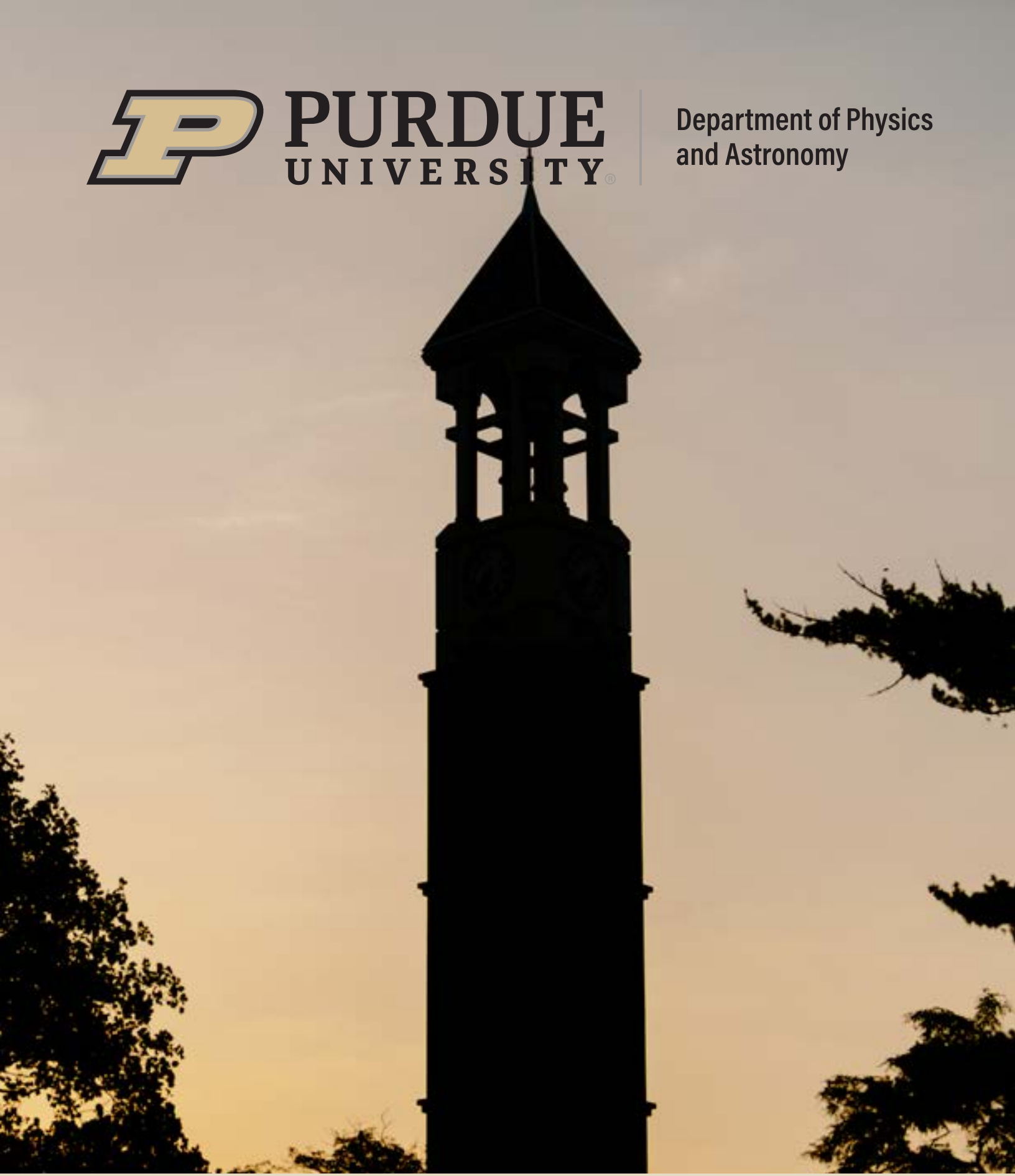
Bahaa Elshimy, Bachelor of Science
Ammar Amgad Mohamed Bayo Ali, Master of Science
Pavani Devabathini, Master of Science
Abigail Rae Hickin, Masters of Science
Shashank Kumar, Masters of Science
Dashan Zhang, Masters of Science
Amandeep Singh Bakshi, PhD, doctor of Philosophy
Yiyang Feng, PhD, doctor of Philosophy
Keiichiro Furuya, PhD, doctor of Philosophy
Juehang Qin, PhD, doctor of Philosophy
Praveen Sharma, PhD, doctor of Philosophy
Ananthesh Sundaresh, PhD, doctor of Philosophy

FALL 2023

Alexander J. Gleason, Bachelor of Science
Xieyuan Guo, Bachelor of Science
Ashwin J. Jayachandran, Bachelor of Science
Forrest E. Lee, Bachelor of Science
Anthony J. Moore, Bachelor of Science
Satyarth Sauhta, Bachelor of Science
John C. Tridico, Bachelor of Science
Donovan G. Trzybinski, Bachelor of Science
Robert H. Wantuch, Bachelor of Science
Yinchen Zhou, Bachelor of Science
Hamza Ather, Masters of Science
Mohamad Ibrahim Abdelhalim Mousa, Masters of Science
Mahmoud Moataz Kassem Moustafa, Masters of Science
Jared Ryan Newton, Masters of Science
Hyeon Seo Yun, Masters of Science
An Gu, PhD, doctor of Philosophy
Abraham Mathew Koshy, PhD, doctor of Philosophy
Andres Llacsahuanga Allcca, PhD, doctor of Philosophy
Uday Sood, PhD, doctor of Philosophy

CONGRATULATIONS

TO OUR NEWEST ALUMNI!



PURDUE UNIVERSITY

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