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BROWN PHYSICS

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FALL 2024

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BROWN
Department of Physics

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MAKE A GIFT TO PHYSICS

Front cover:
Partial Phase and Diamond Ring Appearing
PHOTO BY ROBERT HORTON

Back cover:
"Eclipse Time Lapse," Providence, RI
PHOTO: ANTHONY ENGLERT

MESSAGE FROM THE CHAIR

It is with great sadness that we share the news of the passing of our great colleague, Professor Leon Cooper, who passed away on Wednesday, October 23, at the age of 94.

Leon made the groundbreaking discovery that electrons in metals can form bound pairs (Cooper pairs), making superconductivity possible. Their Bardeen-Cooper-Schrieffer theory of superconductivity is the most successful theory of many-body systems, influencing the development of other groundbreaking theories in physics. Bardeen, Cooper and Schrieffer won the Nobel Prize in Physics in 1972.

Leon joined the Brown faculty in 1958. He and his students made pioneering contributions to neuroscience; his original contribution to synaptic plasticity is the basis of neural memory and the Hopfield neural network model. Dr. John J. Hopfield, awarded the Nobel Prize this year, cited Leon's work on how neurons store information and communicate.

Leon significantly impacted the broader field of physics, and his vision helped Brown Physics maintain the strong group in theoretical physics that it enjoys today. He inspired many of his colleagues and graduate students to tempt the impossible by first well-defining the problem and then outlining how the problem could be solved.

Leon's influence on the legions of students he advised resounds throughout the field. Although he became emeritus faculty in 2020, Leon's presence in the department drew many students to the program. Austin Szuminsky M.S. '24 said Cooper may have initially brought him to the department as he was "inspired by physicists who moved into and around more biological questions or neuroscience at some point in their career by the perhaps less-conventional notion that it is possible to be more than one thing." An engaging speaker, his PHYS0100, "Flat Earth to Quantum Uncertainty: On the Nature and Meaning of Scientific Explanation," was extremely popular. A limited enrollment was ultimately imposed on the course due to the overwhelming response.

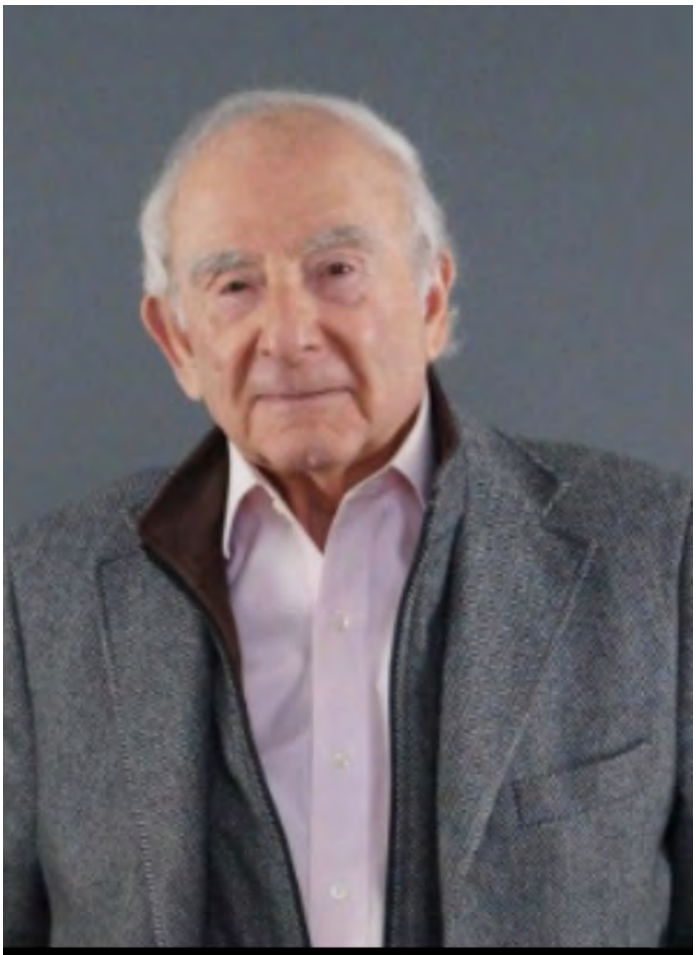
Leon is fondly remembered by both longtime and new colleagues at Brown Physics. Students, staff, and faculty colleagues greatly appreciated his sense of humor, good taste for Scotch whisky and kindness to everyone.

While we mourn the loss of our colleague Leon Cooper, there is much joy in our reflections on this past year of dynamic research from Brown Physics. Our faculty continue to publish in high-impact journals, as you will read about on page 10, and, most notably, continue to receive the highest recognition in physics for their scientific contributions to the field. For example, Dima Feldman was elected a fellow of the American Physical Society. We look to the future with great anticipation of the promise of our new researchers, about whom you will read on page 22, whose teaching enriches and strengthens an already strong and thriving curriculum.

Among the many stories showcasing our students' breadth of expertise and knowledge is the ingenious work of our undergraduate concentrators, whose incredible eclipse installation in the lobby of Barus and Holley is shown on page 35. On page 54, you will read about the remarkable second consecutive award of a Chateaubriand Fellowship to a Brown student, Ilija Nikolov, who was recognized for his outstanding research. On page 46, you will read about Ilija's fascinating journey from physics to finance. Our program trains our students to excel in research and provides unparalleled preparation for the highest levels of the job market.

Vesna Mitrović
Department Chair

Passages: Nobel Prize winner and Brown professor of physics Leon N. Cooper



Leon N. Cooper
Photo: Jessica Pontarelli/Brown University

By Juan Siliezar
Additional reporting by Corrie Pikul

Nobel Prize winner Leon N. Cooper, a professor of physics at Brown University for more than five decades, died on Wednesday, Oct. 23, at age 94.

Cooper's daughter, Coralie Cooper, confirmed his death to the New York Times.

Cooper served as a professor at Brown since 1958 and retired from teaching in 2014. He shared the 1972 Nobel Prize in Physics with physicists John Bardeen and J. Robert Schrieffer for developing a theory explaining how certain materials can conduct electricity without resistance — a phenomenon called superconductivity. The theory, called the Bardeen-Cooper-Schrieffer (BCS) theory, transformed condensed matter physics, paving the way for advancements in understanding quantum phenomena, developing new materials and inspiring further research into exotic states of matter.

In 2013, during Brown's 245th Commencement, Cooper received the Susan Culver Rosenberger Medal, the highest honor the Brown University faculty can bestow.

"Leon Cooper is a giant in the world of physics, yet he wears his mantle of accomplishments lightly," James Valles, a professor of physics, said at the time. "It is extraordinary how engaged in Brown and accessible Leon has remained since winning the Nobel Prize in 1972. He has served as an effective mentor and adviser to countless students and junior faculty over the years. He has burnished our reputation by his scientific prowess and through the many students he has reached over his 55-year career at Brown."

Born in 1930, Cooper grew up in New York City where he attended the Bronx High School of Science before earning a bachelor's degree (1951) and a Ph.D. in physics (1954) from Columbia University. Before joining the Brown University faculty in 1958, Cooper conducted research at the Institute for Advanced Study in Princeton, New Jersey, and taught at the University of Illinois and the Ohio State University.

Cooper's work on BCS Theory began in the mid-1950s, when he was still in his 20s. He teamed up with Bardeen and Schrieffer, and the trio set out to tackle the problem of superconductivity, a phenomenon discovered in 1911 but poorly understood during subsequent decades. Cooper and his colleagues succeeded in solving the mysteries of superconductivity where many of the greatest minds in physics — including Albert Einstein, Werner

Leon Cooper (right), who won the Nobel Prize in Physics in 1972, joined leaders from the University and its Department of Physics in 2016, when fellow Brown Professor of Physics Michael Kosterlitz was awarded the same honor. Photo by Nick Dentamaro/Brown University.

Heisenberg and Niels Bohr — had been unsuccessful.

The group's study, titled the "Theory of Superconductivity," was published in the Physical Review in 1957. A key discovery from Cooper was that, under specific conditions, electrons in a metal could form pairs despite their natural repulsion. This pairing occurs because the motion of one electron subtly affects the environment in the metal, attracting a second electron, and then multiple pairs would form. As a result, these groups of paired electrons move smoothly through the material without causing resistance or heat, allowing superconductors to conduct electricity freely. These pairs would later be named Cooper pairs.

"That was a brand new idea, because people previously thought the electrons were acting alone and independently," Valles said.

The BCS Theory was published one year before Cooper came to Brown, where he was ultimately appointed Henry Ledyard Goddard University Professor in 1966 and Thomas J. Watson Sr. Professor of Science in 1974. At Brown, Cooper continued to research and publish studies about superconductivity, but soon felt drawn to investigate new questions. He turned his attention to another difficult problem: understanding how learning and memory take place in the brain.

With the help of several colleagues, Cooper began investigating ways to model the mechanisms of the brain's visual cortex. The model was based on the idea that synapses, which carry chemical signals between neurons, were crucial in memory. Along with Brown Ph.D. students Paul Munro and Elie Bienenstock, Cooper published a theory in 1982 that was one of the first mathematical models showing how synaptic modification could lead to some forms of learning and memory. The theory was named BCM Theory after Bienenstock, Cooper and Munro.

The BCM Theory and Cooper's other endeavors in brain research helped lay some of the groundwork for many of Brown's programs in neuroscience. For example, the University's Center for Neural Science, which was established in 1973 with Cooper as founding director, helped build an early foundation for what is now the Carney

Institute for Brain Science.

Peter Bilderback, who worked closely with Cooper for more than 20 years in Brown's Department of Physics, said an inexhaustible sense of curiosity was one of Cooper's hallmarks.

"Leon's intellectual curiosity knew no boundaries," Bilderback said. "He was comfortable conversing on any subject, including art, which he loved greatly. Where others might see art and science as diametrically opposed, Leon saw deep commonalities between the two. He recognized both as inherently creative enterprises. He often compared the construction of physics to the building of a great cathedral, both beautiful human achievements accomplished by many hands over many years and perhaps never to be fully finished."

Throughout his career, Cooper was regarded as a dedicated educator with a passion for teaching and mentoring students. Valles, whose office at Brown was located two doors down from Cooper's, said that he never got over feeling starstruck by his Nobel-winning colleague, and remembers him as an educator who found creative ways to inspire students and was ceaselessly open to new ideas.

Cooper taught an introductory physics course, and for many years, Valles recalled, he structured the class around the award-winning stage play "Copenhagen" by Michael Frayn, which centers around the 1941 visit of German nuclear physicist Werner Heisenberg to his former colleague, Niels Bohr. The class was team-taught with two other Brown professors: Cooper explained the physics, historian Abbott Gleason put the information in context, and Oskar Eustis, a professor of theatre, speech and dance, advised on the reading of the play.

"Leon was just this beautiful, intellectual, positive force," Valles said.

Bienenstock, the BCM Theory collaborator and Brown Ph.D. graduate, first met Cooper in 1977 at the Collège de France in Paris, where Cooper was an invited lecturer. He said the esteemed scientist's interests not only crossed academic borders, but also international borders."Beyond his varied scientific interests, he was passionate about art and culture," said Bienenstock, now an associate professor of applied mathematics and of neuroscience at Brown. "He spoke French well and was well-read in both English and French. He positively loved French culture and French life."

Bienenstock noted that Cooper worked intentionally to support all of his graduate students, who came from diverse countries and "sometimes had a bit of a hard time getting used to life on an American campus."
Cooper's retirement from teaching — but not from conducting research — at Brown in 2014 inspired stacks of letters from former students, including one from Stephen Fried, a member of the Class of 1964.

"I took Leon Cooper's brilliant course on quantum mechanics, a subject that had always fascinated me," Fried wrote in a letter to the Brown Alumni Magazine. "I aced both semesters and then went to work on atomic and laser physics. Cooper taught the course right out of Dirac! Every day he would enter the room and write the Schrödinger equation on the upper left-hand side of the blackboard, and we would then analyze the Hamiltonian for a particular system... One of the projects I worked on, the basic research in HF vibrational energy transfer, eventually made the Star Wars laser possible, something that helped end the Cold War. Thanks for the vote of confidence, Professor Cooper. Your course was an example of how physics ought to be taught!"

Along with the Nobel, Cooper won a number of awards and recognitions for his work, including the Comstock Prize from the National Academy of Sci-

ences and the Descartes Medal from the Academie de Paris. He was named a fellow or member of many prestigious organizations, including the John Simon Guggenheim Memorial Foundation, the National Academy of Sciences, and the American Academy of Arts and Sciences.

The New York Times noted that it has frequently been reported that the character Sheldon Cooper, a math and science genius and protagonist in the television sitcom "The Big Bang Theory," is named in part after Cooper.

Despite all the accolades, Cooper remained a steadfast learner throughout his career at Brown and always took on new challenges.

"That's one of the things that has always made me very happy at Brown," Cooper said in a 2013 interview. "I can do what I want to, and for me that's everything... People ask me: What did you do after your Nobel Prize? Did you go to work every day trying to win another one? Absolutely not. You just go to work."

Cooper is survived by his wife, Kay; his daughters from his first marriage, Coralie and Kathleen; and four grandchildren, according to the New York Times.

Leon Cooper (L) and Xinsheng Sean Ling
Photo Courtesy Xinsheng Sean Ling

A Remembrance

By Valerie DeLaCámara

In March 2016, Professor Xinsheng Sean Ling grabbed a passing undergraduate from the hallway to take a quick photo of him with his colleague, Leon Cooper. Although he retired from the department several years earlier, Leon still came in to the office regularly. Prof. Ling recalls that Leon took great pride in his textbook for undergraduate students, "An Introduction to the Meaning and Structure of Physics," first published in 1968 and translated into many languages. "When I was taking a leave in the spring and summer of 2015 in China," Ling said, "I found a copy

Leon Cooper's "An Introduction to the Meaning and Structure of Physics"

of Leon's book in the old book market in Nanjing that had been translated into Chinese. Of course, I immediately bought it. When I brought the book back to Providence in the spring semester of 2016, I showed Leon his book in Chinese; he was delighted. He mentioned that his grandson was learning Chinese and asked if I would be willing to give him the book. I was very pleased to do so. So, we posed for a photo to mark this happy occasion. I miss Leon greatly!"

FACULTY RESEARCH

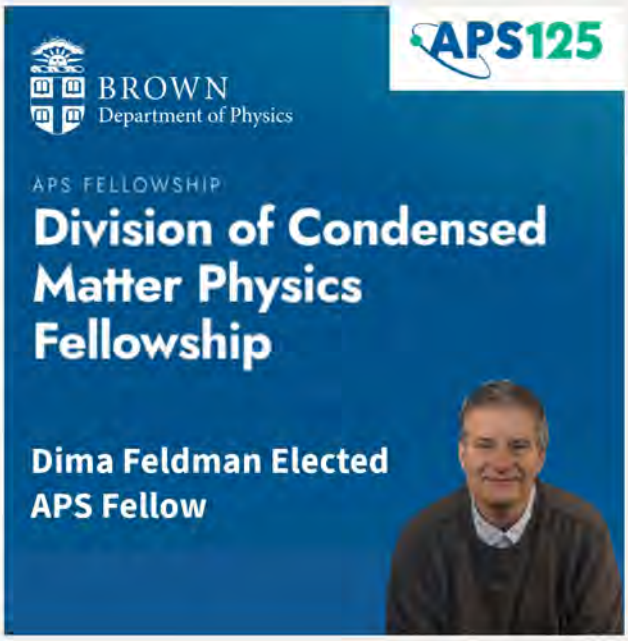
BROWN PHYSICS MAKING AN IMPACT

DIMA FELDMAN ELECTED TO APS

Professor Dmitri Feldman was elected a Fellow of the American Physical Society (APS) in the Division of Condensed Matter Physics for 2024.

The APS award citation notes Feldman was recognized for "significant advances in our understanding of diverse quantum systems, including disordered magnets, superconductors, and fractional quantum Hall systems."

Professor Feldman joins the "one-half of one percent of the Society's membership (excluding student members) recognized by their peers for election to the status of Fellow of the American Physical Society."



ADVANCING THE QUEST FOR DARK MATTER: NEW INSIGHTS FROM THE LUX-ZEPLIN EXPERIMENT

Faculty and student researchers from Brown contributed key expertise on the LZ team's latest findings, refining the search for dark matter particles and pushing the boundaries of detection technology.

Ph.D. students Austin Vaitkus and Jeanne Bang talked about their experiences at the LZ Dark Matter Experiment Collaboration Meeting. Austin: Jeanne:


Richard Gaitskell

MATTHIAS KUEHNE, GAETANO BARONE RECEIVE 2024 SEED AWARDS

Research Seed Funding awards are competitively awarded and help faculty more successfully advance competitive research proposals by supporting the generation of preliminary data, pursuing new directions or collaborations in research, and other endeavors. Investigators may propose projects in one of two categories. Category 1 - single PI projects of any type with budgets up to $50,000 for one year; Category 2 - multi-PI projects supporting a new collaboration between two or more disciplines with budgets up to $100,000 for one year.


Matthias Kuehne


Gaetano Barone

XIAO, ZASLAVSKY AWARDED $3.4M IN ARMY RESEARCH FUNDS FOR CRYOGENIC MAGNETIC CAMERA

Brown University Professor of Engineering and Physics Alex Zaslavsky and Physics Professor Gang Xiao, together with Distinguished Senior Engineer Bill Patterson and colleagues at Tufts and CoolCAD Electronics, have been awarded funds from the Army Research Office toward the development of a novel cryogenic camera, an indispensable asset for characterizing superconducting films and circuits.

The grant titled, "Cryogenic magnetic camera that captures real-time trapped flux vortex dynamics in superconducting electronics," is worth more than $3.4 million over four years.

STEPHON ALEXANDER RECEIVES THE PRESIDENT'S VOLUNTEER SERVICE AWARD AND THE 2024 FRANTZ FANON AWARD FOR OUTSTANDING ACHIEVEMENTS IN SCIENCE

Stephon Alexander received the President's Volunteer Service Award (PVSA) for his many hours of civic participation. The PVSA honors individuals whose service positively impacts communities in every corner of the nation and inspires those around them to take action, too.

The Caribbean Philosophical Association's 2024 Frantz Fanon Award for Outstanding Achievements in Science, Philosophy and Leadership is awarded to Stephon Alexander. Dr. Jacqueline Martinez, President of the Caribbean Philosophical Association, adds:

Stephon Alexander's work shows us how deeply relevant our human artistic endeavors, especially jazz, are to the very energies through which life and matter emerge and evolve at the sub-atomic level. His work reminds us that a concern with the interrelatedness of all life in the universe always marks our highest scientific achievements.

THE CORPORATION OF BROWN UNIVERSITY APPOINTS PHYSICS FACULTY TO NAMED CHAIRS

The Corporation of Brown University's recognition of academic excellence included two physics faculty appointed to named chairs. James Valles was named Royce Family Professor of Teaching Excellence in Physics, and Kemp Plumb was named Christopher M. Barter Assistant Professor of Physics.

In 2023, the Corporation approved the establishment of the Christopher M. Barter '90 Assistant Professorship with the generous support of Christopher M. Barter '90.

Vesna Mitrović

NEWS: FACULTY RESEARCH

RESEARCHERS FIND UNEXPECTED ROADBLOCK TO CONDUCTIVITY IN MOTT INSULATORS

By Juan Siliezar

In the realm of condensed matter physics, few phenomena captivate physicists' curiosity as much as Mott insulators.

According to traditional theory, this odd class of materials should be capable of conducting electricity, yet they behave mostly as insulators. What's even more bizarre is that when electrons are added, the material can actually become a superconductor, conducting an electric current with zero resistance. However, it can also stay an insulator no matter how many electrons are added. The extreme opposite reactions have puzzled scientists for decades, but some of those mysteries may be coming to an end.

"This new understanding could save researchers a lot of time, investment and effort from trying different methods," Mitrović said.

Scientists from Brown University working with an international team of researchers have developed a novel theory, which they verified through a series of laboratory experiments, to fundamentally explain for the first time why one type of Mott insulator stubbornly resists conducting electricity even when electrons are added.It's the first time that we as physicists understand microscopically why the specific type of Mott insulator that we looked at has never been turned into a conductor," said Brown physics department chair and professor Vesna Mitrović, who leads a condensed matter magnetic resonance group at the University and is co-author on the new study. "The work provides a really fundamental picture into why it may never work as a conductor. The main takeaway is the material is useful for other electronic applications, but not for turning into a conductor."

The work is described in Nature Communications and was done in collaboration with researchers from the University of Bologna, University of Vienna, University of Parma, Institute Polytechnique de Paris, Collège de France and the Ohio State University. The work started as an unrelated condensed matter physics experiment between researchers from Brown and the University of Bologna.

The study focused on a type of Mott insulator called $Ba_2Na_1–OsO_6$. The material is what is known as a relativistic Mott insulator because it exhibits strong spin-orbit coupling, a state in which electrons both interact strongly with each other and their spin is greatly entangled with the way they move in their individual orbits. Essentially, this makes the material deviate from more common physics predictions, which may create some special electronic behavior. Because of this, the material, and more generally entire class of relativistic Mott insulators, has garnered considerable attention and investment by the scientific community to understand and control its properties.

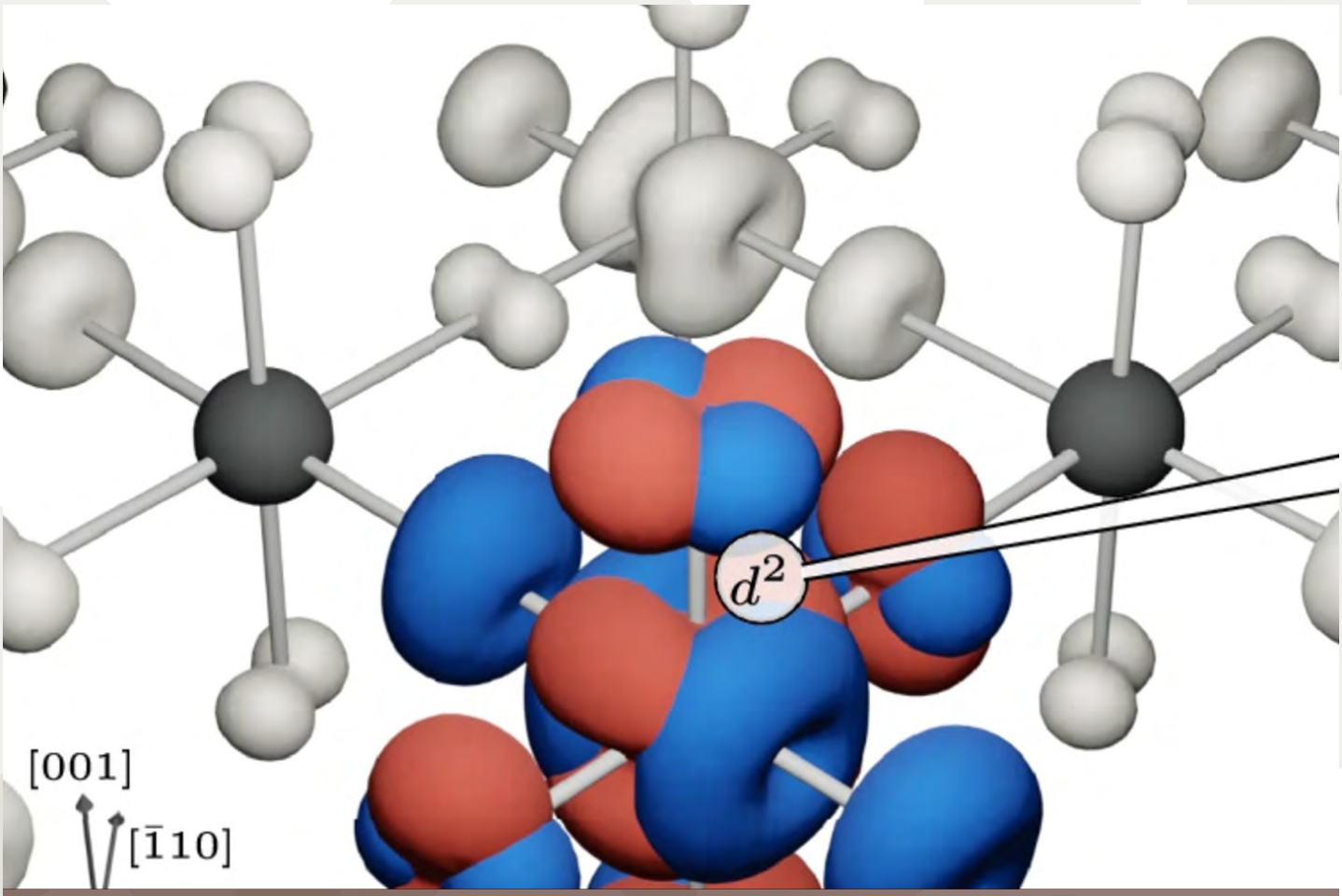
Scientists think the material, like others in its class, can be moved in and out of the Mott insulating state by adding charge with electrons. The new study explains how previously unseen particles in this Mott insulator interact at the quantum level to stop it from turning into a conductor even when many extra electrons are added.

"This new understanding could save researchers a lot of time, investment and effort from trying different methods," Mitrović said.

The researchers found the key is an unexpected collection of particles called bipolarons that form when electronic charge is added to the material. Usually, the electrons spread out evenly in a metal, but here some of the charged electrons get stuck in certain spots of the material when added. These trapped electrons are what comes together with the material's lattice structure to become bipolarons. The bipolarons then act like roadblocks for the electrons, making it hard for them to move around and conduct electricity. Even when trying to overcome this roadblock by adding even more electrons, the bipolarons make sure the electrons keep getting stuck and are unable to move freely. Ultimately, this is what keeps the material an insulator.

This unexpected behavior puzzled

The new understanding from a research team at Brown fundamentally explains for the first time why one type of Mott insulator, which has puzzled scientists for decades, has resisted conducting electricity.



The researchers found the key to their theory is an unexpected collection of particles called bipolarons that form when electronic charge is added to the material. Photo provided by Mitrović Lab.

the scientists because it goes against usual understanding of how materials respond to changes in their electronic structure. It's why results from the study took the researchers by surprise and the calculations for the theory took four years to put together, given that the interactions hadn't been studied before.

"According to our understanding of current physics, this shouldn't happen," Mitrović said.

The researchers now hope to put their new theory and experimentation techniques to the test and see how widespread bipolarons are in relativistic Mott insulators.

"It will be interesting to see if there are any circumstances that you can turn a relativistic Mott insulator into conductor or is this truly universal," Mitrović said.

Along with Mitrović, other Brown authors included graduate students Erick Garcia and Rong Cong. The bipolarons were discovered by Cesare Franchini and Lorenzo Celiberti from University of Vienna and Bologna, while looking at unexpected experimental results from the Mitrović lab at Brown and researchers Samuele Sanna from the University of Bologna and Giuseppe Allodi from University of Parma.

The work at Brown was supported by the National Science Foundation.

FACULTY RESEARCH

Kemp Plumb

RESEARCHERS DETAIL HOW DISORDER ALTERS QUANTUM SPIN LIQUIDS, FORMING A NEW PHASE OF MATTER

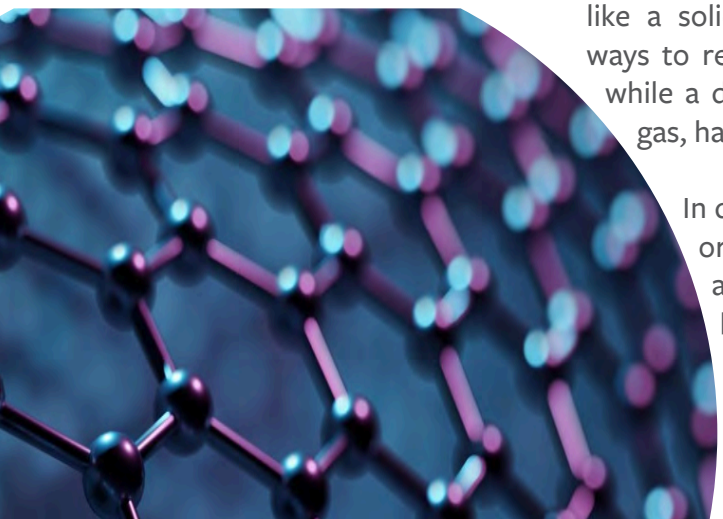
By Juan Siliezar

A study led by Brown scientists begins to address a longstanding question in condensed matter physics on whether disorder mimics or destroys the quantum state in a prominent compound.

Quantum spin liquids are difficult to explain and even harder to understand.

To start, they have nothing to do with everyday liquids, like water or juice, but everything to do with special magnets and how they spin. In regular magnets, when the temperature drops, the spin of the electrons essentially freezes and forms a solid piece of matter. In quantum spin liquids, however, the spin of electrons doesn't freeze — instead the electrons stay in a constant state of flux, as they would in a free-flowing liquid.

Quantum spin liquids are one of the most entangled quantum states conceived to date, and their properties are key in applications that scientists say could catapult quantum technologies. Despite a 50-year search for them and multiple theories pointing to their existence, no one has ever seen definitive evidence of this state of matter. In fact, researchers may never see that evidence because of the difficulty of directly measuring quantum entanglement, a phenomenon Albert Einstein famously termed "spooky action at a distance." This is where two atoms become linked and able to exchange information no matter how far apart they are.



The mystery around quantum spin liquids has led to major questions about this exotic material in condensed matter physics that have to this point gone unanswered. But in a new paper in Nature Communications, a team of Brown University-led physicists begins to shed light on one of the most important questions, and does so by introducing a new phase of matter.

It all comes down to disorder.

Kemp Plumb, an assistant professor of physics at Brown and senior author of the new study, explains that "all materials on some level have disorder" and that disorder has to do with the number of microscopic ways components of a system can be arranged. An ordered system, like a solid crystal, has very few ways to rearrange it, for instance, while a disordered system, like a gas, has no real structure to it.

In quantum spin liquids, disorder introduces discrepancies that essentially butt heads with the theory behind the liquids. One prevailing explanation was that when disorder is introduced, the material ceases to be a quantum spin liquid and instead is simply a magnet that's in a state of disorder. "So, the big question was whether the quantum spin liquid state survives in the presence of disorder and if it does survive, how?" Plumb said.

The researchers addressed the question by using some of the brightest X-rays in the world to analyze magnetic waves in the compound they studied for tell-tale signatures that it's a quantum spin liquid. The measurements showed that not only does the material not magnetically order (or freeze) at low temperatures, but that the disorder that's present in the system doesn't mimic or destroy the quantum liquid state.

It does significantly alter it, they found.

"The quantum liquid state sort of survives," Plumb said. "It doesn't do what you would expect a normal magnet to do where it just freezes. It stays in this dynamic state, but it's like a de-correlated version of that dynamic state. Our interpretation

right now is the quantum spin liquid is broken up into little puddles throughout the material."

The findings essentially suggest that the material they looked at, which is one of the prime candidates to be a quantum spin liquid, does appear to be close to one, yet with an additional component. The researchers posit that it's a quantum spin liquid that is disordered, making it a new phase of disordered matter.

"One thing that could have happened in this material was that it becomes a disordered version of a non-quantum spin liquid state, but our measurements would have would have told us that," Plumb said. "Instead, our measurements show that it's something very different."

The results deepen understanding of how disorder affects quantum systems and how to account for it, which is important as these materials are explored for use in quantum computing.

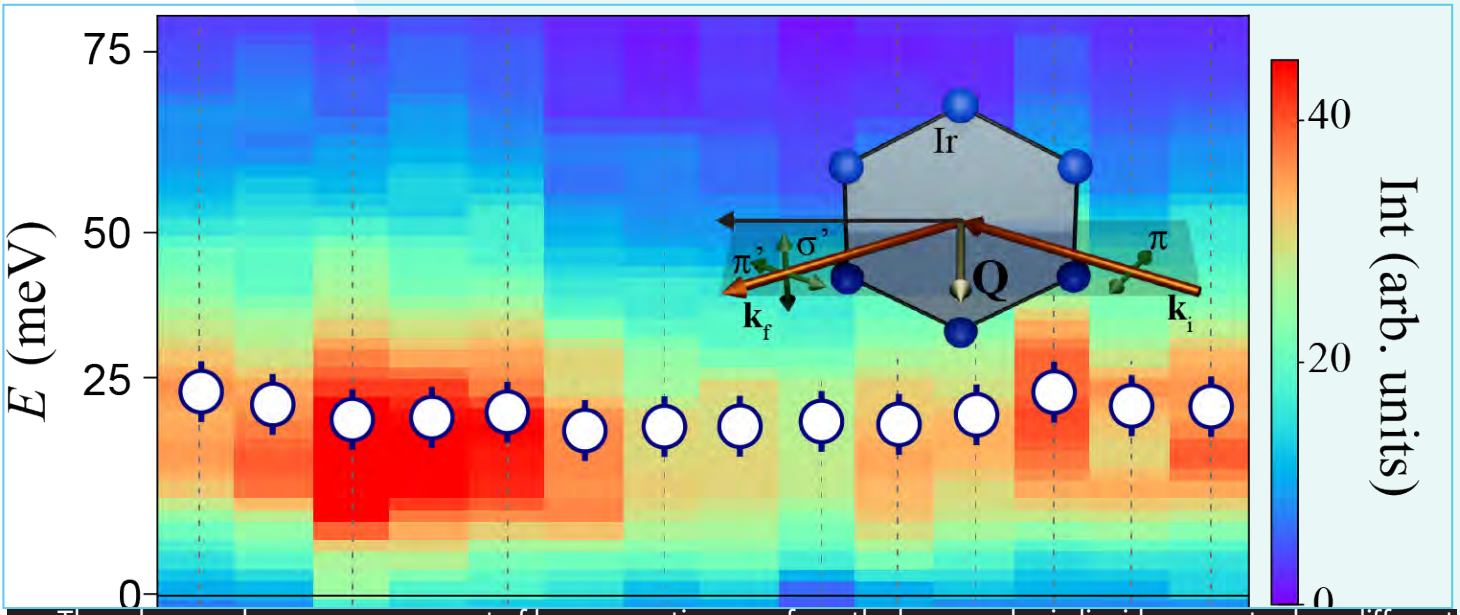
The work is a part of a long line of research on exotic magnetic states from Plumb's lab at Brown. The study focuses on the compound H3LiIr2O6, a material considered to best fit the archetype for being a special type of quantum spin liquid called a Kitaev spin liquid. Though known not to freeze at cold temperatures, H3LiIr2O6 is notoriously difficult to produce in a lab and is known to have disorder in it, muddying whether it was truly a spin liquid.

The researchers from Brown worked with collaborators at Boston College to synthesize the material and then used the powerful X-ray system at the Argonne National Laboratory in Illinois to zap it with high-energy light. The light excites the magnetic properties in the compound, and the measurements that come from the waves it produces are a workaround for measuring entanglement, because the method offers a way of looking at how light influences the entire system.

The researchers hope next to continue to expand on the work by refining methods, the material itself and looking at different materials.

"The biggest thing going forward is something that we've been doing, which is continuing to search the really vast space of materials that the periodic table gives us," Plumb said. "Now we have a deeper understanding of how the different combinations of elements that we put together can affect the interactions or give rise to different kinds of disorder that will affect the spin liquid. We have more guidance, which is really important because it truly is a really vast search space."

Other authors from Brown include Alberto de la Torre Duran, a former postdoctoral fellow in the Plumb lab, and Ben Zager, a current graduate student. This work was supported by the U.S. Department of Energy, which operates the Argonne National Laboratory.



The colormap shows a measurement of how magnetic waves from the hexagonal spin liquid propagate along different directions, with the bright red colors showing a high signal. Image courtesy of the Plumb Lab.

Eight years later, Brown's Michael Kosterlitz reflects on his Nobel win and ponders what comes next

By Juan Siliezar

Editor's note: The story from the original publication has been updated to reflect that Prof. Kosterlitz won the Nobel Prize eight years ago.

The date was Oct. 4, 2016, and it felt like any other Tuesday morning in Finland. On a semester-long sabbatical from his professor of physics role at Brown University, Michael Kosterlitz was walking through a rather loud underground parking lot when he felt his phone buzz in his pocket.

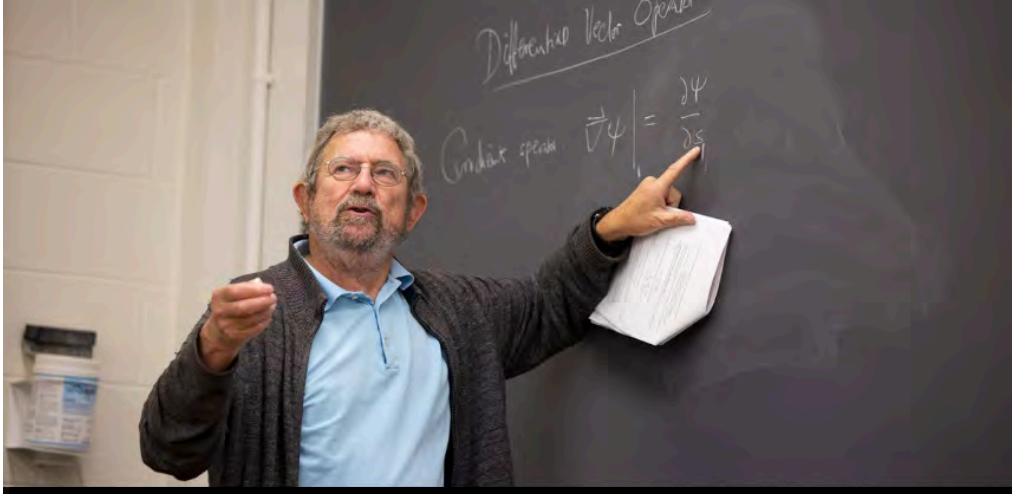
The call was from an unknown number, and the voice on the other line spoke with a thick Swedish accent. What that voice told him left him quite speechless: Kosterlitz, along with David Thouless and Duncan Haldane, had just been awarded the Nobel Prize in Physics for explaining topological phase transitions in exotic states of matter.

"I could barely take it in," said Kosterlitz, who said the work in the 1970s that led to the prize was his first foray into condensed matter physics. "My mind went completely blank for about 30 seconds. The only thing I know I said when I finally could talk was, 'Jesus!'"

Eight years later — with the Nobel Prizes for 2023 set to be announced from Oct. 2-9 — Kosterlitz is more gracious and composed in talking about the honor and what it meant to him. At the time, however, the theorist known for his low-key and humble demeanor remembers wanting to get back to normal as soon as possible after the litany of press conferences, interviews, public lectures, seminars and other appearances mounted.

> "In physics, there's always new or unsolved problems. No matter how much you know, there's always something fascinating that you won't understand. You never get bored. There's always something to sit and think about."
>
> **MICHAEL KOSTERLITZ** — Professor of physics and 2016 Nobel Laureate

"Life is much quieter now," Kosterlitz said. "The experience was all tremendous, but a lot of it just wasn't me so I was actually quite relieved when it was all over. For a couple years,



PHYS 2020: Mathematical Methods of Engineers and Physicists marks one of the final courses Nobel Laureate Michael Kosterlitz will teach at Brown. Photo by Nick Dentamaro/Brown University.

there was this frenzied round of giving talks. I started traveling from pillar to post. Those years passed in a haze for me, and now I just can't remember the places that I went to. One day I'd be giving a seminar in Paris and three days later, I'd be in the U.S. and then in Italy. I was all over the place. I was very much in-demand."

Kosterlitz looks back at it all happily now, especially when considering the perks. He recalls the boisterous Nobel festivities in Sweden where he was feted by the Swedish Embassy and awarded by the King of Sweden. In Washington, he met one of his idols: U.S. President Barack Obama. There were even unexpected honors that happened as an indirect result of the Nobel. One that holds a special place in his heart is being named the 2017 Climbing Ambassador at the so-called "climbing Oscars." The award recognized his other life: mountain climbing.

"I got into it when I was in my teens," Kosterlitz said. "I used to quite like walking in mountains and discovered that there were a few which needed some skills beyond scrambling up and down steepish slopes, so I started to experiment with rock climbing and learned how to use a rope... I became quite strong and fit and able to do many of the hardest climbs in the world at the time. Eventually, I had to make a choice between becoming a professional climber or a professional physicist, and I chose the latter because it earned money and would last much longer."

Another unexpected perk Kosterlitz discovered as a result of the win was a talent he never knew he would need: the ability to dole out words of wisdom. He found it became of great use as a Nobel Laureate, and still does.

"You are asked to pontificate on all sorts of topics," Kosterlitz said. Where is the field of physics going? What advice does he have for those starting out into the field? He's even asked to comment on broader subjects outside of physics, like the global education of children. "You're suddenly expected to become an authority on things you've never even really considered."

With all that in mind, Kosterlitz — who was born in Aberdeen, Scotland, in 1943 and earned his Ph.D. from Oxford University in 1969 — was thankful when things settled down and he gained the freedom to do what he does best: ponder some of biggest problems in physics and try to develop theories to solve them.

"In physics, there's always new or unsolved problems," Kosterlitz said. "No matter how much you know, there's always something fascinating that you won't understand. You never get bored. There's always something to sit and think about."

And Kosterlitz has made a career of exactly that. In fact, it was that open mindset that led to the Nobel in the first place. That and a willingness to "risk complete failure and looking like a fool," he said.

Pondering unsolved questions

After growing frustrated with experimental physics in the early 1970s while at Birmingham University, Kosterlitz began scouring for something theoretical to sit and think about. He ended up connecting with Thouless, who suggested that he look at the problem of phase transitions in two-dimensional systems.

"He also mumbled some things about topology and vortex excitations, which I half understood at the time," said Kosterlitz. But he didn't let that deter him, and he spent the next six months taking a crack at the problem.

Brown physicist Michael Kosterlitz accepts his Nobel diploma and g from The King of Sweden. Credit: Pi Frisk/ ©Nobel Media AB.

The work led to a publication in 1973 where the pair drew on a branch of mathematics called topology to provide a theoretical understanding of phase changes in ultra-thin, two-dimensional systems. Kosterlitz and Thouless's theory of phase transitions became known as the K-T transition and since then has informed the development of materials that could be helpful in making next-generation electronic devices and quantum computers.

gold medal

Today, Kosterlitz is taking a similar risk in his research and is attempting to tackle another of the biggest unsolved problems in the field: the dynamics of nonequilibrium physics. These are physical systems that have emerged from thermodynamically stable states and are constantly heading towards some state of rest. The mystery lies in the mechanics of how they get to this state of rest and how random fluctuations, or noise, affects that process. Ultimately, the highly theoretical work looks to predict where and how this all happens.

"It's a huge unsolved problem," Kosterlitz said. "If you think about the real world and regard it as a big mechanical system, it's certainly not in equilibrium — it's disordered and always evolving," Kosterlitz said. "Almost all real-world systems are affected by some sort of noise... but that noise is important. We found, to my surprise, that there are potentially infinite bands of possible stationary states and that if you apply external noise, a unique stationary state is picked out." Kosterlitz and collaborators from China have published two studies on the subject in the Proceedings of the National Academy of Sciences, so far, detailing the how these systems transition to unique stationary states through a series of nonlinear steps. The theory sounds promising, but being able to generalize it to realistic situations has some serious technical difficulties and may never be solved.

"Understanding out-of-equilibrium statistical mechanics is a problem that's been around for longer than I have," Kosterlitz said. "It's the sort of thing that if you just start doing it out of interest, you probably won't get anywhere, so not many people are looking at this."

Outside of this current research, Kosterlitz also takes the time to teach a graduate physics course on mathematics. It marks one of the last courses he will teach at Brown as he thinks about what comes next. Last year, Kosterlitz, who joined the Brown faculty in 1982, made plans to fully retire in 2025. And while he looks forward to it, he's mindful of everything physics has brought him in life.

"It's a subject which has always suited me," Kosterlitz said.

THE PUERTO RICO BROWN EXPLORATION (PROBE) PROGRAM: AMPLIFYING COMMUNITY, OVERCOMING ISOLATION

By Valerie DeLaCámara

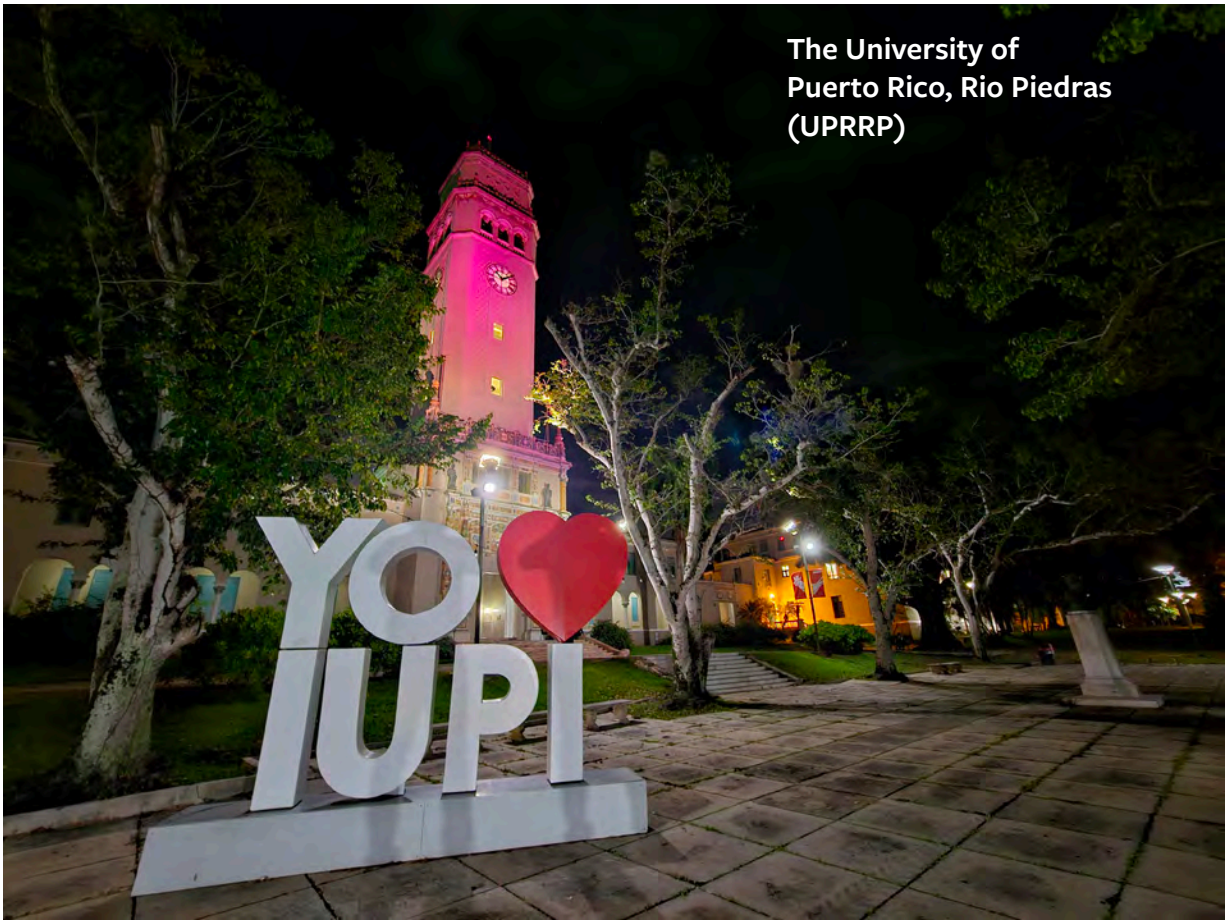
The Puerto Rico Brown Exploration: (PROBE) Computational Physics Initiative at the University of Puerto Rico, Rio Piedras' (UPRRP) UPRRP/Brown Program was made possible by the Simons Foundation, which, given the outcomes, proved to be a prescient investor in the intellectual capital of students of color in physics. The Program consisted of a January 2024 Winter School in Puerto Rico at UPRRP with visiting Brown faculty and a Summer School based at Brown with UPRRP faculty in Providence.

UPRRP student Abnelis Guzmán Román describes the Program's impact as "crucial in reinforcing my academic trajectory and my goal of becoming an astrophysicist." The future implications of retaining students of color in physics cannot be overstated. With this Program, the Simons Foundation paved the way for Brown to grow communities of color in physics; continuing the Program will ensure that the field of physics retains these students. Critical to this endeavor is creating a Caribbean cohort of physics students and researchers. This community supports physics research and provides mentorship and resources for students to continue in physics. Creating this cohort is an effort in which Brown hopes to be the synergistic glue with the continued support of the Simons Foundation.

A happy byproduct of the PROBE Program is that the Simons Foundation also invested in the intellectual capital of faculty of color, invigorating their programs with fresh perspectives and amplifying their capabilities. The Simons Foundation PROBE Program was conceived by Brown's Professor Stephon Alexander '00 PhD and UPRRP's Professor Carlos Vicente '96 ScM, '02 PhD. It was largely successful due to Prof. Vicente's outstanding leadership and mentorship, highlighting the exceptional talent level in Puerto Rico's academia.

When the University of Puerto Rico, Rio Piedras' (UPRRP) Professor Carlos Vicente rounded up his students in June to make the journey from Rio Piedras, Puerto Rico to Providence to attend Brown's PROBE Summer School, one of his students confided their fear and uncertainty. These fears were not rooted in the journey from home, the distance between student and family or cultural differences the student may encounter. The fear centered on their innate ability, specifically, the student's anxiety about whether they could perform at the level of the Brown students among whom they would study and conduct research. Although he knew his students to be confident and exceedingly capable, Carlos understood. He told the student, "Take that thought and kill it right now; I can tell you it's 100% false." Long ago (not that long ago, he will tell you), Carlos made his own journey from Puerto Rico to Providence, where he arrived as a graduate student in the Department of Physics. He knew imposter syndrome could be crippling and that the siloed communities on the island engendered unwarranted self-doubt. Carlos also knew the PROBE Program, with its balm of community and exchange of fresh ideas, would be an infusion of intellectual currency for his students, an antidote to the geographic isolation of the Caribbean.

The PROBE Program was a collaborative conception, the brainchild of Prof. Vicente and Brown Professor Stephon Alexander. Invited to UPRRP in early 2022 by Prof. Vicente to give a talk about his book "The Jazz of Physics," Professor Alexander related over lunch how pleased he was at the quality of the questions from the undergraduate audience and the seeds of an idea took root between them. Over drinks later that evening, Alexander reintroduced the idea, convinced of the intellectual capital the island at once contained and yet constrained. Inspired by his love of the island, he proposed holding a winter school to entice snow-weary faculty from Brown's Providence campus. Prof. Vicente recalls, "The idea of a Winter School for Computational Physics was developed in collaboration with Stephon Alexander – over drinks." The conversation included potential pitfalls of a winter session, such as the delightfully protracted 45-day holiday season in Puerto Rico, which extends from just after Thanksgiving until the Feast of San Sebastián, beginning on the third Thursday of January. Ever the optimist, Prof. Alexander saw this not as an impediment but an oppor-



The University of Puerto Rico, Rio Piedras (UPRRP)

tunity. "Providence faculty will be tired of the snow – let's bring them to Puerto Rico and have a Winter School!"

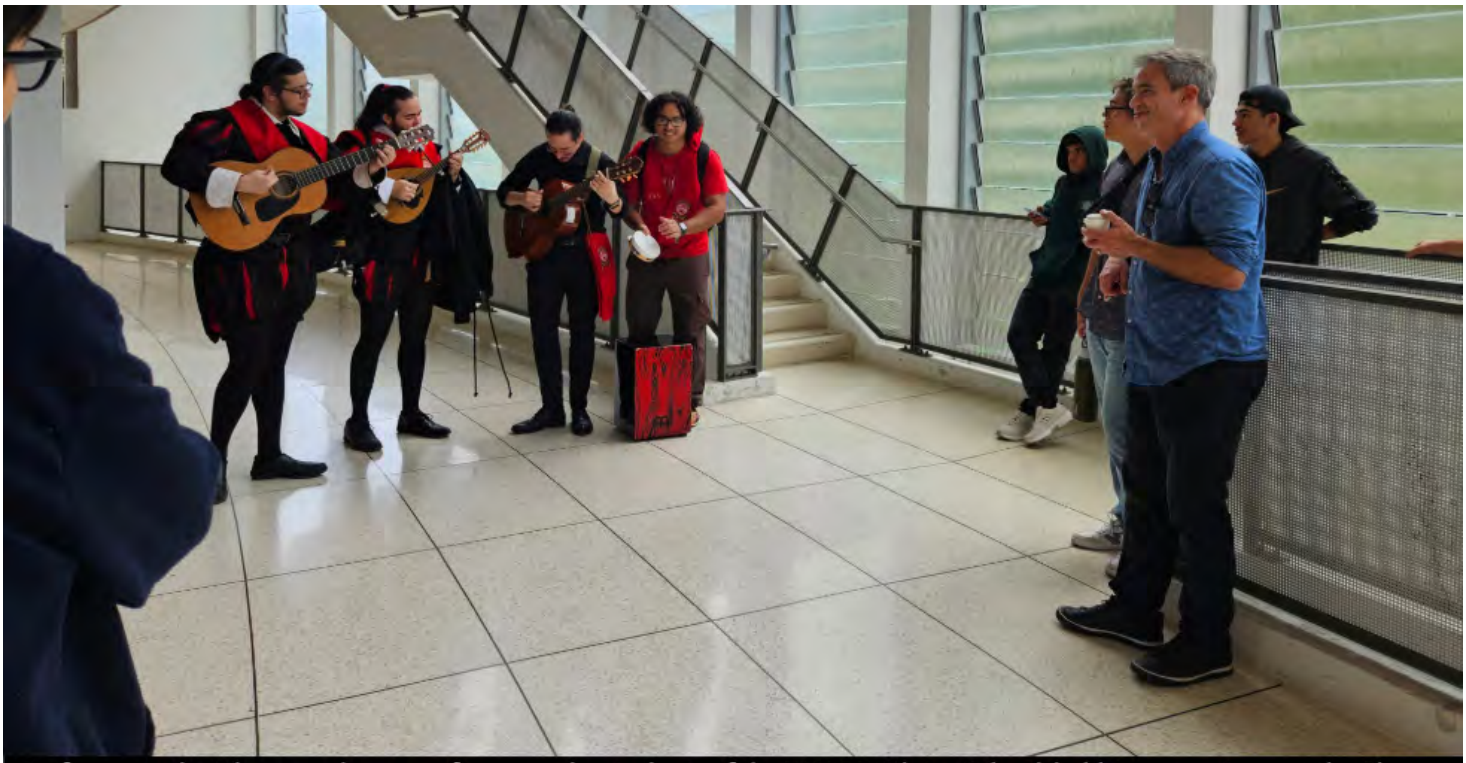
Prof. Vicente recalls the early stages of planning, which included building "a program that would strengthen the students' computing capabilities while at the same time exposing them to exciting fields of research from Brown and UPRRP faculty." The Program would focus on a computational approach to physics and provide intensive Python workshops culminating in Brown and UPRRP faculty-led conferences.

The plan included a post-Winter School selection of a handful of students for a summer internship at Brown to continue their research. The selection process was rigorous and thorough; however, Prof. Vicente's expectations were far exceeded, making the summer school selection process unanticipatedly difficult. Although he had the utmost faith in his students' abilities, he thought the selection process would be far more straightforward than it proved to be. "I had believed only a few students would have the interest and maturity necessary for research," he says. Still, to his delight, "All 26 candidates who completed the Winter School were outstanding candidates for study at Brown."

This revelation is an outcome one could only dream of, and the reality is that given access and instruction, the UPRRP students were more than capable of the material prepared by the Brown faculty, who were impressed with the level at which the UPRRP students could perform. Vicente hopes that future iterations of the Program will have room for the many UPRRP students who can benefit from access to Brown faculty. Of the visiting Brown faculty, he says he was impressed by their dedication. "The enthusiasm with which they prepared their talks was contagious, and the students eagerly participated in the Brown faculty's engaging presentations."

The PROBE Program also positively impacted Brown Physics, connecting the department's mission to the larger vision of the Departmental Diversity and Inclusion Action Plan (DDIAP) Committee, which is charged with bringing fresh perspectives to the Physics community. With the relationship now developed with UPRRP, Brown Physics has a stake in the continued enrichment of the physics students at UPRRP.

Among the many benefits to Brown, the PROBE Program involves all faculty – including faculty of color – getting



Professor Carlos Vicente enjoys a performance by students of the PROBE Winter School, held January 16 - 20 at the Rio Piedras campus of the University of Puerto Rico (UPRRP).

exposure to being in Puerto Rico to mentor, teach and conduct research. For example, Brown's Professor Brenda Rubenstein's cultural takeaways have undoubtedly enriched her almost as much as her guidance impacted the students. "The Brown-UPRRP Winter School was an exceptional opportunity for faculty and students to share their love of physics and computation across traditional cultural barriers. The students were also excellent teachers, sharing much about life and education in Puerto Rico with the faculty in an open forum. As a faculty member, meeting such intelligent and dedicated students who each day overcome significant adversity to advance themselves and their fields was invigorating. It was also a unique opportunity to reflect on the resources we are fortunate to have at Brown and how they can better be used to improve the lives of others. I am eager to see many of the Brown-UPRRP Winter School students continue these invaluable conversations at Brown in the near future!"

Impacts

For Prof. Alexander, both his time in Puerto Rico and his time among the UPRRP students in Providence provided unique insights into the complexities and constraints of isolation and the myriad beneficial impacts of the PROBE Program. Alexander says witnessing the students thrive in Brown's rich intellectual and research environment took them out of the "rut of isolation." He says that the PROBE Program provided the UPRRP students with the perspective that there's a bigger world beyond their experience and that being connected to the larger community of universities in the Northeast gave them a greater sense of value. Notably, he says that when they left Providence, they took an amplified sense of community amongst themselves and the excitement for possibilities, especially for pursuing further studies and graduate school.

Prof. Vicente initially hoped for the PROBE Program to bring new life to the UPRRP physics curriculum; the impacts were much more profound. He describes a fundamental change in the students' self-perception, confidence, motivation, and goal-seeking. In describing the Program's impacts, he uses the words "transformative" and "extraordinary." "The excitement is palpable and contagious," he says. He was overjoyed at the enthusiasm with which the students returned to their studies after the Winter School. "The research experience puts their classwork in the context of the larger goal of scientific advancement. For some of the students, this was their first experience in research. It helped them see themselves as producers of scientific knowledge, not passive consumers." The student who pulled him aside at the beginning of the program to express his fears told Vicente after the summer that he "learned a surprising amount of physics in two months thanks to his interactions with the Brown undergraduate and graduate students. His confidence

that he could continue learning at a higher level than he thought possible is precisely the inspiration we hoped this program could provide our students," Vicente relates. Given the resources and research mentorship, Vicente says the students flourished in the PROBE Program. "The practice of research cannot be learned in the classroom; science is an apprenticeship, and these experiences are crucial."

The consensus among the Brown PROBE faculty is that the UPRRP students could absolutely compete on a level with Brown students, which seemed to surprise no one but the students themselves. Prof. Rubenstein said the students "were remarkably thoughtful and engaged, posing insightful questions about astrophysics, computational biology and everything in between." Professor Alexander reflected, "I definitely felt they could compete at the Brown level. And I think they probably did not expect that. They didn't know how they would measure up, but I am here to tell you they did measure up. They were challenged, and they rose to the occasion. They're like the koi fish. You put them in a big enough pond, and they grow to the size of the pond."

IN THEIR OWN WORDS: PROBE STUDENTS DISCUSS THEIR RESEARCH

Naomi L Núñez Altagracia
Research: Annotating and Tracking of Moving Bacteria in a Dynamic Swarm
PIs: Dr. Jay X. Tang and Dr. Remi Megret
Mentor: Ph.D. Student Danielle Germann

As a biology and physics major, I was thrilled to have a chance to work in Dr. Jay Tang's biophysics lab. Under the guidance of Ph.D. student Danielle Germann, Dr. J. Tang, and Dr. R. Megret, professor of computer science at UPRRP, I further developed my research project titled "Annotating and Tracking of Moving Bacteria in a Dynamic Swarm." In the biophysics lab, we studied Enterobacter sp. SM3, a bacterium that exhibits swarming behavior. Due to its nature, it is highly dense and requires on-site dilution at the swarm front to study intercellular interactions. Taking a computational approach, we developed a machine learning algorithm in Cellpose to minimize manual annotation on movies captured of these bacteria. We are currently still training models to optimize manual annotation since with the labels, we can import the mask into ImageJ's TrackMate to determine position, velocity, angle, orientation, etc.

Professor Brad Marston's lecture "Quantum Physics of Climate Change and Climate Solutions" at the PROBE Winter School at UPRRP.
Photo: Sebastián Hernández Sterling/UPR

In addition to our research projects, we also participated in various workshops and events hosted by The Leadership Alliance. The Leadership Alliance provided numerous activities for professional development and the opportunity to create and present my first poster presentation at the Leadership Alliance National Symposium and at the Brown University Summer Research Symposium. Since this was my first presentation, sharing all my hard work and learning from my peer's diverse summer projects was great. My time at Brown has been amazing, with opportunities to network with faculty, staff, and grad and undergrad students who share the same passion for research. I want to extend my gratitude to all my mentors, faculty, The Leadership Alliance, the PROBE program, and The Simons Foundation for creating these opportunities for underrepresented students.

Adrián Duchesne Acevedo
PI: Dr. Kemp Plumb
Research: Investigating the effects of magnetic dilution on the frustrated magnet K2IrCl6

The physics department at Brown University is full of students, professors, and administrative staff who wish you the best. They work together to advise you and provide you with the necessary tools for your career.

Over the summer, I worked in Dr. Kemp Plumb's lab, studying the magnetic properties of the frustrated magnet K2IrCl6. While there, I was tasked with adding impurities to the crystals, Tin a paramagnetic, and creating the best recipe, if you will, for growing them. It was to my surprise how open Dr. Plumb was with research; he let me explore my ideas and guided me when I had strayed from the best course of action to take in my research. I cherished my time in the lab and am thankful for how the Ph.D. students in the lab take their time to show you how to do things and help you when you are stuck. I came to the program thinking about going straight into astrophysics after I finish my undergraduate degree, but now I've seen other fields in which I am also interested, such as condensed matter physics. I also want to give a special thanks to Dr. Ian Dell'Antonio, who used his knowledge to answer my many inquiries during the summer of applying to graduate school and about astronomy in general. His work was felt by all the PROBE Program students, and his significance was really cherished by all. The Department and Simon's Foundation outdid themselves this year by impacting a new generation of students from underrepresented backgrounds, such as us. Thank You for all!

Above: The Castillo San Felipe del Morro, or El Morro, Old San Juan Puerto Rico

Abnelis Guzmán Román
Research: Finding the Faintest Features in Galaxy Collisions
PI: Dr. Ian Dell'Antonio

I will always describe my internship at Brown University's Department of Physics as crucial in reinforcing my academic trajectory and goal of becoming an astrophysicist. Back in January, I participated in the Winter School at the University of Puerto Rico, Río Piedras campus, funded by the Simons Foundation. The program provided hands-on learning in computational tools, which were helpful for my summer research. Selected as a member of the first Puerto Rico Brown Exploration (PROBE) cohort through the James H. Wyche First Year Research Experience (FYRE) program, I participated in a summer research internship at Brown University. I studied tidal features surrounding galaxy collisions as part of Dr. Ian Dell'Antonio's astrophysics laboratory. This was my first major research project, completed right after my freshman year. The work involved individual analysis of deep archival images from telescopes worldwide, using computation and image processing to uncover these faint features. Identifying tidal features demanded precision, focus, and perseverance, skills I refined, giving me a new level of academic discipline.

Supported by the Leadership Alliance, the internship also included opportunities for professional development workshops and meetings. I presented my research as a poster at the Leadership Alliance National Symposium in Hartford, CT. The experience helped sharpen my communication skills and allowed me to receive feedback from students and faculty. Finally, I presented my research at the Brown University Summer Colloquium, where I interacted with students from diverse research backgrounds. I am beyond grateful to be able to represent Puerto Rico and to contribute to the scientific community through my research. Each of these opportunities has been a stepping stone toward my goals in the field. The knowledge gained, the skills developed, and the challenges faced have all prepared me as a student and researcher. I am thrilled to share that I will continue working on my research project from Puerto Rico and hope to expand my knowledge and findings on the topic.

Above: Puerto Rico's Caribbean coast along Paseo de la Princesa, San Juan

Above: UPRRP's clocktower at FDR Tower, La Torre or El Faro (The Lighthouse)

First-year physics students built a large-scale eclipse model in the Barus & Holley Lobby as part of the Department's eclipse activities.

This phenomenal exhibit was designed, built, and installed in the Brown Design Workshop by first-year physics students led by Professor Rick Gaitskell with the administrative expertise and guidance of Center administrator Ariel Green.
The large-scale, dynamic model built in the Barus and Holley lobby illustrated why partial and total solar eclipses occur. The model allowed us to view what a total solar eclipse looks like from space and see why the Moon, which is nearly 400 times smaller in diameter, can, nevertheless, perfectly block the Sun in one narrow path across the surface of the Earth; this is also known as the path of totality.

This is shown by the darkest shadow on our large Earth model, called the umbra. The partial solar eclipse, also called the penumbra, is demonstrated in our Earth model by a dimmer, larger shadow passing in a wider path across Earth.
The students calculated the distance, angle, and size of their Earth and Moon models and the brightness and positioning needed for the sunlight source. They designed and built the mechanical components to animate the Moon's movement with a small motor.After much trial and error, they designed and constructed all of the components for the eclipse model.

Students in grades 3 - 5 of the French American School of Rhode Island (FASRI) toured the installation on Friday. FASRI's elementary coordinator, Brian Pruvost, said the young students in grades 4 & 5 had a similar assignment, "imagining and designing models representing astronomical phenomena such as the Earth's rotation and revolution, and the phases of the Moon." The FASRI group noted similarities between their work and that of Brown's physics students, including "crafting celestial objects, simulating sunlight, utilizing robotics, trial and error."

The installation caught the attention of local NBC affiliate WJAR, whose Liz Bateson interviewed Professors Gaitskell, Mitrović and student Jason Wu for a segment that aired the day of the eclipse. "It was such a long process," Wu said. "It's really cool that it will help elementary school students (become) more fascinated with science."

Above left: Prof. Rick Gaitskell (right) and CFPU Center Administrator Ariel Green, who oversaw the construction of the eclipse lobby installation in Barus & Holley. Above right: the eclipse lobby installation.
Photos: Valerie DeLaCámara/Brown University

For the Love of Physics: A Celebration of Music, Art & Nature

By Valerie DeLaCámara

On Friday, November 3rd, the Brown Physics Department presented "For the Love of Physics: A Celebration of Music, Art and Nature," an event exploring the intersection of physics and creativity, in which presenters discussed Brown as an inspirational backdrop for their creative endeavors. The audience was immersed in the world of physics in an evening filled with live performances and inspiring interdisciplinary presentations by renowned faculty and celebrated artists.

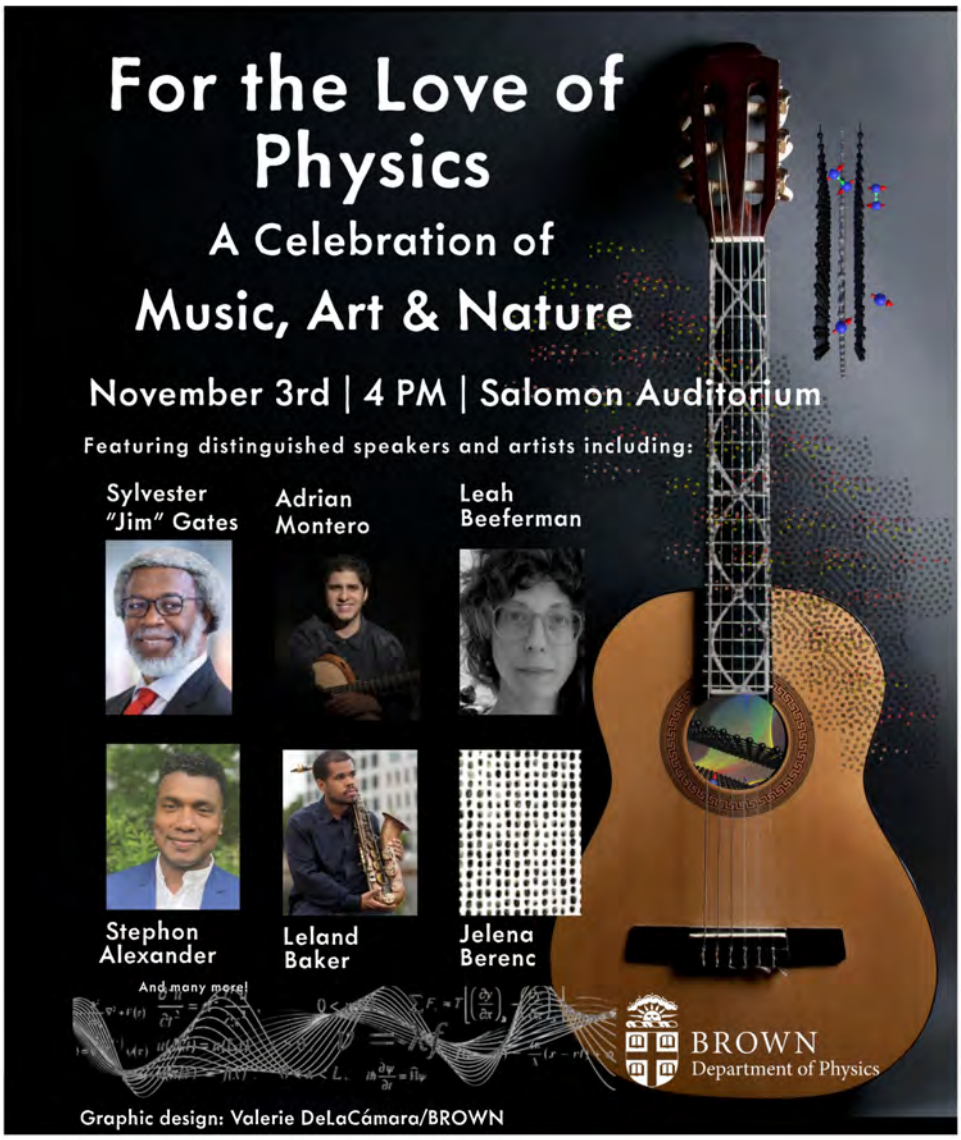
The two-day event began on Thursday, November 2nd, "For the Love of Physics" with a STEM physics workshop for middle-school students to help create new paths to advancement in physics education.

Friday's program featured a lunchtime discussion about challenges faced by underrepresented groups in physics with physicist Sylvester "Jim" Gates, known for his work on supersymmetry, supergravity, and superstring theory.

Following this discussion was the premier of Gates' "Why I Chose Physics" video and a Q&A session with the audience.

The premiere event began later that afternoon in Salomon Auditorium with presentations from distinguished artists and speakers from the fields of physics, music and the arts. Musical presenters included acclaimed classical guitarist and educator Adrian Montero and jazz saxophonist/music educator Leland Baker, who performed several pieces for the audience. Artistic presenters included digital artist Leah Beeferman and visual artist Jelena Berenc. Distinguished speakers included multifaceted physicists Stephon Alexander, Jim Gates, Richard Gaitskell, Jia Li, and Vesna Mitrović.

Adrian Montero PHOTO: Valerie DeLaCámara/BROWN



Top Right: Jelena Berenc
Middle Right: Jim Gates
Lower Right: Jia Li
Lower Left: Stephon Alexander (L) and Leland Baker (M) perform with percussionist
PHOTOS: Valerie DeLaCámara/BROWN

Ilija Nikolov: Bringing a quantum leap to Boston's largest investment company

By Juan Siliezar

Ilija Nikolov knows better than most that a quantum future is coming. In fact, he's so certain of it that he's helping one of the world's largest investment firms prepare for it.

The Brown University Ph.D. student is completing an internship with the Fidelity Center for Applied Technology data science team at Fidelity Investments' Boston headquarters this summer. As an intern at FCAT, which studies the frontiers of computing and how it can be used at Fidelity, Nikolov's primary task is to evaluate and test whether quantum mechanics-inspired neural networks can enhance the company's computer systems.

"Everything people have been hearing about how quantum mechanics will provide real-world breakthroughs across a range of disciplines is not all hype," said Nikolov, who is spending his second summer with FCAT. "There's some serious research and investment going on now. While we cannot really imagine all the applications that advancements in quantum will lead to yet, this is going to start becoming a reality for a lot of companies in perhaps the next 10 years."

The FCAT data team recruited Nikolov because of his range of work at Brown, where he has used machine learning algorithms and also applied ideas from quantum computing to condensed matter in Brown Professor of Physics Vesna Mitrović's lab.

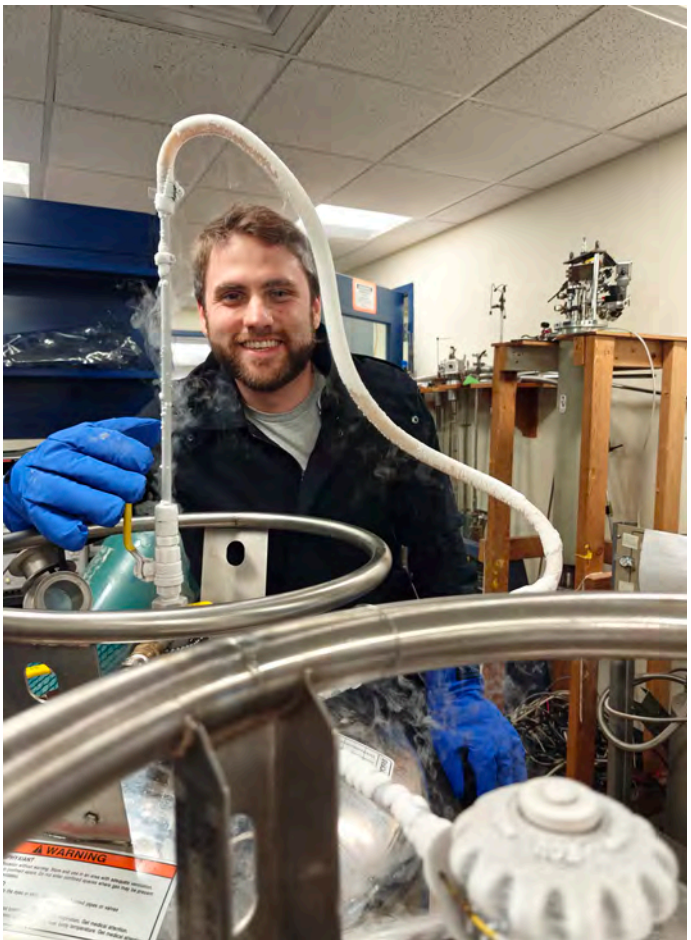
Theoretically, quantum-based hacking technologies will be able to compromise most, if not all, classical computer security systems, while quantum-based security systems will be virtually impossible to hack due to superposition and entanglement. These are the principles that allow quantum bits to exist in multiple states at once and instantaneously influence the state of another, regardless of distance. When applied to financial analysis, superposition and entanglement allow computations to be done simultaneously, providing an exponential speed-up over existing methods.

"Because we don't know what these future systems will look like, what it all means is that my work is more of a feasibility project for now," Nikolov said. "The main goal is to determine how useful this type of quantum system could be for the company."

Nikolov's lab work at Brown has been focused on a family of superconducting metals. Image courtesy of Ilija Nikolov

Much of Nikolov's work over the past two summers with FCAT has involved building and implementing a neural network that is based on both classical and quantum computing to evaluate some the firm's security systems and analyze a range of financial data, such as stocks. Nikolov worked with existing neural network frameworks — which mimic how brain neurons communicate — and adapted them to for the company's specific data needs.

Last summer, for instance, he designed a system to study past financial data for trends and patterns the company could apply to future data. This summer,



A condensed matter researcher and Brown Ph.D. student, Nikolov is spending his summer at Fidelity Investments, exploring how quantum-inspired neural networks could revolutionize financial analysis and security systems.

Ilija Nikolov interned at Fidelity Investments' Boston headquarters this summer, working with the Fidelity Center for Applied Technology data science team. Image courtesy of Ilija Nikolov

Nikolov is using the system to produce high-quality synthetic data to train other machine learning models the company uses for its financial services.

"Because it's all very new, there are no paradigms or existing models to follow, so you're basically inventing the wheel," Nikolov said.

The full-time internship is hybrid, and Nikolov, who is from Macedonia, has taken full advantage of his time in the office to explore downtown Boston, including taking a duck boat tour and catching a Red Sox game at Fenway Park. He is no stranger to New England having completed his undergraduate degree in physics and mathematics at Amherst College. He started at Brown in Fall 2020 and earned his master's in physics in 2021 and master's in computer science in 2024. He is now a fifth year Ph.D. candidate in physics.

The internship at Fidelity has helped Nikolov balance his classroom and lab-based experience at Brown, where his focus has been exploring the exotic mysteries of a family of superconducting metals, with a more applicative scientific experience.

"This rounding out of my overall research background has been the whole idea behind this experience," Nikolov said.

STUDENTS
BROWN PHYSICS STUDENT STORIES

Vineetha Bheemarasetty

Physics Ph.D. Student

Photo: Courtesy Vineetha Bheemarasetty

Awards: Award of Excellence as a Graduate Teaching Assistant (2021)

National Science Foundation Graduate Research Fellowship Program - Honorable Mention (2022)

Jun Qi and Christine Geng Graduate Fellowship in Condensed Matter Experiment (2024)

What advice can you offer to incoming physics students?

My advice to incoming physics students is to never be scared to ask "why?" because the essence of research lies in questioning the things around you. Always seek new opportunities to get involved in different kinds of research — physics is becoming an increasingly more collaborative field. Even more so than the results, the skills you learn along the way will take you much farther than you can imagine!

What is the most impactful lesson you learned?

As I enter my fifth year in the physics Ph.D. program, I am continually reminded of the importance of exploring alternatives. Conventional approaches are often unsuccessful, particularly when studying novel materials and systems that are not well understood. In these cases, seeking out alternative methods becomes essential. Whether it's designing device leads, patterning materials to preserve their integrity, or building fabrication systems that significantly enhance material quality, the pursuit of alternatives has been the key to many of my impactful research results here at Brown.

Who inspired you?

Many of us in Brown Physics would agree that Meenakshi Narain was truly an inspiration. She was driven, strong, supportive, and always spoke her mind. She embodied the courage and dedication that I believe every woman in STEM should aspire to, making a meaningful impact in our field. Meenakshi's journey serves as an inspiration to all of us who have faced challenges on our own paths. What inspires me most is that she did what she loved with unwavering commitment until the very end.

Photo: Valerie DeLaCámara/Brown University

Vineetha Bheemarasetty Cont'd.

Physics Ph.D. Student

Tell us about the impact of these awards on your research.

I was beyond thrilled when I opened the email from our department chair about receiving this award. I had just arranged a visit to a collaborator's research lab in Delaware to learn about a novel measurement technique that I hoped to bring to Brown Physics. This funding will be instrumental in advancing my investigation of spin torque phenomena in low-dimensional materials, and I am eager to continue this exciting research area.

Describe the research that will be funded by this award.

This fellowship will support me in completing one of the two major research projects that I began at Brown. As part of this project, I am developing a novel high-frequency measurement technique called spin-torque ferromagnetic resonance (ST-FMR) to probe the electron spin conversion efficiency of the Ru-Pt alloy. Given that Brown Physics does not currently have this capability, I hope that this will aid me and other CME groups in the department in developing materials for next-generation spin-orbit torque devices that are characterized by low power consumption, faster switching rates, and lower read/write currents.

Who would you like to thank?

I would like to extend my sincere gratitude to the donor for generously supporting my research at this crucial stage of the project. I truly appreciate the recognition of my achievements so far as I strive to complete this exciting endeavor! In addition to the donor, I would like to thank my research advisor, Gang Xiao, for providing me with the guidance and resources to pursue such an impactful project. Furthermore, the prior support I received from the Elbaum foundation enabled me to present my earlier findings of this project at the APS March Meetings in 2022 and 2023. This unique opportunity helped me share the initial results and significance of this project with the scientific community.

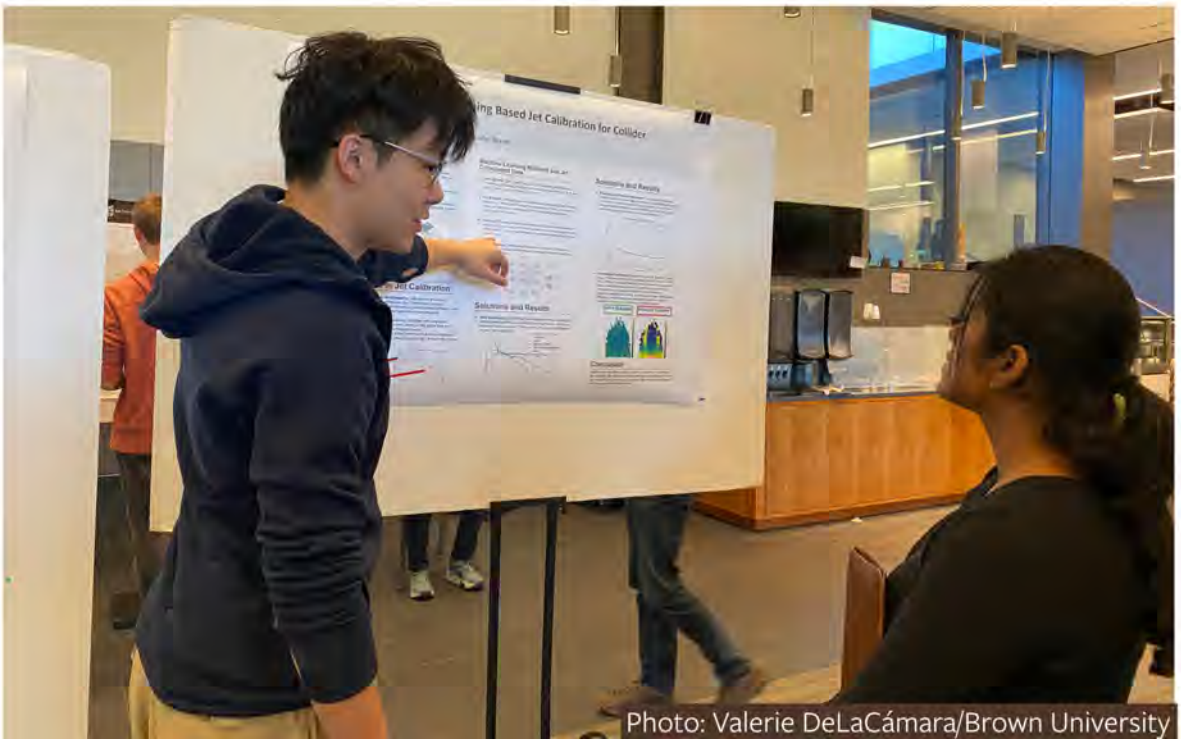


Photo: Valerie DeLaCámara/Brown University

STUDENT SPOTLIGHT
BROWN PHYSICS
AWARDS OF PRESTIGE AND RENOWN

Chateaubriand Fellowship program

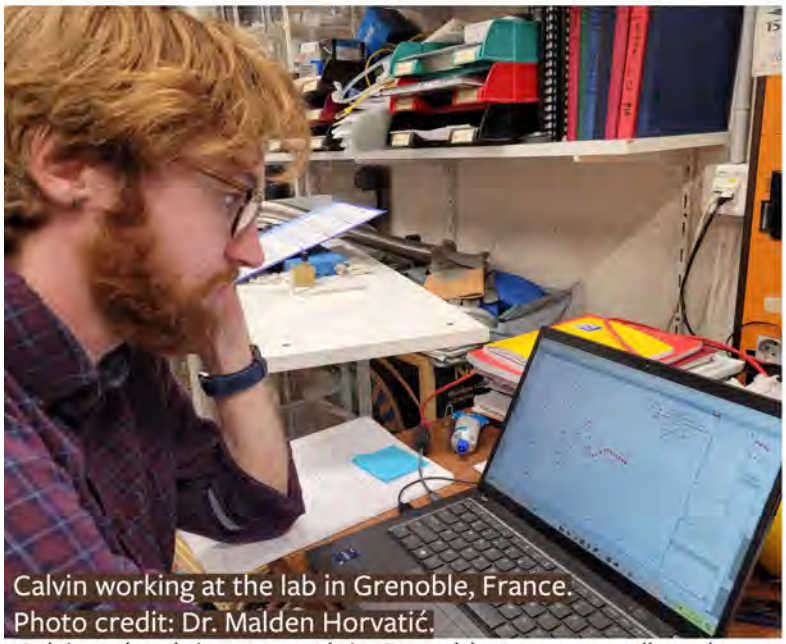
2023 CHATEAUBRIAND FELLOWSHIP

Calvin Bales **Physics Ph.D. Student**

Almost two years ago, I got an email about the Chateaubriand Fellowship, awarded by the French Embassy to the United States, which would enable me to do a portion of my Ph.D. research in France. I was immediately interested. I lived in Grenoble, France for a few years as a kid and grew up speaking French. I had had little opportunity to speak French since coming to Brown, so getting the opportunity to speak French again and do it as part of my Ph.D. research was too good to pass up.

I knew that my PI, Prof. Vesna Mitrović, had been a postdoc at the Laboratoire National des Champs Magnétiques Intenses (LNCMI) in Grenoble, which presented the perfect opportunity to rekindle the research collaboration between our two labs. With the support of Prof. Mitrović and her postdoc advisor, Dr. Malden Horvatić, we developed a collaboration proposal that would enable me to conduct part of my Ph.D. research at the LNCMI under Dr. Horvatić's guidance and in turn share with his group the novel nuclear magnetic resonance (NMR) techniques we've been working on at Brown. A few months later, I found out that the proposal was accepted and that I had been awarded the Chateaubriand Fellowship.

Calvin on a hike up to the Bastille
Photo credit: Evelyn Lindenburg



Calvin working at the lab in Grenoble, France.
Photo credit: Dr. Malden Horvatić.

Calvin Bales doing research in Grenoble. It was not all work, however. Calvin says, "I used my long weekends to travel beyond the city, visiting a childhood friend in Switzerland and exploring Germany with a friend who came to visit.
Photo courtesy of Calvin Bales.

This past spring and early summer, I spent four months in Grenoble, France doing research at the LNCMI. And I learned so much. During my time there, I worked in a research group of full-time researchers and postdocs who were specializing in NMR. The amount of expertise I was surrounded by daily was incredible. I spent my days learning the intricacies of NMR from Dr. Horvatić, a leader in the field, improving my skills in the lab, and developing a deeper understanding of my work. I ate lunch in the shadow of the Alps and brushed up on my French while chatting with my labmates on the break room balcony over our afternoon café. By the end of my four months there, I had enough measurements on one sample to complete a paper we'd started working on before my time in France, some exciting results

2023 CHATEAUBRIAND FELLOWSHIP *Cont'd.*

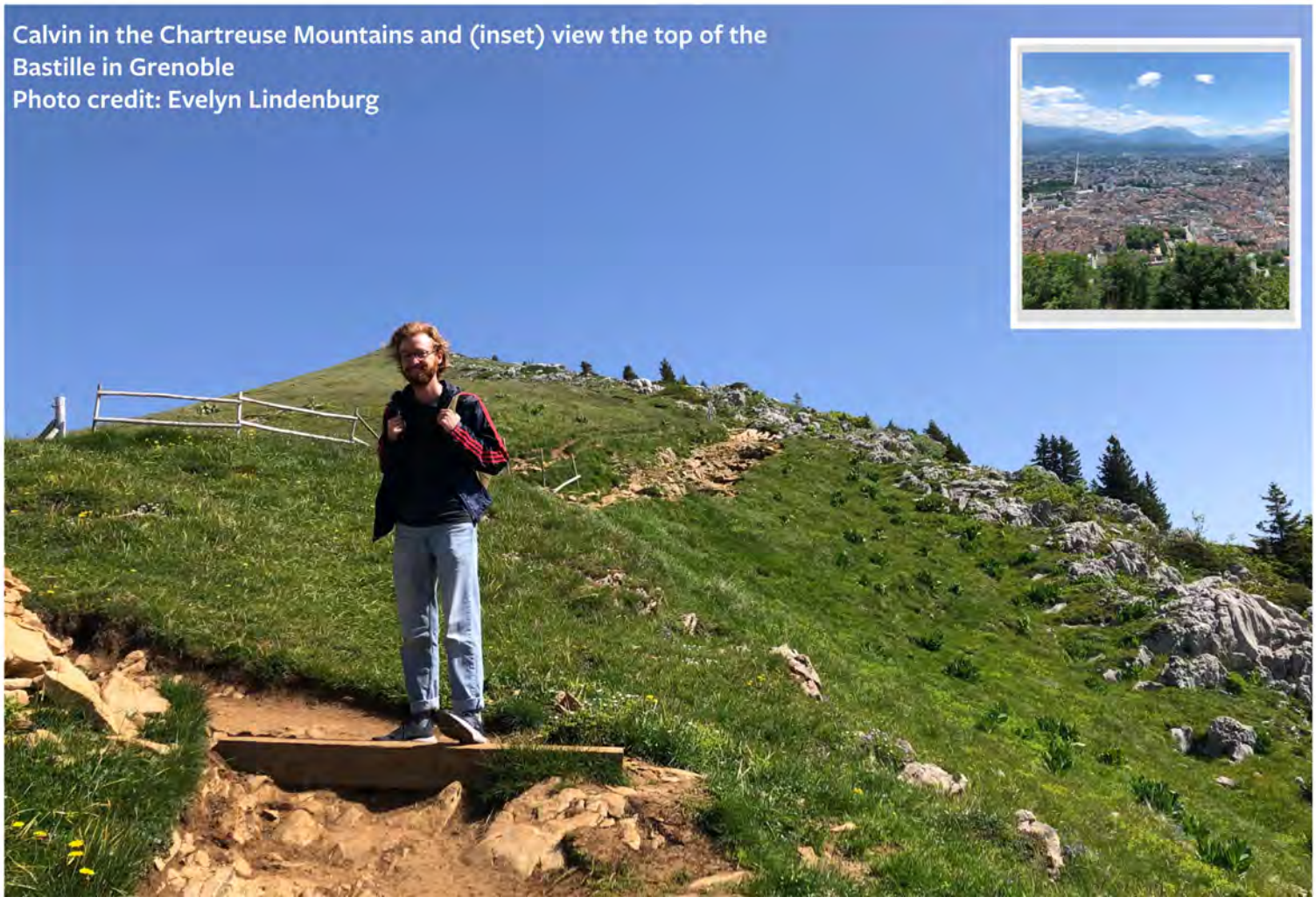
Calvin Bales **Physics Ph.D. Student**

on a second sample, and an increased sense of confidence as I now approach my defense.

Outside of the lab, I explored the city and region. My second favorite part of living in Grenoble (my favorite part was the baguettes) was how bike-friendly the city is. After spending years battling cars on my bike in New England, the designated bike lanes and hoards of daily commuters were heavenly. I got a used bike for cheap, did some basic repairs, bought a helmet (safety first), and hit the road. I biked to work every day, a trip that was completely on designated bike paths and included a stretch along a river at the foot of one of the mountains surrounding the city. The view was stunning. I also explored the city by bike, revisiting the house I lived in as a kid, finding new parks to spend my weekends relaxing in and discovering some of the many murals that adorn the buildings.

I used my long weekends to travel beyond the city, visiting a childhood friend in Switzerland and exploring Germany with a friend who came to visit. Prof. Mitrović and her son stopped by for a few days on her way to a conference in Italy, and, with Dr. Horvatić, we took a scenic hike in the nearby Chartreuse Mountains.

Overall, this experience allowed me to make lasting connections with researchers in another country, brought back French language skills that I was beginning to lose and allowed me to grow tremendously as a researcher and physicist.



Calvin in the Chartreuse Mountains and (inset) view the top of the Bastille in Grenoble
Photo credit: Evelyn Lindenburg

STUDENT SPOTLIGHT
BROWN PHYSICS
AWARDS OF PRESTIGE AND RENOWN

Chateaubriand Fellowship program

2024 CHATEAUBRIAND FELLOWSHIP

Ilija Nikolov **Physics Ph.D. Program**

Ilija Nikolov at his undergraduate graduation from Amherst College. He will study in Grenoble this coming year as a Chateaubriand Fellow.

Ilija Nikolov, an advisee of Prof. Vesna Mitrović, was awarded a prestigious 2024-2025 STEM Chateaubriand Fellowship, marking the second consecutive year a Brown student won the award.

The Université Grenoble-Alpes will co-fund the Chateaubriand Fellowship through the Embassy of France in the United States. The fellowship supports outstanding Ph.D. students from institutions in the United States who wish to conduct part of their doctoral research in France for a period ranging from four to nine months. Chateaubriand fellows are selected through a merit-based competition, with expert evaluation in France and the United States.

The Chateaubriand Fellowship in Science, Technology, Engineering, Mathematics & Biology-Health (STEM) for doctoral students aims to initiate or reinforce collaborations, partnerships or joint projects between French and American research teams. The Office for Science & Technology (OST) of the Embassy of France offers this fellowship in partnership with American universities and French research organizations such as Inserm and Inria. It is a partner of the National Science Foundation's GROW program.

As a Chateaubriand Fellow, Ilija will receive an allowance of 900 Euros per month for nine months, plus additional funds to cover the cost of round-trip travel and health insurance. Ilija discusses his journey to the fellowship below.

CHATEAUBRIAND FELLOWSHIP

By Ilija Nikolov

The joy of condensed matter physics is to be the first to witness the reveal of exciting discoveries as they are unveiled in real-time in the lab and shared with fellow physicists. The Brown Physics Department is a place that has not only enabled me to sharpen my experimental and theoretical physics skills but also provided a place, a sort of a forum, to learn together with fellow peers of a diverse range of interests and backgrounds. Through the open graduate education initiative, I explored a heterogeneous mixture of classes, including quantum computing, advanced statistical mechanics and deep learning. Exposure to different scientific disciplines enabled me to experience a strong appreciation of the scientific method and build a holistic understanding of the scientific production process.

I want to use this occasion to thank my advisor, Prof. Mitrović, who has worked tirelessly to ensure the smooth functioning of the lab and encouraged us to dare to dive right into uncharted territories of the microscopic world. Moreover, thanks to the Brown Department of Physics's collaboration with other world-leading institutions in physics and the Department's practice of encouraging students to participate in educational mobility programs, which include financial support and degree requirement flexibility, I was fortunate enough to share my findings

2024 CHATEAUBRIAND FELLOWSHIP *Cont'd.*

Ilija Nikolov

with and learn from highly renowned experts. For instance, during my trip to MagLAB, which hosts the world's strongest magnet, I was exposed to high-intensity research on an entirely new compound, which taught me how to conduct experiments in a fast-paced environment and how to make the right decisions regarding the measurement based on the scarcely available information.

The recognition as a Chateaubriand fellow will enable me to spend nine months in Europe's top magnetic resonance research facilities for condensed matter physics. This is the second year a student from the Brown Physics Department has received this prestigious award from the scientific committee of the French Embassy in the United States, representing a great honor for me and Brown Physics.

JUANYI YANG

An advisee of Prof. David Lowe, Juanyi Yang is the inaugural recipient of the Academic Acceleration Wu and Ying (AAWAY) Graduate Fellowship. Named for emeritus professor See-Chen Ying and his wife, Wendy Wu, this new fellowship supports a student's effort in training other graduate students as they pursue their advanced coursework.

The Class of 2024

BACHELORS

William F. Albright
Ben Bachmann
Maxim L. Beekenkamp
Raphaël L. Benamran
Anna Bencke
Lucas Z. Brito
Manav M. Chakravarthy
Yaxi Chen
Nathan P. Craig
William L. Deckelbaum
Shivam M. Desai
Uri T. Dickman
Benjamin Y. Eden
Alexander W. Feiner
Brian E. Freedman
Sagan R. Hartley
Sudatta Hor
Yizhong Hu
Valentin K. Kirilenko
Timothy M.H. Launders
Elijah Lew-Smith
Gene Lu
Lia D. Lubit
Max V. Lunievicz
Gareth A. Mansfield
James P. Mullen
Dimitrios Papadimitriou
Lucca Z. Paris
Christopher Pawul
Daniel D. Quinter
Smita Rajan
Ryan-Napali Raymundo
Dani Romero Mejia
Ekin Secilmis
John Michael Slezak
Chloe R. Widman

STUDENT AWARDS

R. Bruce Lindsay Prize for Excellence in Physics
Anna Bencke, Christopher Pawul

Mildred Widgoff Prize for Excellence in Thesis Preparation
Smita Rajan, Daniel Quinter and Chloe Widman

MASTERS OF SCIENCE

Abeywick, Kian V.
Brown, Benjamin
Cao, Hoang Minh N.
Chen, Guanhua
Chen, Vincent
Chen, Wenqing
De, Apurba
Diaz, Kayla
Ding, Chen
Edmond, Lawrence
Ellis, Spencer
Englert, Anthony M.
Figueroa, Sebastian J.
Gao, Hang
Gassama, Abdulai
Germann, Danielle A.
Herrera, Alexis
Li, An
Li, Selina
Li, Yixiao
Liu, Hao
Liu, Yuchen
Loane, Santiago S.
Lokare, Yash M.
Lu, Domino
Lu, Xiaorui
Mason, Samuel R.
Miller-Dickson, Miles D.
Ning, Frank
Qenani, Daniel
Rong, Susu
Serebriakov, Egor D.
Sharma, Nehal
Singh, Praniti
Sun, Botian
Sun, Hanzhi
Szuminsky, Austin J.
Wang, Lihong

STUDENT AWARDS

Master's Research Excellence
Hoang Minh Cao

Excellence in Physics
Daniel Qenani

Engaged Citizenship and Community Service to the Physics Department
Sebastian Figueroa

Physics Department Chair Award
Austin Szuminsky

Wang, Yiru
Washington, Jessica D.
Yan, Shi
Yerger, Gabriel
Zhu, Qingqi

DOCTOR OF PHILOSOPHY

Lijie Ding, Adviser: Robert Pelcovits
Daniel Li, Adviser: Ulrich Heintz
Xianlong Liu, Adviser: Antal Jevicki
Lecheng Ren, Adviser: Anastasia Volovich
Casey A. Rhyne, Adviser: Richard Gaitskell
Zezhu Wei , Adviser: Dima Feldman
Boyuan Xu , Adviser: Yue Qi
Xuli Yan, Adviser: Greg Landsberg

STUDENT AWARDS

Forrest Award
Xuli Yan & Timothy Rehm

Anthony Houghton Award for Excellence in Theoretical Physics
Zezhu Wei

Excellence as a Graduate Teaching Assistant Award
Liam Mitchell & Ron Nguyen

FELLOWSHIP AWARDS

Galkin Foundation Fellowship Award
Lecheng Ren

Physics Merit Fellowship
Xianlong Liu

Physics Dissertation Fellowship
Zezhu Wei

GRADUATE SPOTLIGHT

BROWN PHYSICS

A wealth of options

Elijah Lew-Smith '24 Sc.B.

2024 Hertz Fellowship

Elijah Lew-Smith., an advisee of Prof. Anastasia Volovich, is a recipient of an REU and a 2024 Hertz Fellowship. The fellowship provides each recipient with five years of doctoral-level research funding (up to $250,000), allowing them the flexibility and autonomy to pursue their innovative ideas.

Along his journey to a Sc.B. in mathematical physics, Elijah said he found inspiration in the joy Professor Dima Feldman takes in physics and life. Prof. Feldman's words resonated with Elijah deeply, and he draws upon them as a source of inspiration in life and work.

A theoretical physicist with broad interests in effective field theory (EFT), Elijah received an REU to work on applying EFT systematically to non-equilibrium and active systems such as fluctuating hydrodynamics or flocking birds. Elijah balances his scientific interests with deep gratitude, thanking his family, friends and teachers who have "put up with and heroically supported me."

Of his time at Brown, Elijah said he loved having a community with whom to share excitement about new ideas. "Living in a society where it is possible to devote one's life to physics is truly a privilege."

What was your favorite physics course and why?

My favorite subject has been quantum field theory because I don't understand it at all. My favorite course was PHYS 2410: Solid State Physics my sophomore fall. I wasn't planning on taking the class but I showed up on the second day just because I wanted to go to all the physics classes during shopping period. The professor walked in 5 minutes late with complete confidence, sat down at the front of the room, and asked: "if it were 1860 how would you measure the heat capacity of a metal?" Despite having no idea what heat capacity was and not having taken the undergraduate or graduate level prerequisites, I was immediately hooked. Since I had a lot of gaps to fill in I was forced to rely on the more senior students and we built a great community struggling through PSETS.

What is the most impactful lesson you learned at Brown?

Dima Feldman told me that "the purpose of education

Photo: Courtesy Elijah Lew-Smith

isn't to gain knowledge or skills or even intuition. It is to gain values."

Did anyone at Brown inspire you and, if so, how?

I've always found Dima Feldman's joy in physics and life infectious. A handful of my favorite quotes from the classes I took with him are: "There is no science, only art, the goal of being human is understanding, not answers and textbooks don't want to scare you but you should be scared."

Who would you like to thank?

Of course, I'm very grateful to my family, friends, and teachers who have put up with and heroically supported me. I'm also very thankful to all the people that I rely on in little ways, most of whom I will probably never meet. L

What is your biggest accomplishment during your time at Brown?

Learning to focus my broad desire to understand the world into the real habits and mindset that make a productive physicist. Somewhat in contrast to high school, at Brown I feel like I've built a sustainable life around my learning.

GRADUATE SPOTLIGHT

BROWN PHYSICS

A wealth of options

Austin Szuminsky '23 Sc.M.

Q&A WITH AUSTIN SZUMINSKY

Q. What awards did you win during your time at Brown?

A. I am extremely honored to have received the Physics Department Chair Award and I am enormously grateful to everyone in the Brown Physics Department who inspired and supported me along the way.

Q. Is there anyone you would like to thank?

A. Professor Michael Kosterlitz. Like many at Brown, his door was always left open to me -- at any time, he was always willing to speak to me on any subject and share or contribute his thoughts at length on something I was reading or working on. His immense kindness and humbleness helped me grow not only as a physicist but also as a person as well. I consider myself so privileged and fortunate to have had such an opportunity at Brown to know someone like him and to be granted what I believe to be a lifelong pursuit of living up to his example. In terms of other mentors, I also owe much to every single professor I took a course with at Brown who all also went above and beyond and helped me grow and develop in different ways which includes Professor Vesna Mitrović, Professor John Mallet-Paret of Applied Math, Professor Stephon Alexander, Professor Brad Marston, Professor Antal Jevicki, Professor Kemp Plumb, and Professor Loukas Gouskos.

Q. How have the Department and the faculty supported you?

A. In addition to faculty, the department also hosts a ton of outstanding staff members. At the end of my first spring at Brown and early into the fall I went to 14 weeks of summer schools and workshops in-person -- 12 weeks of which was in Europe. I owe so much to Elizabeth Barlow, Jessica Bello and Douglas Wilkie who were invaluable for helping me navigate financial awards that ultimately made the travel possible. I also owe a great deal to the day-to-day omniscience of Elyse Souliere, who does so much and is very much a master of all things in the Department, and to Jesse Tessier as well for facilitating course grading assignments and always being there to direct or answer a quick question and Ariel Green for events and interfacing with professors at the Theoretical Physics Center. I also need to thank Valerie DeLaCámara for her otherworldly patience in getting this interview.

Q. What was your favorite physics course, and why?

A.. It isn't easy to pick a single course. Quantum Field Theory I and II at Brown is an amazing series. Professor Alexander is so knowledgeable and an incredibly engaging lecturer; following every one of his classes for QFT I, it is possible to get lost for days at a time or longer, reading just on his side notes and comments alone. His coverage of the Noble Prize-awarded contributions to quantum field theory are among the best lectures I have ever heard. Likewise, Professor Jevicki has such an extreme wealth of knowledge of topics, their importance alone, and their significance and relation to developments in other areas. In addition to being genuinely hilarious, he has a certain charisma and way with which he can cut through complexity to reach and elucidate the depth of a particular subject. Every one of his course meetings for QFT II is also a chance at another influential paper or a new way of understanding something, and when coupled with QFT I, the experience of that duration of time is unlike any other and one where it can very much feel at times like someone is whispering secrets about the universe to you. A real highlight for me was when Professor Alexander hosted Abhay Ashtekar, and we were invited to speak with him as students in his course. I had the chance to ask him, among other topics, about navigating postdocs and his time working with Roger Penrose. Just months later, I was at Oxford talking with Penrose about Ashtekar.

Q. What was your favorite part about being a student in the Physics Department?

A. I have come to believe that real learning requires some amount of eagerness or discomfort. The professors at Brown are the type that inspire, and regardless of how tired you might be or the other things you might have going on in your life during every class meeting or interaction with them, it is easy to come away from it excited to suffer, if it makes sense to put it that way.

Q. What advice can you offer incoming physics students?

A. I think the most important thing is not to doubt yourself and just keep working. Eventually, people will come around, and things will fall into place.

Q. What faculty member most impacted your journey?

A. All of them, really. It is hard to understate all of the phenomenal faculty at Brown. I was much less of what people might think of a physicist than others in my cohort coming into Brown. I am so thankful to Professor Jay Tang for his advice and support during and beyond meetings for master's level students. I am also incredibly grateful to Professor Kosterlitz, really on so many fronts and topics, for reminding me to think classically in so

"The professors at Brown are the type that inspire, and . . . during every class meeting or interaction with them, it is easy to come away from it excited to suffer, if it makes sense to put it that way."

- AUSTIN SZUMINSKY

much of what has become a quantum world and to Professor Mitrović for cultivating my interest in periodically driven systems in addition to quantum information and computation, as well as to both of them for their encouragement and inspiring me early on during my time at the Department, which I credit for motivating my studies and the continued development of my research interests. I owe much to Professor Marston for teaching me how to balance the importance of thinking both physically and more mathematically and, in addition, Professor Plumb also on how to more closely relate to and engage with experiments as a theorist as well as to Professor Gouskos for his insight into navigating a career in academia and how to adapt to evolving technology and research. All of these professors are also outstanding lecturers -- I was extremely fortunate to travel to a physics Lindau Nobel Laureate Meeting in Germany with Professor Kosterlitz, where I somehow managed to have hour-long one-on-one conversations with multiple prize-winning theorists and to personally meet around 20 other Nobel laureates, many of whom I also came to know of through my courses and during my time at Brown. It turns out that sometimes it's okay to meet your heroes.

Q. What brought you to Brown Physics?

A. It may have been Leon Cooper and Charles Elbaum who initially brought me to the Department. I was inspired by physicists who moved into and around more biological questions or neuroscience at some point in their career by the perhaps less conventional notion that it is possible to be more than one thing. At the time, I only knew of Jim Gates and, to a lesser extent, of Michael Kosterlitz. After reading more about the Department, professors and research, I decided to apply and very much found the idea of this sort of atmosphere and the academic environment I had hoped for where you do not need to be afraid of your ignorance on the path to goals you may have and can truly become your best self in that pursuit and even find new ones where you are encouraged also to achieve extreme depth at the most intensive scales.

Q. What is next for you?

A. It's a bit hard to say. I very nearly accepted math Ph.D. positions in geometry and topology or mathematical physics, but have since happily taken up a Ph.D. project with InstituteQ and under the QTF Centre of Excellence on the theory of open quantum systems, quantum information theory, and quantum computation for AI where I am supervised by Professor Tapio Ala-Nissilä at Aalto University.

I will be forever grateful to Professor Kosterlitz for first introducing me to him. I currently have access to a quantum computer that's interfaced to the largest supercomputer in Europe, which happens to be here in Finland as well. There are also reindeer running around in some places, and officially, Santa Claus lives here, so in a way, it's like Christmas all the time. Along with any future success, I have Brown to thank for it.

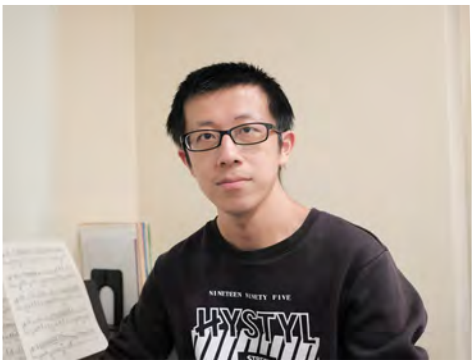
GRADUATE SPOTLIGHT

BROWN PHYSICS

Awards supporting research

Lecheng Ren '24 Ph.D.

2023 GALKIN AWARD



The Physics Department has established an annual award for distinguished alumni of the department. Recipients are nominated based on their contributions in any field of work and awards are presented at the yearly commencement ceremony.

RI native Warren Galkin graduated from Brown University with a Sc.B. in Physics in 1951 and received an MBA from The Wharton School of the University of Pennsylvania. He established physics and brain science fellowships at Brown, including the Galkin Foundation Fellowship, awarded each academic year to one outstanding senior graduate student in the Department of Physics.

We asked the 2023 Galkin Fellowship awardee, Lecheng Ren, to write about the research he conducted that captured the attention of the Galkin Foundation.

Scattering amplitudes are fundamental quantities in quantum field theory that encode the probabilities and patterns of particle interactions, providing valuable insights into the behavior and underlying structure of the physical world. Starting from the 1940s, the most powerful and basic rules to study scattering amplitudes are Feynman diagrams. These calculations become enormously complicated as the loop level and multiplicity of the amplitudes increases, but in many cases the final amplitudes will become surprisingly simple —- pages of formulas from Feynman diagrams would collapse into a few single terms. Therefore, in recent decades physicists have been looking for simpler ways to calculate them in order to circumvent those complexities.

One very powerful tool, developed by Yale mathematician Prof. Goncharov, together with Professors Spradlin and Volovich, and Professor Cristian Vergu from Niels Bohr Institute in 2011, uses a representation of amplitudes in terms of symbols that indicate their singularity structure as a function of the energies and momenta of the particles.

The symbol alphabets found in scattering amplitudes have many deep and fascinating mathematical properties, and have brought a great number of progress in computing explicit amplitudes in many theories, such as maximally-supersymmetric Yang-Mills theory and QCD.

My advisor, Professor Volovich, and I, together with Professor Spradlin, have been using tensor diagrams to study the patterns of the symbol alphabets. According to their studies, the symbols can be related to a certain subset of web diagrams, a special type of tensor diagrams. The tensor diagrams can help visualize the structure of symbol alphabets (especially the more complicated ones) and make the non-trivial identities manifest. Another advantage of tensor diagrams is that it provides a bridge between symbol alphabets and polytopes associated with an underlying Grassmannian, which can help make predictions on symbol alphabets in more complicated scattering processes.

In more recent work Lecheng, together with Professors Spradlin and Volovich and, along with Professor Vergu, found an explicit analytic result for a certain class of amplitudes whose symbols have been known for several years. In their study, such amplitudes are combinations of volumes of hyperbolic orthoscheme (a special type of hyperbolic simplices), using recent work by mathematician Professor Rudenko from the University of Chicago.

Along with Dr. Chi Zhang from Niels Bohr Institute, Lecheng is also working on computing the symbol structure of a more complicated class of amplitudes. According to their study, such amplitudes can be represented by some simpler amplitudes, which has been fully understood by physicists for years, in a polylogarithmic integral that can be performed via the dlog-form prescription.

There are still many interesting questions to be studied in the future. The Galkin Fellowship will allow Lecheng to focus his attention on these problems and to continue exploring the mathematical structure of amplitudes from the explicitly computed results, including those completed by Ren and collaborators. On the other hand, discovering the new hidden mathematical properties will make previously difficult calculations possible.

"It is a great honor to receive the Galkin Fellowship. **I want to express my gratitude to Mr. Warren Galkin for this support."**

Lecheng Ren

ALUMNI SPOTLIGHT

BROWN PHYSICS

CONDUCTING RESEARCH WITH A NOBEL LAUREATE

Yeung Luk Chong '04 Ph.D.

Leon Remembered: An impact resonating like a timeless melody

By Yeung Luk Chong '04 Ph.D.

While at Brown Physics, Yeung Luk Chong worked closely with Nobel Laureate Leon Cooper. Upon completing a postdoc in the Neuroscience Department, she planned to return to Brazil and transition from academia to management consulting at McKinsey. Prof. Cooper advised her during this difficult decision. Yeung says Brown was critical to her success because "the analytical skills that I matured at Brown, the intellectual curiosity to learn new things quickly, were fundamental throughout my career."

I worked under Professor Leon Cooper at the Physics Department's former Institute for Brain and Neural Systems between 2000 and 2004. I came to Brown because of him. As an undergraduate at the University of São Paulo, I was studying neural networks when Leon visited my university just as I was graduating. That visit paved my way to Providence. I remember feeling excitement and trepidation about the prospect of working under a Nobel Laureate. Would he have time for me? Would I feel intimidated?

I needn't have worried. Leon didn't have to take me seriously—a Chinese-Brazilian graduate student born long after he had won his Nobel Prize—but he did. He ensured I had a voice in weekly team meetings (something that didn't come naturally to me). He encouraged me to present at conferences, publish my work, and engage with the scientific community. He supported me with funding, ensured I participated in summer schools, and helped me navigate academic life. These might sound like "PI 101", but anyone who has been through graduate school knows this kind of mentorship cannot be taken for granted.

Combined with his well-known intellect, clarity of thought and passion for the sciences, his lesser-known empathy made him an inspiring advisor who profoundly impacted the careers of many generations of physicists. As Brian Blais (Physics PhD, class of 1998) put in a letter for Leon's 80th birthday: "Although I know that I am, at best, a mediocre physicist, you have always made me feel as if I were much better." Nicola Neretti (Physics PhD, class of 2001) echoed this sentiment: "Dr. Cooper wasn't just an incredibly bright and insightful mind; he was a wonderful human being, a kind and generous mentor who guided those around him with patience and wisdom."

I remember one moment in his office on the seventh floor of the Barus and Holley building. I was showing him results from my computer simulations, attempting to replicate his famous BCM theory, not in neurons that sent continuous, analog signals (as it was commonly done), but in neurons that sent "spikes", or binary ones-and-zeros (an emerging approach at the time). At some point, he asked me: "Why do we study physics?" I shrugged without an answer. To me, it was the most logical of the exact sciences, one that lends its logic to the other sciences I did not comprehend, like Neuroscience.

This was in the early 2000s, and Leon, who had already made a splash around campus with a course titled "Physics for Poets," was then teaching a course based on the amazing play Copenhagen, produced by Providence's Trinity Rep, about physicists Heisenberg and Niels Bohr. A student in that class had asked him, ″ Why do you study physics?"
"It's like music." He offered his answer. He did not say it was the only correct answer, but his smirk was pretty telling. "You could live without it, but why would you?"
This was classic Leon. He treaded physics, neuroscience, music, and art with a mix of ease and

Yeung Luk Chong '04 Ph.D.

Cont'd.

awe. Pete Bilderback, his long-time assistant (from 2000 to 2020), recalls: "Leon's approach to teaching physics was unique. Instead of presenting physics as a set of dry facts and equations that described how the world works, he emphasized that it was a human creation that could and should be appreciated for its aesthetic beauty."

In the end, the BCM theory, which explains how synapses change with neuronal activity, was successfully applied to spiking neurons, and I received, after all, my PhD degree. This theory remains a cornerstone in explaining synaptic plasticity, and, as Nathan Intrator (Applied Math PhD, class of 1990) observed: "As far as I know, this theory ... has not been experimentally refuted. The significance of this work is monumental."

Pete Bilderback writes: "Perhaps the greatest lesson Leon taught me was to ignore anyone who said a problem couldn't be solved. Just because a problem is difficult and seems intractable doesn't mean it can't be solved. Put your head down, keep working on it, and ignore the naysayers."

For Harel Shouval, a Physics PhD student from the class of 1994, the most crucial takeaway from Leon was his approach to science: "I came into Leon's lab thinking sophisticated mathematical techniques were the most important skill. I learned that the most important thing in science is a significant, well-defined problem. Once you have a clear question and an idea, techniques come into play. Fancy methods are useless if they address vague ideas or insignificant problems."

I, too, learned indelible lessons from Leon in the formative years of my career. First, never take yourself too seriously. Leon never came across as too self-important, and even though he would articulate passionately, it was for the sake of science, not pride. Second, it is always about the people -- students, collaborators and the lab community. Leon devoted endless energy to advising students, brainstorming with colleagues, and finding new ways to teach, all with a characteristic smile. Finally, stay curious and marvel at the Sciences as one appreciates good music. This boundless curiosity, I believe, is why Leon was able to leave lasting legacies in such disparate fields—superconductivity and neuroscience. For those of us fortunate enough to have been part of his journey, his impact will resonate like a timeless melody.

Yeung Luk Chong (2nd from left) with Leon Cooper (Center), Nicola Neretti (fifth from left, back), Brian Blais (third from left, in red), Peter Bilderbeck (far left), Harel Shouval (third from right), at her farewell lunch. Photo courtesy of Yeung Luk Chong.

ALUMNI SPOTLIGHT

BROWN PHYSICS

AI: At the intersection of science & finance

Michael Luk '13 Ph.D.

FINDING A SIGNAL IN THE NOISE

By Valerie DeLaCámara

Michael Luk received a Ph.D. in particle physics from Brown in 2013 and a Master of Advanced Study in applied mathematics from the University of Cambridge. He is a managing director and the AI Academy Dean at Deloitte and Chief Technology Officer of SFL Scientific. Michael's work focuses on machine learning, deep learning and AI with a focus on building and integrating large-scale enterprise models, frameworks and solutions that provide a demonstrable return on investment.

On his first day in his Ph.D. program at Brown, Mike Luk '13 Ph.D., met a lab partner and a postdoc, two people who would become cofounders of his company SFL Scientific.

After graduating, they worked in various industries for several years. Mike says, "During grad school, you always say you're going to start a company someday." They said just that while at a barbecue several years later. Mike laughs at the recollection, saying, "We pretty much started the company on LegalZoom and paid a minimal fee to register an L.L.C." He explains they chose AI because of their data science and physics analytics background, "so AI seemed to make sense." Starting with consulting also made sense, given there were no start-up costs. The group subsequently bid on – and landed – several projects and quickly built what Mike refers to as "street cred" by working for companies like Staples and L'Oréal. They built a website around the successes, and word got out about their formidable AI prowess. Soon, clients began to come to them.

Later, they partnered with Amazon Web Service (AWS) and Nvidia, who had plentiful resources but no one to build out their platforms within an AI framework. AWS and Nvidia each outsourced that project to Mike's team, and with this work, the company grew from 0 to 60 clients within eight to nine years.

Now a managing director at Deloitte, Mike's role entails running the delivery team and overseeing technical execution on all projects, with his team now numbering nearly 100 members.

Recently, Mike volunteered to help Deloitte build learning journeys around AI and is currently the "AI Academy Dean." When they were a startup, Mike says, the partners had their work cut out "to learn first; only then could we teach." They learned all they could about the areas they needed to gain background in and used that knowledge to train their team. "There was a lot of trial and error," he says. News of his success training his team on AI spread within the firm. Soon, Deloitte approached him with the proposition of bringing his AI knowledge to everyone at the firm, given the paucity of in-house expertise in AI. As the dean, he now oversees much of the content building, secures relationships with partners in academia, and builds an external footprint with clients.

Mike's purview is anywhere from 10 to 20,000 people in AI, with varying levels of experience, from people who don't have any base of knowledge to those who are advanced. One of the key areas that Mike enjoys is influencing large groups of people in the AI learning space. He says, "We do a lot of theory, how to talk about it with clients, how to run projects, and then we get down to the real nitty-gritty, hands-on keyboard. The participants run the whole spectrum, from just being colloquially good at it to being able to implement high solutions."

When asked about the intersection of physics and AI and how a degree in physics helped him succeed in the AI arena, Mike says Deloitte focuses on hiring those with Ph.Ds. in STEM fields for their talent. He says, "Many of the STEM fields are trained for analytical thinking, methodical ways of working and

Michael Luk '13 Ph.D.

Cont'd.

breaking down a problem systematically; that's exactly how we operate. Most of the time the actual crux of the modeling, the algorithms, aren't that important. It's how you break down the business problem and the thought process of taking a client's huge problem and breaking it down. The algorithms I can tell you, that's the easy part. It's the conceptual aspect of finding value, finding a signal in the noise."

According to Mike, the physics theory and equations in his Brown classes were much more complex than the mathematics necessary in his day-to-day work now, making his work much easier. He says, "It is relatively easy to theoretically understand the problems I face because of the formal foundation (in physics)."

Mike advises current physics students to remember that it's not about the problem; it's how you solve it. He says that AI people are different in how they tackle issues and that you must find your way to break down problems and solve them. "Doing all the problem sets and working through experiments has a lot of value in itself, but that process of learning how you would do it and how you best operate is what you are learning by doing problem sets and physics in general. It's not necessarily the exact physics behind it that's useful for jobs external to academia, but formal physics training teaches you how to solve the problem best. For example, by reading about a resource first and then theorizing, understanding the physics behind it, and then breaking it down in these three ways and working through it. If you do it in that methodical way a million times throughout a five-year physics Ph.D., you get used to doing it. Then, every problem you see in a job is much easier to tackle because you already know a way to break it down so that you can solve it."

In his daily work, Mike frequently draws upon experiences from his time at Brown Physics, primarily the lessons he learned from his advisor, Ulrich Heintz. Mike says, "Ulrich was a great advisor and a personal mentor for my work at Brown, especially his leadership style of trusting me to do my work and helping me when necessary. I try to bring a lot of that into my leadership style." He particularly values Brown's ubiquitous acceptance of curiosity. "My professors were very accepting of inquisitiveness and potentially being wrong. Being wrong and venturing to suggest something should be applauded. One of my professors said, 'There are no stupid questions, only stupid people.' That's one of my favorite quotes because it taught me that you're not showing ignorance by asking questions."

Attending colloquia and seminars was one of the things Mike loved most during his time at Brown. He remembers a theory colloquium where he spied a noteworthy attendee who happened to be visiting Brown to collaborate with the physics faculty. Mike says, "I was shocked to see Nima Arkani-Hamed, who revolutionized three or four fields in physics, in attendance in the audience – and he was taking notes! That made a huge impression on me. It was inspiring to see this towering figure in physics taking notes in a seminar another physicist gave. It resonated deeply with me that he was learning things – I even remember that he was wearing a rugby shirt! These are the types of experiences we hope to provide in the AI Academy. We are trying to create a community of excellence in learning similar to that which I experienced at Brown Physics."

ALUMNI SPOTLIGHT

BROWN PHYSICS

EXCEPTIONAL ACHIEVEMENT

Kam Tuen Law '08 Ph.D.

2024 APS FELLOWSHIP

Kam Tuen Law '08 Ph.D. entered the Brown Physics Ph.D. Program in 2003 under the supervision of Professor Dima Feldman. After graduating from Brown, he spent three years at MIT as a postdoc fellow. He joined the Hong Kong University of Science and Technology (HKUST) as faculty in 2011, where he is currently professor and chair of the Department of Physics, Associate Dean of Science (Research & Graduate Studies), Associate Director of Center for Quantum Materials and Associate Director of Center for Theoretical Condensed Matter Physics. He tells his Brown Physics story below.

Photos: Courtesy Kam Tuen Law

Kam Tuen Law's faculty photo (above) and, at left, he proudly wears his Brown University doctoral robes to preside over the Hong Kong University of Science & Technology graduation on November 24th as associate dean of Science, professor and chair of the Physics Department.

Under Professor Dima Feldman, I studied how electrons confined in a two-dimensional plane and under extremely strong magnetic fields can be fractionalized into quasi-particles with fractional charges. When this happens, the electrons are in the so-called fractional quantum Hall regime. Importantly, when two identical quasi-particles carrying fractional charges are exchanged, the quantum state of the whole electronic state can be altered.

The quasi-particles with this exchange properties are called non-Abelian particles, and they can be building blocks of fault-tolerant quantum computers. Prof. Feldman and I spent several years finding ways to detect non-Abelian quasi-particles in fractional quantum Hall states. I was truly blessed to have worked with a world expert in fractional quantum Hall states. Prof. Feldman's significant contribution to the study of fractional quantum Hall systems is one of the reasons that he was elected an APS fellow this year. My time spent at Brown was instrumental in setting the stage and direction for my career development.

After graduating from Brown, I moved to MIT as a postdoctoral fellow. My first project there was to study another non-Abelian quasi-particle, called Majorana zero modes (MZMs), which emerge in a special type of superconductors called topological superconductors. This type of topological superconductors, in some way, is a superconducting version of quantum Hall states that I had studied at Brown! Therefore, it was very natural for me to study MZMs.

Soon, my collaborators and I discovered some very important properties of MZMs, which could help to detect these exotic particles. We predicted that when a metallic lead is coupled to a MZM of a superconductor, the tunneling conductance from the lead to the superconductor is quantized to 2e^2/h, where e is the electron charge and h is the Plank constant. This prediction is being tested by many experimental groups around the world. Basically, all the projects during my postdoc years were a natural extension of what I had learned at Brown.

In 2011, I joined HKUST as a faculty. In the first few years as a faculty, the study of MZMs remained as my main research focus. In 2014, a very interesting experimental finding attracted my attention. Experimentalists found that superconductivity in some two-dimensional transition metal dichalcogenides cannot be destroyed even by the largest possible in-plane magnetic fields generated in the laboratories.

ALUMNI SPOTLIGHT
BROWN PHYSICS
EXCEPTIONAL ACHIEVEMENT

Kam Tuen Law '08 Ph.D.
Cont'd.

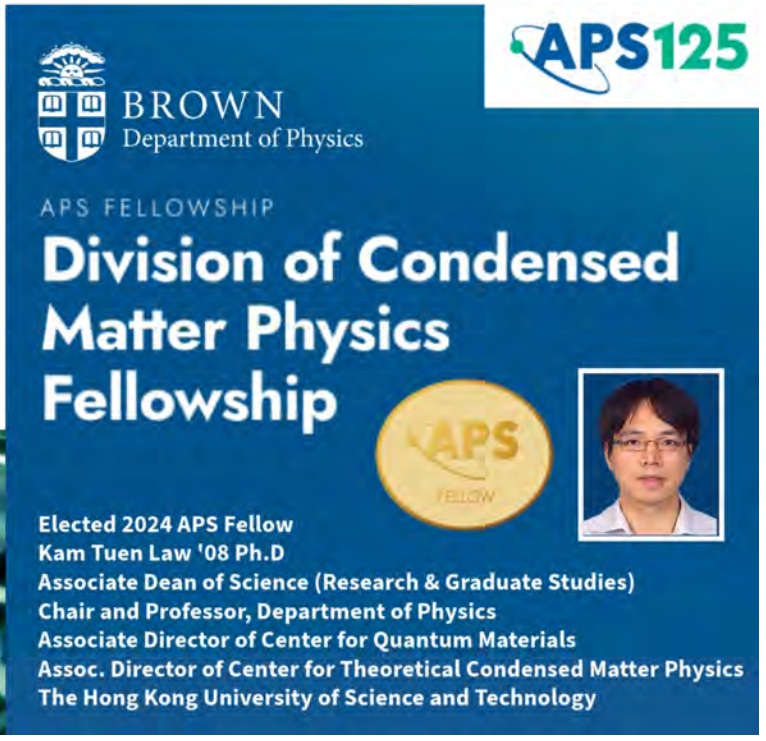
Photo: Courtesy Kam Tuen Law

At left, Kam Tuen Law is shown upon his arrival at Brown in 2003. He has been at the Hong Kong University of Science and Technology (HKUST) as faculty since 2011, where he is currently professor and chair of the Department of Physics, Associate Dean of Science (Research & Graduate Studies), Associate Director of Center for Quantum Materials and Associate Director of Center for Theoretical Condensed Matter Physics. He was nominated a member of the American Physical Society this year.

We explained these experimental results by pointing out that the electron spins in some transition metal dichalcogenides are pinned by a special type of spin-orbit coupling we called Ising spin-orbit coupling. The Ising spin-orbit couplings hugely suppress the detrimental effects of the in-plane magnetic fields on superconductivity. We called superconductors with Ising spin-orbit coupling, Ising superconductors. In recent years, many more Ising superconductors were discovered.

I was elected an APS fellow this year for the study of MZMs and Ising superconductors. I am particularly honored and humbled that I was elected in the same year as Prof. Feldman, who guided me into the world of condensed matter theory!

Looking back, the experience of studying at Brown was precious. We were able to interact with Prof. Leon Cooper regularly during the weekly seminars. We were taught statistical physics, including Kosterlitz-Thouless transitions, by Prof. Michael Kosterlitz. We learned quantum field theory from Prof. Gerald Guralnik, who was one of those who had discovered the Higgs mechanism. The experience at Brown prepared me and gave me confidence to tackle some of the most important problems in theoretical physics. I trust that Brown Physics will keep up the tradition of excellence and students will continue to benefit tremendously from the exceptional faculty members at the department.



PROFESSOR CHUNG-I TAN: OVER FIFTY YEARS AT BROWN PHYSICS

By Valerie DeLaCámara

Celebrating a career spanning five decades, the Physics Department honored Professor Chun-I Tan for his service to Brown.

Humbled by the kind words of those who gave tribute to him, Professor Tan expressed his deep appreciation for the event and all the attendees present to wish him well. He said it "seemed like just yesterday" that he and his wife, Corinne, arrived in Providence in 1970. They thought Providence a strange place, where their search for a "nice Chinese meal" brought them to a corner of Providence known as China Wall – not for the eating establishments, but for the number of Chinese laundries in the area.

A self-described "physics gypsy," Professor Tan describes feeling "bonded together by some mystical forces" with other physicists who, like the physics conferences that move from one exotic location to another, follow the road where physics takes them. Professor Tan and Corinne were also grateful to have bonded with an extended family "tied together through this institution called Brown."

Professor Tan describes being "deeply moved" by the crowd gathered at his retirement party, folks from physics, the larger Brown community, and outside of Brown. He says he will miss the close, informal interactions with colleagues, staff and students and fondly remembers former staff Sara Tortora and Mary Ann Rotundo.

Among the more memorable events Professor Tan remembers over the years is initiating the "annual degree days," where physics alumni return to Brown for a weekend reunion. This event was unfortunately stopped, in part, due to Covid. He recounts a lasting accomplishment of his, convincing the Engineering School to re-organize room space for both the third and fifth floors to yield space for Physics. He recalls that this was a challenging project that he credits with contributing significantly to the Department of Physics, forming a more coherent department. He also fondly remembers the opportunity to get to know physics benefactors Joyce and Warren Galkin in his many interactions with them over the years.

Speaking about the role of faculty throughout one's career, Professor Tan reflected, "As a physics faculty, we all began our careers at Brown balancing our efforts between teaching and research. As one moved up and became a more senior faculty member, one began to spend increasingly more time caring for the department's welfare. Our ultimate role at Brown is to serve as teachers of physics. Our preoccupation has always been finding a better way of explaining abstract physics concepts to others."

Working under 11 department chairs over the years, Professor Tan came to Brown under Bob Beyer, then Art Williams, Phil Stiles, Bob Lanou, Charles Elbaum, Tony Houghton, and David Cutts. After serving his term as department chair, Professor Tan recalls subsequent chairs Jim Valles, Gang Xiao, Meenakshi Narian, and now Vesna Mitrović.

As department chair, Professor Tan consulted with a friend who had become a successful administrator at another school and told him to remember his constituents: faculty colleagues, staff members, and students. These words served him well as department chair, and he fondly remembered former staff who "kept the department running smoothly, dealing with the needs of faculty and students. I am happy to note that the baton has now been passed to Douglas (Wilkie), and the tradition of excellence has continued."

Professor Tan recalls his graduate students over the years and acknowledges Costas Orginos, now a professor at William and Mary, who attended the retirement party to wish Professor Tan well. Others with whom he worked close-

Chung-I Tan addresses the crowd of those who came to wish him well in his retirement. PHOTO: Ariel Green/Brown Univ.

BROWN
Department of Physics
Box 1843
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Providence, RI 02912

Still images from third-year Ph.D. student Anthony Englert's time-lapse video.
Location: Providence, RI
Time: Time-lapse created with images taken from 2:15-4:00pm, April 8, 2024
Equipment: 90mm Coronado Solar Max I, ZWO ASI 1600MM

Anthony says it was a great day to image the sun, as these photos show ". . . the activity scattered around the main disk along with the prominences on its edges. Some high-atmosphere thin clouds were rolling over throughout the event, which is causing the small 'jitter' from frame-to-frame, along with changes in the illumination of the disk."