2024

INTERACTIONS

Carnegie Mellon University
Mellon College of Science
Physics

INTERACTIONS

The Department of Physics

Interactions is published yearly by the Department of Physics at Carnegie Mellon University for its students, alumni and friends to inform them about the department and serve as a channel of communication for our community. Readers with comments or questions are urged to send them to rmandelb@andrew.cmu.edu. The department is headed by Rachel Mandelbaum.

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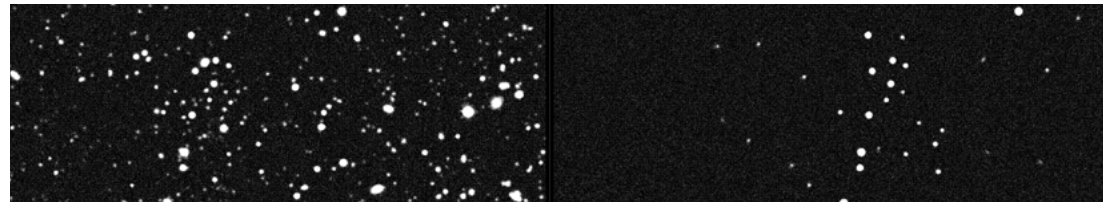


Letter from the Department Head

Dear Colleagues, Students, and Friends of the Department of Physics,

The past year has been an exciting one in the department. Following several consecutive years with many retirements and strategic hires who built on our strengths while opening exciting new research directions, the focus this year has been on supporting and celebrating the success of our fantastic new faculty and their growing research groups. You can find several examples in this edition of Interactions, including the recognitions of Associate Professor Diana Parno and Assistant Professor Fangwei Si with career development chairs; the expanded scope of the renamed McWilliams Center for Cosmology and Astrophysics including new directions led by Assistant Professors Katie Breivik and Antonella Palmese; and three junior faculty (Assistant Professors Valentina Dutta and Matteo Cremonesi, and Associate Professor John Alison) who join Professor Manfred Paulini in an ambitious construction program for the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider.

At the same time, we have established new educational programs that align with the department's strengths. These include a new undergraduate quantum track, and a master's of science in modern physics. These programs provide our students with unparalleled opportunities to engage with the latest advancements and prepare for successful careers in physics. We are thrilled to celebrate the accomplishments of our students, like Yunshu Li and Katherine Parry who were named Goldwater Scholars and Andy Park and Zachary Baldwin who were selected for the Department of Energy's Office of Science Graduate Student Research Program .

The department is well connected to current events in physics. We hosted events for the April 2024 solar eclipse and the Pittsburgh Quantum Institute conference (particularly timely going into 2025, the International Year of Quantum Science and Technology). You can read how we are integrating AI into physics research, which was the subject of the 2024 Nobel Prize, and about the department's involvement in commissioning of the Vera C. Rubin Observatory, the flagship ground-based observatory of the 2020s.

Finally, the department and the Mellon College of Science (MCS) are in a state of transition. I'd like to extend my wholehearted thanks to Professor Scott Dodelson, physics department head for 7 years until August 2024. He not only saw the department through the pandemic — he led it through years with strategic faculty hires across research disciplines and educational programs. He has had an outsized impact on the department and will be missed; I wish him the very best in his next adventure at Fermilab and the University of Chicago. At the same time, with a new MCS dean starting in January 2025, we are all looking forward to great adventures here at CMU.

Sincerely,

Rachel Mandelbaum

Interim Head of the Department of Physics

FACULTY NOTES

Rachel Mandelbaum Named APS Fellow, Interim Department Head

Carnegie Mellon University Physics Professor Rachel Mandelbaum has been elected a fellow of the American Physical Society (APS), as recommended by the society's Division of Astrophysics.

Mandelbaum is a member of the McWilliams Center for Cosmology and Astrophysics. She was recognized for the development of many techniques that have impacted the field of weak gravitational lensing, for discoveries in cosmology and galaxy formation using weak lensing, for international leadership in large cosmic surveys and for thoughtful, inclusive mentorship of many early career scientists.

"I am honored and humbled to be recognized by the APS," said Mandelbaum, who became the interim head of the Department of Physics in August. "I particularly appreciate that this recognition covers multiple facets of my work — scientific discovery along with leadership and mentorship, which have been huge focuses for me in the past few years."

Mandelbaum joined Carnegie Mellon's Department of Physics in 2011 and combines information from cosmological observations with computer science, statistics and data science.

"This award recognizes not just Rachel's scientific discoveries but also her leadership in large collaborations and mentoring of young scientists," said Scott Dodelson, the former head of the Department of Physics.

Mandelbaum is the primary investigator from Carnegie Mellon leading research with the University of Washington to develop software to analyze large datasets generated by the Legacy Survey of Space and Time (LSST), which will be carried out by the Vera C. Rubin Observatory in northern Chile.

Mandelbaum has served in leadership roles and won numerous awards in physics and cosmology. In 2023, she served on the Particle Physics Project Prioritization Panel (P5) that outlined recommendations for U.S. particle physics priorities for the next 20 years and funding for the next 10 years. She was the spokesperson for the LSST Dark Energy Science Collaboration (DESC) between 2019–2021 and previously served as the DESC analysis coordinator and co-leader of the weak lensing working group. She received the Annie Jump Cannon Prize from the American Astronomical Society, a Department of Energy Early Career Award, an Alfred P. Sloan Fellowship and was named a Simons Investigator by the Simons Foundation.

■ *Heidi Opdyke*

Rachel Mandelbaum, right, visits the Vera C. Rubin Observatory in northern Chile.

Three Faculty Members Honored With Professorships

Three faculty members in the Department of Physics were recently honored with professorships to support their work. Diana Parno, Ira Rothstein and Fangwei Si were recognized at a reception Sept. 16 in the Cohon University Center.

“Professorships are among the highest academic honors that the university can bestow upon a member of our faculty,” said James H. Garrett Jr., provost and chief academic officer. “They allow our recipients to access resources that will expand their research and generate meaningful work.”

Rothstein received an endowed professorship that will support his work at Carnegie Mellon. Parno and Si received career development professorships that support scientists at the beginning of their careers.

“As I look at the recipients sitting in front of me, I get really excited about what they represent for the Mellon College of Science, for Carnegie Mellon and for the advancement and future of research,” said Curtis Meyer, interim dean of MCS.

Diana Marwick Seymour Parno was named the Falco DeBenedetti Associate Professor of Physics. Her primary research interest is in the physics of the neutrino, a fundamental particle generated in particle decays and nuclear reactions and that, in the Standard Model of particle physics, interacts via the weak force.

To better understand the properties of the neutrino, she uses the kinematics of tritium beta decay to study the absolute neutrino-mass scale with the KATRIN experiment based in Karlsruhe, Germany, and she studies low-energy neutrino interactions with matter with the COHERENT experiment based at Oak Ridge National Laboratory in Tennessee. She is an analysis co-coordinator for both experiments and serves as KATRIN’s US spokesperson. She is one of two PIs on the TRIMS experiment to better understand the molecular physics of gaseous tritium sources.

Parno earned her Ph.D. at Carnegie Mellon.

Ira Rothstein, the Buhl Professor of Theoretical Physics, utilizes Effective Field Theory to better understand topics in theoretical physics including Higgs particle production, quantum matter and black hole physics. He developed an effective field theory that describes black hole collisions used by the LIGO collaboration in the discovery of gravitational waves.

One of his papers on the subject received an award for being “one of the most influential papers in theoretical physics in the past five years” from the International Congress on Basic Science. He was the Kodolosky lecturer at the University of Texas and the Dirac lecturer at Florida State University.

Rothstein authored the forthcoming book, “The Art of Effective Field Theory,” Oxford University Press, 2025 and developed “Relatively Simple,” a free mobile phone application to teach the theory of relativity.

Fangwei Si was named the Cooper-Siegel Assistant Professor of Physics. His research interests are focused on the drive to discover “biological laws” that can help to understand living systems in a quantitatively precise way. Toward this goal, the lab develops and adapts tools, takes rigorous measurements and defines new concepts. Si’s research group is searching for simple yet fundamental rules connecting the complicated form of bacterial cells and their fitness in different environments, specifically focusing on physiological and biophysical principles of cell surfaces and bacteria-phage interactions.

Si earned his Ph.D. from Johns Hopkins University and completed two postdoctoral fellowships, one in the Department of Integrative Structural and Computational Biology at the Scripps Research Institute and another in the Department of Physics and Section of Molecular Biology, University of California, San Diego.

■ *Heidi Opdyke*

Di Matteo Selected as Astrophysical Journal Scientific Editor

Professor Tiziana Di Matteo has been selected as a scientific editor for the Astrophysical Journal. Her appointment took effect on Oct. 1, 2024. New editors are selected by the editor-in-chief of the AAS Journals, in consultation with the editorial board and its publications committee.

The Astrophysical Journal was founded in 1895, and is the premier journal for the publication of high-impact astronomical research.

Di Matteo, who directs Carnegie Mellon’s McWilliams Center for Cosmology and Astrophysics, studies black holes encompassing a wide range of topics in both high energy astrophysics and cosmology. They include state-of-the-art simulations of galaxy formation and black hole growth across cosmic history as well as investigations of various aspects of the physics of accretion disks around black holes.

New Faculty

Katelyn Breivik

Katelyn Breivik joined the Department of Physics as an assistant professor in 2023. Breivik, a member of the McWilliams Center for Cosmology and Astrophysics, works at the interface of theory, simulations and data to understand how binary stars evolve from birth to death. Binary stars — two stars orbiting a common center of mass — impact almost all aspects of astronomy, from shaping galaxies to making black holes. She develops open source software tools that simulate binary star populations and their observable properties in electromagnetic and gravitational-wave surveys.

Breivik earned her Ph.D. at Northwestern University. Prior to joining Carnegie Mellon, she was a Flatiron Research Fellow at the Flatiron Institute's Center for Computational Astrophysics and CIT Fellow at the Canadian Institute for Theoretical Astrophysics.

Brendan Mullan

Brendan Mullan joined the Department of Physics as an associate teaching professor and director of undergraduate laboratories in January 2024. His primary goal is to advance experimental physics courses using data-informed practices and physics education research. Mullan has developed and taught various astronomy, astrobiology and physics courses at multiple universities, incorporating video game, narrative story and inquiry-based elements.

Before joining Carnegie Mellon, Mullan was a faculty member at Point Park University, co-founded and directed science for The Wrinkled Brain Project and directed the Buhl Planetarium and Observatory. Named a National Geographic Emerging Explorer in 2013, Mullan has received awards from the British Council, NASA and the Creative Nonfiction Foundation. He earned his Ph.D. in astronomy and astrophysics from The Pennsylvania State University.

Readying for Roman

When NASA's Nancy Grace Roman Space Telescope launches in 2027, it will image an area of sky 100 times larger than Hubble, generating enormous, deep 3D images of the universe.

Until then, teams of scientists — including two Carnegie Mellon University physicists — are hard at work creating simulations, scouting the skies with other telescopes, preparing data analysis techniques and calibrating Roman's components. These science teams, chosen and funded by NASA, are serving a vital role.

Professor Rachel Mandelbaum and Associate Professor Matthew Walker, faculty in the Department of Physics and members of the McWilliams Center for Cosmology and Astrophysics, are serving on two of the science teams, which address different goals.

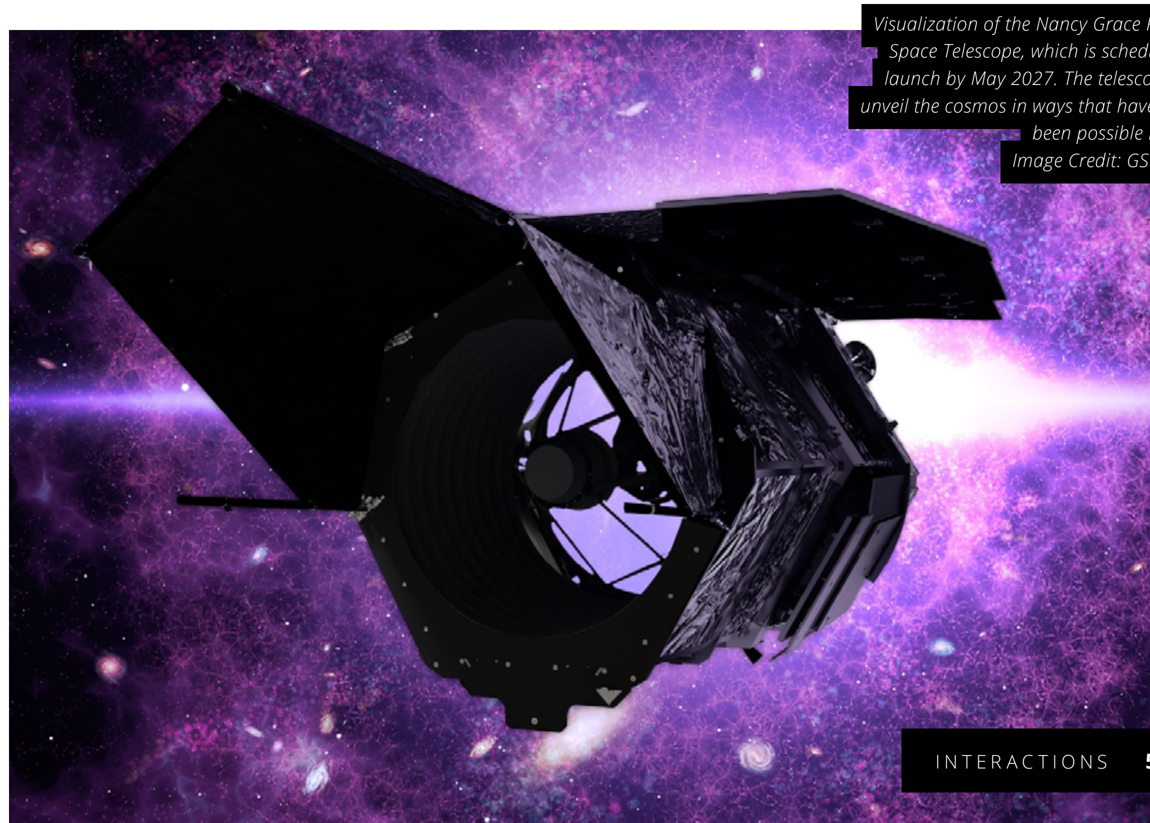
Mandelbaum helps develop tools that will enable Roman's high-latitude imaging survey to achieve its extraordinary cosmological discovery potential. The survey will uncover hundreds of millions of galaxies, allowing scientists to explore why the expansion of the universe is accelerating.

Mandelbaum and colleagues are working to predict what galaxies Roman will see based on their current best understanding of Roman's detector and its other instruments. With those predictions, they are running simulations and analyzing them with the goal of preparing the software infrastructure that will analyze the imaging data once the telescope launches.

Walker is working to optimize Roman's sensitivity to image faint stars and map hundreds of nearby galaxies. His team, the Roman Infrared Nearby Galaxy Survey team, is focusing on how to tell a star apart from a galaxy.

Walker and his team want to understand how the optics of the telescope will smear out the light from what's essentially a point source of a star and how that would differ from an extended source like a galaxy. They are working with scientists at the Space Telescope Science Institute to make simulations of images based on what Roman's detectors should see.

■ *Amy Pavlak Laird*



Visualization of the Nancy Grace Roman Space Telescope, which is scheduled to launch by May 2027. The telescope will unveil the cosmos in ways that have never been possible before. Image Credit: GSFC/SVS

Noble Contributions

The long-standing interplay between artificial intelligence and the evolution of physics played a pivotal role in awarding the 2024 Nobel Prize in Physics to two AI trailblazers.

“AI for physics and physics for AI are concepts you hear,” said Matteo Cremonesi, an assistant professor of physics at Carnegie Mellon University.

The Royal Swedish Academy of Sciences awarded the 2024 Nobel Prize in Physics to John J. Hopfield of Princeton University and Geoffrey E. Hinton of the University of Toronto in recognition of their foundational work in machine learning with artificial neural networks. Hinton served on the Computer Science Department faculty at Carnegie Mellon from 1982-87.

“There’s been a lot of work in recent years in how we can use neural networks for scientific discovery in physics,” said Rachel Mandelbaum, interim head of Carnegie Mellon’s Department of Physics. “This is an important recognition in some of the precursor studies that set us along this pathway, and it’s an area where Carnegie Mellon is very active.”

The Department of Physics has strong research groups working in astrophysics and cosmology, particle physics, biophysics, computational physics and theoretical physics, who play key roles in ongoing experiments in these areas.

Astronomical Datasets

Mandelbaum leads research with the University of Washington to develop software to analyze large datasets generated by the Legacy Survey of Space and Time (LSST), which will be carried out by the Vera C. Rubin Observatory in northern Chile.

“In astrophysics, if we go back, say 20 years, the datasets were pretty small. And one of the main areas for innovation was computational techniques for creating simulations of the universe or galaxies more efficiently. Today we have larger and larger datasets. Those new problems need new tools. It’s very much the case that we have problems that help the field of machine learning evolve.”

Through the LSST, the Rubin Observatory, a joint initiative of the National Science Foundation and the Department of Energy, will collect and process more than 20 terabytes of data each night — up to 10 petabytes each year for 10 years — and will build detailed composite images of the southern sky, including information about changes over time.

“Many of the LSST’s science objectives share common traits and computational challenges,” she said. “If we develop our algorithms and analysis frameworks with forethought, we can use them to enable many of the survey’s core science objectives.”

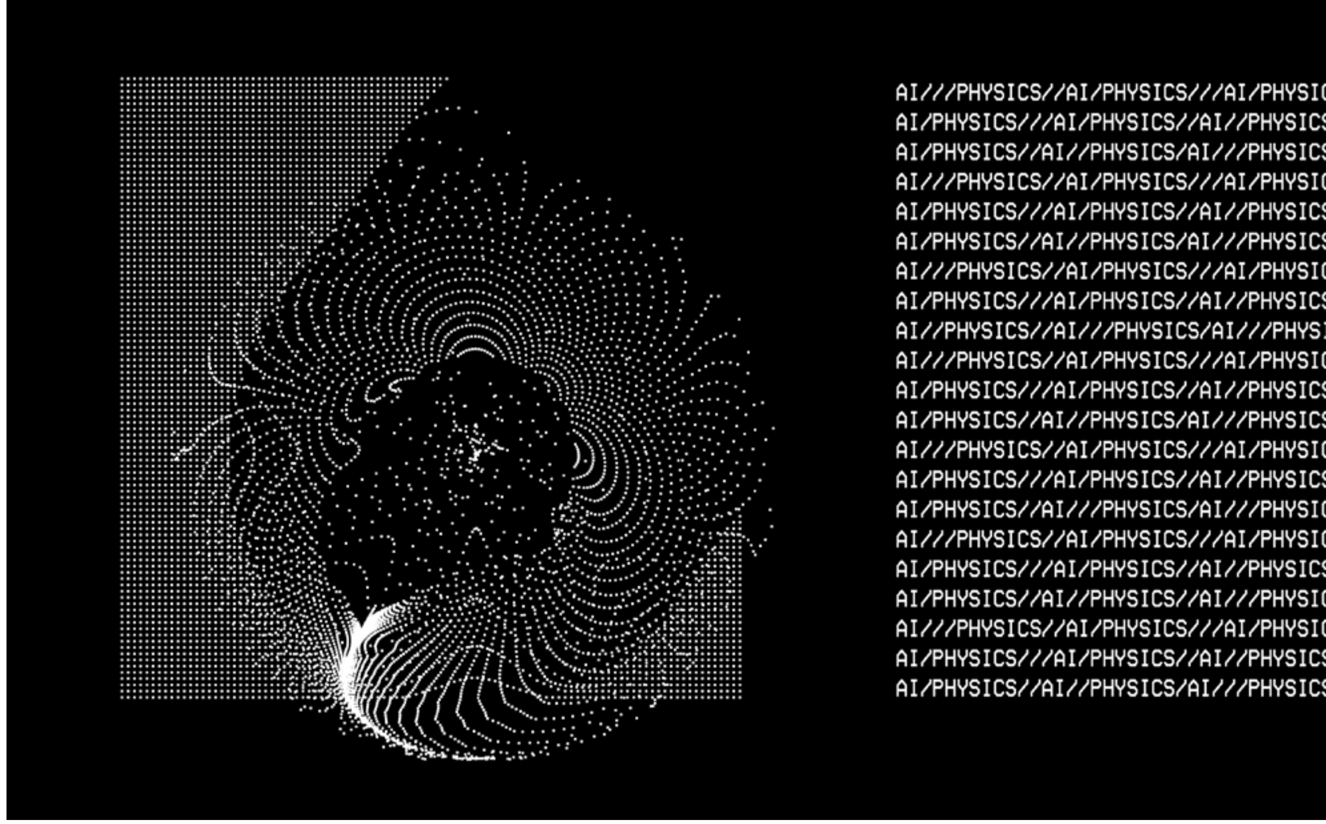
Biological Laws

Fangwei Si, the Cooper-Siegel Assistant Professor of Physics, aims to understand living systems in a quantitatively precise way.

“We look at how individual bacterial cells respond to environmental changes, but we need statistics and to track their life for a very long time,” Si said. “We track thousands of bacterial cells in environments and need to analyze how the health of each cell develops over time.”

Si gathers information on food intake, size, shape, density, reproduction and growth rates, and how those and other factors are connected to internal activities of the subcellular contents, such as proteins, RNA and DNA.

“It used to be that Ph.D. students could spend years on one experiment. But now with machine learning-based analysis, we can finish the same work within one day,” Si said.



The lab develops and adapts tools, takes rigorous measurements and defines new concepts. Using trained machine learning models Si and his colleagues can automatically detect where cells are in images and analyze them.

“One of our ongoing projects is to use the cell images captured and combine them with machine learning to understand the physiological state of the cell. We hope to extend this work to other organisms, for example, human cells, so that in the future we can tell whether the cells are ready to enter different states, like turning into a cancer cell.”

Need For Speed

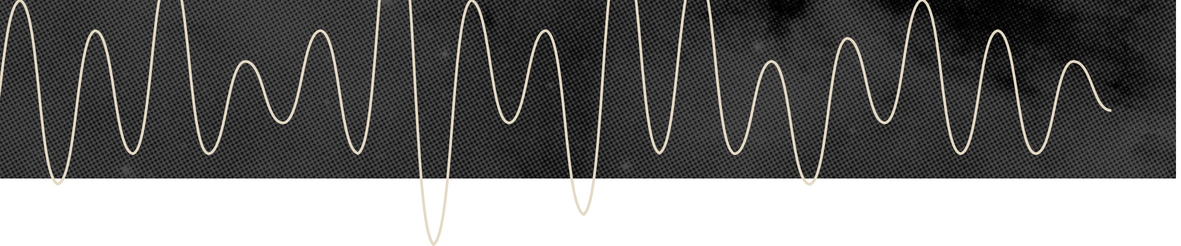
Giant particle accelerators like CERN’s Large Hadron Collider smash protons together at nearly the speed of light. The Compact Muon Solenoid (CMS) detector captures 3D images of these collisions at the rate of one every 25 nanoseconds, or 40 million images a second. This corresponds to a data rate of 10 terabytes per second.

“We don’t have the capability to save all of the information delivered by the collider, so we need an online mechanism to decide if images are interesting or not,” Cremonesi said.

Cremonesi is part of a team building software that will analyze these images in real-time, contributing to the CMS “trigger.” The Next-Generation Triggers project at CERN aims to develop a way to filter the flow of data through a high-performance event-selection system. The trigger is a hardware data filtering system that rapidly decides when an image is interesting enough to save for offline analysis. Out of those 40 million images taken, on average 1,200 images are selected by the trigger, or less than 0.003%. A team of CMU students and researchers led by Cremonesi is studying the usability of AI to improve the accuracy of this crucial decision-making step.

“This is very challenging real-time processing that we do. It’s one of the most challenging real-time AI applications on Earth,” Cremonesi said. To put it in perspective, self-driving cars that use machine learning algorithms operate within microseconds.

■ *Heidi Opdyke*



Radio Telescopes’ Earthbound Perspective Clouds Discovery of Fast Radio Bursts

Carnegie Mellon University researchers have discovered that there’s not only a bias in how telescopes ‘see’ but also in how they ‘hear.’

Fast radio bursts (FRBs), millisecond blasts of energy from deep space, are one of astronomy’s greatest mysteries. The latest research, published in Nature, found that, like optical telescopes that are more likely to detect brighter objects, radio telescopes tend to detect FRBs from galaxies that fully face the Earth.

“In the universe, galaxies do not have a preferred orientation, so from Earth we should view them at random angles,” said Mohit Bhardwaj, a postdoctoral fellow at Carnegie Mellon’s McWilliams Center for Cosmology and Astrophysics. “But when we studied a sample of galaxies from which FRBs have come, we discovered an excess of face-on galaxies and a paucity of edge-on galaxies.”

Face-on and edge-on galaxies are not different — they only appear that way because of the angle at which they are seen from Earth. By preferentially detecting FRB signals from face-on galaxies, Earthbound telescopes introduce a selection bias that excludes FRBs from edge-on galaxies. According to Bhardwaj, this leads to a significant underestimation of the FRB rates reported in the literature.

Their analyses revealed that the estimated rate of FRB production in the universe has been underestimated by a factor of at least two.

Bhardwaj and Jimin Lee, a junior at Carnegie Mellon and co-first author on the Nature paper, carried out extensive analyses using different mathematical and statistical tools to determine the inclination angles of 23 FRB host galaxies. In addition to Bhardwaj and Lee, junior Kevin Ji was involved with the research, which began as an undergraduate research project.

■ *Amy Pavlak Laird*

Study IDs the Origin of the Persistent Emission of Fast Radio Bursts

A team of scientists, including Brendan O’Connor, a McWilliams Fellow in Carnegie Mellon University’s McWilliams Center for Cosmology and Astrophysics, discovered the origin of persistent radio emission observed alongside a fast radio burst (FRB). Most FRBs do not exhibit persistent emission, so understanding its origin allows researchers to add a piece to the puzzle about the nature of these mysterious cosmic sources. The observations, led by the Italian National Institute for Astrophysics, were performed with the most sensitive radio telescope in the world, the Very Large Array Radio Telescope, and with the NOrthern Extended Millimeter Array and the Gran Telescopio Canarias.

“It’s essentially like are you looking at something in 1080p instead of 720p,” O’Connor said. “And in this case, the higher resolution image allows us to better localize what’s going on with this source.”

The data enabled scientists to demonstrate that the persistent emission behaves as expected from the nebular emission model, i.e. a ‘bubble’ of ionized gas that surrounds the central engine powering the FRB. The results were published in Nature.

■

Final Supernova Results from Dark Energy Survey Offer Unique Insights into the Expansion of the Universe

Scientists working on the Dark Energy Survey released the results of an unprecedented analysis to probe the mysteries of dark energy and the expansion of the universe.

The team included Carnegie Mellon University researchers from the National Science Foundation’s Artificial Intelligence Planning Institute for Data-Driven Discovery in Physics and the McWilliams Center for Cosmology and Astrophysics who brought expertise in weak gravitational lensing, artificial intelligence and data science.

The Dark Energy Survey (DES) is an international collaboration led by the U.S. Department of Energy’s Fermi National Accelerator Laboratory. DES mapped an area almost one-eighth the sky using the Dark Energy Camera, a 570-megapixel digital camera mounted on the Víctor M. Blanco Telescope at the National Science Foundation’s Cerro Tololo Inter-American Observatory. DES scientists took data for 758 nights across six years.

Andresa Rodrigues De Campos graduated with her Ph.D. earlier in 2024 from the Department of Physics. She was an analysis team lead for the DES Collaboration.

“Working with DES data has been both a challenging and an immensely rewarding experience,” Campos said.

DES researchers used advanced machine-learning techniques to aid in supernova classification. Among the data from about two million distant observed galaxies, DES found several thousand supernovae. They ultimately used 1,499 type Ia supernovae with high-quality data, making it the largest, deepest supernova sample from a single telescope ever compiled.

Antonella Palmese, former co-chair for the DES Galaxy Evolution & Quasars Working Group, said that the experience has broadened knowledge on more than just dark energy.

“This sample represents a unique opportunity not only to learn about dark energy, but also to understand the physical processes that govern the observed correlations between the supernovae properties and the content of the galaxies that host them,” she said.

The innovative techniques DES pioneered will shape and further drive future astrophysical analyses. Projects like the Legacy Survey of Space and Time to be conducted at the Vera C. Rubin Observatory and NASA’s Nancy Grace Roman Space Telescope will pick up where DES left off.

■ *Madeleine O’Keefe*

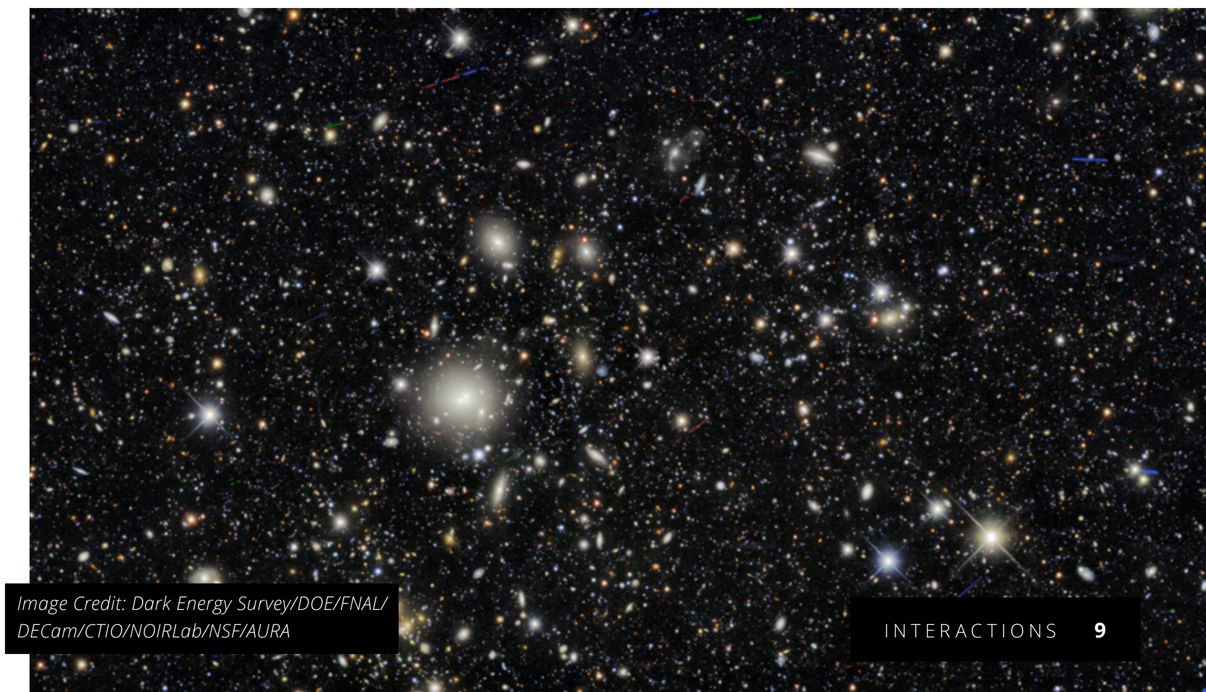


Image Credit: Dark Energy Survey/DOE/FNAL/DECam/CTIO/NOIRLab/NSF/AURA

APS Particles & Fields Meeting Draws Physicists to Pittsburgh

Carnegie Mellon University's Curtis Meyer has high energy when it comes to physics. His enthusiasm for the field showed when he welcomed participants to the APS Division of Particles & Fields (DPF) Meeting, which was co-hosted by Carnegie Mellon University and the University of Pittsburgh May 13–17.

The APS DPF meeting was combined with Pitt's annual Phenomenology Symposium (Pheno) and covered topics in particle physics theory and experiment as well as related issues, e.g., in astrophysics and cosmology. Physicists in attendance were from 15 countries and 42 states.

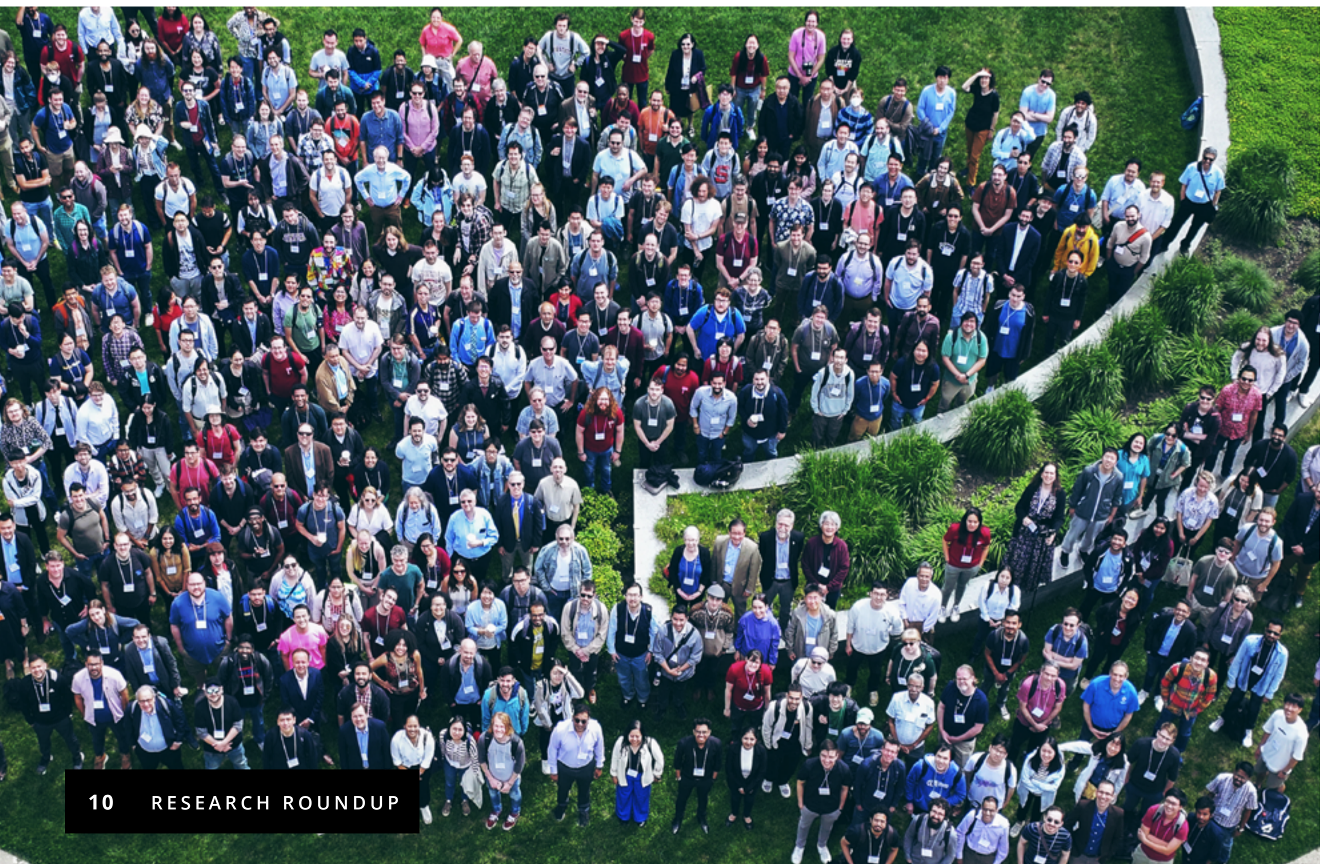
Carnegie Mellon Assistant Physics Professor Valentina Dutta was a speaker at the event and part of the local organizing committee. She discussed work done by the Compact Muon Solenoid (CMS) experiment and the ATLAS experiment at the Large Hadron Collider.

Carnegie Mellon and Pitt last previously jointly co-sponsored the 2017 APS Division of Nuclear Physics Meeting. While most activities at the recent meeting took place at the University of Pittsburgh, a public lecture was hosted at Carnegie Mellon on Tuesday evening.

Hitoshi Murayama, a well-known theoretical particle physicist, gave the public lecture in CMU's McConomy auditorium. Most recently he chaired the 2023 Particle Physics Project Prioritization Panel (P5) that was charged with developing a 10-year strategic plan for U.S. particle physics. In the lecture "How did we come to be? That's a physics question!" he addressed the 10-year plan and related research in areas such as dark matter, the Higgs boson and neutrinos.

Carnegie Mellon has a strong tradition of particle physics going back to the 1940s when the school — which was then known as the Carnegie Institute of Technology — began to construct a synchrotron. At the time it was built, it was one of the two highest-energy accelerators in operation. For the past 80 years Carnegie Mellon has received federal funding support for high-energy physics research.

■ *Heidi Opdyke*



Robert Schoelkopf, professor of applied physics at Yale University, gave the keynote address at the Pittsburgh Quantum Institute Conference on April 17.

Carnegie Mellon Hosts Pittsburgh Quantum Institute Annual Event

Quantum technology has the capacity to revolutionize industries, such as computing, finance, healthcare and materials science. To accomplish that, physicists, engineers and other experts interested in quantum research must collaborate, said Benjamin Hunt, associate professor of physics at Carnegie Mellon University.

"Connecting researchers is probably the most valuable thing we do," said Hunt, who is co-director of the Pittsburgh Quantum Institute (PQI), a joint program between Carnegie Mellon, the University of Pittsburgh and Duquesne University. PQI recently held its annual event at Carnegie Mellon's campus for the first time, drawing over 200 registrants from around the United States. "The fact this event happened at CMU is emblematic of the close partnership between Pitt and CMU that has begun to blossom."

Theresa Mayer, vice president for research at Carnegie Mellon, delivered the opening remarks of the April 17 event. She said that organizations like PQI foster research from foundational principles to practical applications.

The event focused on two primary areas of quantum research: quantum computing and quantum materials.

Quantum computers use qubits to encode information similar to traditional bits used in computers. While traditional bits encode 0 or 1 and work on one task at a time, qubits can encode 0 and 1 at the same time, which allows multiple scenarios to run simultaneously. Quantum materials use some aspect of the wave nature of matter in quantum mechanics to obtain special properties; some of these materials may enable new types of quantum computers.

David Snoke, distinguished professor of physics and astronomy at Pitt and co-director of PQI, said that events like these provide ways for local institutions and companies to come together around quantum research.

"The PQI Event brought together researchers from 16 universities and 10 companies," Snoke said. "The work they're doing will help push the field further to enhance our understanding of quantum science and drive a new era of discovery."

■ *Kirsten Heuring*

U.S. CMS Collaborators Receive Approval for Massive Detector Upgrade

The U.S. Department of Energy has formally approved the production of components for the high-luminosity upgrade of the CMS particle detector at the Large Hadron Collider. Image Credit: CERN

The U.S. Department of Energy has formally approved the start of full production for the $200 million DOE-funded contributions to the upgrade of the CMS experiment at CERN. Together with contributions from other international partners, the upgrade will significantly improve the capabilities of the CMS detector and enable scientists to explore uncharted territory on the particle physics landscape.

“We want to understand what nature is telling us,” said Patty McBride, the CMS spokesperson and a distinguished scientist at DOE’s Fermi National Accelerator Laboratory. McBride is a 1977 physics graduate of Carnegie Mellon University and a 2019 Alumni Award winner. “These upgrades will allow us to extract more information from our detector and unlock more about the world and universe.”

CMS is an international collaboration of scientists who study the fundamental properties of matter using the CMS detector at CERN, an international physics laboratory on the Franco-Swiss border. More than 1,800 researchers from U.S. institutions work on the experiment.

Among those researchers are Carnegie Mellon Physics Professor Manfred Paulini, along with Associate Professor John Alison and Assistant Professors Matteo Cremonesi and Valentina Dutta, who organized the 2023 U.S. CMS Meeting at Carnegie Mellon’s campus in Pittsburgh.

Over the next three years, Alison, Dutta, Paulini and others will build and test 5,000 20-centimeter hexagonal electronics modules at Carnegie Mellon’s module assembly center that will be used for a High-Granularity Calorimeter (HGC) upgrade to the CMS detectors. The upgrade will enhance the quality of the recorded data as well as cope with large amounts of ionizing radiation.

“I feel honored having been part of the team that worked the past 5 years toward this important approval milestone,” said Paulini, the Mellon College of Science associate dean for research who brought the project to Carnegie Mellon. “It will allow us at CMU to focus on starting up module production which, also will offer opportunities for graduate and especially undergraduate students to obtain hands-on instrumentation experience working in our lab.”

Physicists use the CMS detector to collect data from high-energy particle collisions produced by the Large Hadron Collider, the world’s biggest particle accelerator. At the end of the decade, the scientific reach of the LHC will become even more impressive thanks to the high-luminosity upgrade to the machine, which will begin in 2026. The recently released recommendations by the U.S. Particle Physics Project Prioritization Panel, known as the 2023 P5 report, lists the completion of the HL-LHC as a top priority for the U.S. particle physics community.

The upgrade will increase the collision rate by a factor of five, giving scientists a massive dataset to look for new particles and study rare subatomic processes. To keep up with the more intense particle beams, the CMS experiment needs a massive overhaul.

“We need new functionalities to cope with the harsh HL-LHC environment,” said Fermilab scientist Steve Nahn, the project manager for the U.S.-funded CMS upgrade. The project also receives funding from the U.S. National Science Foundation and is part of the international CMS upgrade plan.

Between 2029 and 2042, CMS scientists plan to collect 10 times more data than recorded since the startup of the LHC in 2010. Among many scientific goals, the additional data will enable scientists to develop a deeper understanding of the Higgs boson and how the Higgs field influenced the development and acted as dispersant of matter in the early universe.

“It’s not just looking at what’s unexpected; it’s also about having a deeper understanding of the particles we already know about, especially the Higgs,” McBride said.

The rapid increase in data poses many challenges. The experiment will go from seeing about 60 proton-proton collisions every time the LHC beams cross to around 200. This jump in collision rate means that scientists not only need more bandwidth on their electronics but also new components that will help them get the most out of this surge in data. For example, a new timing detector will tag particles emerging from the collisions with an accuracy of around 30 picoseconds, giving scientists the ability to better determine the trajectory of the particles and gain a better understanding of how the particles interacted with each other.

“We’re not just replacing old pieces; we are pushing the envelope,” Nahn said. “The HL-LHC is going to be a proving ground for new detector technology.”

The U.S.-funded work will be carried out by scientists, engineers and technicians from Fermilab and 45 universities located in 23 states. Much of the work will be done by students, who make up a sizable fraction of the experiment.

At Carnegie Mellon, graduate and undergraduate students will help build the detector modules on the eighth floor of Wean Hall. Starting in early December 2024 and continuing until 2026, Carnegie Mellon will be building 12 modules daily and sending them to Fermilab for further assembly into larger components.

“This is a huge opportunity for students,” said Robin Erbacher, a professor at the University of California, Davis, and the chair of the U.S. CMS collaboration board. “We don’t build detectors every day.”

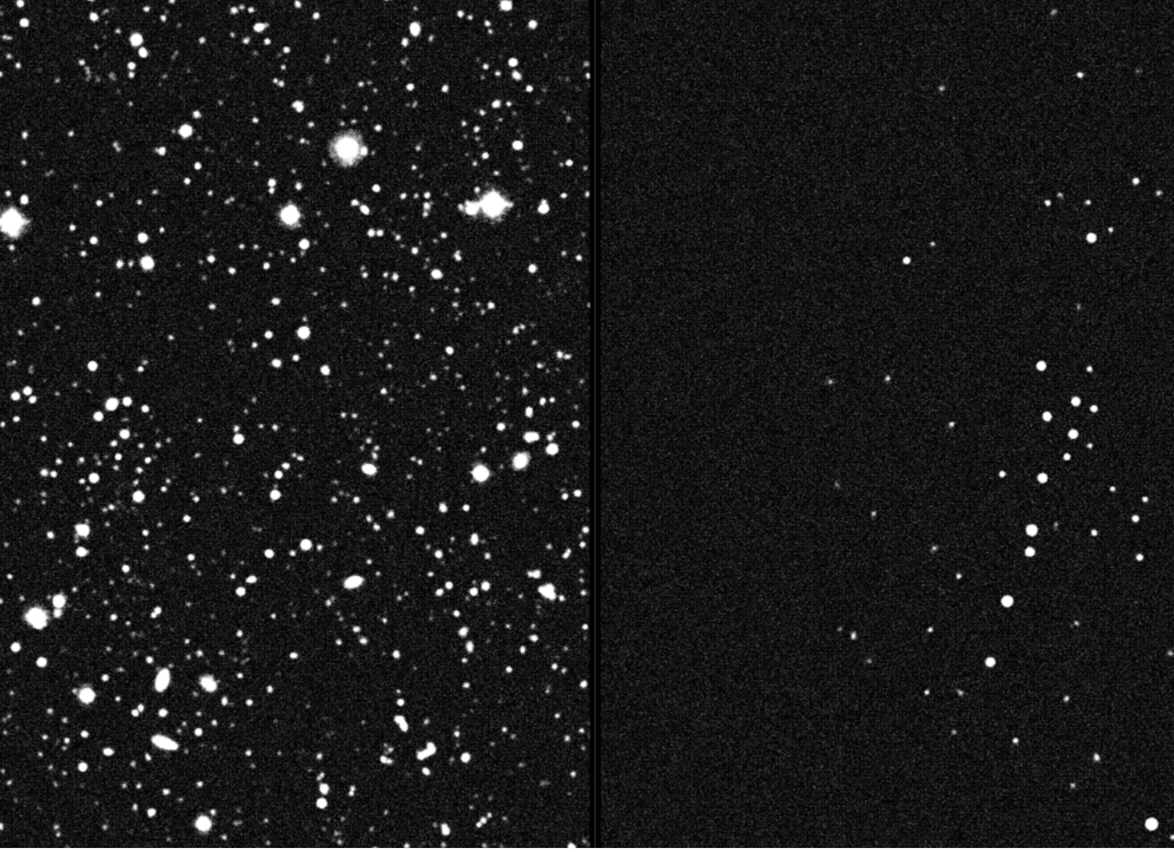
The worldwide CMS collaboration — which comprises 6,000 scientists from 57 countries — has been planning detector upgrades since the early 2000s. In 2016, the U.S.-funded CMS institutions, which make up about one-third of the collaboration, started the approval process with the US funding agencies for their planned contributions.

“This has been in the works for a long time,” Erbacher said.

During the approval process for the upgrade project, experts reviewed the physics goals, technical design reports, construction schedules and cost for the proposed detector components. The DOE approval, known as Critical Decision 3 and announced on January 11, 2024, allows the U.S.-funded CMS collaborators to move into full production on the proposed upgrades.

U.S. CMS collaborators will complete and ship their contributions to CERN between 2026 and 2027. The start-up of the high-luminosity LHC is foreseen for 2029.

■ *Sarah Charley*



Researchers Discover Dim Satellite Orbiting the Milky Way

An international team of scientists, including a researcher at Carnegie Mellon University's McWilliams Center for Cosmology and Astrophysics, has discovered the faintest satellite yet orbiting the Milky Way.

The object, named Ursa Major 3/UNIONS 1 or UMa3/U1 for short, consists of dozens of stars that are more than 10 billion years old. Spread over a volume of only 10 light years across, it is either the faintest ancient star cluster known to date, or the faintest and closest known dwarf galaxy ever discovered.

The latter scenario is the most exciting, since the presence of faint, ancient, dark matter-dominated satellites is a cornerstone prediction of Lambda Cold Dark Matter (LCDM), the leading theory for the origin of structure in the Universe. LCDM predicts that galaxies like the Milky Way have accreted hundreds of satellites during their formation and assembly. Confirming the presence of dark matter in UMa3/U1 is therefore critical for determining its origin.

"Estimating the dark matter content of a dwarf galaxy requires accurate and repeated measurements of its stellar velocities," said Raphaël Errani, a McWilliams Center postdoctoral researcher. "Remarkably, the spectroscopic measurements obtained with the Keck II telescope are tentatively consistent with those predicted by LCDM."

Direct confirmation of UMa3/U1's dark matter content requires detailed velocity measurements of its stars taken over time, which are not yet available. But the presence of dark matter is highly likely. UMa3/U1's orbit takes it through the inner regions of the Milky Way, where gravitational "tidal" forces are strongest. Without the binding presence of large amounts of dark matter, UMa3/U1 would not be able to survive on its current orbit for even a small fraction of its lifetime.

Julio Navarro, the Lansdowne Professor of Science at the University of Victoria who was involved with the study, said this is a momentous discovery and is fully consistent with a long-standing prediction of the "cold dark matter" theory.

■

Image Credit: US NSF/AUI/NSF NRAO S. Dagnello.

Carnegie Mellon Celebrates Eclipse

An astronomical phenomenon overshadowed day-to-day work on April 8 for students, faculty and staff at Carnegie Mellon University. Between 2 p.m. and 4:30 p.m. EDT, the moon passed between the Earth and the sun, causing a solar eclipse.

From Pittsburgh, viewers saw the moon cover over 97% of the sun. Many cities within two hours of Pittsburgh, such as Akron, Cleveland and Erie, were in the path of totality, where the moon blocks 100% of the sun's light from reaching Earth.

Physics Assistant Professor Katie Breivik, Physics Special Lecturer Diane Turnshek and the Carnegie Mellon Astronomy Club (AstroC) prepared for the eclipse and reached out to the Pittsburgh community and beyond.

Art on Earth

Eclipsing, created by Annie Saunders and Andrew Schneider, was a temporary sound walk designed to be experienced at Austin's Lady Bird Lake from March to April. Participants downloaded an app and listened to audio that guided the listeners on a walk and shared information about the history of the area and the science behind eclipses.

Breivik served as a consultant on the installation and recorded interviews with Saunders and Schneider, explaining the physics of black holes, what atoms are made of and how cosmically unlikely eclipses are.

The Earth, the sun and the moon have to be aligned in a specific trajectory and at specific distances to experience a total eclipse.

Education Outreach

Students across the greater Pittsburgh region learned eclipse science and safety thanks to Turnshek, who instructed a physics teacher at Allderdice High School and spoke to students from the Ellis School and Brashear High School. She also shared the science behind the eclipse to students in Carnegie Mellon's spring science writing course, and she helped the Women in Science club coordinate activities and outreach for the day of the eclipse.

Eclipse Excursion

AstroC presidents Jacques Moye and Allison Weller planned a field trip for AstroC members to travel to the path of totality in Akron, Ohio. However, the day's cloud cover led them to Mansfield, Ohio, where they experienced three minutes of totality in a local park.

Moye and Weller, senior physics majors who joined AstroC in their first year, worked with Turnshek on how to share safety and scientific information with the Carnegie Mellon community before they traveled to Ohio.

■ *Kirsten Heuring*

Research During Solar Eclipse Could Shed Light on Shadow Bands

Clouds hid most of the April 8 solar eclipse for recent Carnegie Mellon University physics graduate Norris Bach. But from his vantage in rural Texas Hill Country he still had a thrill. Bach was there with a team of researchers chasing a phenomenon known as shadow bands.

These shimmering bands seen on the ground and on light-colored surfaces are often claimed to be caused by refraction of sunlight minutes before the moon completely covers the sun. The leading hypothesis is that shadow bands occur when sunlight travels through turbulence in the planetary boundary level in the troposphere, about 10,000 feet above the Earth's surface.

David Turnshek, professor of physics and astronomy at the University of Pittsburgh, found that this may not be the only explanation for shadow bands. Instead of the turbulent layer in the troposphere causing the shadow bands, his team's 2017 observations obtained from a high altitude balloon at 80,000 feet indicated that they primarily originate above the Earth's atmosphere.

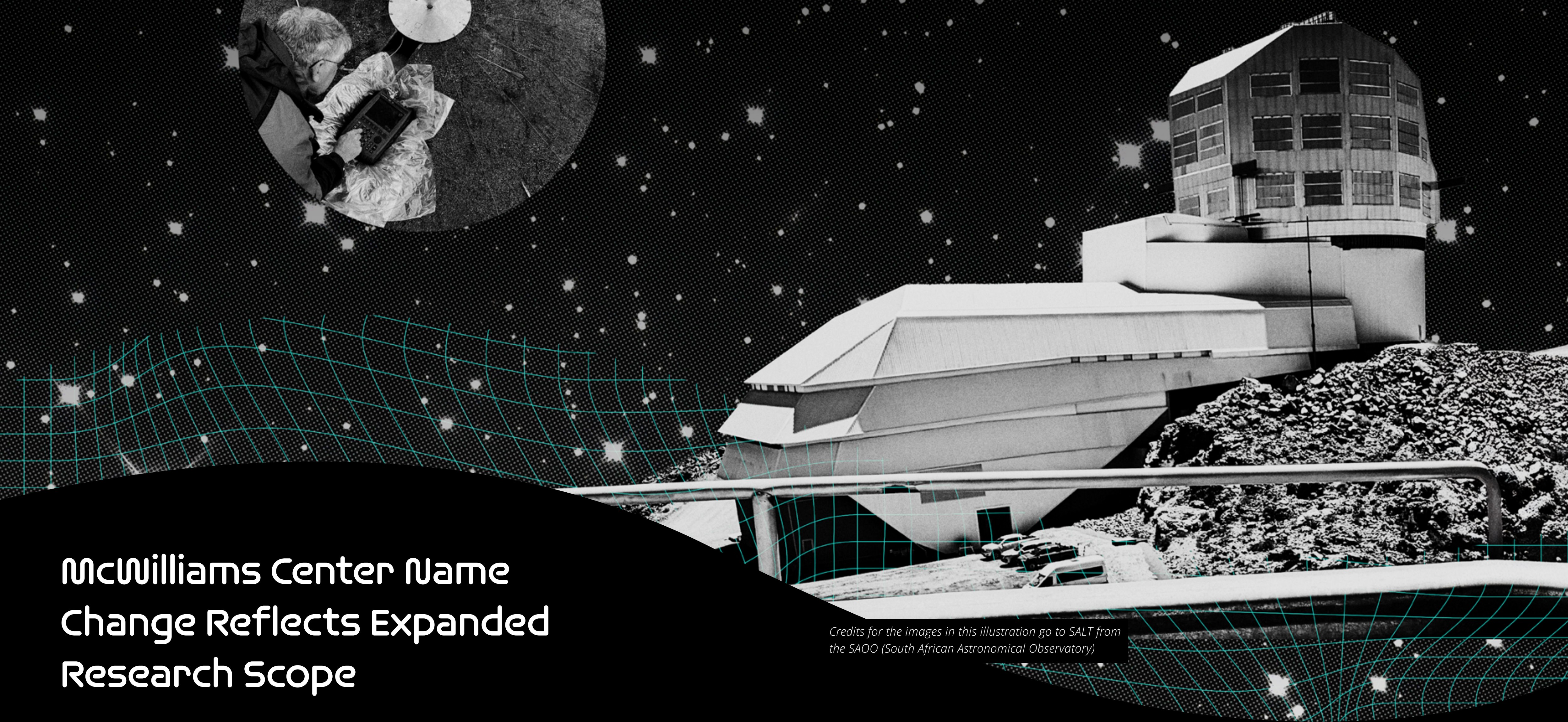
Turnshek wanted to investigate this alternative theory during the 2024 solar eclipse, so he formed the Pitt Shadow Bandits. Bach and Jeffrey Peterson, professor of physics at Carnegie Mellon, helped develop instrumentation for the project.

Bach joined the project to help build the low noise light sensors, which were designed to detect subtle changes in the level of light from data being collected by instrumentation attached to three high altitude balloons launched before the solar eclipse commenced in Concan, Texas, about 80 miles west of San Antonio.

During the April solar eclipse, clouds impeded the team's ability to gather data from the ground, but the balloons sailed above the fray. Despite the balloons drifting up to 200 miles away, the team managed to recover sensors the day after the eclipse. The data collection effort was successful and what they have looks promising.

"Shadow bands been known about since the 1800s, and there are reports of them being observed nearly 1,000 years ago, but they haven't been investigated super deeply," Bach said. "Being able to determine the actual physics behind them is really exciting. We might be able to close the book on this."

■ *Kirsten Heuring*



Credits for the images in this illustration go to SALT from the SAOO (South African Astronomical Observatory)

McWilliams Center Name Change Reflects Expanded Research Scope

Tiziana Di Matteo, professor of physics, is leading efforts to unravel the origins of the universe and decode fundamental principles that govern its functioning. As director of Carnegie Mellon University's McWilliams Center for Cosmology and Astrophysics, she's making gravitational waves.

Astrophysics is now part of the center's name, reflecting its new research direction.

"The name change reflects the broadening not only into more traditional astronomy but also the field of gravitational waves. Cosmology is the study of the universe as a whole. It answers the story of our origins and how everything starts," Di Matteo said. "When we think of astrophysics, we think of understanding the components of the universe: How do galaxies form? What are black holes doing? How do the components of the universe behave and grow?"

Advances in telescopes and gravitational-wave detectors have created a data revolution in astronomy. Large-scale spectroscopic surveys such as the Dark Energy Spectroscopic Instrument (DESI) survey generate information on the scale of petabytes.

"Black holes are one of our greatest intellectual challenges and to reconcile our understanding of the largest structures in the universe with the smallest and other phenomena, we require data and information from many sources," Di Matteo said.

Making sense of trillions of points of data requires a team effort. The McWilliams Center's research lies at the crossroads of astrophysics, data science, artificial intelligence (AI) and machine learning. McWilliams Center members collaborate across disciplines not only within Carnegie Mellon's Department of Physics but also in the Department of Statistics and Data Science and Machine Learning Department.

Connecting Astrophysicists and AI

The connections between astrophysicists and AI researchers at Carnegie Mellon have been ongoing for decades, said Scott Dodelson, former head of the Department of Physics and also the principal investigator for the National Science Foundation (NSF) AI Planning Institute for Data-Driven Discovery.

"From analyzing data being collected from the entire night sky to modeling individual proteins in a cell, physics provides complex use cases and profound problems for researchers to consider as they advance AI techniques," Dodelson said. "Carnegie Mellon is known for our expertise in computer science and artificial intelligence. The McWilliams Center is already making significant contributions to large collaborations because of our interdisciplinary approach."

Physics Professor Rupert Croft has helped organize conferences showcasing AI-assisted research across disciplines. He said that foundational work in both physics and computer science moves quickly, so researchers in diverse areas need to communicate and collaborate.

"For cosmology and astrophysics, the next step in AI simulations is to incorporate more of the physics," Croft said. "Right now, we use gravity and dark matter. In stars and galaxies there is gas and dust, and those can be difficult parts to add to models. AI provides a framework for doing this quickly in the future."

Multi-Messenger Astronomy Unlocks Data Secrets

Di Matteo said the McWilliams Center is becoming a leader in multi-messenger astronomy (MMA), a secret weapon for making sense of a sea of data.

"Through research efforts in big data and simulation modeling, Carnegie Mellon's McWilliams Center is solidifying itself as a leader in this emerging field," Di Matteo said.

"MMA has two main components of this research: big data, and simulation modeling," she said. "By integrating multiple streams of information, encompassing light, particles, and gravitational waves, the ultimate vision in MMA is to foster a deeper understanding of the universe's most enigmatic phenomena."

Physics Professor Rachel Mandelbaum is a leading expert in developing analysis tools and techniques in cosmology. She is leading research to develop software to analyze large datasets generated by the Legacy Survey of Space and Time (LSST), which will be carried out by the Vera C. Rubin Observatory.

Through the LSST, the Rubin Observatory, a joint initiative of the NSF and the Department of Energy, will collect and process more than 20 terabytes of data each night — up to 10 petabytes each year for 10 years — and will build detailed composite images of the southern sky.

"We'll have all the data we need to make major discoveries about the origin of our solar system, the Milky Way, and the evolution of the universe, but we don't have the software," Mandelbaum said. "Many of the LSST's science objectives share common traits and computational challenges. If we develop our algorithms and analysis frameworks with forethought, we can use them to enable many of the survey's core science objectives."

Faculty Grows to Support Expanded Research

The McWilliams Center hired additional faculty in astrophysics, Di Matteo said.

"We are expanding research in new directions, which involves our new hires such as Katie Breivik and Antonella Palmese," she said.

Breivik, who joined Carnegie Mellon in 2023 as an assistant professor, studies how binary stars evolve from birth to death. The phenomena — two stars orbiting a common center of mass — impact almost all aspects of astronomy, from shaping galaxies to making black holes. She teases information from datasets on stellar objects such as black holes, stellar cores and normal stars to develop simulations of binary star interactions. Along with machine learning experts, Breivik combines these models with data from gravitational-wave and electromagnetic surveys.

"We have a whole faculty that share a wide range of tools that range from theory to simulation to computation and are forging a path that actually develops new methods with each of these tools," Breivik said. "When collaboration happens, you get magic way better than the sum of the parts."

Simulations and computations are reinforced through observations by telescopes. McWilliams Center researchers have been involved in large telescope projects including the LSST and NASA's James Webb Space Telescope and the upcoming Nancy Grace Roman Space Telescope.

Palmese, who joined Carnegie Mellon in 2022 as an assistant professor in physics, collaborates on international projects such as the Dark Energy Survey, DESI and the Laser Interferometer Space Antenna.

Palmese uses optical telescopes and sky surveys to find the light from catastrophic events giving rise to ripples of space-time that can be detected from collisions between neutron stars or black holes. To do this, she looks for evidence of transients, time periods where astronomical objects change over seconds, hours or decades, within photometric and spectroscopic datasets.

"We have to deal with these very large data sets, whether it's from galaxy surveys or sky surveys that are imaging the sky over and over again," Palmese said. "You need big data techniques and machine learning to help you analyze those data and analyze it fast."

Connections in Pittsburgh and Beyond

The McWilliams Center has access to resources at the Pittsburgh Supercomputing Center (PSC), a joint collaboration between CMU and the University of Pittsburgh. This includes the dedicated cluster known as Vera.

"Having access to the Vera cluster has enabled a lot of the science that we're able to do," Palmese said.

The McWilliams Center also recently acquired direct telescope access on the South African Large Telescope (SALT) with a mixture of internal funds. Researchers will use the time to rapidly observe explosions following the mergers of compact objects discovered through gravitational waves as well as provide students with crucial observing training.

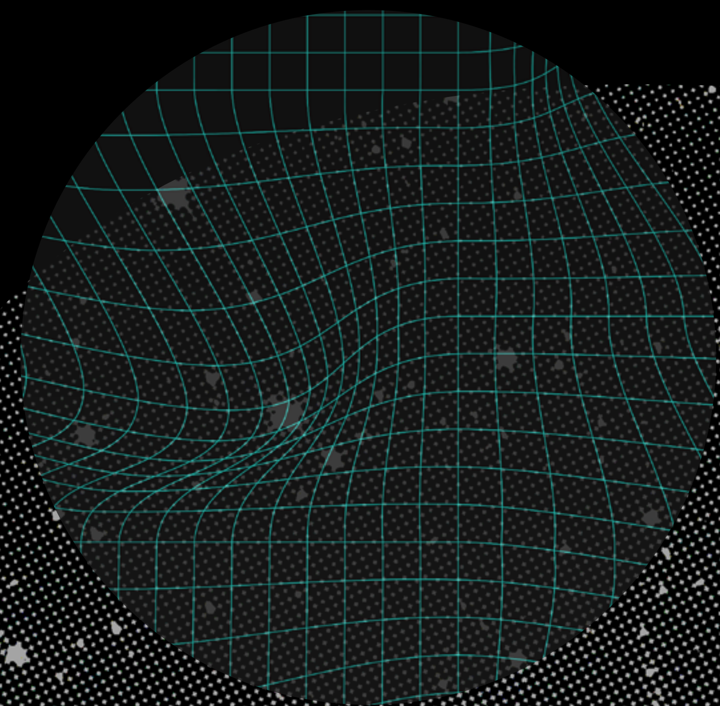
McWilliams postdoctoral researcher Brendan O'Connor worked with Palmese on a McWilliams seed grant to purchase time on SALT, which will be in part to study cosmic explosions. One target he wants to study is the collision of two neutron stars, which produces a rare, short-lived transient, referred to as a kilonova. He said this is a developing area of astrophysics.

"Even a few observations of these rare objects can have a high impact at this point," O'Connor said.

Postdoctoral fellows have been a part of the McWilliams Center since its beginning.

"Because of the McWilliams endowment we are competitive when it comes to being a destination for top candidates, who are, in turn, sought after for faculty positions," Di Matteo said. "It's a prestigious fellowship, and their success has been tremendous. They help make advancements possible. Postdocs ignite the place with new ideas and excitement."

■ *Heidi Opdyke*



Scan this code to watch videos by the McWilliams Center

Postdoctoral Fellows Shine at McWilliams Center for Cosmology and Astrophysics

In the grand dance of the cosmos, stars are born, live their lives and eventually die. Sometimes they collide, sending ripples through the fabric of space and time. Other times, a galaxy's gravitational pull may stretch stars, creating glittery trails in the night sky.

No matter what their fate, stars hold a lot of clues to solving some of the biggest mysteries of the universe — from stellar evolution to the nature of dark matter. At Carnegie Mellon University's McWilliams Center for Cosmology and Astrophysics, researchers are working to unravel some of these puzzles.

Ignacio Magaña Hernandez, Brendan O'Connor, Anna O'Grady and Nora Shipp joined the McWilliams Center in the fall of 2023 as McWilliams Postdoctoral Fellows. One of the center's highest profile programs, the fellowship, a gift from the late Bruce McWilliams, provides funds to support promising scientists pursuing independent research.

Ignacio Magaña Hernandez

Astronomers know that the universe is expanding at a rate referred to as the Hubble constant. But the two main ways to determine its value have produced very different results. Ignacio Magaña Hernandez is using a third way — gravitational waves from merging binary black holes.

When black holes or neutron stars collide, they release gravitational waves and, in the case of neutron stars, big bursts of light. Details from these observations enable astrophysicists to calculate the Hubble constant. Binary black hole mergers are more frequently detected than neutron star collisions, making studying black hole mergers more advantageous. But when black holes collide, there is no second electromagnetic signal to constrain the cosmology.

A common method is to use the information in galaxy surveys to determine a merger's redshift. But surveys are not complete and are usually biased toward observing the brightest and most massive galaxies. Magaña Hernandez takes into account galaxy clustering and the observed large-scale structure of the universe to better model the correction, which should offer a more powerful method to constrain the Hubble constant.

Brendan O'Connor

Brendan O'Connor studies massive but brief cosmic explosions that release huge amounts of energy in only a second or two. He's particularly interested in short gamma-ray bursts (GRBs), bright flashes of light that occur when two neutron stars collide, merge and become a new black hole.

As a graduate student at George Washington University, O'Connor led a study of GRB 221009A — the most energetic and brightest GRB ever seen. Unlike short GRBs, this burst lasted for several minutes with its afterglow lasting for months. Using the Gemini South telescope, O'Connor examined the opening angle of the GRB jet, providing information about the process that emits the gamma rays.

In addition to releasing a burst of gamma rays, the collision of two neutron stars also sends out a blast of gravitational waves and electromagnetic radiation called a kilonova. O'Connor is working with faculty who are experts in investigating gravitational waves and searching for kilonova emissions.

Anna O'Grady

Anna O'Grady studies a type of massive star called yellow supergiants. These stars exist for brief periods of time, but they hold vital clues about stellar evolution. Over the past decade, astronomers have realized that most massive stars — including yellow supergiants — exist in binary systems, fundamentally changing our understanding of how these celestial objects live and die.

While other types of stars in binaries have been extensively studied, yellow supergiant binaries represent uncharted territory. Using archival data and her own observations from ground-based telescopes, O'Grady has identified a group of candidate yellow supergiant binaries that exhibit an excess of blue light that hints at the presence of a smaller, hotter companion star. She has her sights on the Hubble Space Telescope, hoping to secure ultraviolet data that will allow her to characterize these companion stars in unprecedented detail.

O'Grady works closely with theorists like Assistant Professor Katie Breivik, who creates simulations to understand how binary-star interactions shape stellar populations as they evolve.

Nora Shipp

Glittering threads of stars orbit the Milky Way, the remnants of satellite galaxies and star clusters that are stretched and disrupted by its gravitational forces. Nora Shipp studies these stellar streams, which provide critical insight into dark matter and the physics governing galaxy formation.

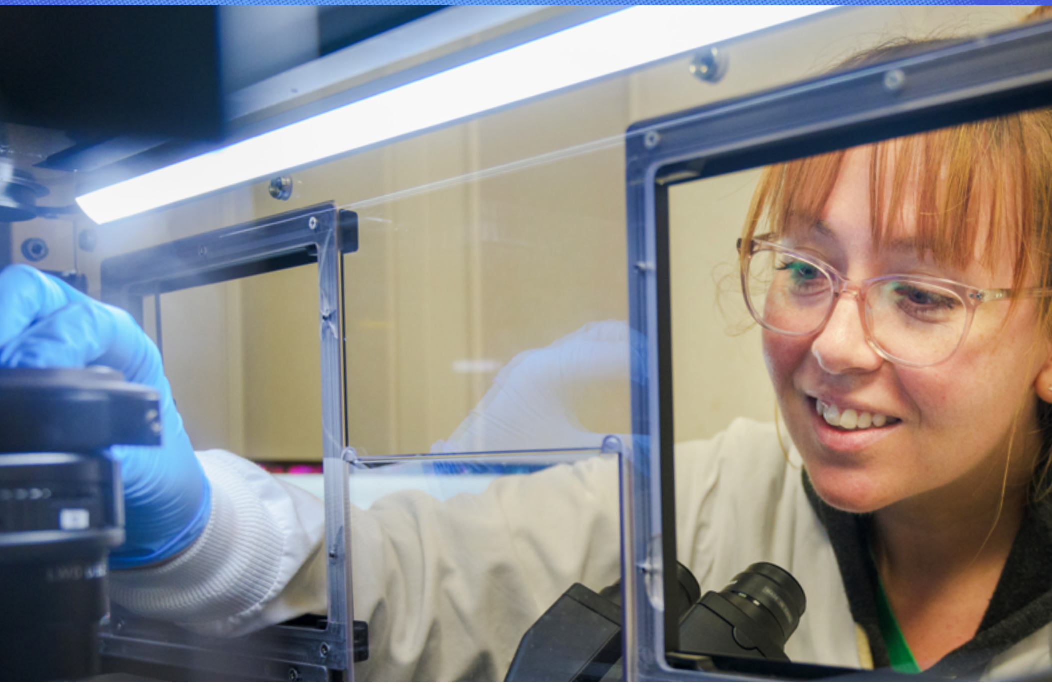
Shipp chose to spend a year at the McWilliams Center before beginning her faculty position as an assistant professor at the University of Washington.

Evidence suggests that a halo of dark matter surrounds the Milky Way. When clumps of dark matter interact with stellar streams, it disrupts their gravitational dynamics and changes their observed appearance, causing kinks or gaps in the starry trails. These changes provide a way to study the otherwise invisible dark matter.

As a graduate student at the University of Chicago, Shipp discovered several new stellar streams in data from the Dark Energy Survey. She also uses data from the Gaia satellite, which provides measurements of how the stars in the Milky Way are moving in the sky, and the Southern Stellar Structure Spectroscopic Survey, which maps stellar streams with the Anglo-Australian Telescope. By combining those data sets, Shipp worked to characterize and model streams to learn about the local distribution of dark matter.

■ *Amy Pavlak Laird*

From left, Anna O'Grady, Brendan O'Connor, Ignacio Magaña Hernandez and Nora Shipp.



Finding Answers in Extremes

Gabrielle Illava is no stranger to pressure. The postdoctoral fellow in the Biophysics Initiative within the Department of Physics at Carnegie Mellon University began her higher education journey as a single mom at Tompkins Cortland Community College near Ithaca, New York.

Illava made a name for herself through her work ethic and was encouraged to participate in an immersive summer research partnership with Cornell University. There, Illava fell in love with the Cornell High Energy Synchrotron Source (CHESS) — a device that looks like it came from "Honey, I Shrunk the Kids."

She transferred into Cornell and completed her undergraduate work while developing new research techniques using the beamline to fabricate graphene-based X-ray windows.

As she manipulated proteins along the synchrotron beamline, Illava became involved with research efforts to study proteins under conditions that are found deep underground and underwater.

She learned how researchers use ultra high-pressure liquid chromatography to mimic the environments deep below the Earth's surface where many organisms somehow survive.

Illava valued her mentors at Cornell, who allowed her the flexibility necessary to complete her doctorate after her mother died and she was left to take care of a middle schooler on her own. In finding a postdoctoral program, Illava sought the same atmosphere. She found a home in Carnegie Mellon University Cooper-Siegel Assistant Professor of Physics Fangwei Si's lab.

Si has brought together a diverse team to explore how life emerges from non-living matter.

Si said he considers bacteria to exist at the border between non-living matter and living organisms. His team studies how bacteria perform under extreme conditions, including heat, cold and starvation environments. Illava proposed adding the dimension of pressure to their experiments.

Illava will be using hydrostatic pressure, simulating the environment of the deep ocean, to examine how bacteria optimize, both individually and as parts of larger communities. She said she feels the symbiotic link between phages and bacteria could help society better understand the rules of life.

■ *Katy Rank Lev*

CMU Launches New Quantum Track for Physics

Claire Gist's great love for physics has expanded Carnegie Mellon University's offerings for the smallest of scales. The Department of Physics has added quantum physics to the list of optional tracks for undergraduate physics majors wanting to study the most fundamental elements of matter.

Gist, a senior physics major, first became interested in quantum physics in middle school. In high school, she completed an independent project on quantum mechanics and developed a guide on quantum cryptography, looking at cybersecurity through the lens of quantum computing.

"Looking at CMU's course catalog, I happily came here because of the opportunities in quantum physics. Once I was here, I saw that there was untapped potential for giving more students the opportunity to explore quantum physics research," Gist said.

Quantum physics as discovered 100 years ago underlies the most compelling technologies of today, from lasers and semiconductors to powerful microscopes and magnetic resonance imaging. The Second Quantum Revolution has identified new regimes that may give birth to new technologies such as quantum materials, devices and computing.

The track courses include Advanced Quantum Physics I and II, Quantum Computation and Quantum Information Theory, a research course and STEM electives. There also is a course option in nuclear and particle physics, solid-state physics, or nanoscience and nanotechnology. Students gain experiential learning in addition to traditional coursework.

In addition to quantum physics, the department also offers tracks in applied physics, astrophysics, biological physics, chemical physics and computational physics to give students the opportunity to customize their programs with a focus in an area of interest. Physics majors are not required to select a track.

The new quantum physics track is launching just ahead of a centennial marking 100 years since pioneers Werner Heisenberg and Erwin Schrödinger wrote the foundational equations of quantum mechanics in 1925.

■ *Ann Lyon Ritchie*

Physics Launches New Master's Degree Program

A new master's degree created by Carnegie Mellon University's Department of Physics will help students hone the talents and expertise needed for applying to Ph.D. programs and for future job opportunities in technical fields.

The Master of Science in Modern Physics is designed to help develop the next-generation workforce. Through a combination of in-depth coursework and rigorous hands-on research and training, students will gain the specialized skills and knowledge of modern physics needed to apply to Ph.D. programs and meet the growing demand for experts in the U.S. semiconductor industry and other fields where logic, problem solving and critical thinking can help solve some of the world's most pressing problems.

Launching in fall 2025, the program is designed to be completed in two years. Research or internship experience is highly encouraged to ensure that students develop a deep understanding of the area of focus in which they are interested and gain practical experience in real-world applications. The curriculum is designed to provide rigorous foundational training in modern physics while allowing students to focus on areas of interest.

■ *Heidi Opdyke*

Scan this code to learn more about the M.S. in Modern Physics degree

Physics Students Yunshu Li, Katherine Parry Named Goldwater Scholars

Carnegie Mellon University physics students Yunshu Li and Katherine Parry have been selected to receive the 2024 Barry Goldwater scholarship. The students were selected from a pool of more than 5,000 applicants for the federally endowed award, which provides full coverage for tuition, fees, books, and room and board.

The award from the Barry Goldwater Scholarship and Excellence in Education Foundation is specifically awarded to sophomores or juniors who display academic rigor and a strong commitment to pursuing education in the natural sciences, engineering or mathematics.

Yunshu Li, a physics senior, is a Pittsburgh native whose academic research has spanned multiple fields at both Carnegie Mellon and the University of Pittsburgh.

Li received the Robert W. Kraemer Award for her work as a first-year student. Her first research experience at CMU was in Stephanie Tristram-Nagle's experimental biophysics lab, where she studied novel antibiotic treatments for multidrug-resistant bacteria. She continued to make progress in the study of novel antimicrobials in the laboratory of Dr. Berthony Deslouches at Pitt.

Li currently conducts research into the effects of attention on different levels of the auditory processing pathway in the Lab in Multisensory Neuroscience at CMU.

Katherine Parry is a senior studying electrical and computer engineering and physics. Her research focuses on designing faster computers through alternative approaches to computation.

Parry is not a stranger to research. At the age of 16, she was working on a Mandelbrot generator for a science fair project. While focusing on increasing the processing speed, she discovered instances that had yet to be addressed. She shared her findings at the IEEE Symposium on Computational Arithmetic, resulting in her first published paper.

At Carnegie Mellon, she has co-authored papers in the Computational Arithmetic community. She said the reputation and resources at Carnegie Mellon have helped her further establish herself as a researcher.

■ *Alex Johnson and Krista Burns*

Rokas Veitas Earns McQuade Fellowship

Rokas Veitas investigates magnetic dynamics in a long-range interacting spin system.

"It's about setting up a lattice of atoms in particular positions, generating a particular pattern in their spins using a laser, and then watching how easily this pattern falls apart or moves," said Veitas, a Ph.D. student in Carnegie Mellon University's Department of Physics.

Long-range interacting spin systems are lattices of atoms in two dimensions. Each atom spins in a certain direction, and each atom's spin influences others. This means that the atoms tend to spin in the same direction. In most magnetic systems, atoms only affect the spins of their neighbors, but in long-range interacting spin systems, atoms can affect other atoms across large distances.

Veitas investigates how external forces affect these. He likens the systems to a magnetized compass. Left alone, a compass points north. If a magnet is applied, the compass points in the same direction as the magnet. However, if the magnet and the Earth's magnetic field exert the same amount of force on the compass, it spins out of control.

Atoms in long-range systems respond in a similar way. Veitas is most interested when the atoms are out of control, known as the critical point.

"If I poke at the system a little bit, or if I throw something at it, or if I heat it up, what happens?" Veitas said. "What you get is a spin wave or a magnon, and our question is how many of these are there, and how long do they stick around?"

Veitas is part of the Chatterjee group run by Shubhayu Chatterjee, assistant professor of physics. Chatterjee said that Veitas' work is helping to answer questions about how atoms interact with each other.

For his work, Veitas earned the J. Michael McQuade Nanophysics and Energy Fellowship.

■ *Kirsten Heuring*

Baldwin, Park Earn DOE Awards To Work at National Labs

Two graduate students, Zachary Baldwin and Chanhyuk (Andy) Park, in Carnegie Mellon University's Department of Physics, are recipients of the Department of Energy Office of Science Graduate Student Research Program award.

Baldwin is spending nine months working at the Thomas Jefferson National Accelerator Facility in Newport News, Virginia. Since arriving at Carnegie Mellon, Baldwin has been deeply involved with the Gluonic Excitation (GlueX) Experiment at the Jefferson Lab, studying and analyzing two significant decay processes that subatomic particles may undergo. His advisor, Mellon College of Science Interim Dean Curtis Meyer, is a former leader and experiment spokesperson for the GlueX experiment.

While at the Jefferson Lab, Baldwin will analyze experimental data from smashing highly energetic, polarized photons into protons at the accelerator, especially particle decay channels that could experimentally confirm the existence of what are known as exotic mesons. He also will develop and test a new algorithm using AI and machine learning techniques to address the complex wave sets commonly encountered in high-energy physics experiments.

Park will head to Argonne National Laboratory in Lemont, Illinois, in January. His primary research is weak gravitational lensing with a particular interest in using statistical and machine learning methods to perform cosmological analysis on large survey datasets.

Argonne is home to many researchers involved in the Legacy Survey of Space and Time (LSST), which will be carried out by the Vera C. Rubin Observatory in northern Chile. At Argonne, Park will be part of the commissioning team working on validating data to ensure the software used in the telescope performs as intended.

Carnegie Mellon has a long history with LSST, and Park's adviser, Interim Physics Head Rachel Mandelbaum, is the primary investigator from the university leading research with the University of Washington to develop software to analyze large datasets generated by LSST.

■ *Kirsten Heuring and Heidi Opdyke*

Physics Major Tees Up Early Success

Samantha Wang checks scores obsessively when competing in golf tournaments. On the last round of the Women's Division III National Golf Championships, she kept even closer tabs on how the Carnegie Mellon University team was doing.

"I was sitting there clicking the refresh button almost after every shot," said Wang, a sophomore majoring in physics. "After I hit my shot on hole 17, I had to check to know. And when I saw the score, in my mind, there was no way we could lose."

The Carnegie Mellon women's team won their first national championship that day, with Wang being named as Division III National Women's Golf Freshman of the Year, and she was recognized nationally by the Women's Golf Coaches Association.

Wang became interested in golf growing up in Singapore. She received a set of toy clubs at the age of 5. Her real passion started when she joined her father on the links.

At 13, she started beating her father. In high school she joined the varsity team and competed in tournaments against students from other international schools in southeast Asia.

When she started her college search, she said golf was a factor. She met Dan Rodgers, Carnegie Mellon's coach of the men's and women's golf teams, on a visit to Pittsburgh, and she said that his demeanor and attitude helped her realize that Carnegie Mellon was the right fit.

Wang competed in her first collegiate tournament in fall 2023. She said she struggled during her first semester, both in her golf game and with the transition to college. With the help of teammates, she found herself growing in confidence both in her sport and in the classroom. She won two tournaments as an individual.

Wang is looking forward to the future and wants to conduct research into astrophysics and cosmology. On her team, she said she has her eye on being captain, so she can give her teammates the same support she received.

■ *Kirsten Heuring*

From the Ballroom to the Bay Area

Carnegie Mellon University alumni Marc Fasnacht and Vidhya Ramachandran enrolled in similar classes during their doctoral programs in the Department of Physics. Where they got to know each other, though, was the dance floor. They each signed up for lessons from CMU's Ballroom Dancing Club.

"It was a great way to get to meet people and do something different," Ramachandran said. "We both had two left feet."

"We still argue over about who stepped on the other person's feet more," Fasnacht added.

After that, they studied together and attended regular events for international students.

Fasnacht came to Pittsburgh through an exchange program at École Polytechnique Fédérale de Lausanne, a Swiss Federal Institute of Technology, and returned to CMU to pursue a Ph.D. in physics. While earning his Ph.D. in physics, he also earned a master's degree in Knowledge Discovery and Data Mining from the School of Computer Science.

With Robert Swendsen, emeritus professor of physics, he investigated computational condensed matter physics with a focus on biological and physical systems.

"I was working on some biological problems related to proteins, and I was doing computational simulations," Fasnacht said. "The interactive collaboration between departments was great. I was working with the Department of Physics and the University of Pittsburgh Biological Sciences department, so it was very interdisciplinary."

Ramachandran came to Carnegie Mellon after earning her master's in physics from the Indian Institute of Technology, Kanpur. She worked with Randall Feenstra, emeritus professor of physics, as his first Ph.D. student at Carnegie Mellon.

As part of Feenstra's group, Ramachandran studied gallium nitride, which can be used as a semiconductor in blue LEDs and in high-speed transistors. Ramachandran used scanning tunnel microscopy, which images surfaces at the atomic level, to investigate its molecular makeup and its uses.

"Vidhya did excellent work in the lab, both with a stand-alone scanning tunnel microscope and on the combined molecular beam epitaxy scanning electron microscope we built up here," Feenstra said. "She was always quick to pick up new aspects of the work, and she had an excellent attitude toward the work in general."

After graduation, Fasnacht worked as a postdoctoral fellow at the Howard Hughes Medical Institute at Columbia University using computational methods to investigate structure and function of biological macromolecules, and Ramachandran accepted a position at IBM developing new chips for wireless technology.

They also went from being dance partners to life partners, marrying in 2001.

In 2006, the pair moved to San Diego when Fasnacht earned a position as a software development scientist at Biovia, a company that focuses on creating scientific software. Ramachandran continued at IBM before moving to Qualcomm as a process integration engineer.

Fasnacht now works at Illumina helping to analyze and interpret genetic data, and Ramachandran works at Apple, designing chips and other technologies for MacBooks and iPhones. Both said their Ph.D.s at Carnegie Mellon helped them develop the skills and knowledge they needed to succeed in their respective work.

"When I was at CMU, I was also doing a lot of computational work," Fasnacht said. "That helped me prepare for software engineering."

"Physics is foundational," Ramachandran added. "Engineering is based off physics, and so it really gives you an insight into how things will behave and where things go. I have found that to be very, very valuable throughout my career."

The pair's stories about Carnegie Mellon helped inspire their daughter to apply. She is a first-year student in the College of Engineering. Fasnacht and Ramachandran said that Carnegie Mellon is an ideal place for students, including their daughter, to grow.

"Carnegie Mellon is such a diverse community. To me, it's the ideal place where people can have hard and interesting conversations," Ramachandran said. "We're really glad our daughter is going here, too."

Though the pair haven't danced much since their time at Carnegie Mellon, they hope to get back into it.

"We're thinking about starting lessons again now we're empty nesters," Fasnacht said.

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