JOHNS HOPKINS UNIVERSITY

2022 Year in Review

Physics & Astronomy

JOHNS HOPKINS
KRIEGER SCHOOL of ARTS & SCIENCES

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Physics and Astronomy is an annual publication of the Johns Hopkins University Zanvyl Krieger School of Arts and Sciences and the William H. Miller III Department of Physics and Astronomy. Send correspondence to: jon.schroeder@jhu.edu.

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Front cover: The capabilities of the James Webb Space Telescope came into focus in July of 2022 and the department's relationship with the Space Telescope Science Institute also shines. Currently, over 50 Hopkins researchers are involved with JWST through Hopkins-led research. Read more about the historic JWST science launch in the cover story on page 6: "Far & Away: Members of the Johns Hopkins community respond to seeing the first images from the James Webb Space Telescope."

Credit: Deian, AdobeStock

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Letter from the Chair

Dear alumni, colleagues, and friends,

I am pleased to be writing to you as the new chair of the Department of Physics & Astronomy.

Let me begin by thanking my colleague and predecessor Professor Tim Heckman for his devoted service and inspired leadership as chair for the past seven years as well as for his patient mentorship in preparing me for the role. I expect a goal of every chair is to leave the position with the department stronger than when she or he began, and I cannot imagine anyone fulfilling that goal better than Tim has.

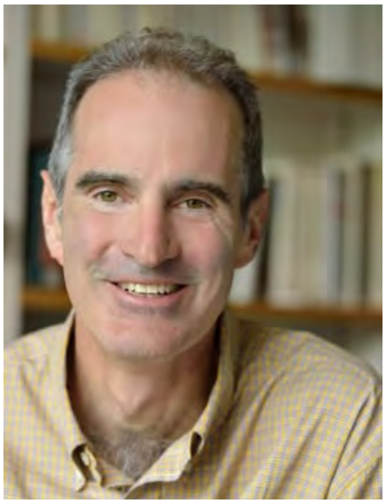
I took over as chair at a significant moment in the department's history, as we began our first full academic year as the William H. Miller III Department of Physics & Astronomy. As many of you know, this new name recognizes the tremendously generous and visionary gift Hopkins alumnus Bill Miller made to endow the department. We are very excited to be realizing the transformative potential of the Miller gift. The gift's impact is already being felt through the contributions of the outstanding young scholars we have recruited with the newly created Miller Graduate Fellows and Miller Postdoctoral Fellows programs. Among the first cohort of independent Miller Postdoctoral Fellows we are delighted to have join us are Hannah Tillim, who is working to develop a quantum mechanical theory of gravity, Beatriz Tapia Oregu, who is conducting searches for previously undiscovered particles that might comprise the elusive dark matter, and Ken K.Y. Ng, who is researching the creation and properties of gravitational waves in the universe. They join our other new endowed postdoctoral fellows, Sweeney Fellow Eli Zoghlin, who is developing novel quantum materials, and Davis Fellow Daniel Thorngren, who is studying extra-solar planets.

I also want to mention another momentous event of the past year, the successful deployment of the James Webb Space Telescope (JWST), which opens an auspicious new chapter in the partnership between our department and the Space Telescope Science Institute, the home of JWST, located just across the street from us. As articles you'll find in the newsletter describe, Hopkins astronomers are already making astounding discoveries with JWST, and we can expect many more in the years ahead.

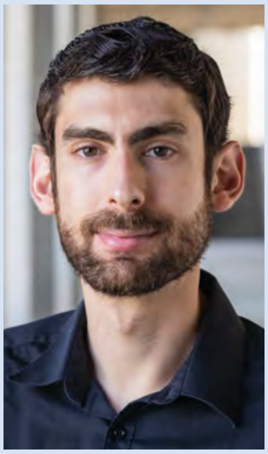
I hope you enjoy this year's edition of the newsletter, in which you will also learn about major awards, accolades, and accomplishments of our students, research staff, faculty, and alumni/ae as well as about some recent groundbreaking developments in particle physics and condensed matter physics led by department members. Thank you for your interest in and support of physics and astronomy at Johns Hopkins.

Best regards,

Bob Leheny



WELCOME NEW FACULTY MEMBERS



Dan Beller joined the department as an assistant professor in January of 2022. Beller is a theoretical soft matter and biological physicist who creates comprehensive simulations of liquid crystals, topological defects, and biological population evolution. Beller earned his PhD from the University of Pennsylvania in 2014 and has since held postdoctoral fellowships at Harvard and Brown Universities and has served as an assistant professor at the University of California, Merced. The Beller Research Group for Soft Matter and Biological Physics explores the basic physics underlying complex phenomena in ordered soft materials, biological matter, and living systems. In 2022 the group had papers published in the *Proceedings of the National Academy of Sciences* and *Frontiers in Physics*.

Yahui Zhang joined the department as an assistant professor in the summer of 2022. Zhang is a theoretical condensed matter physicist with a focus on strongly correlated physics. He obtained his PhD in physics from MIT in 2019 and served as a postdoctoral fellow at Harvard University from 2019 to 2021. Zhang's research focuses on pseudogap metal and strange metal in hole doped cuprates, new physics in t-J models with spin-one holes, and spin liquids and topological phases in moiré systems. He employs quantum field theory, parton theory, and numerical methods in his research. Zhang is also interested in exploring new directions related to cold atom systems, quantum simulation, and quantum computation.

Credit: Rachael Porter

Sean Carroll joined the department in the summer of 2022 as Homewood Professor of Natural Philosophy. Carroll holds a joint appointment with JHU and Fractal Faculty at the Santa Fe Institute. He received his PhD in 1993 from Harvard University. His research focuses on foundational questions in quantum mechanics, spacetime, cosmology, emergence, entropy, and complexity, occasionally touching on issues of dark matter, dark energy, symmetry, and the origin of the universe. Shortly after arriving to JHU, Carroll co-founded the Natural Philosophy Forum with Jenann Ismael, William H. Miller III Professor of Philosophy. The Natural Philosophy Forum is an interdisciplinary space for Hopkins affiliates to investigate the foundations of reality at the intersection of science and philosophy. Carroll is the author of several books at both the popular-level and textbook-level. His most recent book is *The Biggest Ideas in the Universe: Space, Time, and Motion*. Carroll has been awarded prizes and fellowships by the National Science Foundation, NASA, the Sloan Foundation, the Packard Foundation, the American Physical Society, the American Institute of Physics, the American Association for the Advancement of Science, the Freedom From Religion Foundation, the Royal Society of London, and the Guggenheim Foundation. Carroll has appeared on TV shows such as *The Colbert Report*, PBS's *NOVA*, and *Through the Wormhole* with Morgan Freeman. He is also host of the weekly *Mindscape* podcast, in which Carroll has conversations with the world's most interesting thinkers about science, society, philosophy, culture, arts, and ideas.

Yaojun (Jun) Zhang joined the department as an assistant professor in the summer of 2022. Zhang is a theorist working in the interdisciplinary field of biological physics, she has a joint appointment with the Department of Biophysics at JHU. She received her PhD in physics from the University of California, San Diego in 2015. She was then a postdoctoral fellow at the Princeton Center for Theoretical Science from 2015 to 2018, and the Princeton Center for the Physics of Biological Function from 2018 to 2021. Zhang's lab at JHU seeks to understand the complex behaviors of biomolecules and their assemblies across scales, from single-molecule folding and DNA bending, to macromolecular transport through nuclear pore complexes and intracellular space, to biomolecular phase separation and self-organization. Zhang works closely with experimental groups to identify outstanding conceptual questions posed by biology and then utilizes physical, mathematical, and computational tools to answer these questions, and more broadly to develop new theories and models that apply across systems and across the panoply of living creatures.

Brian Welch Leads Hubble Discovery of Most Distant Star Ever Seen

Dr. Brian Welch, who earned his PhD from the department in 2022, was the lead author of a *Nature* publication in early '22 that employed the Hubble Space Telescope to detect the light of a star that existed within the first billion years after the universe's birth—the farthest individual star ever seen to date. Welch dubbed his discovery "Earendel."

Welch's research focuses on studying distant galaxies using gravitational lensing, where massive foreground objects distort and magnify the light from background objects—a pivotal process in making the Earendel discovery. He defenended his PhD thesis titled "Investigations of Star Formation and Ionizing Radiation Across Time and Spatial Scales" in April of 2022. At his thesis defense, Welch also presented his newly

Brian Welch, PhD '22, is now employed by the University of Maryland working at NASA Goddard Space Flight Center
Credit: Daily Herald

published result on, "A Highly Magnified Star at Redshift 6.2."

The find is a huge leap further back in time from the previous single-star record holder; detected by Hubble in 2018. That star existed when the universe was about 4 billion years old, or 30% of its current age, at a time that astronomers refer to as "redshift 1.5." Scientists use the word "redshift" because as the universe expands, light from distant objects is stretched or "shifted" to longer, redder wavelengths as it travels toward us.

The newly detected star is so far away that its light has taken 12.9 billion years to reach Earth, appearing to us as it did when the universe was only 7% of its current age, at redshift 6.2. The smallest objects previously seen at such a great distance are clusters of stars, embedded inside early galaxies.

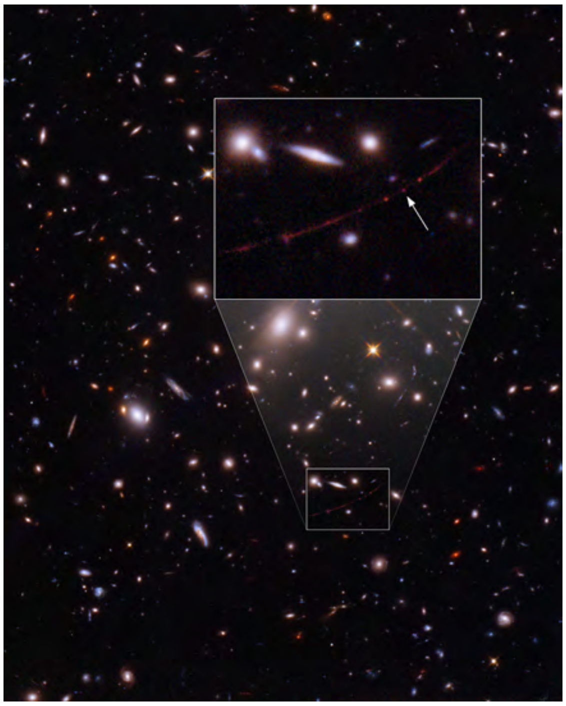
"We almost didn't believe it at first, it was so much farther than the previous most-distant, highest redshift star," Welch said. He was lead author of the paper describing the discovery, published in the March 30, 2022 journal *Nature* with co-author Dan Coe at the Space Telescope Science Institute.

Earendel is one star among millions, but in the magnified galaxy Welch was studying, the star aligned perfectly to appear magnified by a factor of thousands, highlighting the star among the rest. Welch made a model of the lensing effect of the galaxy cluster in which Earendel was found; in making that model, he discovered the object was too small and too highly magnified to be anything larger than a star. While Welch says entire galaxies look like small smudges at such far distances, gravitational lensing offered the magnification and distortion necessary to make the discovery.

Because Welch made the discovery, he had the chance to choose the star's nickname. He thought Earendel, an Old English word meaning "morning star," was fitting, as he says the star is seen during the era often referred to as the cosmic dawn.

The research team estimates that Earendel is at least 50 times the mass of our sun and millions of times as bright, rivaling the most massive stars known. But even such a brilliant, very high-mass star would be impossible to see at such a great distance without the aid of natural magnification by a huge galaxy cluster, WHL0137-08, sitting between us and Earendel. The mass of the galaxy cluster warps the fabric of space, creating a powerful natural magnifying glass that distorts and greatly amplifies the light from distant objects behind it.

Thanks to the rare alignment with the magnifying galaxy cluster, the star Earendel appears directly on, or extremely close to, a ripple in the fabric of space. This ripple, which is defined in optics as a "caustic," provides maximum magnification and brightening. The



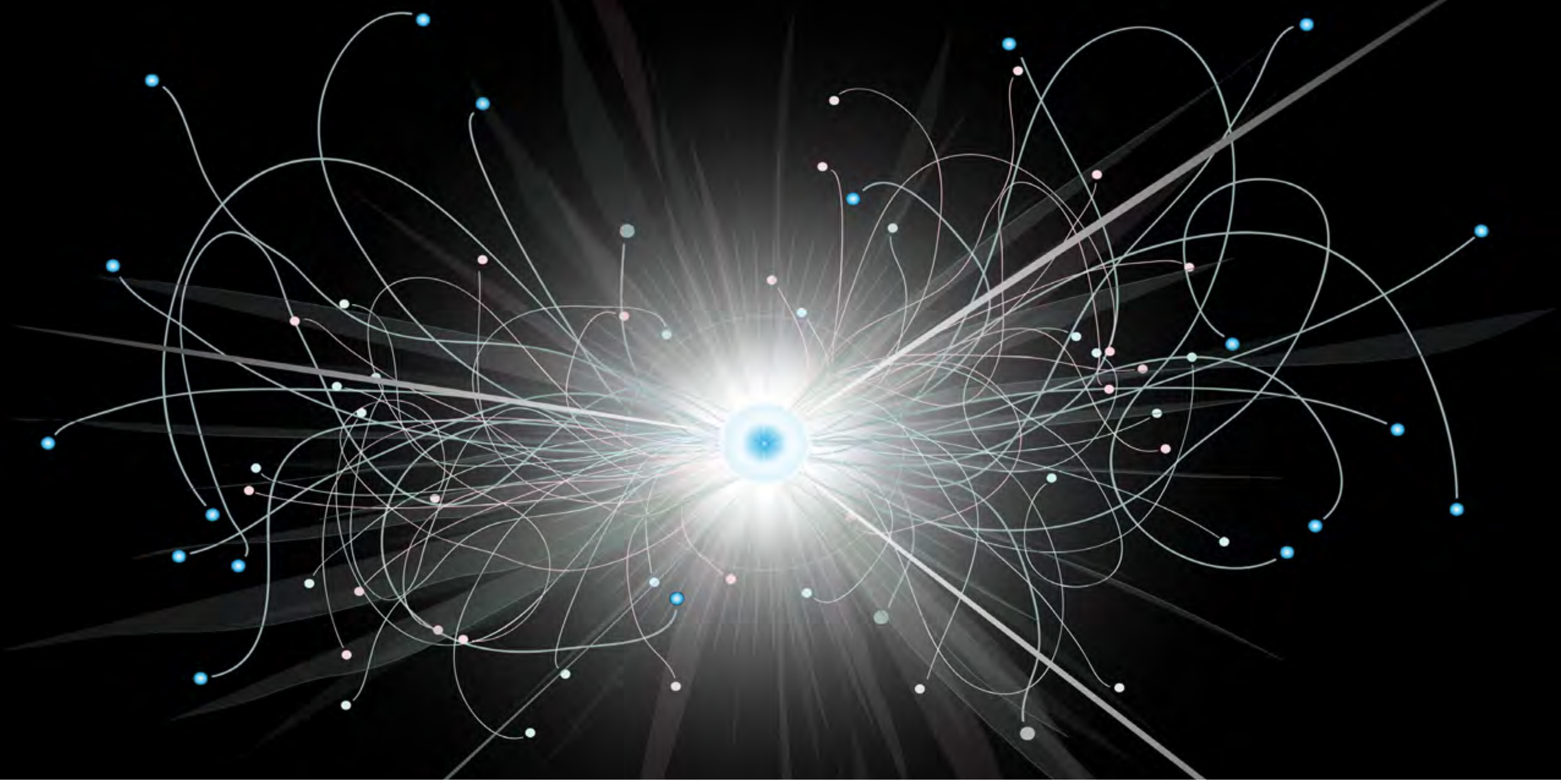
The star nicknamed Earendel (indicated with arrow) is positioned along a ripple in spacetime that gives it extreme magnification, allowing it to emerge into view from its host galaxy, which appears as a red smear across the sky.
Credit:NASA/ESA/Alyssa Pagan

effect is analogous to the rippled surface of a swimming pool creating patterns of bright light on the bottom of the pool on a sunny day. The ripples on the surface act as lenses and focus sunlight to maximum brightness on the pool's floor.

Earendel's composition will be of great interest for astronomers, because it formed before the universe was filled with the heavy elements produced by successive generations of massive stars. If follow-up studies find that Earendel is only made up of primordial hydrogen and helium, it would be the first evidence for the legendary Population III stars, which are hypothesized to be the very first stars born after the big bang. While the probability is small, Welch admits it is enticing all the same.

"Earendel existed so long ago that it may not have had all the same raw materials as the stars around us today," Welch explained. "Studying Earendel will be a window into an era of the universe that we are unfamiliar with, but that led to everything we do know. It's like we've been reading a really interesting book, but we started with the second chapter, and now we will have a chance to see how it all got started," Welch said.

— Saralyn Cruickshank



10 YEARS SINCE DISCOVERY: USING THE HIGGS BOSON AS A TOOL

BY ANNIE PRUD'HOMME-GENEREUX

There was a bump in the middle of the night.

On June 14, 2012, Physics and Astronomy Professor Andrei Gritsan analyzed data in a small meeting room at the CERN in Switzerland. He worked alongside his graduate student, his postdoctoral fellow, and a dozen particle physicists from around the world. Staring at their laptop screens, they were searching for the elusive Higgs boson.

For years, researchers had smashed protons, one of the components of atoms, at phenomenal speeds and observed new particles created in the process. This occurs naturally in space when energetic cosmic ray particles collide. The Large Hadron Collider (LHC), the world's largest particle accelerator, re-creates these events here on Earth.

Gritsan's team plotted graphs of the predicted data based on their model. That day, when they compared their plots to the experimental data from the collisions, they noticed a small deviation from the smooth curve predicted by theory. They found an unexpected bump in the curve.

Realizing the significance of this discovery, Gritsan delayed his return to Baltimore. His team was one of several groups sifting through the data from the collisions, analyzing the results using different methods, and the findings needed to be confirmed by all groups. Three weeks later, on July 4, 2012, amidst a media circus, the research teams jointly announced they had detected the Higgs boson.

This was the missing piece of the Standard Model of particle physics that describes the array of fundamental particles that make up everything (indeed, combined together they make up atoms), as well as the forces that guide their interactions.

Fifteen months later, Peter Higgs and François Englert, two of the theorists who had predicted the existence of the Higgs boson in the 1960s, were awarded a Nobel Prize.

Detecting the Higgs boson confirmed the existence of the Higgs field. This field permeates the Universe, and it gives particles their mass. Without it, the planets, stars – indeed our very existence – would not be possible. The energy provided by the LHC had excited the Higgs field, and in doing so, conjured the Higgs boson into existence.

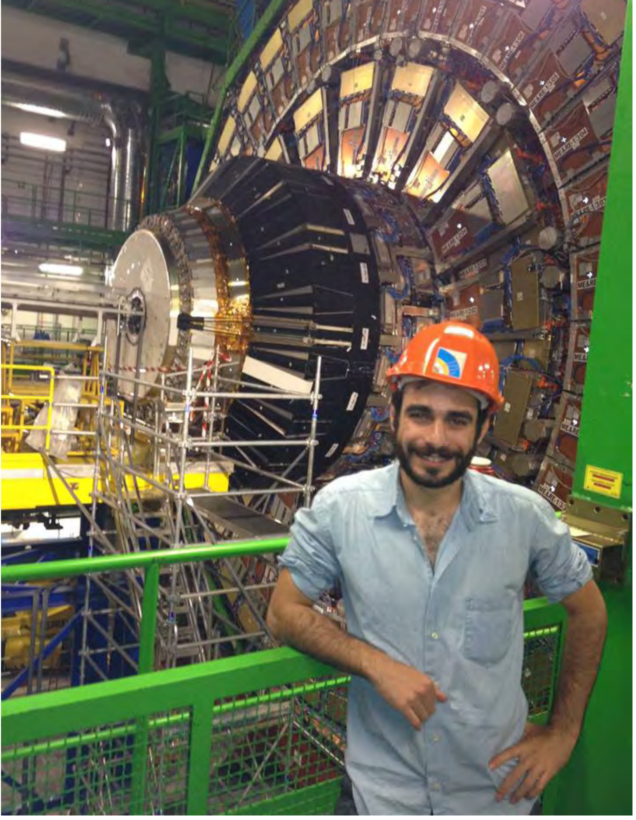
While doing so 10 years ago was a momentous achievement, today researchers routinely create the Higgs bosons in the collider. Gritsan's team has shifted the focus of their study from detecting the particle to measuring the Higgs's properties to incredible accuracy.

"You tickle it, and you see how it giggles," explains Savvas Kyriacou, a postdoctoral fellow in Gritsan's team.

Andrei Gritsan, Professor

Credit: Will Kirk

Making these precision measurements requires considerable backend work to align the 16,000 sensors that detect and tract the more than one billion proton collisions per second that take place inside the LHC.



Savvas Kyriacou, Postdoctoral Fellow

"You can think of it as focusing a telescope," explains Gritsan.

Once the detector is properly calibrated, Gritsan and his team use it to characterize the Higgs boson's mass, lifetime, and decay to other particles.

For reasons best explained by quantum mechanics, when a Higgs particle is created, it can adopt one of a range of masses.

"Something very important to understand is that the collider is like a huge slot machine," says Kyriacou, alluding to the fact that the quantum world is probabilistic, not deterministic like our own. Events and properties have a probability of occurring, but they are not set.

One Higgs boson can have a mass of 125 GeV/c^2 (the most common mass for a Higgs), others may have a mass that is a bit lower or higher, and on rare occasions, a Higgs boson is created that has a mass twice that size. When researchers plot the number of Higgs particles they detect at different masses, they see a curve showing the range of masses, not a single point.

Gritsan and his team have been measuring "the width of the Higgs," meaning, the range of values that the Higgs's mass can take (the width of the bump, as it were). In quantum mechanics, it is known that the larger the range of possible masses for a particle, the shorter its lifetime. So, the point of precisely measuring the width of the Higgs is to get at its lifetime.

Due to the level of precision required in the measurements, Gritsan's team is one of the few to have attempted it.

Indeed, the lifetime is pretty short. On the order of 10^{-22} seconds. "Even if the Higgs boson travels close to the speed of light, the distance it will travel over its lifetime is smaller than the size of an atom," explains Gritsan.

Nearly as soon as it is created, the Higgs boson disintegrates. So why is knowing the lifetime of something so ephemeral important?

The Standard Model makes predictions about what the Higgs boson can decay into. But, "what if there are some unknown particles that it can decay to?," asks Gritsan. If a particle has more avenues to decay than known through the Standard Model, its lifetime will be shorter than predicted. "Measuring the lifetime of the Higgs is an indirect way to get evidence that it decays to something unknown," says Gritsan.

After 10 years of investigation, "we didn't make any discovery that shows deviation from the Standard Model," says Kyriacou.

And that's a good thing. It means our understanding of the building blocks of the Universe are fundamentally accurate. Jeffrey Roskes, who completed his PhD under Gritsan's supervision and is now an assistant research scientist in another group at Hopkins puts it this way. "The Standard Model is a really good theory. I don't mean that in the sense that it is beautiful, although it is that. But it makes very precise predictions, and those predictions have been confirmed to a ridiculous degree of precision. There are certain measurements that are confirmed up to 7 or 8 decimal places, exactly as the Standard Model predicted. That is unbelievable."

"But there are also certain parts that have holes in it," acknowledges Roskes.

"It can not say anything about dark matter, dark energy, or the acceleration of the Universe," adds Kyriacou. "And since these are observable – it's not something that somebody said 'oh this isn't happening' – we have very strong evidence for all these things, we know that the Standard Model needs to be expanded."

"The Higgs boson appears to be a tool which can help us to look further," asserts Gritsan. In a sense, the Higgs boson is transitioning from being the object of study, to becoming a tool to probe the laws of nature that were hitherto inaccessible to us.

"It's not just that the Higgs is a new tool," says Roskes, "it's also a versatile tool, because it interacts – or at least is expected to interact – with every other Standard Model particle that has mass."

One of the hopes is that it will unlock new ways of studying dark matter. This substance is thought to make up 85% of the matter in the Universe. It's invisible, but we know it has mass because of the way it affects galaxy rotations. "We have no idea what it's made of, but it's probably some sort of particle," says Roskes. "If there's a Standar Model dark matter particle that has mass, we would expect the Higgs boson to interact with it."

Dark matter, dark energy, the imbalance of matter and antimatter in the Universe. None of these things are explained by the Standard Model, but the Higgs has ways to probe them. We are entering a new age of particle physics, one in which the past decade of tickling the Higgs particle and watching how it giggles is about to pay off.

Jeffrey Roskes, Assistant Research Scientist

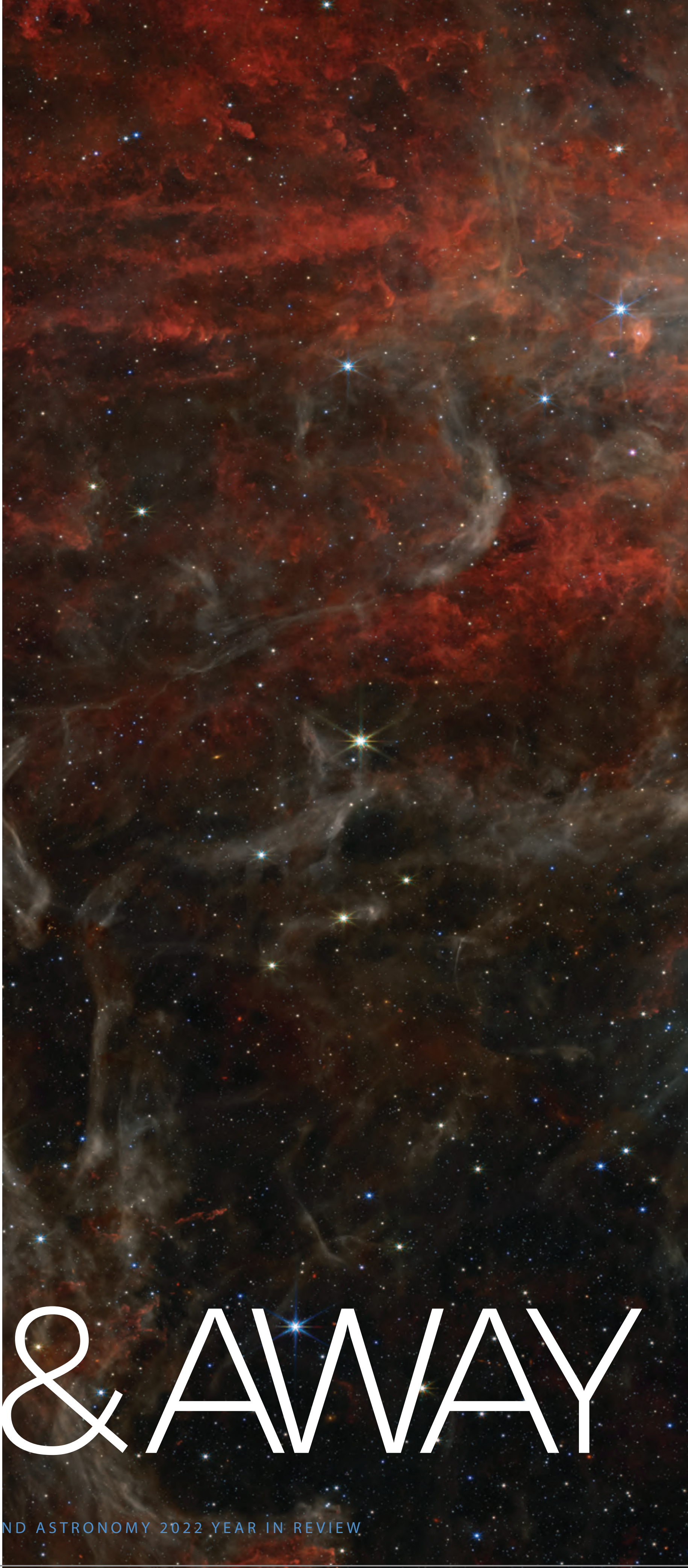
"We had a guiding light, the Standard Model, which told us more or less what to expect," says Kyriacou. "Now we are walking in the dark. It's like a whole new continent, and you don't have a map, or even fairy tales or myths about it. Nobody knows what to expect, but that's when exciting things happen…"

July 4th, 2022, marked the 10 year anniversary of the announcement of the discovery of the Higgs boson. To celebrate this landmark, Dr. Andrei Gritsan and his collaborators explained the significance and impact of this discovery, and the research that has taken place since then, in an article published in the prestigious journal *Nature*. A second paper focussing on the works from Gritsan's team, and specifically on the Higgs boson lifetime, also appeared in *Nature Physics* in 2022.

LAST JULY 12, people around the world witnessed a first-ever in science: the release of initial images from the James Webb Space Telescope (JWST). A veritable smorgasbord of stunning cosmic visuals, the data from the telescope will enable scientists to learn and see more about the universe than ever before. Currently, over 50 Hopkins researchers are involved with JWST through Hopkins-led research. Following are some of the early images as well as comments from members of the Johns Hopkins community.

COMPILED BY RACHEL WALLACH

FAR & AWAY



Members of the Johns Hopkins community respond to seeing the first images from the James Webb Space Telescope.

In this mosaic image stretching 340 light-years across, Webb's Near-Infrared Camera (NIRCam) displays the **Tarantula Nebula** star-forming region in a new light, including tens of thousands of never-before-seen young stars that were previously shrouded in cosmic dust. The most active region appears to sparkle with massive young stars, appearing pale blue.

CREDITS: NASA, ESA, CSA, STSCI, WEBB ERO PRODUCTION TEAM

Reality check

"I just kept looking at it and thinking, like, 'Is this real? How could this be real?' And, really, at some level, I think the thing that struck me the most was, I grew up, like many of us, thinking of the sky as a place that was dark at night with a few exceptions of stars and little blobs of light. And when you can see this deeply, and with this kind of resolution, actually you start to see most of the image is actually light. The darkness starts to become the rarity, if you know what I mean. And so it's almost like a completely different conception of the universe as a place that's mostly filled with activity, mostly filled with luminous things, mostly not empty."

Adam Riess
Bloomberg Distinguished Professor,
Thomas J. Barber Professor of Physics and Astronomy,
Nobel Laureate

Only the beginning

"There were times when we weren't sure if things would work, but they're working spectacularly. It's just amazing. It's blowing my mind. We get these amazingly detailed images of distant galaxies and all these tiny little clumps and star clusters that

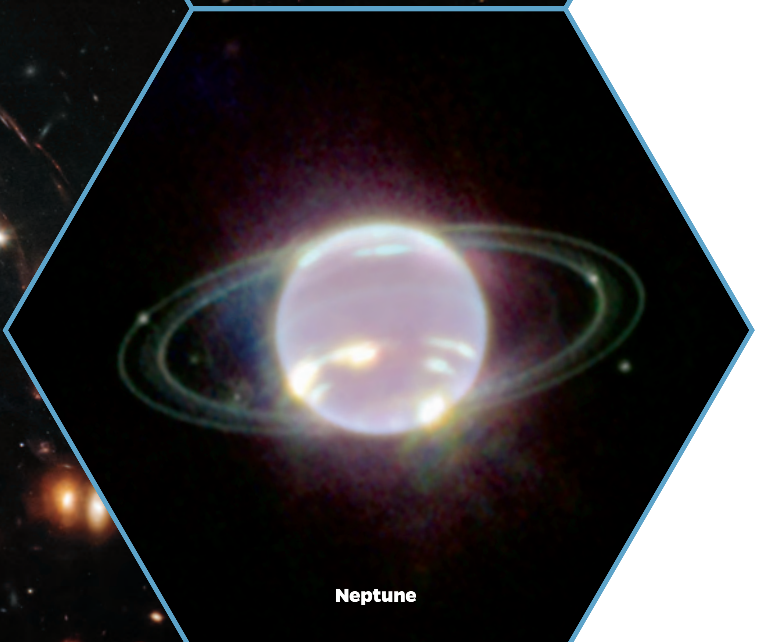
just pop out that we could never see before. And so, we're really seeing for the first time what galaxies looked like in the early universe. Every observation that Webb makes for the first year has the potential to transform our understanding of the universe. For many years to come, we're going to be doing so many exciting things. We're going to answer so many questions, and then, of course, we're going to have more questions that we never dreamed of."

Dan Coe, '04 (MA), '07 (PhD, Advisor: Holland Ford)
Astronomer, instrument scientist,
Space Telescope Science Institute/JWST

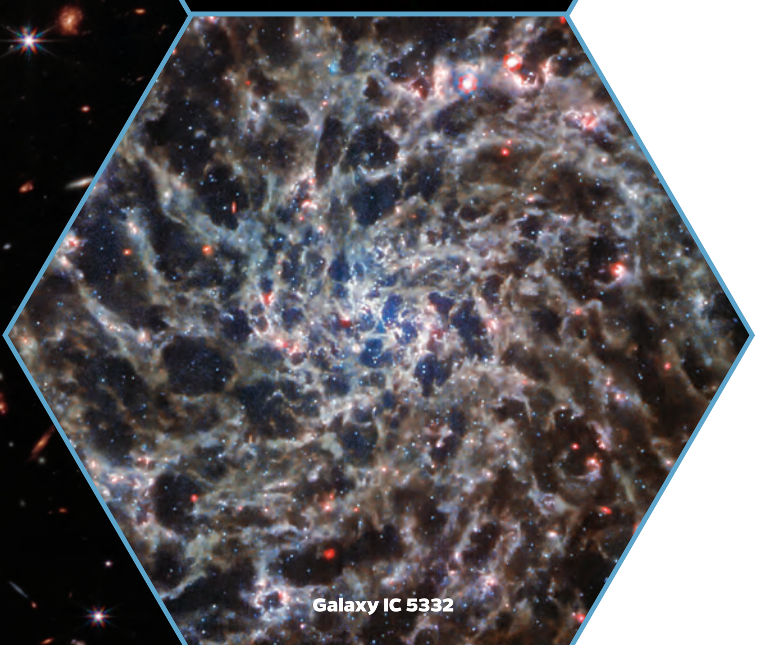
Known as **Webb's First Deep Field**, this image of galaxy cluster SMACS 0723 is overflowing with detail. Thousands of galaxies—including the faintest objects ever observed in the infrared—have appeared in Webb's view for the first time.

CREDITS: NASA, ESA, CSA, STSCI, NIRCAM

Stephan's Quintet



Neptune



Galaxy IC 5332

A remarkable achievement

"Just the fact that this mission was decades in preparation and having a textbook-perfect launch. Just being involved in seeing all these different subsystems that need to work together—having 18 different individual mirror segments working as one—for all the instruments getting initial data and starting to process it and getting things working to the point where we could take these amazing images. It was a lot of work, people giving it their all for months on end. From a scientific perspective, there is something about humanity that just really wants to know about where we are and where we came from. And what we're going to learn from JWST is definitely going to feed into that and give us probably more questions—it always does—but also give us some answers that I think will only increase our awe and appreciation of the universe."

Stephanie LaMassa, '08 (MA), '11 (PhD, Advisors: Andy Ptak and Tim Heckman)
Scientist, branch manager,
Space Telescope Science Institute/JWS

Revealing an Exoplanet Atmosphere

"The JWST data of [exoplanet] WASP-39b is so rich, it was great to work together with the scientists at the Applied Physics Lab in such a way that we could better understand how this new observatory works, dive deeper into the different instruments, and verify our results. With APL focusing on JWST's Near Infrared Camera, PhD student Zafar Rustamkulov and I were able to focus on the Near Infrared Spectrograph instrument. We were then able to cross-compare our results to see if the planet's atmospheric features matched up, which they did beautifully!"

David Sing
Bloomberg Distinguished Professor,
Physics & Astronomy and Earth & Planetary Sciences Departments

Images at left, top to bottom:

- An enormous mosaic of **Stephan's Quintet** is the largest image to date from Webb, covering about one-fifth of the moon's diameter. It contains over 150 million pixels and is constructed from almost 1,000 separate image files.
CREDITS: NASA, ESA, CSA, STSCI

- In September, Webb delivered the clearest look at **Neptune's** rings in 30-plus years and, for the first time, in infrared light.
CREDITS: NASA, ESA, CSA, STSCI

- Image of **galaxy IC 5332** as taken by the Webb telescope's MIRI instrument, resembling gray cobwebs in the shape of a spiral. These "cobwebs" are patterns of gas spread throughout the galaxy.
CREDITS: ESA/WEBB, NASA & CSA, J. LEE AND THE PHANGS-JWST AND PHANGS-HST TEAMS

WEBB REVEALS UNPRECEDENTED GLIMPSE OF MERGING GALAXIES

JILL ROSEN

Postdoctoral fellow Andrey Vayner, Professor Nadia Zakamska and graduate student Yuzo Ishikawa are part of an international team that published the first results from an Early Release Science program on James Webb Space Telescope (JWST). The team looked at a distant quasar — a massive black hole which is in the process of swallowing large amount of gas — and discovered a swarm of galaxies around it moving with very high velocities. The discovery indicates that the quasar is located in an actively forming, extremely massive cluster of galaxies.

Nadia Zakamska, Professor

"We think something dramatic is about to happen in these systems," said co-author Vayner, of their research in press with *Astrophysical Journal Letters.* The quasar imagery was one of just 13 "early look" projects selected through a highly competitive global competition to decide where the telescope was pointed during its first months of operation.

On Saturday, July 16th, 2022, Vayner and Ishikawa were repeatedly refreshing the Webb database when suddenly the data arrived, leading to a hastily assembled multinational team confab on Sunday to try to make sense of the jaw-droppingly detailed raw images.

Although earlier observations of this area of the sky by NASA/ESA Hubble Space Telescope and the Near-Infrared Integral Field Spectrometer instrument on the Gemini-North telescope pinpointed the quasar and hinted at the possibility of a galaxy in transition, no one suspected that with Webb's crisp imaging they'd see multiple galaxies, at least three, swirling the region.

"With previous images we thought we saw hints that the galaxy was possibly interacting with other galaxies on the path to merger because their shapes get distorted in the process and we thought we maybe saw that," said co-principal investigator Zakamska, who helped conceive the project back in 2017 with then-Johns Hopkins postdoc Dominika Wylezalek.

"But after we got the Webb data, I was like, 'I have no idea what we're even looking at here, what is all this stuff!' We spent several weeks just staring and staring at these images."

JWST revealed at least three galaxies moving incredibly fast, suggesting a large amount of mass is present. The team believes this could be one of the densest-known areas of galaxy formation in the early universe.

Andrey Vayner, Postdoctoral Fellow

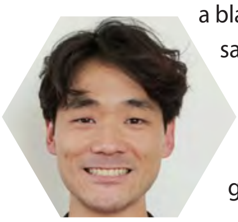
Because light takes time to travel to us, when we look at objects like this one in the very distant regions of the universe, we're seeing light that was emitted from the earliest stages of the universe's evolution. Massive galaxy swarms like this one were likely common then, Zakamska said.

"It's super exciting to be one of the first people to see this really cool object," said Ishikawa, who contributed to the interpretation of the galaxy swarm.

Even Vayner, who'd dreamed of using Webb data since he first heard about the telescope as an undergraduate more than a decade ago, and thought he knew what to expect, was shocked to see his long-studied spot in the universe revealed with such clarity.

"It really will transform our understanding of this object," said Vayner, who was instrumental in adapting the raw Webb data for scientific analysis.

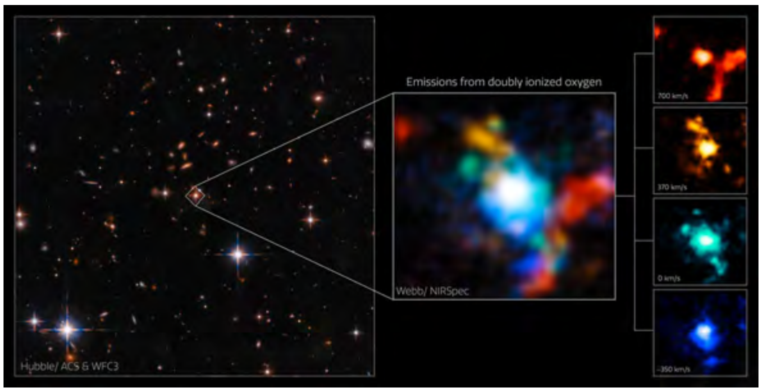
The blindingly bright quasar, fueled by what Zakamska calls a "monster" black hole at the center of the galactic swirl, is a rare "extremely red" quasar, about 11.5 billion years old and one of the most powerful ever seen when the universe was so young. The universe is 13.8 billion years old, as determined by the Wilkinson Microwave Anisotropy Probe, so the quasar formed at only 2.3 billion years into the evolution of the universe. It's essentially a black hole in formation, Vayner said, eating the gas around it and growing in mass. The clouds of dust and gas between Earth and the glowing gas near the black hole make the quasar appear red.



Yuzo Ishikawa, Graduate Student Space Fellow, Space@Hopkins

The team is already working on follow-up observations into this unexpected galaxy cluster, hoping to better understand how dense, chaotic galaxy clusters form, and how it is affected by supermassive black hole at its heart.

"What you see here is only a small subset of what's in the data set," Zakamska said. "There's just too much going on here so we first highlighted what really is the biggest surprise. Every blob here is a baby galaxy merging into this mommy galaxy and the colors are different velocities and the whole thing is moving in an extremely complicated way. We can now start to untangle the motions."



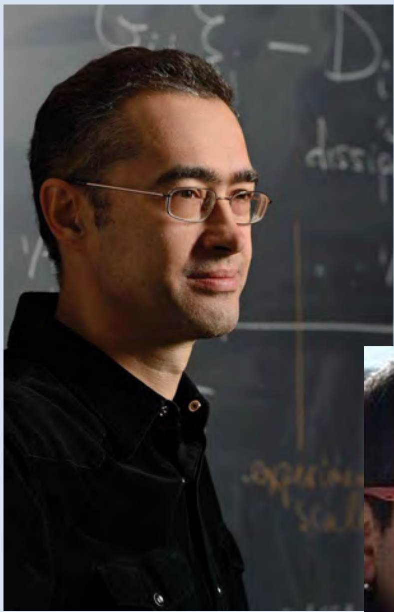
A Hubble image of the quasar and the same area viewed with the James Webb Space Telescope. The Webb image shows multiple galaxies coalescing, with each color representing a different velocity: Red is moving away from us. Blue is moving toward us.

CREDIT: ESA/WEBB, NASA & CSA, D. WYLEZALEK, A. VAYNER & THE Q3D TEAM, N. ZAKAMSKA.

MAGNETS IN FLUX

RACHEL WALLACH

A team of physicists at the Johns Hopkins Institute for Quantum Matter, housed within the department, has discovered that they can control a metal's electromagnetic properties by manipulating it mechanically. The finding suggests potential developments in the technologies involved in magnetic random access memory, or RAM, as well as other applications.



Professor Oleg Tchernyshyov
Credit: Will Kirk

Scientists usually manipulate a material's magnetic state by applying a magnetic field or by passing an electric current through it. The discovery that stretching or compressing the metal can also control its electromagnetic properties was unexpected, says professor Oleg Tchernyshyov, a co-author of a paper published in *Nature Physics* that outlines the findings.

"Imagine you squeeze a magnet and that changes the direction of the orientation of its magnetic dipoles. That's hard to imagine, but in this case it works like that. So it was a rather unusual finding," said Tchernyshyov.

Mechanical control of electric properties, known as piezoelectricity, is broadly used. But its magnetic counterpart, piezomagnetism, is rare and weak, and until now has required extremely cold temperatures.

Satoru Nakatsuji, a research professor at JHU within the Institute for Quantum Matter and a physics professor at the University of Tokyo, had been working with an antiferromagnetic metal known as Mn_3Sn. Antiferromagnetic metals have atomic or molecular components that align in a particular alternating pattern. By chance, his research group realized that they were able to reverse the directions of the atomic magnetic dipoles by stretching or compressing the material, even at room temperature. The finding was surprising because mechanical stress on its own does not create a magnetic field.

Nakatsuji mentioned the puzzling observation in a talk at a meeting of the IQM in November of 2019. Theoretical physicist Tchernyshyov, who was in the audience, got to work trying to explain how the magnetic reversal was possible. He and his graduate student at the time, Sayak Dasgupta (PhD, '20), went on to develop a theory that explained how mechanical forces can influence magnetic degrees of freedom in antiferromagnetic materials. The *Nature Physics* paper describes both the experiments and the theory.

Sayak Dasgupta, now a Data Scientist at Intel Corporation

The researchers were motivated by the current push to utilize spintronics—the study of the spin of an electron and the associated magnetic moment it produces—in electronic devices. In hard-drive technology, memory bits are stored as magnetized areas in a thin magnetic film. A magnetic dipole with the north pole up is 1, for example, while one with the north pole down is 0. IBM physicist Stuart Parkin proposed "magnetic racetrack memory," in which bits are stored as the presence (1) or absence (0) of a domain wall. But it turns out that these domain walls—barriers of microscopic magnetic fields—are able to attract or repel other nearby domain walls, potentially scrambling the bits.

To overcome this hurdle, researchers turned to antiferromagnets, where adjacent spins alternate between two or three directions. This staggering of spins also staggers their magnetic moments, so the domain walls do not produce a magnetic field, and do not react to it.

But this solution creates yet another problem: how can the scientists detect the domain walls, now camouflaged by the alternating spins? Nakatsuji's group solved this issue in their antiferromagnetic material Mn_3Sn by measuring the magnetic state indirectly, with the aid of the anomalous Hall effect. In the Hall effect, which was discovered at Hopkins in 1881 by physics graduate student Edwin Hall, an electric current flowing along a wire induces an electric field perpendicular to the wire; the resulting transverse voltage can be picked up by a voltmeter hooked up to the opposite edges of the wire. A reversal of the voltage indicates that the direction of spins has reversed, signaling the passage of a domain wall through the area monitored by the voltmeter.

For now, the finding sits in the realm of basic science—a previously unsuspected result that offers new insight into the intricacies of electromagnetic properties. But engineers may want to explore whether the phenomenon could be useful in the spintronics they hope will characterize the next generation of computer memory, Tchernyshyov says.

A highlight for Tchernyshyov is that much of the research was carried out independently by graduate students. Dasgupta, Nakatsuji's student, and a third at Cornell collaborated closely with one another.

"This illustrates the opportunities that our grad students have at the institute," Tchernyshyov said. "They don't just talk to their advisors; they go out in the field and work with people well outside of their area of expertise—with theorists, experimentalists, different groups with different capabilities. I think that's a really great opportunity."

NEWS BRIEFS

Danielle Speller Receives 2022 Sloan Fellowship and 2022 Packard Fellowship

Assistant Professor Danielle Speller received a Sloan Research Fellowship and a Packard Fellowship in 2022. The Sloan Research Fellowship honors early-career science researchers who show exceptional promise in their fields. Speller is among 118 researchers who received a Sloan Research Fellowship in 2022. Each recipient receives a two-year, $75,000 fellowship to advance their research. "The Sloan Research Fellowship is an honor, indicating support from the community of scholars and providing an important source of early funding in the realization of my research goals," Speller said. "I am excited, and I look forward to joining other fellows in continued research and the pursuit of a deeper understanding of the natural world."

Speller's 2022 Packard Fellowship is in the category of Science and Engineering. Speller is one of a small group of innovative early-career scientists and engineers who are boldly pursuing new areas of research who were chosen for the fellowship. She is recognized for her research on new particles and never-before-seen radioactive decays using novel detection techniques to understand the origins and interplay of matter and light.

Each Packard Fellow will receive $875,000 in unrestricted funds that they can use over five years in any way they choose. The Packard Fellowship, which is heading into its 35th year, is one of the largest non-governmental fellowships for research and, for many Fellows, is a critical steppingstone in their career.

Speller's research focuses on finding new particles and radioactive decays. Her team is particularly interested in specific particles called axions, which could help explain the presence of dark matter in galaxies. She and her team search for axions by using turntable cavities immersed in large magnetic fields. If axions interact with the magnetic field, the interaction would appear in the collected data as a small amount of excess power. Her work in nuclear and particle physics is designed to create a fuller, more accurate description of the natural world. Speller plans to use the fellowship funds to gain research support for a graduate student and to purchase equipment which will allow her team to build and collect data to continue the search for axions.

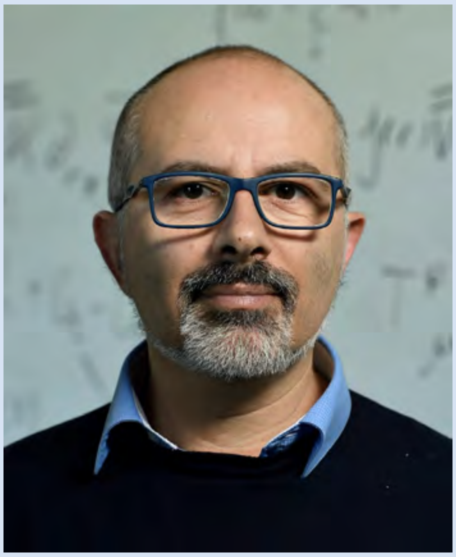
Chia-Ling Chien Honored with Special Issue of The Journal of Magnetism and Magnetic Materials

The Journal of Magnetism and Magnetic Materials published their final issue of 2022 in honor of Professor Chia-Ling Chien's 80th birthday. The issue includes 32 research articles and a foreword cowritten by Samuel Bader and Nobel laureate Albert Fert. A portion of the forward reads as follows:

> *"Over the past few decades, Professor Chia-Ling Chien has made numerous discoveries in magnetic nanostructures, superconductivity, and spintronics. In honor of his sustained contributions to the field and in celebration of his 80th birthday, this Special Issue brings together a collection of invited articles from leading researchers, to provide historical perspectives, to highlight exciting ongoing developments, and to discuss future opportunities and challenges in nanomagnetism and spintronics."*

NEWS BRIEFS

Emanuele Berti Receives 2023 Richard A. Isaacson Award in Gravitational-Wave Science



Credit: Will Kirk

In October of 2022 Professor Emanuele Berti was chosen as the recipient of the 2023 Richard A. Isaacson Award in Gravitational-Wave Science from the American Physical Society. Dr. Berti is being recognized "for contributions to gravitational-wave science through groundbreaking studies of black hole quasinormal modes, higher multipole radiation, astrophysical detection rates, spin evolution, and tests of general relativity, and for leadership in preparing impactful white papers and review articles."

The Richard A. Isaacson Award in Gravitational-Wave Science is made possible through the generous support of Kip S. Thorne and Rainer Weiss. It honors the contributions of Richard Isaacson, retired Program Director of Gravitational Physics at the National Science Foundation, to the development of the Laser Interferometer Gravitational-wave Observatory (LIGO) and to the entire field of gravitational-wave physics.

Jami Valentine Miller Receives 2022 JHU Distinguished Alumna Award

Jami Valentine Miller, who earned her PhD in the department in 2007 working with Professor Chia Ling Chien, has received the 2022 JHU Distinguished Alumna Award. After successfully defending her dissertation, "Spin Polarization Measurements of Rare Earth Thin Films", Dr. Valentine Miller became the first Black woman to earn a PhD in physics at Johns Hopkins. While at Hopkins, she started the website African American Women in Physics (AAWiP.com), a site that honors women who have paved the way to inspire future physicists, and connects allies interested in promoting diversity in physics and other STEM fields. Upon graduating, Dr. Valentine Miller pursued a career as a patent examiner with the U.S. Patent and Trademark Office, working on applications for semiconductor and spintronic memory devices, including those in Samsung and Apple products. In 2012, she was appointed to the level of primary examiner. Dr. Valentine Miller has devoted much of her career to efforts to improve diversity in physics. In addition to founding and continuing to oversee the AAWiP website, she has worked with the National Society of Black Physicists to increase awareness of underrepresented groups in the physics arena. She continues to work as a motivational speaker focused on non-academic careers in physics, perseverance in STEM, and intellectual property. Recent speaking engagements include the Scholars Spring Preview at Florida A&M University, and the Conference for Undergraduate Women in Physics at The College of New Jersey. She also serves as the national chair for diversity for American Mensa, and has been a featured physicist in Cool Careers in Physics published by Sally Ride Science.

Mark Ho Yeuk Cheung Receives Croucher Fellowship

Graduate student Mark Ho Yeuk Cheung has received a Croucher Fellowship from the Croucher Foundation in Hong Kong. The Fellowship helps graduate students from Hong Kong pursue a PhD and supports the early stages of their scientific careers. Cheung earned his undergraduate degree Physics from the Chinese University of Hong Kong. He has previously been awarded the Hong Kong Special Administrative Region Government Scholarship and the Grantham Scholars of the Year Award. Cheung's advisor is Emanuele Berti, guiding him in the field of gravitational-wave astronomy.

Cheung's work in the field of black hole perturbation theory is focused on determining how pseudo spectral instability would affect the ringdown signals of black holes. He will also extend his work to more general black hole spacetimes. He is also developing data analysis techniques for detecting higher order ringdown modes.

Within gravitational-wave lensing, Cheung is working on modelling wave-optics diffraction effects that could leave a detectable imprint on lensed gravitational waves, and he hopes to contribute towards the effort to detect the first lensed event. These projects will help extract the most physics out of the catalog of events detected in the next decades.

NEWS BRIEFS

Vishal Baibhav Receives Ehlers Thesis Prize from the International Society on General Relativity and Gravitation

Vishal Baibhav, who received his PhD from the department in 2021 working with Emanuele Berti, has received the Ehlers Theseis Prize for best PhD thesis. The prize was awarded by the International Society on General Relativity and Gravitation in recognition of Baibhav's PhD thesis titled "Black hole beasts and where to find them."

The International Society on General Relativity and Gravitation instituted a Thesis Prize in memory of Professor Jürgen Ehlers (1929-2008), a distinguished relativist and a past President of the Society. Professor Ehlers made seminal contributions to foundations of general relativity, many of its mathematical aspects and cosmology. He was the founding director of the Albert Einstein Institute of the Max Planck Society of Germany and won the Max Planck Medal, the highest honor bestowed by the German Physical Society.

Baibhav's Prize motivation reads: "For the innovative use of semi-analytic and numerical methods to study mass gaps and spin gaps in the dynamical evolution of black holes and the ground-breaking work on the use of the gravitational wave signals of binary mergers to determine information about the progenitors of the black holes.

The prize was awarded at the tri-annual conference of the International Society on General Relativity and Gravitation in Beijing, China.

Kaze Wong Receives Braccini Prize for PhD Thesis from the Gravitational Wave International Committee

Kaze Wong, who received his PhD from the department in 2021 working with Emanuele Berti, has received the Gravitational Wave International Committee's Braccini Prize in recognition of his PhD thesis titled "Building new tools for gravitational wave astronomy." Each year the GWIC and the Friends of Stefano Braccini recognize an outstanding PhD thesis in the field of gravitational waves. Wong's prize was announced at the 14th International Laser Interferometer Space Antenna Symposium.

Sumit Dahal Selected by *Forbes* for "30 Under 30" in Healthcare & Science

Sumit Dahal, who earned his PhD in the department in 2020 working with Professor Toby Marriage and Bloomberg Distinguished Professor Chuck Bennett, has been selected by Forbes as a "30 Under 30" recipient for his work developing sensors for telescopes. While at JHU, Dahal deployed three microwave telescopes in Chile's Atacama Desert to pick up microwave remnants from the earliest moments of the universe as part of the ongoing Cosmology Large Angular Scale Surveyor (CLASS) project. The data collected by CLASS are used to test the theory of cosmic inflation and consider new physics models.

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Dahal is now a postdoctoral fellow at NASA Goddard Space Flight Center. His work is focused on continuing to develop highly sensitive superconducting sensors for telescopes.

Maryam Haytham Esmat Featured in the Forbes Middle East 30 Under 30 List

Graduate student Maryam Haytham Esmat, currently working in Assistant Professor Danielle Speller's lab, was chosen to be part of the Forbes Magazine Middle East "30 Under 30" list in October of 2022. Esmat has interned at the Space Telescope Science Institute, working on the James Webb Space Telescope in the instrumentation team. In 2020, NASA presented her research findings with the Exoplanet Characterization Toolkit Team at the American Astronomical Society Meeting in Hawaii. She covered the James Webb Space Telescope launch in Arabic at the Egyptian Society for Astronomy in 2021. She also co-translated the James Webb Space Telescope Key Facts International from English to Arabic on the NASA Goddard Space Flight Center website and was featured on a NASA video saying "Good Luck, Webb" in Arabic.

Forbes Middle East, October 2022

NEWS BRIEFS

Arshia Jacob Receives Otto Hahn Award and Medal from Max Planck Society

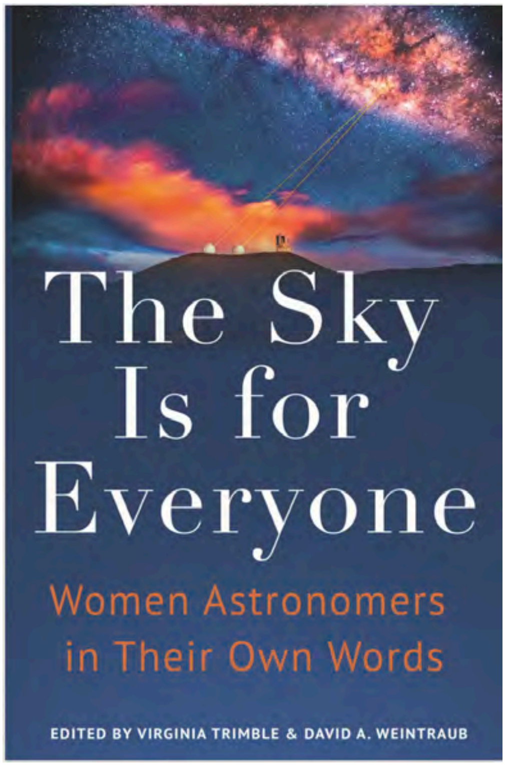
Postdoctoral researcher Dr. Arshia Jacob has received the Otto Hahn Award from the Max Planck Society. Jacob, who has been working with Professor David Neufeld, is being recognized for her novel investigations of the physics and chemistry of the interstellar medium.

The Otto Hahn Award provides for a long-term research residency abroad followed by leadership of a research group at one of the Max Planck Institutes. Jacob's residency will take place in Bonn, Germany. Jacob also received the Otto Hahn Medal from the Max Planck Society in early 2022. The Otto Hahn Award goes to a small subset of particularly worthy Medal recipients. Jacob was among only four other Award recipients.

Arshia Jacob pictured next to the Stratospheric Observatory for Far-Infrared Astronomy which provided data for her 2021 research.

Rosemary Wyse Writes Autobiographical Chapter in *The Sky is for Everyone: Women Astronomers in Their Own Words*

Alumni Centennial Professor Rosemary Wyse joined an assemblage of influential women astronomers in 2022 by writing an autobiographical chapter in "The Sky is for Everyone: Woman Astronomers in Their Own Words." The book focuses on women who have broken down barriers and changed the face of modern astronomy. Virginia Trimble and David Weintraub bring together the stories of the tough and determined women astronomers from 1960 to today. The anthology serves as an inspiration to current and future generations of women scientists while giving voice to the history of a transformative era in astronomy.



Nicole Crumpler, Hector Cruz, Rojin Jafari ,Yi Luo, and Thomas Waddleton Receive Graduate Teaching Awards

The department's Graduate Program Committee chose their selection of the most outstanding graduate student teaching assistants in 2022 with their annual graduate teaching awards. The recipients were:

EJ Rhee TA award for Flair in Teaching: **Nicole Crumpler**

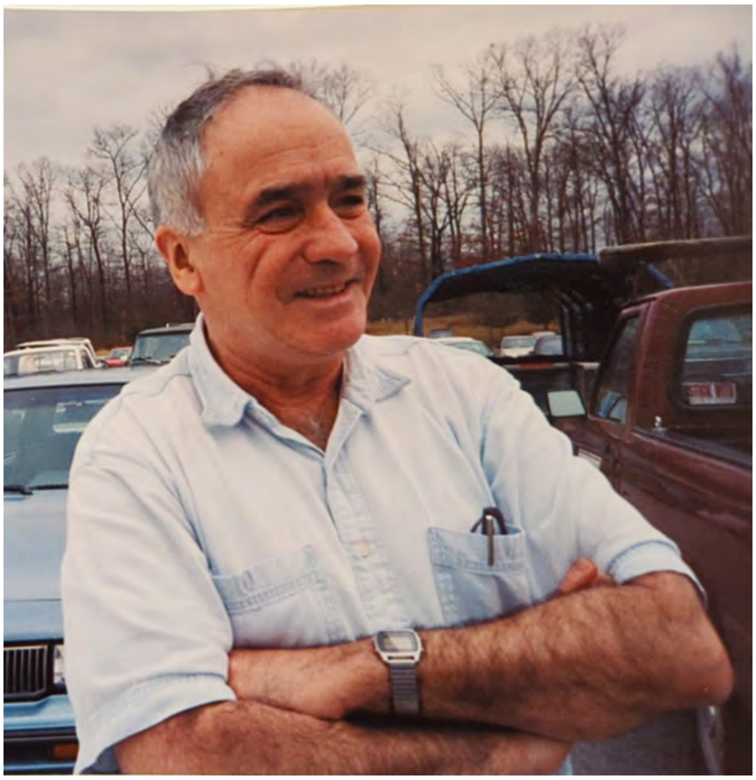
Rowland Prize for Innovation in Teaching: **Hector Cruz**

Kilby Prize for Excellence in Teaching: **Rojin Jafari**

Tatum Prize for Excellence in Teaching: **Yi Luo**

Agnew Prize for Excellence in Teaching: **Thomas Waddleton**

IN MEMORIAM



Gabor Domokos, Professor Emeritus of the department passed away in 2022, shortly after his 89th birthday. He had been a member of the Johns Hopkins community since 1965. His work in particle physics spanned several areas, including possible algebraic properties of quarks, neutrino physics, and extracting information about beyond-the-Standard Model physics from high energy cosmic rays.

Gabor and his wife Susan Kovesi-Domokos, Professor Emerita of the department, started the well-known Johns Hopkins Workshops on Current Problems in Particle Theory in 1974. In 1978, Roberto Casalbuoni of the University of Florence joined them, and the Workshops became an international annual event. A number of European and Asian universities participated in organizing the series and co-hosting the Johns Hopkins Workshops on Current Problems in Particle Theory for 42 years.

Domokos graduated from Eötvös Loránd University in Hungary in1957. Upon graduation, he worked as a researcher at the Central Research Institute in Budapest. In the early 1960s Domokos became a researcher in the Joint Institute for Nuclear Research in Dubna, Russia where he worked on theoretical nuclear physics. In 1965, he was invited to JHU as visiting researcher for a year. Following his year at JHU, he spent an additional year in the United States as a researcher at the University of California, Berkeley before he returned to Hungary in 1967. It was in 1967 that Gabor was reunited with his love Susan Kovesi and they married later that year.

In 1968, Gabor and Susan were both working at the European Council for Nuclear Research (CERN) in Switzerland during the "Prague Spring" and the subsequent Soviet occupation of Czechoslovakia. Upon the conclusion of their visiting appointments at CERN, Gabor and Susan decided not to return to Hungary amid the unrest in Europe. They decided instead to head to Johns Hopkins University where they continued their particle physics research together until their joint retirement in 2015.

Gabor Domokos
1933 - 2022

IN MEMORIAM

Astronomer Paul Feldman, a worldwide leading authority on comets who pioneered the field of ultraviolet spectroscopy of comets, died at home on Jan. 26, 2022. He was 82.

In addition to pioneering contributions to cometary science, Feldman—professor emeritus in the department and Academy Professor—made similar contributions to the fields of planetary and satellite atmospheres and astronomical instrumentation. He was principal investigator of a NASA-supported sounding rocket program and was responsible for more than 50 sounding rocket launches to study the Earth's upper atmosphere, the aurora and the airglow, the atmospheres of comets and planets, the spectra of hot stars, and cosmic background radiation. He is largely responsible for Johns Hopkins' reputation as a leader in solar system ultraviolet astrophysics and spectroscopy.

"Paul has been a major presence in the department for many decades and served with great effectiveness and distinction as department chair during a critical period of departmental growth and reinvigoration. He was really one of a kind, and his leadership, wit, and wisdom will be sorely missed," said Timothy Heckman, professor and former chair of the department.

Feldman's program also developed the UVX experiment that flew on the Space Shuttle Columbia in January 1986. He was principal investigator for a program of comet studies, including Comet Halley in 1985-1986, using the International Ultraviolet Explorer satellite observatory. He was a co-investigator on the team that developed the Hopkins Ultraviolet Telescope for FUV astronomy as part of the Astro payload that flew on the space shuttle in December 1990 and again in March 1995, and was a general observer with the Hubble Space Telescope and served on the Space Telescope Users Committee from 1992 to 1995. He was also a member of the FUSE science team and a co-investigator on the HST Advanced Camera for Surveys, and a member of the NASA science teams for the Rosetta and LRO ultraviolet spectrometers team and the Europa Clipper UVS team.

"Paul was on the ground floor of developing the instruments and analytic techniques used to understand the chemical and dynamical makeup of comets, planets, and moons in our solar system, which he eagerly shared with anyone who walked into his office," said Stephan McCandliss, a research professor in the department whom Feldman hired in 1988 to work on the sounding rocket program. "His expertise and enthusiasm for spectroscopy made him a key developer and informed user on dozens of U.S. and international space astronomy missions, where he could always be counted on for sage mentorship, wry witticisms, and a readiness for fine dining. But perhaps most importantly, working for him was easy and always interesting."

Paul D. Feldman
1939 - 2022

Feldman's work was notable for its great breadth and depth, said Harold (Hal) Weaver, research professor in the department, principal professional staff at Hopkins' Applied Physics Laboratory, and a former student of Feldman's. Feldman first ventured into the field of cometary science with an ultraviolet sounding rocket experiment to observe the Comet Kohoutek in 1974, and made an inventory of the hydrogen, oxygen, and carbon abundances in the comet's coma. For the rest of his career, he was what Weaver describes as a "planetary archaeologist," investigating the origin and evolution of our solar system.

In 1976, during a sounding rocket experiment to observe Comet West, Feldman made the first detection of the carbon monoxide molecule in a comet, recording what is still one of the finest examples of a cometary ultraviolet spectrum ever obtained, Weaver said. The amount of CO in cometary nuclei is key to understanding their formation, conditions, and evolutionary history. Since then, Feldman remained at the forefront of attempts to study cometary CO, using sounding rockets, the International Ultraviolet Explorer satellite observatory, the Hubble Space Telescope, FUSE, and the Rosetta spacecraft.

As a child, Feldman—a native of Brooklyn—made hand-drawn sky maps and was a member of the junior astronomy club at the Hayden Planetarium in New York. He graduated from Brooklyn Technical High School, and earned a bachelor's degree and PhD (1964), both in physics, from Columbia University. He served as instructor at Columbia (1964-1965) and as an E. O. Hulburt Fellow at the Naval Research Laboratory (1965-1967), and arrived at Hopkins in 1967, where he chaired the department from 1996 to 2002. He retired in 2010.

Feldman was an Alfred P. Sloan Foundation fellow (1969-1974) and a Fellow of the American Physical Society, and was a member of the American Astronomical Society, American Geophysical Union, and International Astronomical Union. He served as associate editor of Journal of Geophysical Research: Space Physics, and was a member of the editorial board of Icarus and of the Committee on Planetary and Lunar Exploration of the National Academy of Sciences' Space Science Board from 1985 to 1988.

Feldman's family has established The Paul D. Feldman Fellowship in Far Ultraviolet Spectroscopy from Space. Gifts in his memory can be made to the fellowship fund at https://secure.jhu.edu/form/krieger.

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The First Images From the James Webb Space Telescope

The audience gathered to witness the unveiling of the first images from the James Webb Space Telescope (JWST) overflowed from Schafler Auditorium last July. The capacity crowd pictured below is viewing an extremely detailed image of the Southern Ring Nebula for the first time captured by JWST's near-infrared camera. Currently, over 50 Hopkins researchers are involved with JWST through Hopkins-led research. Read more about the historic JWST science launch in the cover story on page 6: "Far & Away: Members of the Johns Hopkins community respond to seeing the first images from the James Webb Space Telescope."