BROWN PHYSICS

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FALL 2022

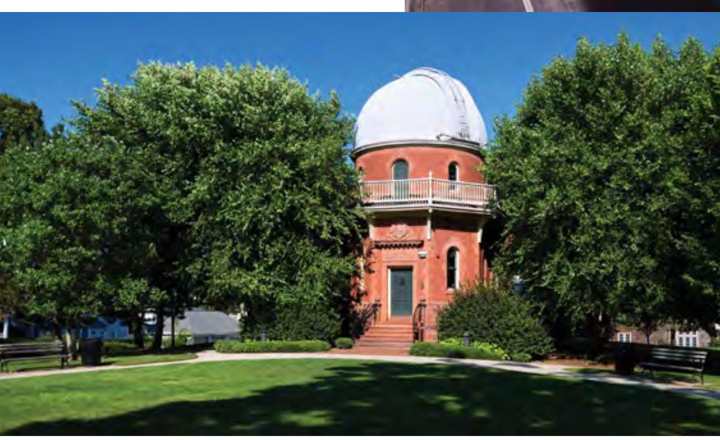
BROWN

4

CELEBRATING OUR GRADUATES!

25

LHC CELEBRATES HIGGS DISCOVERY, BEGINS RUN 3



29

FRANCINE JACKSON, 50 YEARS AT LADD OBSERVATORY

IN THIS ISSUE

FACULTY & RESEARCH

STUDENTS

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Front cover:
Inside the dome at Ladd Observatory.
PHOTO: BOB HORTON/BROWN UNIVERSITY

Back cover:
"A Window Between Worlds," South Window Arch, Arches National Park, Utah.
PHOTO: DONOVAN DAVINO/BROWN UNIVERSITY

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BROWN TOGETHER

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MAKE A GIFT

GREETINGS FROM THE CHAIR...

Greetings from Brown University's Department of Physics, and welcome to the Fall 2022 edition of Imagine magazine.

In this issue, you will read about the many accomplishments of our faculty and students. Here at Brown we are doing cutting-edge research in multiple fields of physics that will shape our future understanding of the universe's structure from its largest scale down to the sub-atomic level.

Our faculty and students are working on some of the most ambitious science experiments ever undertaken. Brown physics researchers are pushing the boundaries of nanomaterials and biological physics, while others probe the universe's structure and explore the interconnection between the smallest and largest entities in the cosmos. We have 28 faculty members engaged in six different research areas. Our department has about 160 graduate students, 70 undergraduate physics concentrators (juniors and seniors), and 22 post-doctoral fellows.

As we celebrate the tenth anniversary of the first observation of a Higgs boson, Brown high-energy experimental researchers are participating in the Compact Muon Solenoid collaboration at the CERN Large Hadron Collider looking for new particles beyond what is predicted by the Standard Model to solve some of the deepest mysteries in physics.

Meanwhile, nearly a mile below the surface of Lead, South Dakota, Brown researchers are working on the LUX-ZEPLIN experiment, searching for the elusive entity that comprises 85% of the universe's mass – dark matter.

Cultivating a diverse and welcoming environment remains among the department's highest priorities. Our current cohort of Ph.D. students is 32% female. For comparison, according to the American Physics Institute, as of 2019, only 20% of physics doctorates were awarded nationally to women. The class of 2022 saw us graduate our largest ever cohort of female Ph.D. students. At Commencement, the department awarded seven Ph.D. degrees to female students, representing 50% of our spring graduating class.

In addition, this year, the department awarded 13 undergraduate and 10 Sc.M. degrees to female students, our highest total ever. Over the past 10 years, the percentage of departmental undergraduate degrees awarded to women has risen from 26% to 38%. This progress is a testament to the department and the University's dedication to equity and inclusion and our hard work to create an inclusive culture.


Meenakshi Narain
PHOTO: COURTESY SCOTT LAPHAM

I'm very grateful to our excellent faculty, who continue to do cutting-edge research while teaching and mentoring the next generation of physicists. As you will read, many of our faculty members have been recognized with prestigious awards and had their research published in high-impact journals over the past year.

Two stories in this issue brought added public attention to the department and the University.

Manfred Steiner earned his Ph.D. from the department at the age of 89, fulfilling a lifelong dream of becoming a physicist. His story traveled around the world and reminded us that you are never too old to stop learning.

One of our Ph.D. students, Rutendo Jakachira, recently earned national attention for her work creating a new kind of pulse oximeter that will give accurate readings across a variety of skin tones. The device could lead to better health outcomes for communities of color in the U.S. and worldwide.

I'd like to thank our administrative staff, who have worked tirelessly to keep the department running as we deal with the fallout from the pandemic. Retaining good staff is more difficult than ever, and we owe a debt of gratitude to our team for their commitment to the department and willingness to move outside their comfort zones and shoulder extra responsibilities.

Finally, I'd like to thank Professor Gang Xiao, who stepped down as chair after guiding the department for the past six years. Gang's vision and dedication to excellence brought the department to new heights, including strengthening the focus on new research initiatives.

Meenakshi Narain
Department Chair

AN UPDATE FROM LADD OBSERVATORY

There was good news for Ladd Observatory this year. Although the pandemic was still part of the community, we were able to open on clear Tuesday nights, but with caveats: First, of course, everyone had to wear a mask; also, only a certain number of persons were allowed in at one time; plus, each person was given a particular time frame to come in. The two-hour openings were broken into four half-hour increments, with each person assigned one of the four times. Finally, every guest had to register on Eventbrite, and Curator Michael Umbricht, stationed at the door, checked and welcomed every visitor. As all who came were so glad to return to the building, there were no hassles or discouraged patrons.

Once inside, each visitor went up the stairs to the dome. At first, it was felt the safest views would be by video, where the 12-inch refractor's eyepiece was replaced with a camera, and the images projected on a screen elsewhere in the room. But as all of us are aware, nothing compares to actually viewing the chosen object directly. So, as long as caution and sanitary procedures were taken, every visitor was once again allowed to climb the stairs and look directly at whatever object the telescope was set to.

After several minutes upstairs, many of the guests chose to come downstairs to view the rest of the building. Ladd Observatory was dedicated in 1891, and to this day, the staff does everything possible to keep the feeling of that time. No one wants Ladd to "grow up." It is too beautiful as is to bring it into the 21st century. The antique clocks, the 19th century time mark recorder, and even the transit room, used for decades as the community timepiece, are all as perfectly preserved as possible.

A couple of years ago, community residents realized this block-long section of Providence had no actual designation, and it was suggested to have the city name this area "Observatory." As of yet, there has been no further known work performed to honor Ladd in this way. We are still hoping, though.

To increase Ladd's exposure in the community, in addition to the highly successful weekly Ladd notes, the staff is working on a monthly newsletter, bringing more astronomy information to the public. The articles will be written by professional and amateur astronomers and students who have realized the beauty of the subject and want to further show their love of astronomy. The first edition will be available soon.

Finally, someone in the physics department realized I have been a fixture at Ladd for several decades. Overall, it has been a wonderful 50 years being a part of this incredible part of Brown's history, and I'm definitely planning on continuing to stay here and view Halley's Comet up on the deck when it returns—in 2061.

Francine Jackson
Staff Astronomer

TABLE OF CONTENTS

CELEBRATING OUR GRADUATES!

"Find community in the department!"

PHOTO: COURTESY JOELLE DONG

HANNAH MCFARLAND

A.B. Physics/History of Art and Architecture

Do you have any advice for new physics students?

Find community within the department! Whether it's with the DUG or the WiSE or just going to conference sections and making groups with the other people in your classes. It will be a lifesaver and will also just make things more fun!

What was your favorite physics course (and why)?

My favorite course was Medical Physics (which is slightly cheating since it's my field). I really enjoyed getting to think about bigger picture stuff and apply all the physics knowledge we've been working on and learning for years. It was also nice to be in a smaller class (there were only four of us) where we could really interact with each other and the professors, which was a huge benefit of the upper level/seminar style courses.

SANCHI S. SAITIA

Sc.M. Physics

What was the biggest lesson you learned during your time in the department?

My two years spent at Brown were actually some of the most transformative years for me. I learned a lot, both good and bad, about myself and the world around me. My top three lessons learned: I learned to be kind to myself (and others) when it comes to studying and understanding material—no one is expected to understand everything right away! I also learned the importance of prioritizing mental and physical health above all. No matter how hard you force yourself to work, sometimes your brain just needs a break. And finally, I learned the value in putting myself out there both socially and professionally to open myself up to new opportunities and relationships. Take advantage of all that an institution like Brown has to offer!

What is next for you?

I will be starting my Ph.D. in physics at University of California, San Diego in September 2022!

PHOTO: COURTESY KHING KLANGBOONKRONG

PHOTO: COURTESY AMBER FEHRS

ADAM FURMAN

Sc.B. Mathematical Physics
A.B. Computer Science

Tell us a story about your time at Brown.

The first time I applied to be a DUG coordinator, I didn't get the job. I was told very politely that my enthusiasm was very much appreciated, but that at this time they had chosen someone else. I was crushed. Jean Allen, then one of the coordinators, who I knew a little, stopped me in the lobby and asked me if I'd like to meet over some tea or coffee later. So I went, slightly nervous, and unsure. And he sat me down, and we talked philosophy—ideas about the physics department, about the DUG, about how organizations in general should be structured and led, and of course, about our own lives and troubles. We talked for hours and I didn't realize time had passed. Afterwards, he told me to be sure to apply again. I made a friend that day, but I also learned something I will never forget: the emotional, almost spiritual weight, of someone taking that kind of time to talk and to connect. There are many ways to express love, and that day, I learned a new one.

LEAH JENKS

Ph.D. Physics

What was your favorite course?

General Relativity.

What will you remember most fondly about your time in the department?

I will always have great memories with the amazing people in my cohort.

Do you have any advice for new physics students?

Physics can seem intimidating and scary, but with perseverance and hard work anyone can succeed!

Who at Brown have you found inspirational and why?

I have found Professors Volovich, Narain, Fan, and Mitrović extremely inspiring! It was great to have successful women in the department who I could look up to as role models.

What is next for you?

I will be starting as a postdoc at the University of Chicago in the fall!

PHOTO: COURTESY LEAH JENKS

"It was great to have successful women in the department who I could look up to as role models."

TABLE OF CONTENTS

PHOTO: COURTESY DARRYL SHAW

BATIA FRIEDMAN-SHAW

Sc.B. Mathematical Physics

What will you remember most fondly about your time in the department?

My friends. We had a great time mulling over problem sets for days on end, getting a better understanding with each tiny breakthrough.

What was the biggest lesson you learned during your time in the department?

It's normal for unfamiliar areas of physics to look like indecipherable hieroglyphics half the time. You just have to take your time, ask plenty of "dumb" questions, and eventually you get a strong foothold.

What was the biggest obstacle you had to overcome in obtaining your degree?

COVID. Physics is always better with friends and the isolation was extraordinarily difficult for me in general. But I was so happy to come back to Barus and Holley (BH: the "Beloved Home") as soon as classes were back in person. One lady in the building actually thought I was a first-year student because of how excited I looked to be back.

What is next for you?

Next year I'll be heading to Canada for a one year Master's program and then to California for a Ph.D.

RONG CONG

Ph.D. Physics

What is next for you?

I am doing a postdoc at Brown after graduation.

With adviser Vesna Mitrović.

PHOTO: COURTESY ERICK GARCIA

KHING KLANGBOONKRONG

Sc.M. Physics

What was your favorite course at Brown and why?

PHYS2280—Astrophysics and Cosmology. The class structure was nice and helpful. We got to read a paper every week, and Ian is an amazing teacher.

What will you remember most fondly about your time in the department?

The people at Brown!

What is next for you?

I will be staying at Brown.

PHOTO: COURTESY CHAYAPUNTIKA INDOUNG

"The majority of success is perseverance."

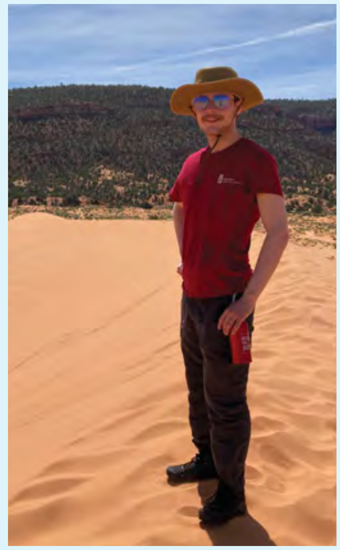


PHOTO: COURTESY NICHOLAS IDE

ALEX JACOBY

Sc.B. Mathematical Physics

What will you remember most fondly about your time in the department?

All the interesting characters! Some of them turned into very good friends.

Do you have any advice for new physics students?

Failing is the majority of what you do in research, so make sure to get a lot of practice! A closely related piece of advice is to continue challenging yourself until you fail. I find that's the best way to learn things (at least for me).

Who at Brown have you found inspirational and why?

Most people at some level. I think almost everyone has something important to offer, but sometimes it requires you to squint a bit to see what that is.

What was the biggest obstacle you had to overcome in obtaining your degree?

My father died in my first week at Brown. My first year here was really challenging.

What is next for you?

I will pursue a Ph.D. in theoretical physics at Princeton this fall.

MANFRED STEINER

Ph.D. Physics

What was your favorite course and why?

I was fortunate enough to be able to attend Professor Guralnik's last course before his untimely death. I cannot remember the exact title, but it was about general cosmology.

What was the biggest lesson you learned during your time in the Physics department?

There are always new subjects that caught my interest.

What will you remember most fondly about your time in the department?

My good relations with faculty and students.

Do you have any advice for new physics students?

If you love physics which I would assume is a given since you took up this study, immerse yourself in the many new findings and choose the one most appealing to you to dig in deeper.

What was the biggest obstacle you had to overcome in obtaining your degree?

There is nothing that I would classify as an obstacle but because of my age some problems arose that are common in my age group.

What is next for you?

To write a paper on one of the most important parts of my thesis.

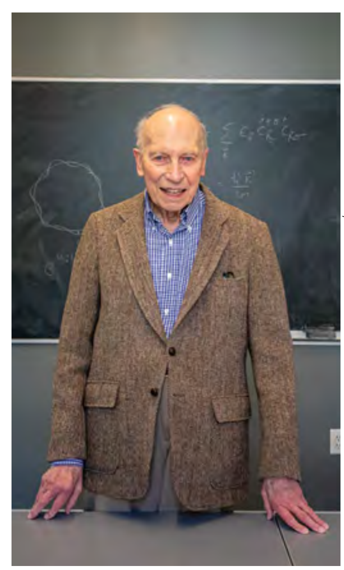


PHOTO: NICK DENTAMARO/BROWN UNIVERSITY

TABLE OF CONTENTS

The Class of 2022

BACHELORS

Ilya Bodo
Alexander Brown
Joseph Cavanagh
MinSik Cho
Duncan Crane
Eli Doyle
Alexandra Ekstrom
Andrew Friberg
Batia Friedman-Shaw
Adam Furman
Chace Hayhurst
Isabel Horst
Alexander Jacoby
Sean Kinnally
Jeremy Lutz
Hannah McFarland
Laurel McIntyre
Max Melendez
Shray Mishra
Nathaniel Nguyen
Rahul Shahi
Lucy Yujie Shao
Eli Silver
Phum Siriviboon
Liam Storan
Christopher Turner
Edgar Eduardo Villegas
Derek Waleffe
Stacey Xiang
Sean Yamamoto

STUDENT AWARDS

R. Bruce Lindsay Prize for Excellence in Physics
Alex Jacoby and Phum Siriviboon

Mildred Widgoff Prize for Excellence in Thesis Preparation
Liam Storan

Chair's Award for Excellence in Scholarship & Service to the Physics Department
Adam Furman and Isabel Horst

Smiley Prize for Excellent Contribution to the Astronomy Program
Edgar Eduardo Villegas

MASTERS OF SCIENCE

Shoog Saud Alharbi
Lily Anderson
Katharine Bancroft
Yunjia Bao
Kyle Barnes
Navketan Batra
Stellan Bechtold
Vineetha Bheemarasetty
Christian Capanelli
Zhemin Chen
Tatsuya Daniel
Donovan Davino
Zacharias Escalante
Yanyu Gu
Zhaochong Han
Rutendo Jakachira
Andrew Kent
Khing Klangboonkrong
Jaewoo Lee
Christopher Li
Shuangpeng Lin
Xiangcheng Liu
Xiaoyang Liu
Birzhan Makanov
Akshay Nagar
Musqan Nighojkar
Xiaochang Peng
Alejandra Rosselli-Calderon
Sanchi Saitia
Jiwoo Seo
Xinhao Wang
Ryan Weiss
Yuhao Ye

STUDENT AWARDS

Master's Research Excellence
Christopher Li

Outstanding Academic Accomplishment in Master's Program
Kyle Barnes

Engaged Citizenship and Community Service to the Physics Department
Sanchi Saitia

DOCTOR OF PHILOSOPHY

Bjorn Burkle, *Adviser: Ulrich Heintz*

Rong Cong, *Adviser: Vesna Mitrović*

Shenming Fu, *Adviser: Ian Dell'Antonio*

Erick Garcia, *Adviser: Vesna Mitrović*

Yangrui Hu, *Adviser: S. James Gates Jr.*

Leah Jenks, *Adviser: Stephon Alexander*

Chang Liu, *Adviser: David Lowe*

Jorge Mago Trejo, *Adviser: Anastasia Volovich*

Sze Ning (Hazel) Mak, *Adviser: S. James Gates Jr.*

Daniya Seitova, *Adviser: Jonathan Pober*

Charles Snider, *Adviser: Vesna Mitrović*

Manfred Steiner, *Adviser: Brad Marston*

Wai Shing Tang, *Adviser: Lorin Crawford*

William Taylor, *Adviser: Richard Gaitskell*

Wing Yan (Jess) Wong, *Adviser: Meenakshi Narain*

Wenyu Zhang, *Adviser: Meenakshi Narain*

Yiou Zhang, *Adviser: Gang Xiao*

Zekun Zhuang, *Adviser: Brad Marston*

STUDENT AWARDS

Galkin Foundation Fellowship Award
Yiou Zhang and Sze Ning (Hazel) Mak

Physics Merit Fellowship
Jorge Mago Trejo and Wing Yan (Jess) Wong

Physics Dissertation Fellowship
Yangrui Hu and Lijie Ding

Anthony Houghton Award for Excellence in Theoretical Physics
Yangrui Hu and Leah Jenks

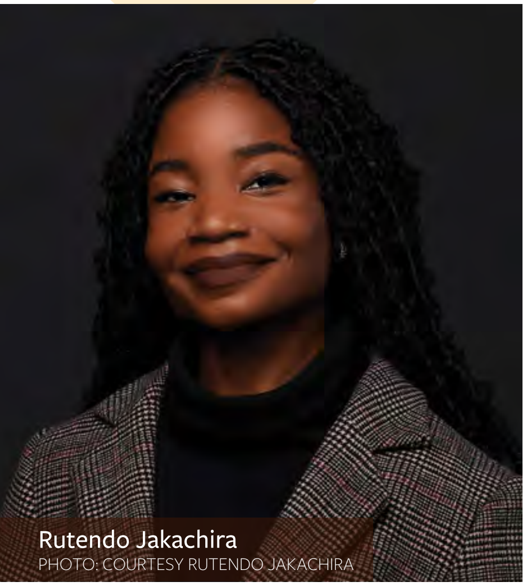
Forrest Award for Excellence in Work Related to Experimental Apparatus
Yiou Zhang

Jun Qi and Christine Geng Graduate Fellowship in Condensed Matter Experimental Physics
Michael DiScala

STUDENT SPOTLIGHT

RUTENDO JAKACHIRA WORKING TO CORRECT SKIN COLOR BIAS IN PULSE OXIMETERS

By Pete Bilderback


Rutendo Jakachira
PHOTO: COURTESY RUTENDO JAKACHIRA

Pulse oximeters provide a quick, non-invasive way to check someone's pulmonary health, using light shown through the skin to estimate the amount of oxygen in a person's blood. But the devices, which usually clip onto a finger, don't work well for everyone. Research has shown that people with darker skin are at much greater risk for inaccurate readings than those with lighter skin.

Rutendo Jakachira, a Brown University Ph.D. student in physics, is working to change that. She is developing new optical techniques that return accurate oxygen saturation levels results regardless of skin tone. She presented promising preliminary results for a potential device at a conference hosted by SPIE, an international society for optics and photonics. And another professional society, Optica, awarded Jakachira its Amplify Scholarship to continue her work.

The incorrect readings arise because melanin, the dark pigment found in skin and hair, tends to absorb light traveling through the skin. In people with dark skin, that high level of melanin scattering can interfere with oxygen readings. Jakachira, working with Professor of Engineering and Senior Associate Engineering Dean Kimani Toussaint, is looking to reduce the interference caused by the surface of the skin by carefully controlling the distribution of the electric and magnetic fields, oscillating at frequencies in the hundreds of THz, as it interacts with tissues. Jakachira and Toussaint are developing an algorithm that separates the melanin contribution from the oxy/deoxy hemoglobin contributions at any wavelength. Their algorithm is invariant to unwanted temporal fluctuations.

Jakachira and Toussaint have revealed the first single-shot, single-wavelength demonstration of pulse oximetry by leveraging an inhomogeneous wavefront distribution of the electric and magnetic fields for parallelization in their algorithm.

Testing of a prototype device's ability to detect blood-oxygen levels looks good so far, Jakachira said, "It looks like our device is working. We did a preliminary study on about five people, and although it was a small study, the results are promising and show a signal in the noise. We are looking toward doing a study on a larger population group, and the next step would be a clinical trial."

The fact that pulse oximeters are less reliable in Black patients has been known for many years but little has been done to address the problem until recently. In 1990, only a few years after the introduction of pulse oximetry, researchers published a study in CHEST Journal that reported that pulse oximetry was almost two and a half times less accurate in mechanically ventilated Black patients.

Pulse oximetry is an area in medicine where racial bias, whether overt or not, has had a negative impact and contributed to the documented lower quality of medical care for Black people in the United States. It's one of many problems that led the National Academy of Medicine (NAM) to release a report in 2002 that concluded that, "racial and ethnic minorities receive lower-quality health care than white people—even when insurance status, income, age, and severity of conditions are comparable."

Complicating the situation is the fact that pulse oximeters aren't just less accurate on patients with darker skin, they systematically overestimate their blood oxygen levels, creating situations in which patients with dangerously low blood oxygen levels receive readings in the acceptable range. The problem became particularly acute during the COVID-19 pandemic, during which doctors have relied on pulse oximeter readings taken in clinics and in homes to gauge the severity of a patient's illness.

A study published in the New England Journal of Medicine in 2020 found that "Black patients with critically low oxygen levels were three times more likely than white patients to have their levels overestimated." Recently, a study published in the Journal of the American Medical Association Internal Medicine revealed that inaccurate blood-oxygen measurements from Hispanic and Black patients resulted in these patients being about 25% less likely to be recognized as eligible for COVID-19 treatment."

Investigation of the problem has intensified since the beginning of the COVID epidemic; A recent study by researchers at Nottingham University determined that pulse oximeters provided false readings 5.8% higher for individuals of Black ethnicity with COVID-19 than individuals of white ethnicity.

Readings were found to be nearly 7% higher among individuals of mixed ethnicity. Dr. Andrew Fogarty, the lead author of the study, said, "This data builds on what we know, which is that patients with darker skin have less accurate oxygen measurements using the pulse oximeters. Any error of measurement of oxygen levels will make assessing the severity of COVID-19 infection more difficult, and may delay delivery of timely medical care."

Jakachira said her background in optics, which she studied as an undergraduate at Drew University working under Professor Bjorg Larson, attracted her to the project. She explained, "Last summer I was looking for research opportunities. I was introduced to Professor Toussaint because he has an optics background, and he proposed this project to me. It was a project started by one of his past master's students, Teniola Oguntolu." She adds, "I thought it was a perfect fit and happily accepted." Beyond the intellectual challenge, Jakachira said, "it's highly motivating to know that my Ph.D. work will help people in my community."

For his part, Professor Toussaint has been impressed with Jakachira's work. He said, "Rutendo has approached this project with a combination of dedication, ingenuity, and strong interest. This has allowed us to gain a better understanding of the problem in terms of the underlying optical physics, and to creatively think outside of the box in developing a solution."

UPDATE

Jakachira and Toussaint's work on pulse oximetry has gained national recognition. It was featured in stories on NPR's All Things Considered and NBC NOW, and in reports published by CNN, Bloomberg Business Week, The Boston Globe and POLITICO.

TABLE OF CONTENTS

FARRAH SIMPSON, EXPLORING THE UNKNOWN UNIVERSE AND MENTORING THE NEXT GENERATION

STUDENT SPOTLIGHT

By Lauren Borsa-Curran

Farrah Simpson
PHOTO: IDALINA ALARCON/BROWN UNIVERSITY

In speaking with Farrah Simpson, the excitement in her voice when the conversation turns to physics—and mentoring young students who might pursue the science she loves—is unmistakable.

"I love being able to have a positive impact on other people's lives," said Simpson, a Ph.D. student at Brown University. "I was always curious growing up. I remember I would always ask random questions that my physics teacher wasn't able to answer, and I'd go off and try to figure them out myself."

Simpson, who is from Jamaica, enrolled at Brown in 2018 after earning a bachelor's degree at Columbia University. Last fall, Fermilab—the U.S. Department of Energy's particle physics and accelerator laboratory—named her as one of two students in the nation appointed as 2022 Graduate Scholars to work at the lab's Large Hadron Collider Physics Center.

Simpson was overjoyed at the honor: "I honestly didn't really believe it," she said.

The award is related to the globally prominent Large Hadron Collider (LHC) program—the world's largest and most powerful particle accelerator, headquartered in Geneva. The LHC pushes protons or ions to near the speed of light in an effort to search for particles beyond the Standard Model, including a potential candidate particle for dark matter, the mysterious stuff thought to account for a majority of matter in the universe. Simpson will spend a year at Fermilab, the U.S. region lab, under the mentorship of Dr. Anadi Canepa, head of Fermilab's Compact Muon Solenoid (CMS) Department, pursuing thesis research focusing on the search for long-lived particles.

As part of her research at Brown, Simpson has been conducting searches for new particles predicted in Beyond Standard Model physics theories under the mentorship of Professor of Physics Meenakshi Narain—who chairs the collaboration board of U.S. institutions in the CMS experiment, one of two large-scale experiments happening at the LHC in Geneva—and in collaboration with current and former members of Brown's High-Energy Theory research group.

"The Standard Model describes what we currently know about particle physics," Simpson said. "But there are some discrepancies. Beyond Standard Model physics, which predicts the existence of these new particles, attempts to address these discrepancies."

Simpson said Narain played a crucial role in her decision to enroll at Brown.

"My main focus when deciding on a graduate program was to go somewhere I felt supported, where I could do the research I wanted to do," she said. "Brown has a very strong high-energy physics department with professors who are not just excellent at what they do, but who also take the time out to teach and mentor their students."

Simpson's other research at Brown, under the leadership of Professor of Physics Ulrich Heintz, involves upgrades to the Compact Muon Solenoid particle detector, which is at the LHC, to prepare for more frequent particle collisions that could lead to new physics and physics processes discoveries, she said.

"I think that's why I fell in love with physics," Simpson said. "The learning never stops, and it will never stop. There's so much more to learn and discover. You can never know everything or learn everything about the universe. Particle physics: it's not really about us humans. It's about something so much more."

In addition to her own research, Simpson is active in mentoring young physicists and promoting the role of women in physics.

"I have loved teaching since a pretty young age, but as I've gotten older and as I've entered spaces where women and people of color and Black people are underrepresented, I've realized the importance of mentorship," she said. "Mentorship is the reason I am where I am today."

A member of the Sigma Xi scientific research honor society, Simpson co-leads the Women in Physics group at Brown and sits on the organizational planning committee for the Conferences for Undergraduate Women in Physics (CuWip).

"Dr. Narain is the faculty adviser of the Women in Physics group and chair of the organizing committee for CuWiP, so we work closely in creating initiatives and programming for a more diverse and inclusive environment for women here at Brown," Simpson said. "One of the main reasons I chose Brown was community. Brown is very community-driven."

Last summer, Simpson worked with another mentor, physics professor Stephon Alexander, and the Harlem Gallery of Science to launch Dream+Inspire: Mentoring Future Leaders to recruit professors and graduate students from the ranks of the National Society of Black Physicists to serve as mentors for middle and high-school students, many of whom are from groups historically underrepresented in STEM fields, from Harlem and the South Bronx. Simpson serves as executive student representative on NSBP's board.

From 2017 to 2018 while a middle school teacher at Success Academy Charter Schools in New York, Simpson served as an adviser to students, helping them through challenges they faced as they worked to succeed in school. Locally, she has served on the planning committee for the Big Bang Science Fair, and event hosted by the physics department at WaterFire Providence. Simpson organized and guided hands-on workshops for kids that demonstrated the intersection of science and art.

As she looks toward her time at Fermilab and the final stages of her Ph.D. pursuit, Simpson said she expects mentoring and teaching to remain a significant part of her life. Giving back is a way of paying it forward after having mentors like Narain, Alexander and National Medal of Science winner S. James Gates Jr., a Brown professor and another mentor.

"Professor Gates has motivated me to continue because the truth is that this Ph.D. isn't really just for me," Simpson said "It's also for many other Black girls who feel like they want to be physicists, and they're not sure they can."

COMMENCEMENT 2022

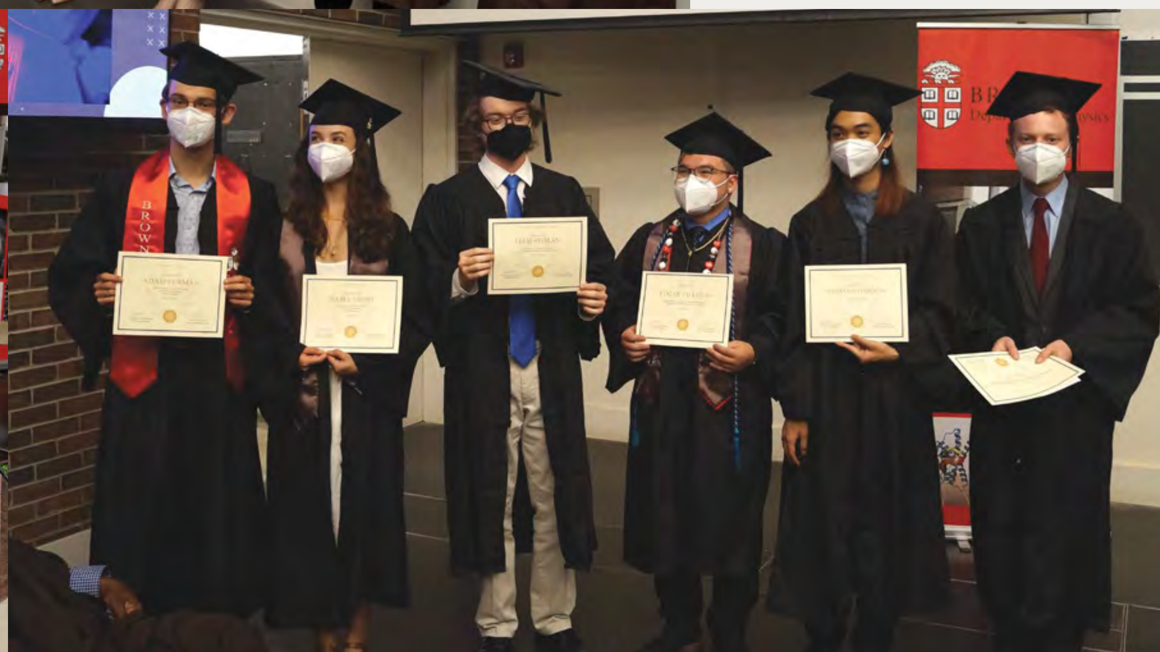
In person again at last!

Top: The Brown Physics Undergraduate Class of 2022

Center: Department Chair Gang Xiao delivers Commencement address / The Brown Physics Sc.M. Class of 2022

Bottom: The Brown Physics Ph.D. Class of 2022 / Stephon Alexander delivers keynote address

Left - Graduate Student Award Recipients (l-r): Wing Yang (Jess) Wong ’22 Ph.D., Jorge Mago Trejo ’22 Ph.D., Yiou Zhang ’22 Ph.D., Leah Jenks ’22 Ph.D., Yangrui Hu ’22 Ph.D., Christopher Li ’22 Sc.M., Sanchita Saitia ’22 Sc.M.



Above - Undergraduate Award Recipients (l-r): Adam Furman ’22, Isabel Horst ’22, Liam Storan ’22, Edgar Eduardo Villegas ’22, Phum Siriviboon ’22, Alexander Jacoby ’22

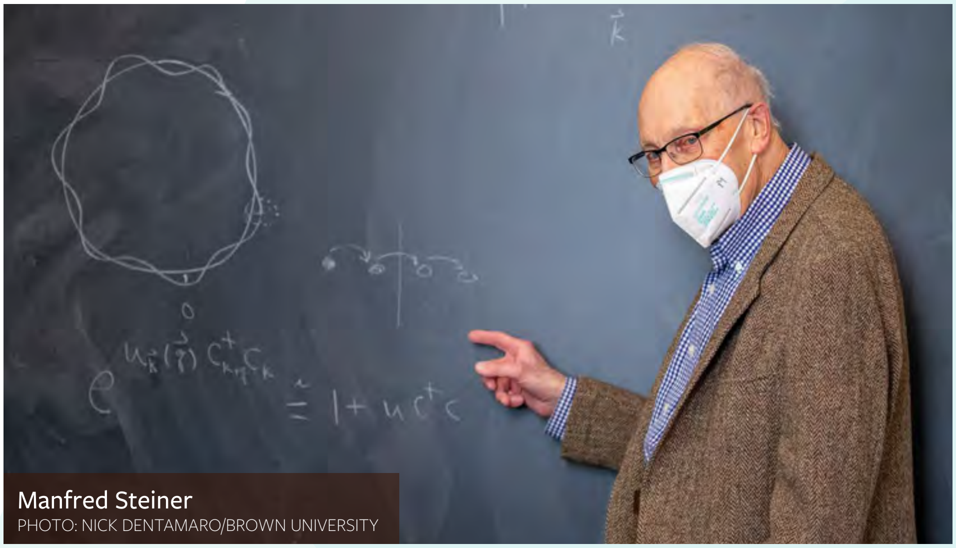
Left (top to bottom): Batia Friedman-Shaw ’22, Ryan Weiss ’22 Ph.D., Brian Barker ’22 Sc.M.

PHOTOS: PETE BILDERBACK/BROWN UNIVERSITY

TABLE OF CONTENTS

BROWN PHYSICS STUDENT MANFRED STEINER EARNS PH.D. AT AGE 89

By Pete Bilderback



Manfred Steiner
PHOTO: NICK DENTAMARO/BROWN UNIVERSITY

At the age of 89, Manfred Steiner is finally what he always wanted to be: a physicist.

Steiner successfully defended his dissertation in November of 2021 and received his Ph.D. from Brown University's Department of Physics in February of 2022. For Steiner, it is the realization of a lifelong dream—albeit one that was temporarily interrupted by a 30-plus-year career in medicine.

"It's an old dream that starts in my childhood," Steiner said. "I always wanted to become a physicist."

Now that he's done it, he plans to continue working with his adviser, physics professor Brad Marston, to publish journal articles based on his dissertation, titled "Corrections to the Geometrical Interpretation of Bosonization."

A WINDING ROAD

To say that Steiner's path to a Ph.D. in physics was not a traditional one would be an understatement. As a young man, Steiner fled the chaos of his birthplace of Vienna as World War II ended and eventually made his way to the United States.

"I knew physics was my true passion by the time I graduated high school," Steiner said. "But after the war, my uncle and my mother advised me to take up medicine because it would be a better choice during the turbulent after-war years."

Although he excelled at and loved physics, Steiner followed his family's advice.

"My uncle was a physician, an ear, nose and throat specialist, and he had taught in the United States for a while," Steiner said. "He taught plastic surgery—showing people how to make noses smaller or how to straighten them out. My family's advice was that medicine was the best path for me. So I reconciled myself, 'they are older and wiser,' and I followed their advice."

Steiner went on to earn a medical doctorate in 1955 from the University of Vienna and soon after his graduation he made his way to Washington, D.C. where he finished his initial training in internal medicine. He next began a traineeship in hematology at Tufts University under Dr. William Damashek, who the American Society of Hematology describes as "the preeminent American clinical hematologist of his time." The traineeship included a three-year training in biology at the Massachusetts Institute of Technology and he earned a Ph.D. in biochemistry there in 1967.

Steiner moved to Rhode Island when he was offered a position as a hematologist in the newly established Program in Medicine at Brown University (now the Warren Alpert Medical School). In 1968 he was appointed as an assistant professor of medicine, working primarily in research. He was promoted to full professor in 1978. In 1985 Steiner was appointed head of the hematology section of the medical school, a position he held until 1994.

When approaching retirement, an associate of Steiner's became chief of hematology at the University of North Carolina, Greenville, and asked Steiner to join him to establish a research program in hematology. Steiner went on to direct that program until 2000, when he retired from medicine and returned to Rhode Island.

All the while, Steiner's passion for physics never left him.

"Even when I was in medical school I went at times to lectures by renowned physicist Walter Thirring," Steiner said. "His lectures always fascinated me. I was captivated by quantum physics and wished I could go into more detail in this."

That deep dive into quantum mechanics would have to wait, however. "You cannot do medicine halfway," Steiner said. "You really have to dedicate your life to it."

But throughout his long career in medicine, Steiner said he never stopped thinking about physics. "Physics was always a part of me," he said, "and when I retired from medicine and I was approaching age 70, I decided to enter the world of physics."

THE 70-YEAR-OLD UNDERGRAD

Steiner started taking physics classes at MIT, but soon found the demands of commuting to Boston overwhelming so he decided to transfer to the program in physics at Brown, where he had spent a good part of his academic life.

He found the Brown physics department a welcoming environment for a late-in-life learner. Teachers were "delighted to have me in class," Steiner said, and his fellow students liked him and treated him well.

Steiner did not consciously set out to earn a third doctoral degree when he began his studies at Brown. "Originally I just wanted to take classes, doing something that helped my mind and was interesting to me," Steiner said. But by the Spring of 2007, Steiner had completed enough classes to be admitted to the graduate school as a Ph.D. degree candidate.

After admission to the Ph.D. program, Steiner continued his coursework at the graduate level and set out to look for a dissertation adviser. Initially, Steiner considered nuclear physics, but thought it might take him away from his family, so he approached Brad Marston who is a condensed matter theorist who also works on climate science. Marston said he did not work on nuclear theory, "so I gave Manfred a project that was the closest to high-energy physics that I did, which was bosonization."

Marston recalls initially being skeptical when approached by a septuagenarian student about serving as a dissertation adviser. "To be honest, I was skeptical because people do not usually do physics, especially theoretical physics, at an advanced age," Marston said. "But in a moment of weakness, I agreed and said 'yes.' I knew his story, and I was very sympathetic to his desire to fulfill his lifelong dream of becoming a physicist."

With that, Steiner began working on his dissertation with Marston advising. Throughout the process, Steiner said he made many new friends, especially the faculty who served on his dissertation committee, including professors James Valles Jr. and Antal Jevicki. "I highly respect my committee," Steiner said.

And he tackled a very difficult problem. In the everyday world there are two types of particles: fermions and bosons. Particles have an angular momentum, or "spin." Particles with half-integer spins are fermions and particles with whole integer spins are bosons. While this might seem like a small difference, it has enormous consequences.

"Electrons are fermions and photons are bosons," Marston said. "But there are certain circumstances under which you can characterize a fermion as a boson. That is what is known as bosonization, and there are certain advantages to doing that. Usually people do this for one-dimensional problems, but for years I had been working with people like the late Tony Houghton trying to extend this to higher dimensions, such as two dimensional or three-dimensional metals. We had some success with this, but also discovered some limitations, so I gave Manfred the job of trying to move beyond those limitations. That was a challenging project. I did not give Manfred an easy project."

Valles said he considers Steiner an inspirational figure.

"I remember meeting Manfred in the hallway when he was taking undergraduate classes," Valles recalled. "He was unabashed about wanting to do physics and having wanted to do it all his life. His excitement about physics as someone who had such a stellar career in another field felt really affirming."

Valles describes working with Steiner as "really pleasurable," and adds, "the theory that he was doing involves techniques that are incredibly advanced and challenging to master." Of his dissertation, Valles said Steiner, "did an amazing job describing the march of physics in the context of bosonization. He believes in the human mind's capacity to advance and create knowledge. Seeing him do it was incredibly inspiring, enabling, and empowering to me as a physicist."

THE NEWLY MINTED PH.D.

Having successfully defended his thesis and completed all requirements for a Ph.D. in physics, Steiner said he's ecstatic.

"It feels really good," he said. "I am really on top of the world." And despite this being his third doctoral degree, it's particularly special to him. "This Ph.D. is the one that I most cherish because it's the one that I was striving for my whole life."

Steiner is not prepared to rest on his laurels. He is currently reworking part of his dissertation for publication and plans to continue his theoretical physics work.

"Even though I am old, I would like to continue with physics," he said. "And even after writing and publishing this paper, I want to continue my research."

That perseverance is consistent with Steiner's approach to life, and he believes he still has more to offer. "I always tried to keep my brain sharp," he said. "Physics certainly helped me do that."

Steiner admits he sometimes wonders how his life might have gone differently if he had not heeded his mother and uncle's advice as a young man. "I do sometimes wonder how things might have gone differently," he said. "I do not really regret it now. It was a good life and I made many great friends. It felt very good, particularly after I got my Ph.D. and worked in academic medicine. But physics always lurked in the background."

When asked what those approaching retirement age should do Steiner said everybody needs to make their own choices. But for him, the choice was clear.

"I could not imagine spending my life playing golf all the time," Steiner said. "I wanted to do something that keeps my mind active. But it is a matter of whatever you want to do. If you have a dream, follow it. Sometimes that dream may never have been verbalized, it may be buried in the subconscious. It is important not to waste your older days. There is a lot of brainpower in older people and I think it can be of enormous benefit to younger generations. Older people have experience and many times history repeats itself."

As for young people choosing between following a passion and taking a more conventional path in life Steiner said, "I think young people should follow their dreams whatever they are. They will always regret it if they do not follow their dreams."

Steiner confers with dissertation adviser Brad Marston.
PHOTO: NICK DENTAMARO/BROWN UNIVERSITY

UPDATE

This story was originally published on the Brown Physics website in November of 2021. The story quickly went viral on social media and was picked up by many media outlets including NPR, The Washington Post, The Associated Press, USA Today, and many others.

Many people of all ages from around the globe have contacted us to tell us they found Manfred's story inspiring. Some of them have decided to pursue long-deferred dreams based on Manfred's example.

Richard Gaitskell

FACULTY RESEARCH

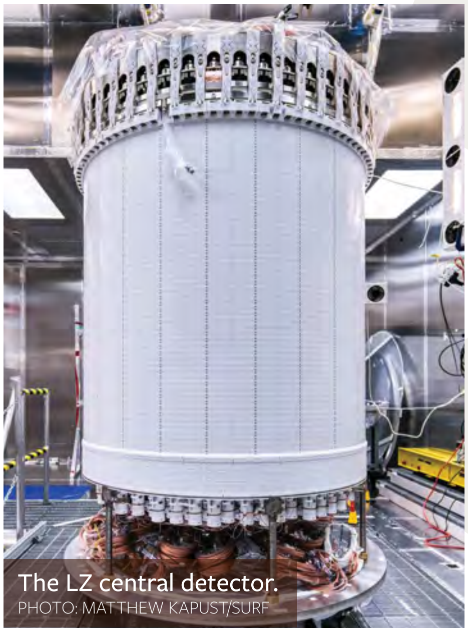
LZ EXPERIMENT BRINGS US ONE STEP CLOSER TO DETECTION OF DARK MATTER

By Pete Bilderback

Deep below the Black Hills of South Dakota in the Sanford Underground Research Facility (SURF), an innovative and uniquely sensitive dark matter detector—the LUX-ZEPLIN (LZ) experiment, led by Lawrence Berkeley National Lab (Berkeley Lab)—has passed a check-out phase of startup operations and delivered first results.

THE BROWN RESEARCH GROUP

Brown University's LZ research group made many major contributions to the project. Brown University Hazard Professor of Physics and Director of the Center for the Fundamental Physics of the Universe Richard Gaitskell, who leads the Brown group, said, "This has been a monumental effort and many Brown doctoral, master's and undergraduate students, as well as postdocs and technicians, contributed. It's amazing how much work we did in the labs and cleanrooms in the basement of Barus and Holley. This included the building, testing and integration of over 14,000 components for the two massive photodetector arrays for this unprecedented experiment."



The LZ central detector.
PHOTO: MATTHEW KAPUST/SURF

Brown doctoral and master's students on the team included Amjad Alqahtani, Jihyeun (Jeanne) Bang, Samuel Chan, Chen Ding, Dongqing Huang, Renée Kirk, Runxuan Liu, Jan Makkinje, David Malling, Casey Rhyne, Nat Swanson, William Taylor, Austin Vaitkus and James Verbus.

Undergraduates who contributed included Sissi Chen, Eamon Hartigan-O'Connor, David Heffren, Yizhong (Richard) Hu, Charles Kocher, Jacob Migneault, Napali Raymundo, Grant Rutherford, Angela White and Anna Zuckerman.

Three Brown postdocs–Junhui Liao, Monica Pangilinan, and Xin Xiang–worked on the experiment. Dario Garcia, Jake Lyle and Devon Seymour made huge contributions as technicians.

The heart of the LZ dark matter detector is comprised of two nested titanium tanks filled with nearly 10 tonnes of very pure liquid xenon and viewed by two arrays of photomultiplier tubes (PMTs) able to detect faint sources of light. The titanium tanks reside in a larger detector system to catch particles that might mimic a dark matter signal.

The Brown research group's work building the detector's PMT arrays was central to the experiment's successful launch. The arrays serve as the "eyes" of the experiment and will do the actual detection of dark matter by looking for the faint flashes of light that would be produced if a dark matter particle collides with a xenon atom inside one of LZ's tanks. The Brown team worked with Berkeley Lab and Imperial College London researchers to design, test, and assemble all of the array's components. Testing of the PMTs, which the Hamamatsu Corporation manufactures in Japan, was performed at Brown.

After testing the PMTs for more than two years, the team assembled them into the final arrays used in LZ. Taylor, who worked on building and testing the PMT arrays, said, "LZ has the potential to be the most sensitive WIMP [weakly interacting massive particles] search experiment in the world. The fact that the PMT arrays, some of the most critical systems in the detector, were built at Brown by our group makes it all the more exciting."

Because it is looking for extremely weak interactions, the "eyes" of the experiment need to be sensitive enough to detect single photons and have to be calibrated precisely. The Brown group also contributed nuclear recoil calibrations using an Adelphi Technology, Inc. deuterium-deuterium (DD) fusion neutron generator. Bang said, "The Brown group is in charge of every aspect of the DD neutron generator from operation to analysis."

To prepare for the nuclear recoil calibrations, the Brown group worked extensively with Adelphi Technology, Inc. to ensure the neutron generator would deliver the performance needed in LZ. Taylor said, "Because the dark matter search is a top priority, it was important to perform calibrations quickly." He continued, "The neutron calibrations need to acquire many thousands of neutron events to achieve statistical significance. To do that within the timespan allotted for calibrations, we worked with Adelphi to develop impressive neutron production intensities and pulse characteristics. This custom R&D was possible thanks to our longstanding relationship with Adelphi."

"We shot a bunch of neutrons into the detectors to observe how they respond because neutrons have a weak interaction with xenon similar to what we expect with dark matter," Bang said. "We observed that tens of thousands of neutron events are distributed within a narrow band in the signal space, the Nuclear Recoil Band." These calibrations measured the signal that dark matter is predicted to generate when it interacts with xenon.

In addition, the Brown team provided a portion of the data acquisition (DAQ) system and computational power needed to analyze the data using Brown University's computing cluster run by Brown's Center for Computation and Visualization (CCV). Gaitskell noted that the Brown team's work followed on from the precursor Large Underground Xenon (LUX) experiment. He added, "Brown also contributed an enormous amount of horsepower for the data analysis and simulations of that precursor experiment."

DARK MATTER

Dark Matter particles have never actually been detected—but perhaps not for much longer. The countdown may have started with results from LZ's first 60 "live days" of testing. These data were collected over a three-and-a-half-month span of initial operations beginning at the end of December. This was a period long enough to confirm that all aspects of the detector were functioning well.

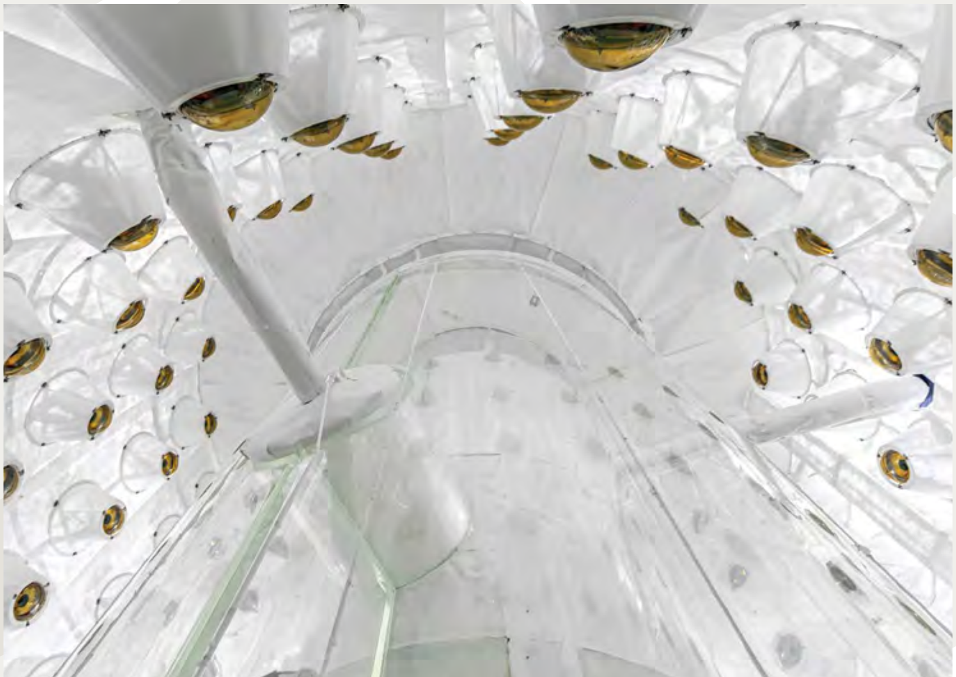
Unseen, because it does not emit, absorb, or scatter light, dark matter's presence and gravitational pull are nonetheless fundamental to our understanding of the universe. For example, the presence of dark matter, estimated to be about 85% of the total mass of the universe, shapes the form and movement of galaxies, and it is invoked by researchers to explain what is known about the large-scale structure and expansion of the universe.

The search for dark matter has a long history. Humans have speculated about the possible existence of invisible forms of matter as far back as the Greek Atomists in the fifth century BCE. In 1884 Lord Kelvin estimated that the mass of the Milky Way had to be greater than the total mass of visible stars based on the observed velocity dispersion of stars in the galaxy. But it is Swiss astrophysicist Fritz Zwicky who is generally credited with calculating that dark matter constituted the bulk of the universe's mass in 1933.

But to date, all attempts to observe this elusive hypothetical form of matter have failed. The LZ collaboration is the most ambitious attempt to observe dark matter yet. "So far, we have not seen a signal consistent with dark matter," said Gaitskell. "But we have only run the experiment for 100 days. Already the results are more sensitive than the world's best results by a significant factor." He added, "With the LZ experiment going on to run for 1,000 days, the next results will explore many new models for particle dark matter. We believe we are in a strong position to discover the universe's missing mass."

If the LZ experiment detects dark matter, it will come in the form of a brief flash of light. Particle collisions in the xenon produce visible scintillation or flashes of light, which are recorded by the PMTs, explained Aaron Manalaysay from Berkeley Lab who, as Physics Coordinator, led the collaboration's efforts to produce these first physics results. "The collaboration worked well together to calibrate and to understand the detector response," Manalaysay said. "Considering we just turned it on a few months ago and during COVID restrictions, it is impressive we have such significant results already."

The collisions will also knock electrons off xenon atoms, sending them to drift to the top of the chamber under an applied electric field where they produce another flash permitting spatial event reconstruction. The characteristics of the scintillation help determine the types of particles interacting in the xenon.



Looking up into the LZ Outer Detector, used to veto radioactivity that can mimic a dark matter signal. PHOTO: MATTHEW KAPUST/SURF

AN UNDERGROUND DETECTOR

Tucked away about a mile underground at SURF in Lead, S.D., LZ is designed to capture dark matter in the form of WIMPs. The experiment is underground to protect it from cosmic radiation at the surface that could drown out dark matter signals.

As you approach it, SURF, the site of the former Homestake gold mine and home to the LUX experiment until 2016, looks unimposing. But once inside, there is something awe-inspiring about traveling over a mile underground. "Going underground can feel a bit surreal," said Taylor, "The elevator–or cage, as it's called–takes about 10 minutes to reach the 4,850 level."

Vaitkus described the trip down the shaft as an incredible ordeal: "You have to garb up in dirty coveralls and boots. You put on safety glasses, a helmet and a headlamp in case you end up trapped somewhere without light. You have to wrap all of your stuff in plastic bags so that it doesn't get dirty on your way into the lab. You carry a brass tag with your name on it so they can identify your body in case something horrible happens."

But members of the team said that once inside, the lab feels like a normal workspace. There's even wi-fi and a well-stocked espresso machine. "Once you've gone through the changing rooms and gotten out of your coveralls, it's easy to forget you're underground," Taylor said. "One could imagine the lab was in a large building if it weren't for the exposed rock and lack of windows serving as reminders." Bang added, "It's not that different from the basement of Barus and Holley because we don't have any windows there either."

But it's difficult to entirely forget where you are, "Frankly, most of the time, you don't think too much about the fact that you have a mile of rock over your head, but sometimes you do ponder the incredible scale of it all," said Gaitskell. "And you trust the expertise of the engineers that have been able to put us there."

In addition to Gaitskell, Bang, Taylor and Vaitkus, other team members who visited SURF included Hartigan-O'Connor, Huang, Rhyne and Xiang. All team members worked many long shifts at the experiment site.

The group found the stays incredibly gratifying and were aware of the potential historical significance of their work. Taylor said, "It's incredibly exciting to finally see LZ's first WIMP-search results. It's quite thrilling to be able to say that I helped build part of this massive project with my own hands and to see the results of those many years of labor finally come to fruition."

"I'm deeply grateful to the many doctoral, master's and undergraduate students and other Brown personnel who have participated in this experiment so far," said Gaitskell. "Their work assembling and testing PMTs, constructing the huge arrays, providing nuclear recoil calibrations, and analyzing a huge range of data from the detector have been critical to the experiment's successful launch." He added, "Now that we have confirmed LZ is operational and full-scale observations have begun, we hope to start observing dark matter particles colliding with xenon atoms in the detector. It's an exciting time. We're ready to make history."

This research is supported by the Department of Energy (DE-SC0010010).

Marcus Spradlin & Anastasia Volovich

FACULTY RESEARCH

UNLOCKING THE SECRETS OF QUANTUM FIELD THEORY

By Marcus Spradlin and Anastasia Volovich

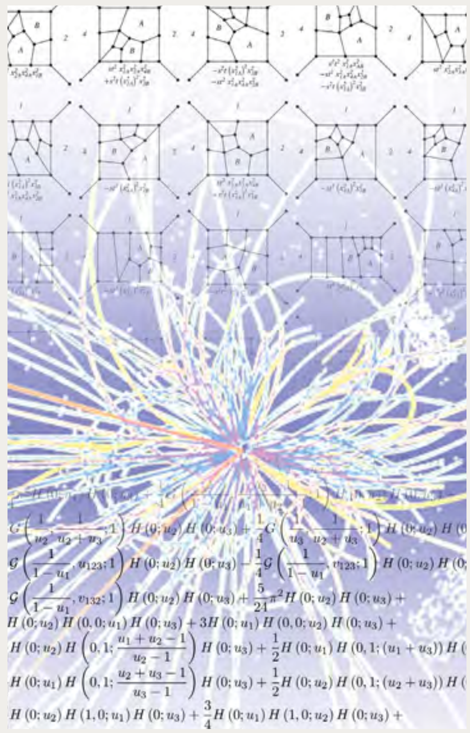
Quantum field theory is the mathematical language in terms of which our understanding of elementary particle physics is expressed. It is a very rich and beautiful language, but it can also be very complex. Compared to other advanced graduate courses a physics student might take, quantum field theory has a particularly notorious reputation for the tedious and lengthy calculations often required even for "simple" homework problems.

Brown University physicists Marcus Spradlin and Anastasia Volovich work to explore the hidden mathematical structure of quantum field theory and exploit new insights to make previously difficult calculations possible, sometimes even trivial. Hints that such things were possible have been in the literature for a few decades—examples where pages of formulas miraculously collapse to a single term—but the field really took off following the 2004 "Collider Physics" program at the Kavli Institute for Theoretical Physics in Santa Barbara, where Spradlin and Volovich were postdocs.

A month before the program, something happened that changed the course of their careers, as well as an entire sub-field of science. In December 2003, particle physics collided with string theory when Professor Ed Witten from the Institute for Advanced Study at Princeton University published a groundbreaking paper called "Perturbative Gauge Theory as a String Theory in Twistor Space."

The work applied ideas from string theory to the mathematical structure of scattering amplitudes, predictions that calculate the likelihood that when two particles collide, other particles form. Spradlin, Volovich and fellow postdoc Radu Roiban (now a professor at Pennsylvania State University) showed that the framework described in Witten's paper applies to essentially all scattering amplitudes of gluons. (Gluons are the particles that carry the strong nuclear force, in the same way that photons carry the electromagnetic force.)

Progress ensued rapidly. A December 2004 article by Roiban, Spradlin and Volovich published in Physical Review Letters presented a formula for an eight-gluon interaction that would have been impossible to compute six months prior but which today would be considered a "trivial" homework problem for an undergraduate



who has been taught the tricks.

In 2011 Spradlin and Volovich, together with their Brown University postdoc Cristian Vergu (now at the Niels Bohr International Academy in Copenhagen), teamed up with mathematician Alexander Goncharov (then a professor in the Brown Department of Mathematics, currently at Yale University) to tame the complexity of even scarier "loop" amplitudes—these are physical processes that involve the creation and annihilation of virtual particles, represented by closed "loops" in a Feynman diagram.

Using ideas Goncharov was familiar with from a branch of mathematics called the theory of motives, the team attacked a 17-page long formula (perhaps among the longest formulas ever written out in the text of a published article) and found a completely equivalent expression that fit on a single line. Goncharov was shocked that some of the very abstract ideas he had worked on for much of his career turned out to be so useful to physics.

Now a decade later, the methods introduced in their paper (referred to as GSVV by the initials of the authors) have become an indispensable part of the standard toolkit for quantum chromodynamics (QCD) calculations that are part of the necessary input for data analysis at the Large Hadron Collider (LHC).

This year Spradlin and Volovich have contributed to two white papers reviewing related developments and highlighting likely avenues for future progress in the Snowmass community planning exercise.

Snowmass is a scientific study organized by the Division of Particles and Fields (DPF) of the American Physical Society (APS). According to their website, the Snowmass process "provides an opportunity for the entire particle physics community to come together to identify and document a scientific vision for the future of particle physics in the U.S. and its international partners. Snowmass will define the most important questions for the field of particle physics and identify promising opportunities to address them."

The white paper "Solving Scattering in N=4 Super-Yang-Mills Theory," written together with Nima Arkani-Hamed of the Institute for Advanced Study at Princeton, Lance Dixon of the SLAC National Accelerator Laboratory at Stanford, Andrew McLeod of CERN and Jaroslav Trnka of the University of California, Davis highlighted ongoing research into the problem of completely solving a toy model of gluon interactions.

The white paper "Beyond Multiple Polylogarithms for Precision Collider Physics," written with a collaboration of 15 European physicists, outlined prospects for tackling classes of computations beyond the realm of those for which the GSVV tools apply. Hopefully, one day even these will become "simple" homework problems.

Spradlin and Volovich continue their work on mathematical structures in quantum field theory with their graduate students Rishabh Bhardwaj, Shounak De, Luke Lippstreu and Lecheng Ren, and postdocs Adam Ball, a 2022 Ph.D. from Harvard University, Andrzej Pokraka, a 2022 Ph.D. from McGill University and Akshay Yelleshpur Srikant, a 2020 Ph.D. from Princeton University.

This research is supported by the Department of Energy (DE–SC0010010). Professor Volovich is also supported by Simons Investigator Award (#376208).

A portion of this article was adapted from the Kavli Institute for Theoretical Physics Spring 2022 Newsletter.

James Valles Jr.

FACULTY RESEARCH

NEWLY DISCOVERED TYPE OF 'STRANGE METAL' COULD LEAD TO DEEP INSIGHTS

By Kevin Stacey

Scientists understand quite well how temperature affects electrical conductance in most everyday metals like copper or silver. But in recent years, researchers have turned their attention to a class of materials that do not seem to follow the traditional electrical rules. Understanding these so-called "strange metals" could provide fundamental insights into the quantum world, and potentially help scientists understand strange phenomena like high-temperature superconductivity.

Now, a research team co-led by Brown University physicist James Valles Jr. has added a new discovery to the strange metal mix. In research published in the journal Nature, the team found strange metal behavior in a material in which electrical charge is carried not by electrons, but by more "wave-like" entities called "Cooper pairs."

While electrons belong to a class of particles called fermions, Cooper pairs act as bosons, which follow very different rules from fermions. This is the first time strange metal behavior has been seen in a bosonic system, and researchers are hopeful that the discovery might be helpful in finding an explanation for how strange metals work—something that has eluded scientists for decades.

"We have these two fundamentally different types of particles whose behaviors converge around a mystery," said Valles Jr, a professor of physics at Brown and the study's corresponding author. "What this says is that any theory to explain strange metal behavior can't be specific to either type of particle. It needs to be more fundamental than that."

STRANGE METALS

Strange metal behavior was first discovered around 30 years ago in a class of materials called cuprates. These copper-oxide materials are most famous for being high-temperature superconductors, meaning they conduct electricity with zero resistance at temperatures far above that of normal superconductors. But even at temperatures above the critical temperature for superconductivity, cuprates act strangely compared to other metals.

As their temperature increases, cuprates' resistance increases in a strictly linear fashion. In normal metals, the resistance increases only so far, becoming constant at high temperatures in accord with what's known as Fermi liquid theory. Resistance arises when electrons flowing in a metal bang into the metal's vibrating atomic structure, causing them to scatter. Fermi-liquid theory sets a maximum rate at which electron scattering can occur. But strange metals don't follow the Fermi-liquid rules, and no one is sure how they work.

What scientists do know is that the temperature-resistance relationship in strange metals appears to be related to two fundamental constants of nature: Boltzmann's constant, which represents the energy produced by random thermal motion, and Planck's constant, which relates to the energy of a photon (a particle of light).

"To try to understand what's happening in these strange metals, people have applied mathematical approaches similar to those used to understand black holes," Valles said. "So there's some very fundamental physics happening in these materials."

OF BOSONS AND FERMIONS

In recent years, Valles and his colleagues have been studying electrical activity in which the charge carriers are not electrons. In 1952, Nobel Laureate Leon N Cooper, now a Brown professor emeritus of physics, discovered that in normal superconductors (not the high-temperature kind discovered later), electrons team up to form Cooper pairs, which can glide through an atomic lattice with no resistance. Despite being formed by two electrons, which are fermions, Cooper pairs can act as bosons.

"Fermion and boson systems usually behave very differently," Valles said. "Unlike individual fermions, bosons are allowed to share the same quantum state, which means they can move collectively like water molecules in the ripples of a wave."

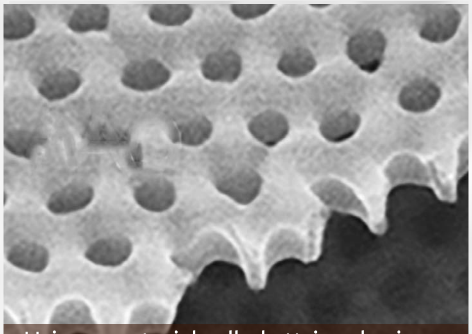
In 2019, Valles and his colleagues showed that Cooper pair bosons can produce metallic behavior, meaning they can conduct electricity with some amount of resistance. That in itself was a surprising finding, the researchers say, because elements of quantum theory suggested that the phenomenon shouldn't be possible. For this latest research, the team wanted to see if bosonic Cooper pair metals were also strange metals.

The team used a cuprate material called yttrium barium copper oxide patterned with tiny holes that induce the Cooper pair metallic state. The team cooled the material down to just above its superconducting temperature to observe changes in its conductance. They found, like fermionic strange metals, a Cooper pair metal conductance that is linear with temperature.

The researchers say this new discovery will give theorists something new to chew on as they try to understand strange metal behavior.

"It's been a challenge for theoreticians to come up with an explanation for what we see in strange metals," Valles said. "Our work shows that if you're going to model charge transport in strange metals, that model must apply to both fermions and bosons—even though these types of particles follow fundamentally different rules."

Ultimately, a theory of strange metals could have massive implications. Strange metal behavior could hold the key to understanding high-temperature superconductivity, which has vast potential for things like lossless power grids and quantum computers. And because strange metal behavior seems to be related to fundamental constants of the universe, understanding their behavior could shed light on basic truths of how the physical world works.



Using a material called yttrium barium copper oxide arrayed with tiny holes, researchers have discovered "strange metal" behavior in a type of system where charge carriers are bosons, something that's never been seen before. PHOTO: VALLES LAB/BROWN UNIVERSITY

TABLE OF CONTENTS

Jia (Leo) Li

FACULTY RESEARCH

WITH SUPERCONDUCTING DIODES, SCHOLARS ADVANCE WORK TOWARD ULTRA-EFFICIENT QUANTUM ELECTRONIC DEVICES

By Pete Bilderback

A research team including Brown University faculty and students created a superconducting diode without a magnetic field in multi-layer graphene, a development that could form the basis for future "lossless" electronics.

Superconductors — materials that conduct electricity with zero loss of energy — have been well-understood since the development of what's called the BCS theory in the mid-1950s. However, the recent development of superconducting diodes using twisted, multi-layer graphene has made understanding how unconventional superconductors function an important new topic of fundamental research.

Now, an international research group that includes Brown Assistant Professor of Physics Jia (Leo) Li has reached a critical milestone: Using graphene, a material with unique properties, they've demonstrated a prominent superconducting diode effect in a single two-dimensional superconductor. They reported their findings in a study in Nature Physics.

A superconducting diode effect occurs when there is a magnitude of current in which a material behaves like a superconductor in one direction of electricity flow and like a resistor in the opposite. In contrast to a conventional diode, a superconducting diode exhibits zero resistance and thus no energy loss in the forward direction.

The researchers' new development could form the basis for ultra-efficient lossless quantum electronic devices.

Originally, the concept of a superconducting diode was predicted with an external magnetic field, which has some fundamental limitations. In the new experiments carried out at Brown, Li's team created an extremely strong diode effect without a magnetic field. When turning on an electric current in one direction, the system almost immediately becomes a resistor, while it remains a superconductor in the opposite direction.

The system creates a unique situation with a diode effect with no external magnetic field in a single superconductor. The results confirm a hypothesis theorized by study co-author Mathias Scheurer, a theoretical physicist at the University of Innsbruck in Australia — namely, that superconductivity and magnetism can coexist in a system consisting of three graphene layers twisted against each other. The system can generate its own internal magnetic field, creating a diode effect.

Moreover, the team managed to reverse the diode direction using a simple electrical field.

"The demonstration of the field-free diode effect in a homogeneous superconductor creates a wonderful opportunity to explore possible device application," Li said. "And the extra experimental control we demonstrated adds more possibilities for designing a programmable network of dissipation-less diodes."

A PROMISING MATERIAL

The diode effect was produced using graphene, a material consisting of a single layer of carbon atoms arranged in a honeycomb pattern. Stacking several layers of graphene leads to completely new properties, including the ability of three graphene layers twisted against each other to conduct an electric current without loss. This was demonstrated in previous experiments carried out by Li and his collaborators.

The fact that a superconducting diode effect can exist without an external magnetic field in this system has significant implications for the study of the complex physical behavior of twisted tri-layer graphene. It demonstrates the coexistence of superconductivity and magnetism.

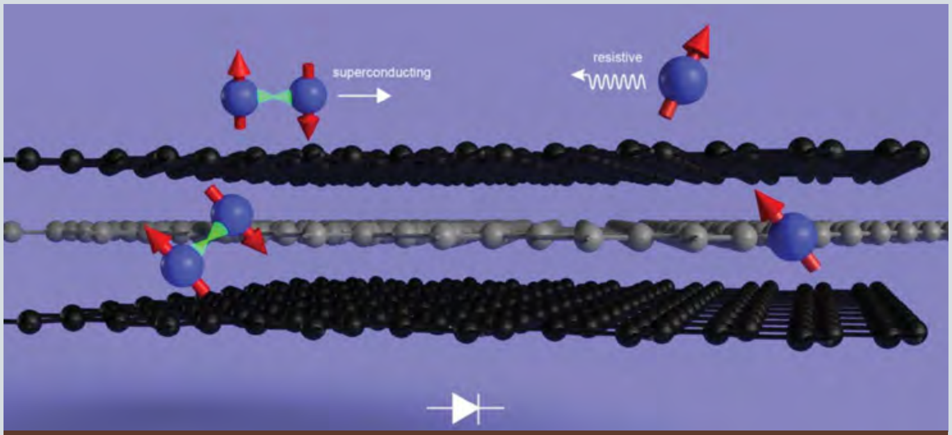
"Superconductivity and ferromagnetism usually occupy opposite ends of the material spectrum," said Jiang-Xiazi Lin, a postdoctoral researcher at Brown and one of the lead authors of the study. "Coexistence between these two quantum phases is rare, and it is almost synonymous with exciting physics."

Phum Siriviboon, who conducted research in Li's lab as an undergraduate and earned a bachelor's degree from Brown in May 2022, was the study's other lead author: "This is the first time that the coexistence between superconductivity and ferromagnetism has been observed in two-dimensional materials," Siriviboon said. "Our result establishes a new method for studying the interplay between superconductivity and ferromagnetism."

The team's latest research demonstrates that the observed diode effect not only has technological relevance but also the potential to improve understanding of fundamental processes in many-body physics. Li and Scheurer, along with Harley D. Scammell of the University of New South Wales, published the theoretical basis of this phenomenon in a 2022 article. That theoretical work points to the next step in the team's work, which is to examine the dependence of the superconducting diode effect when electric currents flow in different directions.

"Phum and Jiang-Xiazi formed a wonderful team working together," Li said. "This type of collaboration provides an ideal model for involving undergraduate students in cutting-edge research and enabling them to make meaningful and critical contributions."

This story was prepared using materials provided by University of Innsbruck.



Using graphene, a material with unique properties, a research team demonstrated a prominent superconducting diode effect in a single two-dimensional superconductor — a finding that could form the basis for ultra-efficient lossless quantum electronic devices. PHOTO: LI LAB/BROWN UNIVERSITY

BROWN PHYSICISTS REACT TO FIRST PHYSICS NOBEL PRIZE ADDRESSING CLIMATE CHANGE

By Pete Bilderback

PHOTO: WIKIMEDIA COMMONS

For the first time, the Royal Swedish Academy of Sciences has awarded a Nobel Prize for Physics to scientists working on the problem of climate change. On October 5, 2021, the Academy awarded half the prize to Princeton climatologist Syukuro Manabe and Klaus Hasselmann at the Max Planck Institute for Meteorology "for the physical modeling of Earth's climate, quantifying variability and reliably predicting global warming." The other half of the prize was awarded to Giorgio Parisi, a physicist at Sapienza University of Rome "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales," work that has also been important in understanding the complex system that is the Earth's climate.

Professor S. James Gates Jr. praised the work of all three scientists, "This is the work of physics done on a grand scale for all of humanity." He added, "this prize in physics reflects the deep connections of our field to delving into mysteries that shroud the laws that determine the environment of our home—planet Earth. The citation of the award clearly shows our discipline's efforts to establish deep scientific knowledge behind such challenges as global climate change, pollution, and similar processes in complex systems. For with such knowledge, science and physics once more can be shown to be the 'survival instinct' of our species."

Brown Professor of Physics Brad Marston also applauded the Nobel committee's "recognition that physics is part of climate science," and finds the recognition long overdue. "People have understood a lot of the important physics behind this for some time. Manabe's work on climate began in the 1960s." Marston credited Hasselmann for being "really instrumental in giving us a concrete understanding of the climate of the Earth and how it might change with added carbon dioxide. It was important for understanding how rapidly climate could change and how to distinguish climate change from weather fluctuations."

Gates called Manabe's work "beach-head research" noting it was done "quite some time ago and at the time there wasn't a lot of attention paid to it." While it has taken a long time for Manabe's work to earn the recognition it deserves, it has proven prescient. In 1967 he developed a climate model that predicted that doubling the carbon dioxide in the Earth's atmosphere would lead to an average temperature increase of 2.3 degrees Celsius, a calculation that remains in line with the results of the latest modeling.

Gates credited Manabe with starting "the serious work in physics of figuring out how complex systems like the climate work." He also noted that Parisi has addressed a large number of complex systems including "the flocking of birds and fish" over a long period of time, "the unifying theme of his work is that he takes complex systems and looks for simple equations that can describe them."

2021 Nobel Prize in Physics winners (l-r) Syukuro Manabe, Klaus Hasselmann and Giorgio Parisi.
PHOTO: COURTESY THE ROYAL SWEDISH ACADEMY OF SCIENCES

The ability to simplify complex systems characterizes the work of all three physicists, and according to Marston it has helped us create, "a simplified model of climate that allows us to highlight certain processes that are important."

Marston noted that Hasselmann's work helps us understand the "chaotic fluctuations of our climate system over different time scales." And while he did not study climate specifically, Marston credited Parisi's vast body of work on statistical mechanics with helping to find "an underlying simplicity in the description of complicated systems that leaves out a lot of things, but gets at certain essential parts of complicated systems." He said all three physicists' work is distinguished by their "thinking about complicated systems and trying to get at the essential physics behind those systems."

Marston said it's important to understand that climate is "both complicated and simple." He noted, "there are relatively simple aspects of it, and even one-hundred years ago we had a basic understanding of climate thanks to the pioneering work of Fourier and others." But there are aspects of the climate system that are complex, "and there are details we'd really like to know, like if rainfall is going to increase in Rhode Island. But those kinds of questions are much harder to answer than, say, if the average temperature of the Earth is going up, which is relatively simple physics."

While physics may struggle to tell us if we should reach for our umbrellas on the way out the door in the morning, it does a much better job modeling long-term climate trends. Associate Professor of Physics Derek Stein noted "this year's Laureates showed how the constraints physics imposes and statistical methods of analysis enable us to understand important long-term and large-scale trends, which is what we mean when we talk about the Earth's climate." Stein also noted how the work of this year's prize winners can be applied to both the biggest and smallest systems in physics. "These are big ideas with broad applications. To illustrate, 40 years ago Parisi explained the Earth's periodic ice ages with a phenomenon called 'stochastic resonance' which applies equally well to the behavior of single DNA molecules in certain nanofluidic devices in my own laboratory at Brown."

For his part, Marston hopes this prize will spur further research on climate within the discipline of physics, "I've long tried to encourage physics students to think about working on the climate system, which is something that I've been interested in for a long time. There are powerful aspects to [physics] that can help with better understanding the climate system."

Marston noted that while it is common for there to be a few people in any given physics department working on climate change he "would like to see physics departments make this a more a mainstream field, and maybe this Nobel Prize will help with that task. Certainly, as the climate changes, more and more people are going to be thinking about it. Right now the pandemic has been preoccupying us, but if you could look ahead, in twenty years, climate change will very much be at the forefront, and unfortunately, there's not going to be a shot that can make climate change go away."

Dimitri Feldman & Vesna Mitrović

FACULTY RESEARCH

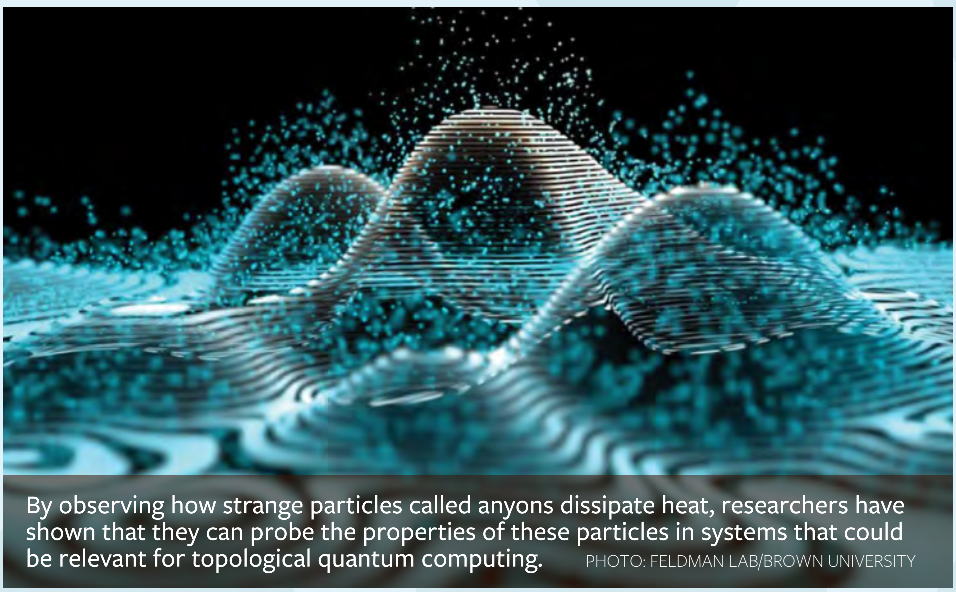
RESEARCHERS SHOW NEW STRATEGY FOR DETECTING NON-CONFORMIST PARTICLES CALLED ANYONS

By Kevin Stacey

A team of Brown University researchers has shown a new method of probing the properties of anyons, strange quasiparticles that could be useful in future quantum computers.

In research published in the journal Physical Review Letters, the team describes a means of probing anyons by measuring subtle properties of the way in which they conduct heat. Whereas other methods probe these particles using electrical charge, this new method enables researchers to probe anyons even in non-conducting materials. That's critical, the researchers say, because non-conducting systems have far less stringent temperature requirements, making them a more practical option for quantum computing.

“We have beautiful ways of probing anyons using charge, but the question has been how do you detect them in the insulating systems that would be useful in what's known as topological quantum computing,” said Dimitri Feldman, a physics professor at Brown and study co-author. “We show that it can be done using heat conductance. Essentially, this is a universal test for anyons that works in any state of matter.”



By observing how strange particles called anyons dissipate heat, researchers have shown that they can probe the properties of these particles in systems that could be relevant for topological quantum computing. PHOTO: FELDMAN LAB/BROWN UNIVERSITY

Anyons are of interest because they don't follow the same rules as particles in the everyday, three-dimensional world. In three dimensions, there are only two broad kinds of particles: bosons and fermions. Bosons follow what's known as Bose-Einstein statistics, while fermions follow Fermi-Dirac statistics.

Generally speaking, those different sets of statistical rules mean that if one boson orbits around another in a quantum system, the particle's wave function—the equation that fully describes its quantum state—does not change. On the other hand, if a fermion orbits around another fermion, the phase value of its wave function flips from a positive integer to a negative integer. If it orbits again, the wave function returns to its original state.

Anyons, which emerge only in systems that are confined to two dimensions, don't follow either rule. When one anyon orbits another, its wave function changes by some fraction of an integer. And another orbit does not necessarily restore the original value of the wave function. Instead, it has a new value—almost as if the particle maintains a “memory” of its interactions with the other particle even though it ended up back where it started.

That memory of past interactions can be used to encode information in a robust way, which is why the particles are interesting tools for quantum computing. Quantum computers promise to perform certain types of calculations that are virtually impossible for today's computers. A quantum computer using anyons—known as a topological quantum computer—has the potential to operate without elaborate error correction, which is a major stumbling block in the quest for usable quantum computers.

But using anyons for computing requires first being able to identify these particles by probing their quantum statistics. Last year, researchers did that for the first time using a technique known as charge interferometry.

Essentially, anyons are spun around each other, causing their wave functions to interfere with each other occasionally. The pattern of interference reveals the particles' quantum statistics. That technique of probing anyons using charge works beautifully in systems that conduct electricity, the researchers say, but it can't be used to probe anyons in non-conducting systems. And non-conducting systems have the potential to be useful at higher temperatures than conducting systems, which need to be near absolute zero. That makes them a more practical option for topological quantum computing.

For this new research, Feldman, who in 2017 was part of a team that measured the heat conductance of anyons for the first time, collaborated with Brown graduate student Zezhu Wei and Vesna Mitrović, a Brown physics professor and experimentalist. Wei, Feldman and Mitrović showed that comparing properties of heat conductance in two-dimensional solids etched in very specific geometries could reveal the statistics of the anyons in those systems.

“Any difference in the heat conductance in the two geometries would be smoking gun evidence of fractional statistics,” Mitrović said. “What this study does is show exactly how people should set up experiments in their labs to test for these strange statistics.”

Ultimately, the researchers hope the study is a step toward understanding whether the strange behavior of anyons can indeed be harnessed for topological quantum computing.

This research is supported by the National Science Foundation (DMR-1902356, QLCI-1936854, DMR-1905532).

TABLE OF CONTENTS

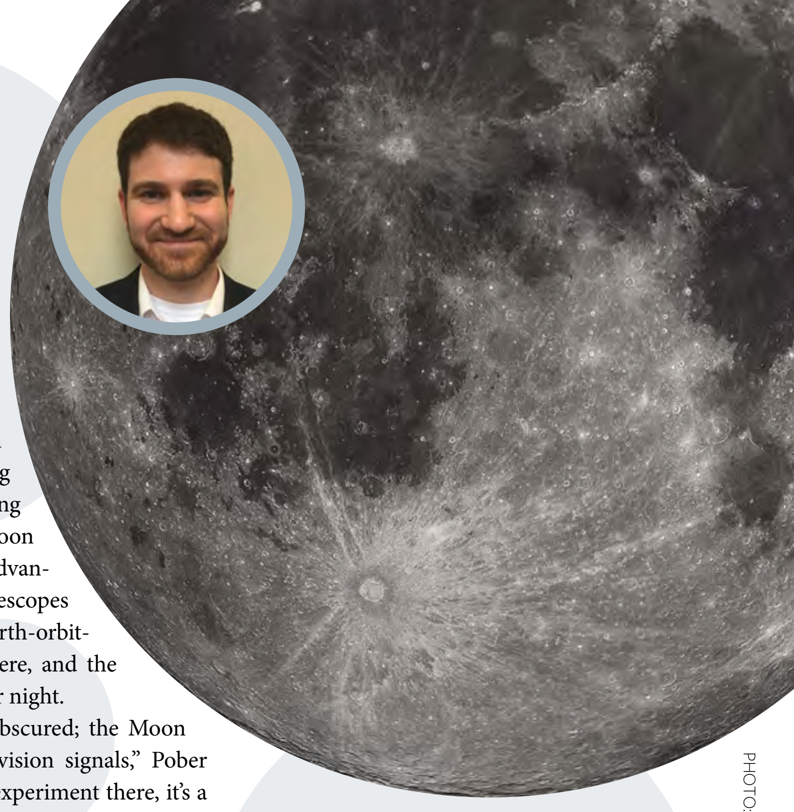


PHOTO: WIKIMEDIA COMMONS

Jonathan Pober

FACULTY RESEARCH

NASA FELLOWSHIP TO FUND WORK ON GROUNDBREAKING LUNAR RADIO TELESCOPE

By Pete Bilderback

The secrets of the cosmic dark ages that followed the Big Bang may be found on the far side of the Moon—and Assistant Professor of Physics Jonathan Pober is working to help NASA unlock them.

NASA awarded Pober the prestigious Nancy Grace Roman Technology Fellowship in Astrophysics, which will support Pober in advancing the ambitious NASA-funded project to design a giant radio telescope array on the far side of the Moon.

"A successful mission design will require a team with expertise in radio antenna design, space systems engineering, astrophysical cosmology, and data science," Pober said. "The Roman Technology Fellowship will provide funding to assemble key personnel with expertise spanning these areas, delivering key technological advances to make this concept a reality."

Pober is among only six early-career researchers nationwide to receive the 2021 Roman Technology Fellowship, which aims to help young researchers develop innovative technologies that have the potential to enable major scientific breakthroughs in the future.

"(We're) focused upon investigating in exquisite detail the unexplored cosmic dark ages," Pober said, "looking way back in cosmic history to a time when the universe was one hundredth its current size and there were no galaxies, no stars, no planets…and identifying the conditions and processes under which the first stars, galaxies and accreting black holes formed."

While there is no formal NASA mission, the federal agency has committed to exploring the novel antenna array, referred to as "FarView" and previously called the "Cosmic Dawn Mapper."

"A lunar radio array…could give extraordinarily precise measurements of the early structure of the universe because the sea of neutral hydrogen from which protogalaxies formed can be directly imaged using radio waves," reads the "NASA Astrophysics in the Next Three Decades" report.

"It's an ambitious project," Pober said. "This grant is just for simulation and design of a future experiment that could be on the far side of the Moon."

The ultra-long-wavelength radio telescope will need to be gigantic in order to be sensitive to long radio wavelengths. The siting on the far side of the Moon would have additional advantages over earth-based telescopes by blocking noise from earth-orbiting satellites, the ionosphere, and the sun's noise during the solar night.

"The Earth will be obscured; the Moon will block radio and television signals," Pober noted. "If you can get an experiment there, it's a fantastic place to do ultra-low frequency or ultra-long wavelength radio astronomy."

EXPLORING THE COSMIC DARK AGES

The cosmic dark ages began approximately 400,000 years following the Big Bang, when the universe cooled enough to form neutral hydrogen and helium atoms. During this period, which ended when protogalaxies produced enough light to ionize the universe about a billion years after the Big Bang, the universe was enveloped by a fog of neutral hydrogen that trapped all light.

"The wavelengths stretched along with the universe as they've traveled to us," Pober said, "so now we're talking about a 20-meter wavelength that absolutely can't make it through the Earth's atmosphere."

Any light from this period cannot reach the Earth, so the only way for humans to peer back into this period is using radio telescopes. Cosmologists currently know very little about this period, but it could hold the answers to some of science's biggest mysteries.

No equivalent observatory exists today.

"This radio telescope will be the first of its kind at this scale and sensitivity and will open a new window (low-frequency radio) into the early universe," NASA stated in a 2021 article on the project, "analogous to the detection of gravitational waves by LIGO (Laser Interferometer Gravitational-Wave Observatory) and the details of the CMB (cosmic microwave background) by Planck."

Pober has no immediate plans to visit the far side of the Moon. If everything goes perfectly, the project could be completed in 30 years at the earliest, he said. The project's timescale is long, but the grant will allow Pober to make important contributions to advancing the array's design.

> "To actually do the science we want, we'll need to have hundreds of thousands of radio antennas on the far side of the moon."
> ***JONATHAN POBER***

The project will also tackle the logistical challenges involved in building a large array in a difficult-to-reach location.

"The first couple of radio antennas will be landing on the Moon in the next couple of years as pathfinders," Pober noted. "Those are just to show that radio astronomy can be done from the Moon, but to actually do the science we want, we'll need to have hundreds of thousands of radio antennas on the far side of the Moon.

"You have to change the antenna design to make them deployable," Pober added, "because people aren't going to go to the far side of the Moon to set them up. The deployment will need to be automated, so a lot of this grant will involve figuring out how that will work."

The other 2021 Roman Technology Fellowship recipients were Brandon Chalifoux of the University of Arizona; Jake Connors of the National Institute of Standards and Technology at Boulder; Sona Hosseini of the Jet Propulsion Laboratory; Paul Szypryt of the University of Colorado at Boulder; and Brown physics alumnus Christopher Mendillo Sc.B. '05, currently of the University of Massachusetts.

This research is supported by NASA.

TABLE OF CONTENTS

FACULTY UPDATES

MEENAKSHI NARAIN NAMED CHAIR OF PHYSICS DEPARTMENT, APPOINTED TO APS COMMITTEE ON MINORITIES IN PHYSICS

Meenakshi Narain was named Chair of Brown University's Department of Physics effective July 1, 2022. She was also appointed to a three year term on the American Physical Society (APS) Committee on Minorities in Physics. According to APS, the committee "addresses the production, retention, and career development of minority physicists and gathers and maintains data on minorities in physics in support of these objectives. It may recommend and supervise studies and programs relevant to this charge."

STEPHON ALEXANDER ELECTED APS FELLOW

Stephon Alexander was elected a Fellow of the American Physical Society. Alexander is the first Black physicist to earn this distinction in the Division of Gravitational Physics. Alexander has also been named to the editorial board of the Journal of Cosmology and Astroparticle Physics (JCAP). JCAP covers all aspects of cosmology and particle astrophysics and encompasses theoretical, observational and experimental areas as well as computation and simulation.

S. JAMES GATES JR. HONORED WITH ANDREW GEMANT AWARD

The American Institute of Physics awarded S. James Gates Jr. the 2021 Andrew Gemant Award. The award is presented annually to those who have made significant contributions to the cultural, artistic, or humanistic dimension of physics. Gates was chosen by the award selection committee "for instilling a deep and humanistic love of physics in generations of students, being a steadfast ambassador of science policy and the history of physics, and his persistent dedication to communicating the wonders of the field."

GREG LANDSBERG APPOINTED CMS PUBLICATION COMMITTEE CHAIR

Greg Landsberg was named chair of the publications committee for the Compact Muon Solenoid (CMS) Collaboration, one of the major particle physics experiments happening at the Large Hadron Collider in Geneva, Switzerland. The publications committee assures the quality of around 100 research papers produced by the CMS Collaboration each year.

BRAD MARSTON NAMED BTPC DIRECTOR, APPOINTED TO EDITORIAL BOARD OF PRE

Brad Marston has been named Director of the Brown Theoretical Physics Center. He was also appointed to the editorial board of Physical Review E (PRE). PRE is a broad and interdisciplinary journal focusing on collective phenomena of many-body systems. In addition, Marston recently published a story, written with his daughter Anna, entitled "A future filled with gratitude." The story is featured in the book, "Crossing Paths: A Pacific Crest Trailside Reader." In the story, the authors imagine a future significantly affected by climate change, but not catastrophically so thanks to efforts to reduce greenhouse emissions.

VESNA MITROVIĆ NAMED SENIOR CHAIR, ELECTED TO TWO APS LEADERSHIP POSITIONS

The Corporation of Brown University recently named Vesna Mitrović the L. Herbert Ballou University Professor of Physics. Mitrović has also been elected to serve in two leadership positions in the American Physical Society (APS). Mitrović will serve as Executive Committee Vice-Chair of the Group on Instrument and Measurement Science and as a Member at Large on the Executive Committee of the Division of Condensed Matter Physics, the largest division of APS.

GANG XIAO NAMED FORD FOUNDATION PROFESSOR OF PHYSICS

The Corporation of Brown University recently named Gang Xiao the Ford Foundation Professor of Physics. Named professorships are a prestigious honor for individual faculty members, and they also provide an ongoing source of financial support to the University. Xiao stepped down as chair of the physics department on June 30, 2022. In a statement announcing Meenakshi Narain's appointment as chair, Dean of the Faculty Kevin McLaughlin expressed gratitude to Xiao for being a strong advocate for the department during his six years as chair.

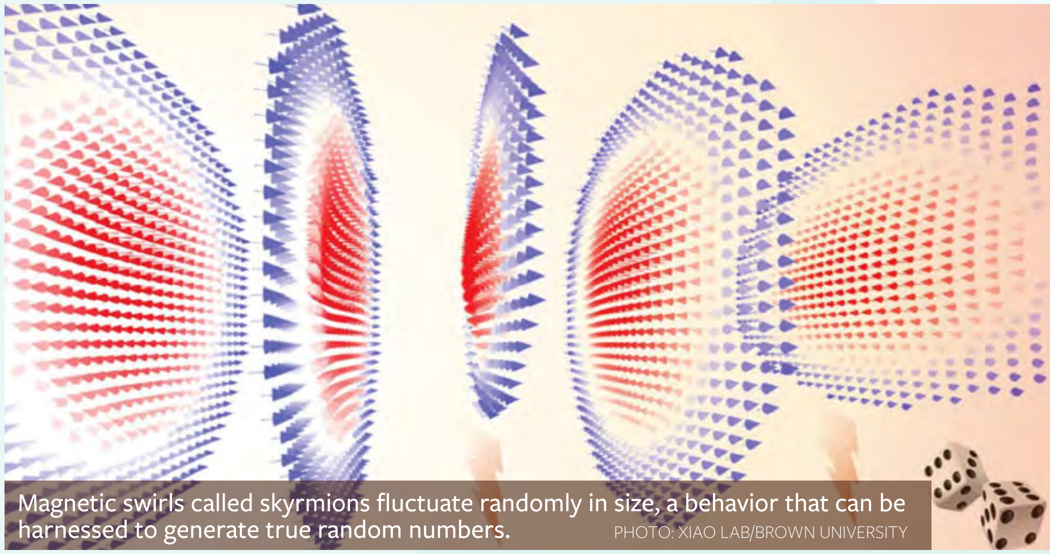
Gang Xiao

FACULTY RESEARCH

RESEARCHERS USE TINY MAGNETIC SWIRLS TO GENERATE TRUE RANDOM NUMBERS

By Kevin Stacey

Whether for use in cybersecurity, gaming or scientific simulation, the world needs true random numbers, but generating them is harder than one might think. But a group of Brown University physicists has developed a technique that can potentially generate millions of random digits per second by harnessing the behavior of skyrmions—tiny magnetic anomalies that arise in certain two-dimensional materials.



Magnetic swirls called skyrmions fluctuate randomly in size, a behavior that can be harnessed to generate true random numbers. PHOTO: XIAO LAB/BROWN UNIVERSITY

Their research, published in Nature Communications, reveals previously unexplored dynamics of single skyrmions, the researchers say. Discovered around a half-decade ago, skyrmions have sparked interest in physics as a path toward next-generation computing devices that take advantage of the magnetic properties of particles—a field known as spintronics.

"There has been a lot of research into the global dynamics of skyrmions, using their movements as a basis for performing computations," said Ford Foundation Professor of Physics Gang Xiao, senior author of the research. "But in this work, we show that purely random fluctuations in the size of skyrmions can be useful as well. In this case, we show that we can use those fluctuations to generate random numbers, potentially as many as 10 million digits per second."

Most random numbers produced by computers aren't random in the strictest sense. Computers use an algorithm to generate random numbers based on an initial starting place, a seed number. But because the algorithm used to generate the number is deterministic, the numbers aren't truly random. With enough information about the algorithm or its output, it could be possible for someone to find patterns in the numbers that the algorithm produces. While pseudo-random numbers are sufficient in many settings, applications like data security—which uses numbers that can't be guessed by an outside party—require true random numbers.

Methods of producing true random numbers often draw on the natural world. Random fluctuations in electrical current flowing through a resistor, for example, can be used to generate random numbers. Other techniques harness the inherent randomness in quantum mechanics—the behavior of particles at the tiniest scale.

This new study adds skyrmions to the list of true random number generators.

Skyrmions arise from the "spin" of electrons in ultra-thin materials. Spin can be thought of as the tiny magnetic moment of each electron, which points up, down or somewhere in between. Some two-dimensional materials, in their lowest energy states, have a property called perpendicular magnetic anisotropy—meaning the spins of electrons all point in a direction perpendicular to the film. When these materials are excited with electricity or a magnetic field, some of the electron spins flip as the energy of the system rises. When that happens, the spins of surrounding electrons are perturbed to some extent, forming a magnetic whirlpool surrounding the flipped electron—a skyrmion.

Skyrmions, which are generally about 1 micrometer (a millionth of a meter) or smaller in diameter, behave a bit like a kind of particle, zipping across the material from side to side. And once they're formed, they're very difficult to get rid of. Because they're so robust, researchers are interested in using their movement to perform computations and to store data.

This new study shows that in addition to the global movement of skyrmions across a material, the local behavior of individual skyrmions can also be useful. For the study, which was led by Brown Postdoctoral Fellow Kang Wang, the researchers fabricated magnetic thin films using a technique that produced subtle defects in the material's atomic lattice. When skyrmions form in the material, these defects, which the researchers call pinning centers, hold the skyrmions firmly in place rather than allowing them to move as they normally would.

The researchers found that when a skyrmion is held in place, they fluctuate randomly in size. With one section of the skyrmion held tightly to one pinning center, the rest of the skyrmion jumps back and forth, wrapping around two nearby pinning centers, one closer and one farther away.

"Each skyrmion jumps back and forth between a large diameter and a small diameter," Wang said. "We can measure that fluctuation, which occurs randomly, and use it to generate random numbers."

The change in skyrmion size is measured through what's known as the anomalous Hall effect, which is a voltage that propagates across the material. This voltage is sensitive to the perpendicular component of electron spins. When the skyrmion size changes, the voltage changes to an extent that is easily measured. Those random voltage changes can be used to produce a string of random digits.

The researchers estimate that by optimizing the defect-spacing in their device, they can produce as many as 10 million random digits per second, providing a new and highly efficient method of producing true random numbers.

"This gives us a new way of generating true random numbers, which could be useful for many applications," Xiao said. "This work also gives us a new way of harnessing the power of skyrmions, by looking at their local dynamics as well as their global movements."

This research is supported by the National Science Foundation (OMA-1936221).

DOE GRANT TO TRAIN NEXT GENERATION OF HIGH-ENERGY EXPERIMENTAL PHYSICISTS

By Pete Bilderback

The Department of Energy (DOE) awarded a $2 million grant over five years to a team consisting of lead PI Professor Ulrich Heintz and co-PIs Professor Meenakshi Narain and L. Herbert Ballou University Professor of Physics Vesna Mitrović to train the next generation of high-energy experimental (HEE) physicists in the use of silicon detectors, quantum sensors and electronics for high-energy physics. The Brown group teamed up with researchers from Brookhaven National Lab and Princeton University to develop a unique curriculum that enables HEE students to learn how to exploit the interaction of particles with matter to detect them in a particle physics experiment.

This grant will exploit the synergy with the Brown silicon lab, which is dedicated to the development and construction of a new silicon tracker for the Compact Muon Solenoid (CMS) experiment at the High-Luminosity Large Hadron Collider, which will start operation in 2029. "The tracker upgrade project provides a unique opportunity for students to learn how to design and build a state-of-the-art detector for a high-energy physics experiment," said Heintz.

The 2019 DOE report, "Basic Research Needs for High-Energy Physics Detector Research & Development," identified a shortage of physicists with the skills to design next-generation high-energy detectors and sensors. Heintz was a founding member of the Coordination Panel for Advanced Detectors of the Division of Particle Physics of the American Physical Society, which has promoted the creation of such programs.

"Researchers cannot just purchase particle detectors off the shelf. Experimentalists must custom-design every aspect of the detector to optimize the performance of each new experiment," said Heintz. University programs typically do not teach these skills. The Brown/Brookhaven/Princeton collaboration seeks address this need. "The traineeship program will fill in the gaps in the training of high-energy experimentalists so they can innovate and build the particle detectors of tomorrow," said Heintz.

Brown Ph.D. students are admitted to the DOE training program after passing their comprehensive exam at the start of their second semester. Students will be required to take certain advanced courses already in the Brown curriculum. In addition, students will take four specially designed modules: "Silicon Sensors for Tracking and Timing," "Silicon Trackers," "Quantum Sensors and Detectors," and "Detector Electronics." These modules will be integrated into current research and development projects so that students learn HEE physics in a practical environment at the discipline's cutting edge. At Brown, students will conduct research projects related to upgrading the CMS silicon tracker.

Trevor Russell, a department of physics Ph.D. student enrolled in the program, expressed enthusiasm about the opportunity to study detectors in such detail, "The DOE traineeship is exciting because high energy experimentalists don't always get the opportunity to learn about the intricacies of particle detection and all the factors that are important to creating effective detectors."

Russell noted that students "rarely get the opportunity to learn about the underlying physics of those devices, especially in a formal setting. Massive detectors such as CMS require tons of design choices at every level to accommodate the relevant physics in every small piece of the detector, and it is important for high-energy experimental students to understand what is influencing those design choices for the field to be able to develop new and better systems of particle detection for the future."

In addition, Russell praised the internships that are integral to the program, he noted they enable students to spend the summer doing research at Brookhaven National Laboratory, which has resources and equipment for research and design far beyond the means of any university.

Senior Research Associate Andrei Korotkov, program trainee Nikolas Pervan and lead PI Professor Ulrich Heintz with trainee Trevor Russell.
PHOTO: BROWN UNIVERSITY/DEPARTMENT OF PHYSICS

This research is supported by the Department of Energy (DE-SC0022541).

LARGE HADRON COLLIDER CELEBRATES HIGGS ANNIVERSARY AND BEGINS RUN 3

On July 5, 2022, after three years of upgrades and maintenance work, the Large Hadron Collider (LHC) is up and running again, marking the beginning of "Run 3."

The LHC is the world's largest and most powerful particle accelerator and one of the largest machines that humans have ever built. It consists of a ring of superconducting magnets, more than 16 miles in circumference, in which two beams of protons circulate in opposite directions near the speed of light. When the beams collide, the protons explode into exotic subatomic particles that are observed by the Compact Muon Solenoid (CMS) and ATLAS detectors. Those observations provide critical information about how our universe works at the most basic level.

The restart date is 10 years and one day after the LHC made history on July 4, 2012, when both the CMS and ATLAS experiments revealed the first detection of the Higgs boson, arguably the most important result in experimental physics of the twenty-first century.

The mechanism that gives rise to the Higgs boson was proposed in 1964 to explain the existence of massive elementary particles. The Higgs boson was the last missing particle needed to verify the Standard Model.

Brown University Professor of Physics Greg Landsberg was Physics Coordinator of CMS from 2012-2013 and led this exciting quest for a long-sought after particle. Professor Ulrich Heintz was an internal peer reviewer of the Higgs discovery analysis and Professor Meenakshi Narain led the group responsible for developing the techniques to find bottom quarks among the data, which was critical in looking for one of the possible indirect signals of a Higgs.

On June 30, 2022, Narain co-organized the celebration of the 10th anniversary of their participation in the discovery of the Higgs boson by the CMS and ATLAS experiments at the LHC by the U.S. High Energy Physics community. The High Energy Experiment (HEE) group at Brown University participated in this celebration via Zoom with other institutions.

During Run 3, the collider will operate around the clock for nearly four years at a record energy of 13.6 trillion electronvolts (TeV) – 6.8 TeV per beam, providing greater precision and discovery potential than ever. "We will be focusing the proton beams at the interaction points to less than 10-micron beam size to increase the collision rate," said Director for Accelerators and Technology Mike Lamont in a CERN press release. The CMS and ATLAS detectors expect to record more collisions during Run 3 than in the two previous runs combined.

The Brown HEE group is led by Heintz, Landsberg and Narain, and includes four post-doctoral researchers, 10 Ph.D. students and a number of undergraduate students. They are busy developing innovative analysis techniques using machine learning and artificial intelligence to study the data that will be collected during Run 3. Advanced analysis techniques, increased data samples, and higher energy collisions will allow them to probe the nature of the Higgs boson and the limits of validity of the Standard Model with unprecedented precision.

The CMS detector was upgraded along with the LHC in advance of Run 3 to deliver more precision and power. PHOTO: COURTESY CERN

Brown researchers will examine how strongly the Higgs boson interacts with matter and force particles. They will explore whether it decays into new particles and how it interacts with the heaviest known particle, the top quark. They will also search for candidates for dark matter and look for new particles beyond what is predicted by the Standard Model in hopes of solving some of the deepest mysteries in physics. "We're looking forward to seeing all the new discoveries made possible by Run 3," said Brown Professor of Physics and Chair of the Collaboration Board of U.S. CMS Meenakshi Narain.

Brown Ph.D. student Daniel Li is assisting in Run 3 data certification as a shifter and soon-to-be shift leader. Li said, "My role is to look at the Run 3 silicon tracker detector performance after off-line processing and to effectively give a 'stamp of approval' that the tracker operated as expected during the data-collection period."

The dissemination of the results is just as important as recording and analyzing the data. Landsberg chairs the CMS Publication Committee, which oversees all of the collaboration's publications in order to disseminate the many results derived from the data collected by the experiment. The committee ensures that the 100 or so papers that CMS publishes annually meet the highest scientific standard.

In the last year, CMS published one Nature and two Nature Physics papers, which were highly publicized because of their importance and impact on the field. "It's been a thrilling ride with the editors, authors, and science journalists to make these publications happen and to publicize our results," Landsberg said.

"Meanwhile, our team at Brown is already hard at work on the High-Luminosity (HL) LHC upgrades," Narain said. The HL-LHC is scheduled to start operations in 2029 and is expected to increase the amount of data collected by the LHC by almost an order of magnitude. This requires upgrades to the LHC and the detectors.

Heintz is coordinating the development and construction of detector modules for a new silicon tracker for the HL-LHC. Over 13,000 such modules will be built at 10 centers in the U.S., Europe and Asia before being assembled into the CMS tracker at CERN.

At Brown, Heintz leads a team of five technical staff, a post-doc, and several graduate students working on designing and building Brown's share of the modules. "The challenge is that these modules are supposed to have as little material as possible, they have to be assembled to a 10-micrometer precision, and they have to operate at a temperature of -30 degrees Celsius for 10 years in the radiation environment created by the particle collisions in the HL-LHC," Heintz said.

This year also saw the conclusion of Snowmass 2021, the 2-year community planning exercise that brought together the U.S. high-energy physics community to strategize the experiments for the coming 10 years.

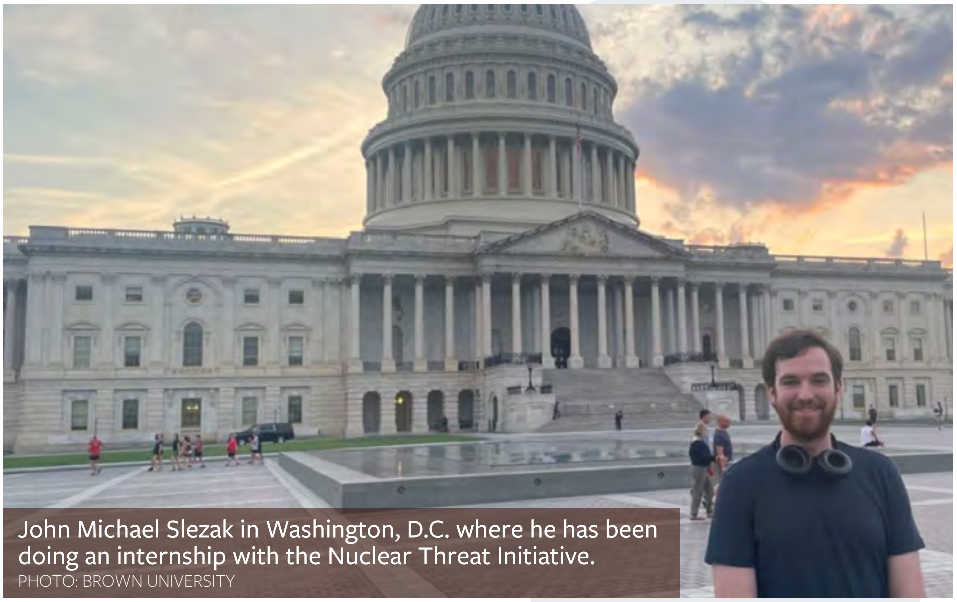
Narain was one of the three leaders of the effort as a convener of the Energy Frontier Group, charged with investigating the potential of a range of proposed future colliders to explore physics at the highest energy scales. Under her leadership, the community defined the long-term vision for U.S. participation, recommending construction of a Higgs factory as rapidly as possible, with the possibility of hosting it in the U.S., and research and development towards an ultimate multi-TeV discovery collider for the long-term future. There were about 150 white-papers submitted to her group. In addition, Heintz was one of the conveners of the Electron-Positron Collider Forum. The effort concluded with the publication of the final reports after a meeting at the University of Washington in July.

This research is supported by the Department of Energy (DE-SC0010010).

STUDENT SPOTLIGHT

JOHN MICHAEL SLEZAK: RESEARCHING THE RISKS, IMPACTS OF NUCLEAR WAR WITH THE NUCLEAR THREAT INITIATIVE

By Lauren Borsa-Curran



John Michael Slezak in Washington, D.C. where he has been doing an internship with the Nuclear Threat Initiative.
PHOTO: BROWN UNIVERSITY

On a Friday afternoon in July, amid a thick heat that had settled over Washington, D.C., rising Brown junior John Michael Slezak found some time to unwind with a book under a shade tree on the National Mall. As an intern with the Nuclear Threat Initiative, NTI a global security nongovernmental organization focused on reducing nuclear and biological threats, Slezak is spending his summer immersed in complex global issues.

"Thinking all week about how a nuclear war would start and then what happens as a result can be taxing," said Slezak, who is working on NTI's Science and Technical Affairs team. "I go to the Mall to read anytime I have a break—I am always out reading on the National Mall."

That's not to say his reading material is the latest summer beach read.

Slezak, who is concentrating in mathematical physics at Brown with plans to declare a second concentration in international and public affairs, ventured to Washington to join NTI in June. As part of a role developing written communications to better engage the public on critical nuclear and cybersecurity issues, his responsibilities include poring over and synthesizing complex data and source materials, with a focus on topics like the impact of artificial intelligence on nuclear weapons systems.

"The Nuclear Threat Initiative has in prior years produced reports on the modernization currently happening in the United States on cybersecurity and nuclear weapons systems," Slezak explained. "They've done a piece on misinformation in nuclear crises. What I am trying to do is take all of these issues together and write one comprehensive look at artificial intelligence in nuclear systems."

He also co-created a summer book list—some of that National Mall reading—for the public to learn more about the nuclear and biosecurity fields, and has been combing through studies depicting outcomes from nuclear war, condensing the information into an easy-to-use, publicly accessible format: "I am looking at scientific articles and research declassified from the U.S. Department of Defense, trying to make it more understandable, and synthesizing it into a one-pager for policymakers and other audiences," he said.

Slezak said that taken together, the projects for NTI are helping him sharpen his academic focus at Brown and providing an even clearer idea of what he'd like to do professionally. He said he envisions a role working with policymakers on scientific issues: educating them on critical issues like climate change and helping them make evidence-based policy decisions.

"I want to be able to take other people's research and convey it effectively, whether to the general public or to policymakers to help enact legislation," he said. "There is a lot of scientific research done and there is a lot of policy written—however, there is also a lot of disconnect when scientists meet policymakers. I want to fill the gap of being able to understand the science and the technical side, while also being able to negotiate and talk to politicians in their native language of policy and politics."

When Slezak came to Brown as part of the Class of 2024, he initially expected to begin long-term study toward a Ph.D. in physics, a discipline he continues to study and love. But a set of policy-related experiences ultimately led him down a different path. He completed a legislative internship with the Rhode Island Secretary of State's office, for example; and he serves as secretary for the campus organization No Labels, which promotes bipartisan cooperation on large challenges.

Slezak is also working on a research project with Reid Pauly, an assistant professor of nuclear security and policy at Brown's Watson Institute for International and Public Affairs. Pauly's project, "Threats That Leave Something to Chance," is investigating how nuclear powers compete under the shadow of nuclear war that threatens their mutual annihilation. Slezak is helping to conduct a literature review and build a dataset of cases of global brinkmanship, including in Ukraine. He's also now learning to speak Mandarin with an eye toward potential opportunities to work on issues related to U.S. and China relations.

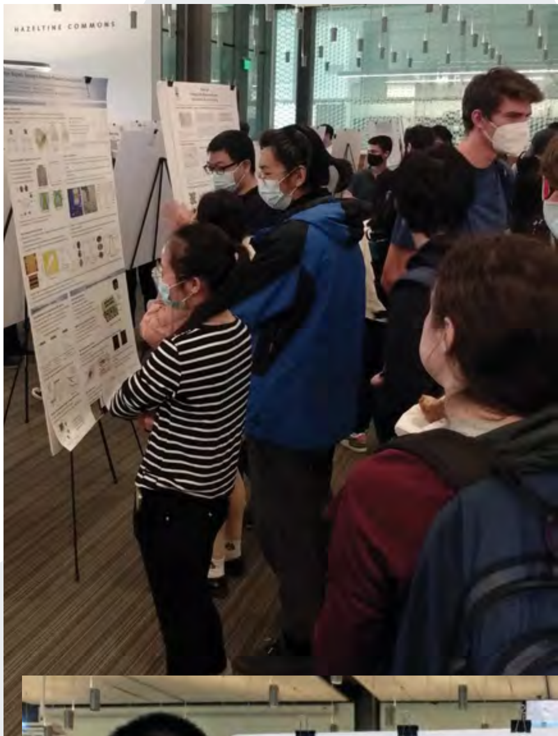
Beyond his formal role with NTI, Slezak said he has enjoyed the independence of life in Washington this summer. The experience has, however, made him long for one aspect of living on College Hill:

"I miss the Ratty and Brown Dining Services!" he said. "While I do enjoy cooking, it's nice to not have to cook for yourself 24/7 and just be able to stop by the Ratty for food."

After his internship ends in August, Slezak will return home to his native Colleyville, Texas, before heading back to Providence. He's excited to come back to campus in the fall, he said, for a semester of classes ranging from physics to political science.

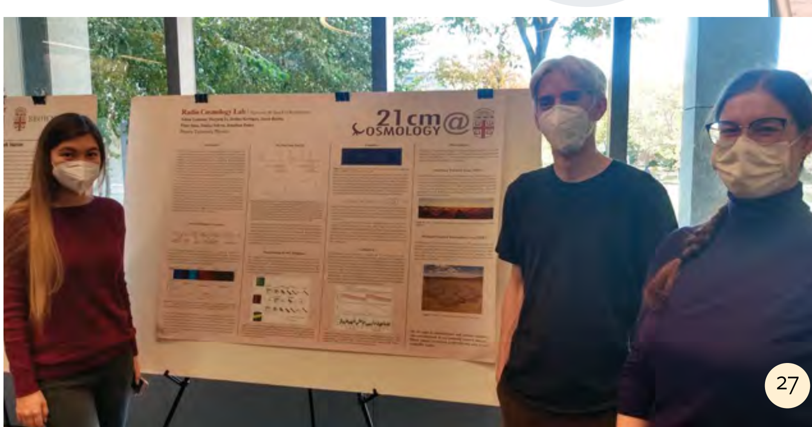
"I'm just looking forward to getting back to learning as much as I can at Brown, with the hope that in the next job I have, I'm even more productive and useful," he said.

The Department of Physics hosted its **annual poster session** on Wednesday November 3, 2021. Student researchers proudly displayed more than 30 posters, representing innovative and engaging projects from all of the department's research areas in the lobby of the Engineering Research Center. It was the first in-person poster session in two years.



Poster sessions offer undergraduate and graduate students a unique opportunity to find research opportunities in the department. Students currently engaged with a research group are able to present their topic to the department, including their project methods and findings.

Over 100 undergraduate and graduate students, staff, and faculty participated in the event, asking questions and discussing projects, findings and new ideas. The event also included cider, doughnuts and friendly conversation.



PHOTOS: MAE JACKSON/BROWN UNIVERSITY

TABLE OF CONTENTS

Angella Johnson

COMMUNITY OUTREACH

JOHNSON DEVELOPS EDUCATIONAL VIDEO SERIES PHYSICS FUNDAMENTALS

By Pete Bilderback

Physics Fundamentals is a new educational video series from the Brown University Department of Physics intended to make essential physics concepts accessible and fun for young science students. The series is the brainchild of Physics Demonstrations Manager Angella Johnson and produced in collaboration with Media Services in Brown's Office of Information Technology with the aid of Brown Physics faculty members.

The first video in the series, "How does a slinky walk down the stairs?" has already been posted to the department's YouTube channel and garnered attention with over 1,000 views. In the video, students discover the physics behind the ubiquitous toy's seeming ability to "walk" down a flight of stairs with the aid of Brown Professor of Physics James Valles and demonstrations set up by Johnson.

A second video that explains the physics behind the skateboarding trick known as "the ollie" premiered on YouTube on Friday, May 6, 2022. In the video, Associate Professor of Physics Derek Stein explains the fundamental physics behind the famous trick in which both the skateboarder and the skateboard leap into the air simultaneously. Brown physics graduate students Nicholas Drachman and Jacob Burba assisted Stein by demonstrating the trick at a local skate-park. Drachman held the world record for landing the most consecutive ollies (302) from October 14, 2018, until August 24, 2021, a feat memorialized in Guinness World Records. Stein is enthusiastic about the result and said, "We hope this will become known as the 'Video Days' of skateboarding physics videos."

A third video featured Professor Bob Pelcovits demonstrating how to make a skateboard go really fast using a fire extinguisher for propulsion.

The fourth video in the series focused on the physics of rock climbing with Professor Jia (Leo) Li. The video was complemented by an event titled "A Conversation on Excellence: The Convergence of Physics and Rock Climbing." Organized by Johnson and Li, the event featured a conversation between Brown Professor of Physics and Nobel Laureate (and acclaimed rock climber) J. Michael Kosterlitz and top professional rock climbers and filled the 500+ capacity large auditorium in Salomon Hall.

Graduate student Nicholas Drachman demonstrates how to do an "ollie." PHOTO: DEPARTMENT OF PHYSICS/BROWN UNIVERSITY

Physics Demonstrations Manager Angella Johnson created and hosts the series. PHOTO: DEPARTMENT OF PHYSICS/ BROWN UNIVERSITY

INSPIRATION

Johnson said the inspiration for Physics Fundamentals came to her while she was in her previous position at the University of Southern California. She said she was inspired to create a physics video series after doing some behind-the-scenes work on commercials and television programs and from working with USC Professor of Physics Clifford Johnson. Professor Johnson is renowned for his ability to explain complex physics concepts to the general public through blogging, videos, multimedia, and graphic novels.

While the videos "are primarily targeted at middle and high school age students," Johnson said she believes they will be "enjoyed by anyone interested in science regardless of age." According to Johnson, the purpose of the videos is twofold, "to serve as a resource that teachers can use in the classroom, but also to pique the interest of young minds to pursue science as a career path."

A TEAM EFFORT

Soon after starting at Brown, Johnson approached then physics department chair Gang Xiao about a video series and quickly gained his enthusiastic support. Xiao recognized the idea aligned with his priorities as chair and would serve as a valuable means of outreach into the community. She then met with former Director of Educational Media, Tanya Waldburger, who put her in touch with Associate Director of Media Services Giovanna Roz Gastaldi.

Gastaldi was also excited by the idea and assigned members of her team, including Paul Marsella and Michael Spaur, to work with Johnson on developing scripts and shooting the videos. Johnson said she also found Brown Physics faculty members eager to participate in the project and that their expertise was essential in creating videos that are both informative and accurate.

Johnson said she is happy to be working at a university with both the resources and vision that allowed her to pursue such an ambitious project. She said she is "grateful for the support I've received from all corners of the University."

COMMUNITY OUTREACH

JACKSON CELEBRATES 50 YEARS AT LADD OBSERVATORY

By Pete Bilderback

Department of Physics Staff Astronomer Francine Jackson began volunteering at Ladd in 1972.
PHOTO: COURTESY JIM HENDRICKSON

Ladd Observatory's Staff Astronomer, Francine Jackson, began volunteering at Ladd in 1972, shortly after completing a B.S. in Astronomy at the University of Illinois, Champaign-Urbana. Fifty years later, she's still working there, helping Ladd to continue its long tradition of community engagement.

Jackson recalls that shortly after graduating, she took a trip to Halifax with a classmate to observe a solar eclipse. "It was there that I saw a Winnebago that said 'Skyscrapers of Rhode Island,' and I was very interested in talking to them since I knew I'd be moving back to Rhode Island soon." (Skyscrapers is a local amateur astronomy society that was formed in 1932 and originally met regularly at Ladd.) "I learned from them that Ladd Observatory had volunteer opportunities," said Jackson. "So when I returned home, I started volunteering, and I've been working there ever since."

Jackson's interest in astronomy began at the age of eight. "That's when I started taking astronomy books out of the library," said Jackson. "It just hit me all of a sudden, and I don't know why. No one in my family was science-oriented. I just fell in love with it. I decided I wanted to be an astronomer even though I didn't really know what they do," she said.

As a girl, Jackson received little encouragement to pursue her ambitions. "People just kind of looked at me cross-eyed when I told them what I wanted to do," she said. Her parents were indifferent at best, "My mother was a bookkeeper, and she wasn't willing to pay for me to go to college unless I went somewhere like Katharine Gibbs."

She didn't initially receive much more encouragement at the University of Illinois. "My first day, the adviser I was assigned told me, 'We have too many women in this field already. You should go down the hall to the English department,'" said Jackson. "And my adviser was a woman!" she added. "But I got my degree in astronomy anyway, and I've loved it ever since."

At the time Jackson began volunteering, Ladd's future was uncertain. Charles Smiley, Ladd's former Director and Chair of the Department of Astronomy, retired in 1969, and the University was considering demolishing the observatory and selling off the equipment. "Ladd was over a mile away from campus, and a lot of students didn't even know it was there," said Jackson. "The University wasn't sure what to do with it. At one time, Burger King and another time McDonald's thought it would be ideal to have a location there."

Jackson said she and the other volunteers saw it as their duty to make sure the observatory remained active and engaged with the community so the University would continue to see its value. Ladd had been regularly holding open nights for public viewing since 1930.

Jackson continued Smiley's tradition of having the observatory open to the public every Wednesday evening. On those nights every month, Jackson booked two speakers, screened one movie, and held one open house. "Wednesday night was the tradition for many years," said Jackson, "At some point, the University decided they couldn't just have volunteers running the facility, and the physics department's Lab Manager Bob Horton became involved. Unfortunately, he worked on Wednesday nights, so we had to switch to Tuesday nights."

Horton remembers first meeting Jackson as a teenage astronomy enthusiast, "I first met Francine after getting involved with Skyscrapers at a meeting at Ladd in 1975," he said. "Francine was very welcoming. She loved showing people around the observatory and had a way of getting people very excited about what they were about to see in the telescope."

Horton said Jackson had a significant impact on his career. "Years later, Francine was looking for speakers and brought me in to show some of my astronomy photographs," he said. "It turned out to be very impactful because it led directly to my employment with the physics department."

By the eighties, Ladd was starting to show its age. "The building needed repointing," said Jackson, "so we started a fundraising campaign to cover the cost of repairs." But around the same time, the City of Providence noticed the building was not ADA compliant. "The University had to spend that money to install an elevator in the building," said Jackson.

Ladd earned a spot on the National Register of Historic Places in 2000, and Jackson helped the observatory obtain grants from the Providence Historical Society and Heritage Commission to renovate its transit room in 2008. Brown University and an anonymous donor also contributed funding. "The transit room was falling apart," said Jackson. "But now it's beautiful, and it helped to bring the public back, which is the main reason why the observatory is still there."

In 2012, Ladd was honored with a Rhody Award for its restoration of the transit room, which was once used to keep time for the City of Providence. By tracking the transit of stars across the meridian, the telescope provided a consistent time standard, and the observatory's clocks were calibrated to it. From 1893 to 1916, Ladd sent the time via telegraph to businesses and government offices in downtown Providence, where it was used to synchronize clocks and watches.

Ladd was closed to the public for 18 months due to the pandemic but reopened in October of 2021. Jackson said the public's interest in the observatory has been high since its reopening. "People keep coming. We take them upstairs to look through the telescope, and I take them downstairs to show them our beautiful Conant clock," she said. "[Observatory Curator] Michael Umbricht has a waiting list of people wanting to visit the observatory," she adds. "As long as people keep wanting to come, Ladd will remain a viable entity, and we'll keep educating and entertaining them."

Stephon Alexander & Farrah Simpson

COMMUNITY OUTREACH

PROFESSOR AND GRAD STUDENT LAUNCH MENTORING PROGRAM FOR UNDERREPRESENTED STUDENTS

By Kevin Stacey

During his sabbatical leave last semester, Brown physics professor Stephon Alexander did what most scholars do with their time away from teaching: He concentrated on his research. In Alexander's case, that meant honing a theory of gravity that could explain puzzling aspects of the universe.

But that's not all he did with the time.

"I had a few different opportunities for my sabbatical, but I really wanted to do something that provided an opportunity to give something back to the neighborhood where I grew up in the Bronx," Alexander said. "I was very lucky when I was growing up to have great mentors who got me interested in math and science. I wanted to be able to do something similar for another generation of kids."

So working with Brown Ph.D. student Farrah Simpson, Alexander pooled resources from the Harlem Gallery of Science, where he serves as executive director, and the National Society of Black Physicists (NSBP), where he serves as president, to launch a program called "Dream+Inspire: Mentoring Future Leaders." The idea was to recruit professors and graduate students from the ranks of NSBP to serve as mentors for middle and high school students, many of whom are from groups historically underrepresented in STEM fields, from Harlem and the South Bronx.

Over the course of 13 weeks, mentors and mentees met weekly via Zoom, working on math and science exercises, reviewing students' homework assignments, and sometimes just talking about what's happening in each other's lives. On a monthly basis, the entire cohort of 10 mentors and around 20 mentees met for larger group activities and discussions. The first cohort of students completed the program last January. A second cohort completed the program this summer.

"It's much more than just kids getting help with help with homework," Alexander said. "When they see their mentors in this program, the kids see their future selves. Just meeting a Black person who's at Brown or Harvard, that gives kids a lot of hope and a lot of confidence. And it may also get a kid thinking about college who hadn't otherwise thought about it."

Stephon Alexander
PHOTO: COURTESY HEATHER GOODELL

Simpson, a graduate student representative on NSBP's executive board, helped to coordinate the effort as a mentor leader. She worked with other mentors, mostly graduate students from universities across the country, to develop activity plans used in one-on-one and cohort meetings. She said the experience has meant just as much to the mentors as it has to the mentees.

"I remember when I was that age, I loved the sciences, but I didn't have many mentors to look up to and didn't know of any scientists who looked like me," Simpson said. "So having the chance to be that for these students, and to see our other mentors put in the work to be that for these students, has really been amazing."

One student named Zainab said that interacting with her mentor provided a huge confidence boost.

"It was a reminder that I should never doubt myself and I know what I'm doing," she said. "Just believing and trusting in me, in who I am, I will achieve success."

Working with the National Society of Black Physicists and the Harlem Gallery of Science, Brown physicist Stephon Alexander with the help of Ph.D. student Farrah Simpson launched the 'Dream+Inspire: Mentoring Future Leaders' program

Other mentees said the relationships with mentors have been important well beyond math and science. Particularly during the pandemic, mentees said they appreciated the personal bonds formed with mentors.

"My mentor, Elon, guides me on things not just in the program but also in school," said a student named Tanaya. "I can talk to her about anything that's bothering me."

Simpson said it's also been inspiring to watch students grow and thrive as the program unfolded.

"We have one student, Cherif, who learned that he had just gotten into a science program at Penn State, which is really exciting," she said. "We have another student, Isabella, who is only in sixth grade but asks such incredibly advanced questions it's hard to believe she's so young. I'm so excited to see where these students go from here, as well as where this program goes from here."

Alexander and Simpson say that they consider work they've done in Harlem and the Bronx to be a successful pilot of something they hope will become much larger.

"We'd love to scale up and do this in other places," Alexander said. "It would be great to try this in Providence, for example. Now that we've shown how well this can work, it would be great to expand."

For now, Alexander said he's happy with what these first cohorts were able to accomplish.

"Things really happened to come together just right for us to create something beautiful—especially amid the pandemic, which was really isolating for our mentees and mentors," Alexander said. "I think it was quite rewarding for everybody involved."

TABLE OF CONTENTS

UPDATE FROM THE BTPC
(Brown Theoretical Physics Center)

Brad Marston
Director, Brown Theoretical Physics Center

The BTPC leadership saw some changes this past summer. Brad Marston became the director following the departure of S. James Gates Jr., and JiJi Fan joined the BTPC Executive Committee. She, along with Savvas Koushiappas and Robert Pelcovits, represent the core physics areas of the center (high-energy theory, astrophysics and cosmology, and condensed matter theory). Two new postdocs, Humberto Gilmer and Tucker Manton will join the center as members of Stephon Alexander's group in September. They will co-organize the "InterDisciplinary made EAsy" (IDEA) seminar created by postdoc Stephen Carr. Jeff Oishi, on sabbatical from Bates College, will be a visiting member of the BTPC this coming year, and will give a series of lectures on "An Introduction to Computational Fluid Mechanics" supported in part by the Houghton fund.

One of Marston's goals this coming year is to find unifying scientific themes that can spur the development of new proposals for center funding. The Boulder Summer School on "Hydrodynamics Across Scales" that ran during July suggests one possibility. Three BTPC faculty participated in the program, and length scales considered ranged over 36 orders of magnitude (from the quark-gluon plasma to cosmic rays viewed as an intergalactic fluid). Thus, the theme is one in which faculty from high-energy, cosmology, condensed matter and climate physics could participate.

The BTPC is also connected to Brown's emerging Initiative for Sustainable Energy (ISE) and research being carried out at Brown in the quantum information sciences. Both areas recently received substantial federal funding from the Inflation Reduction Act and CHIPS and Science Act.

A monthly "Walk with the Director" will start in the fall. Friends of the BTPC, students, staff and faculty will be invited to join Marston on walks from the Barus building to the Blackstone Park Conservation District.

UPDATE FROM THE CFPU
(Center for the Fundamental Physics of the Universe)

The CFPU has had another active and successful year advancing its mission to enhance and increase research collaboration and output amongst its members. You can read about some of that activity in this issue.

Director Richard Gaitskell's group has continued its work on the LUX-ZEPLIN experiment (see page 14). Stakeholder Jonathan Pober was awarded a NASA Nancy Grace Roman Technology Fellowship in Astrophysics (see page 21). Meanwhile, stakeholder Gregory Tucker will work with center affiliate stakeholders from the Department of Earth, Environmental and Planetary Sciences to study exoplanets and determine where life may exist beyond Earth.

Graduate students Michael Toomey, Austin Vaitkus, Bjorn Burkle and Nikolas Pervan have been leading the CFPU-sponsored Student Machine Learning Initiative. The group has organized frequent workshops and seminars to ensure the physics undergraduates, graduates and postdocs gain important new insights and examples of how to apply machine learning to their research studies.

The center has been successful in its mission to attract funding. Gaitskell and stakeholders JiJi Fan, Ian Dell'Antonio, Greg Landsberg and Ulrich Heintz, along with other Brown physics collaborators, were awarded a three-year Department of Energy (DOE) grant to study fundamental problems in astroparticle physics and cosmology. Heintz and other physics faculty were also awarded a DOE grant to help train the next generation of high-energy experimental physicists. Stakeholder Stephon Alexander was awarded a grant from the Simons Foundation to study dynamical Chern-Simons gravity and a National Science Foundation grant to study dark matter through the phenomenon of gravitational lensing.

Stakeholder Greg Landsberg was named chair of the publications committee for the Compact Muon Solenoid Collaboration, and Alexander was appointed to the editorial board of the Journal of Cosmology and Astrophysics (see page 22). Alexander also established, with Brown Ph.D. student Farrah Simpson, a new mentorship program for students from historically underrepresented groups (see page 30).

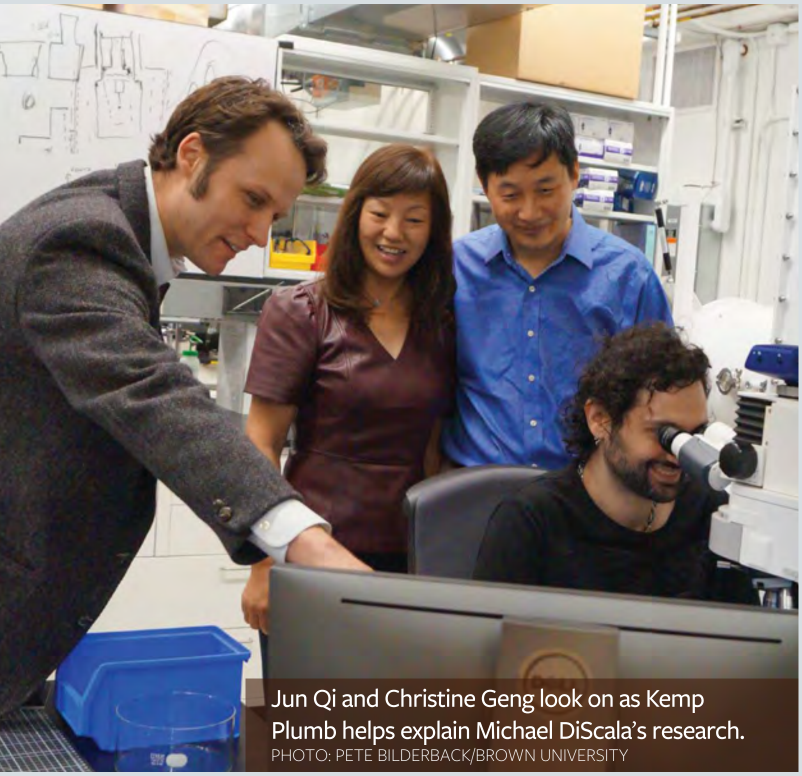
Center stakeholders will build on these accomplishments in the coming year and continue their interdisciplinary research to deliver further successful research proposals and papers.

Richard Gaitskell
Director, Center for the Fundamental Physics of the Universe

STUDENT SPOTLIGHT

2021 - 2022 AWARDS AND FELLOWSHIPS

JUN QI AND CHRISTINE GENG GRADUATE FELLOWSHIP IN CONDENSED MATTER PHYSICS



Jun Qi and Christine Geng look on as Kemp Plumb helps explain Michael DiScala's research.
PHOTO: PETE BILDERBACK/BROWN UNIVERSITY

Michael DiScala was the second student to be awarded the Jun Qi and Christine Geng Graduate Fellowship in Condensed Matter Experimental Physics. The Fellowship allowed DiScala to focus their attention on cutting-edge research in condensed matter physics with their adviser, Professor Kemp Plumb. Qi '03 Ph.D. and his wife, Christine, recently visited Brown and toured the department to see the work they have been supporting in person.

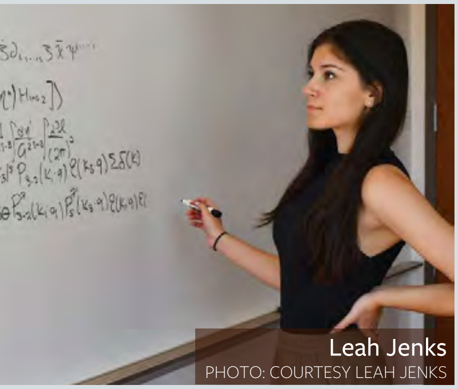
DiScala's work focuses on studying novel magnetic materials through the use of x-ray scattering, in particular, what is known as Resonant Inelastic X-Ray Scattering (RIXS). Their primary project involves studying the electronic and magnetic properties of van der Waals (vdW) materials, specifically, how the number of atomic layers affects these properties approaching the 2D limit.

DiScala noted, "my research also involves the development of microscopic patterns used for precise sample localization using an x-ray beam in an ultra-high vacuum, where limitations on optical microscopes prevent direct visualization of exfoliated samples." All of the components of these microscopic fine-detailed patterns are developed in the nano-fabrication facilities at Brown. According to DiScala, these strongly correlated vdW materials "present an unparalleled opportunity to explore fundamental theorems of magnetism in 2D experimentally."

The majority of DiScala's experiments are conducted at synchrotrons located at various research institutes worldwide. DiScala said, "This fellowship will support me in my travels and allow me to continue to develop new techniques that expand the feasibility of RIXS and other x-ray spectroscopy experiments well into the 2D limit."

ANTHONY HOUGHTON AWARD FOR EXCELLENCE IN THEORETICAL PHYSICS

The 2021-2022 Anthony Houghton Award for Excellence in Theoretical Physics was awarded jointly to Leah Jenks, Ph.D. '22 and Yangrui Hu, Ph.D. '22. The award is given each year to a deserving student or students and is named for Anthony "Tony" Houghton, who was a world-renowned theoretical condensed matter physicist and was a faculty member in Brown University's Department of Physics for over 40 years.



Leah Jenks
PHOTO: COURTESY LEAH JENKS

Jenks' research lies at the various interfaces of cosmology, gravitational physics and high-energy physics. Her graduate work, done under the supervision of Professor Stephon Alexander, focused mostly on two threads: higher spin cosmology and modified theories of general relativity.

Hu's research revolves around supersymmetry, supergravity, and celestial holography. Her graduate work, done under the supervision of Professor S. James Gates Jr., focused on investigating the long-standing problem of the off-shell theory of 10D and 11D supergravity via novel tools.

Hu said, "It is a great honor to be affiliated with this award. I am grateful to receive this recognition from those who have contributed so much support and encouragement to my experience as a grad student in high energy theory."

Both Jenks and Hu earned their Ph.D. from the department this Spring. Hu is currently a Postdoctoral Research Fellow a the Perimeter Institute, and Jenks is a KICP Postdoctoral Fellow at the University of Chicago.

Yangrui Hu with adviser S. James Gates Jr.
PHOTO: COURTESY YANGRUI HU

FORREST AWARD FOR WORK RELATED TO EXPERIMENTAL APPARATUS

The Forrest Award for Excellence in Work Related to Experimental Apparatus for 2021-2022 was awarded to Yiou Zhang. The award is made every year in honor of Charles "Charlie" Forrest, who was head of the physics instrument shop and later the Joint Engineering Physics Instrument Shop.

Zhang, along with a team that included Brown Postdoctoral Research Associate Kang Wang and Ford Foundation Professor of Physics Gang Xiao, developed a new type of compact, ultra-sensitive magnetometer. The device is detailed in a paper published in Applied Physics Letters.

Zhang believes the device could have widespread applications. "Because the device is very small, we can put thousands or even millions of sensors on one chip," Zhang said. "That chip could test for many different things at one time in a single sample. That would make testing easier and less expensive."

HONORING CHARLES ELBAUM

By Pete Bilderback

The Physics Department and family and friends of Charles Elbaum, as well as several of his graduate students, were finally able to gather to dedicate a maple tree on the Barus and Holley lawn in his memory on April 29, 2022. The dedication was initially postponed due to scheduling issues and again in 2020 due to COVID.

Elbaum joined Brown's physics department in 1959 as an assistant professor of applied physics. He served as department chair from 1980 to 1986, and was named the Hazard Professor of Physics in 1991. He was also named a fellow of the American Physical Society. He retired from teaching in 2001 but stayed on as a professor of research. Elbaum took emeritus status in 2006 and remained active in the department for several additional years before he passed in 2018.

During his time at Brown, Elbaum's distinguished research in condensed matter physics at low temperatures placed him in much demand as an adviser to government and industrial research laboratories. He made many important contributions to the field of condensed matter physics, particularly, at very low temperatures, and was a prolific author of many highly-cited scientific papers, books, and book chapters, as well as the owner of eight patents.

In addition to his work in physics, Elbaum made key contributions to the areas of neural networks and synaptic plasticity. In 1975, along with his friend and colleague Leon N Cooper, Elbaum co-founded Nestor, Inc., a pioneer in creating commercial applications using neural networks that allow computers to learn by example. Nestor's impressive list of customers included General Electric, Ford Motor, Chemical Bank, Hughes Aircraft, Lockheed, Morgan Stanley, and Salomon Bros.

Elbaum was also a beloved teacher and mentor to countless students. Brown Professor of Physics Stephon Alexander '95 Sc.M., '96 Sc.M., '00 Ph.D. recalled that Elbaum played a key role in his development as a scientist, "Professor Elbaum was one of the big reasons I ended up at Brown. He was always a force for good and promoted our excellence and well-being in the department."

Top (l-r): David, Daniel and Deborah Elbaum
Bottom (l-r): Noah, Eleanor and Hannah Elbaum
PHOTO: ERIN BIEBUYCK/BROWN UNIVERSITY

Charles Elbaum, Chair, Department of Physics 1980-1986.
PHOTO: DEPARTMENT OF PHYSICS/BROWN UNIVERSITY

Because of his slight build and easygoing demeanor, many were surprised to learn that Elbaum was an outstanding, highly competitive athlete. He had a passion for skiing, and his exploits on Mt. Washington's treacherous Tuckerman Ravine are legendary. Knee problems forced Elbaum to give up skiing, but he stayed active, taking up windsurfing and sticking with it through two knee replacements until the age of 81.

Chaplain of the University, Reverend Janet Cooper Nelson, made remarks and read a poem at the ceremony. She shared memories of being one of the few faculty members, along with Elbaum, to consistently attend university-wide faculty meetings.

Elbaum's widow, Eleanor Elbaum P'84, P'91, GP'21, attended the ceremony along with two of their three sons, David '91 and Daniel P'21. Her third son, Michael '84, joined via WhatsApp video chat from Israel, where he currently resides. Daniel was accompanied by his wife, Deborah P'21, and two of their three children, Hannah and Noah. Their third child, Nathan '21, was unable to attend.

In addition to the tree, the family made a generous gift to endow a graduate student travel fund. Over the past year it has been used to fund student travel to the American Physical Society and National Society of Black Physicists conferences.

Less than four months after the ceremony, Eleanor Elbaum passed away quietly at home on August 19, 2022. She was instrumental in the building of Hasbro Children's Hospital and had many friends in the Brown medical community and physics department. The entire Department of Physics wishes to express its deepest condolences to the Elbaum family.

STUDENT SPOTLIGHT

BROWN PHYSICS STUDENTS EARN NATIONAL RECOGNITION

The Brown University chapter of the Society of Physics Students (SPS) has won an Outstanding Chapter Award from the SPS National Office. This is a designation given to fewer than 10% of all SPS chapters at colleges and universities in the United States and internationally. "We are proud that our chapter has been recognized for its excellence as a top-tier student-led physical sciences organization," said Ford Foundation Professor of Physics and out-going department chair Gang Xiao.

The Society of Physics Students (SPS) is a professional association designed for students and membership is open to anyone interested in physics and related fields. SPS operates within the American Institute of Physics (AIP), an umbrella organization for professional physical science societies.

The SPS chapter at Brown is advised by Professor Ian Dell'Antonio and is led by the student undergraduate departmental group, including Joseph Taylor, Taylor Knapp, Adam Furman, Isabel Horst, Smita Rajan, Ethan Swagel, and Ekin Secilmis.

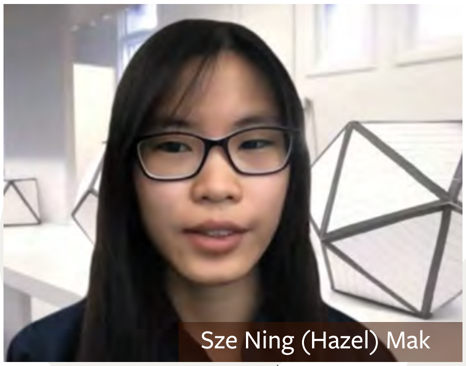
"We do care about building a warm and close-knit community in Physics," said Secilmis, a first-year physics concentrator "and this award has been so encouraging and shows that our work actually matters."

SPS chapters are evaluated on their level of interaction with the campus community, the professional physics community, the public, and with SPS national programs. The Outstanding Chapter Award recognizes high levels of outreach as well as unique approaches to fulfilling the mission of SPS to "help students transform themselves into contributing members of the professional community."

2021 - 2022 GALKIN FOUNDATION FELLOWS

Every academic year Brown Physics awards the Warren B. Galkin Foundation Fellowship, made possible by the generosity of Warren Galkin '51, to one outstanding senior graduate student in the Department of Physics. However, the 2021-2022 academic year was an exception because the Galkin Committee judged both Yiou Zhang '22 Ph.D. and Sze Ning (Hazel) Mak '22 Ph.D. equally worthy of recognition.

At the presentation on April 22, 2022, then department chair Gang Xiao noted that Galkin could not attend, so it was being recorded for him to watch later. Xiao praised Galkin's support of the department and noted that "Warren's donations to the Department of Physics have supported more than twenty graduate students over the years. We are deeply grateful for his ongoing support."



Sze Ning (Hazel) Mak

PHOTOS: DEPARTMENT OF PHYSICS/BROWN UNIVERSITY

Xiao served as dissertation adviser for Zhang, who presented his research on developing ultrasensitive magnetic tunnel junction (MTJ) sensors. His presentation, "Correlation Between Noise and Sensitivity in Ultrasensitive Magnetic Tunnel Junction Sensors," detailed how superparamagnetic and vortex MTJs would improve the performance of sensors.

Professor S. James Gates Jr. served as Mak's adviser and introduced her presentation. Gates had high praise for her research, noting that he had co-authored 17 published papers with Mak, which he said was unprecedented in his forty years of directing Ph.D. students. He told Galkin that his support for her research is "an investment in the future." Mak's presentation, "Superfields in Supergravity and Amplitudes," described her research in the area of superfields.

Yiou Zhang

Both Zhang and Mak successfully defended their dissertations in the Spring of 2022. Zhang accepted an appointment as a Postdoctoral Research Associate at Emory in Atlanta, Georgia. Mak is a data scientist in the personalization technologies team at Epsilon Data Management, LLC.

STUDENT FELLOWSHIPS

- Ph.D. student **Aaron Baumgart** was awarded a two-year DRAPER Fellowship award from The Charles Stark Draper Laboratory, Inc.
- Postdoctoral Research Associate **Stephen Carr** was awarded the 2022 IUPAP Early Career Scientist Prize in Computational Physics.
- Ph.D. student **Nicholas Drachman** was awarded a one-year Graduate Fellowship for STEM Diversity award.
- Postdoctoral Research Associates **Jingyu Luo** and **David Yu** were awarded 2022 Large Hadron Collider Physics Center (LPC) Distinguished Researcher Fellowship awards from Fermilab/DOE.
- Ph.D. student **Farrah Simpson** was awarded a 2022 LPC Graduate Scholar award by Fermilab/DOE. Simpson was one of only two students selected.

BRIAN G. KEATING AWARDED HORACE MANN MEDAL

(l-r): Dean Andrew G. Campbell, Professor Stephon Alexander, Professor Brian Keating, and Professor S. James Gates Jr. celebrate Keating's Horace Mann Medal Award.
PHOTO: ERIN BIEBUYCK/BROWN UNIVERSITY

The Graduate School of Brown University awarded Brian G. Keating '95 Sc.M., '00 Ph.D. the 2022 Horace Mann Medal. The Medal is awarded annually at Commencement to a Brown University Graduate School alumnus who has made significant contributions to their field.

Keating is currently the Chancellor's Distinguished Professor of Physics at University of California San Diego's Center for Astrophysics and Space Sciences and the Principal Investigator and Director of the Simons Observatory Project Office, which is currently under construction in the Atacama Desert in Northern Chile. This observatory will provide scientists a unique opportunity to study the nature of fundamental physical processes that have governed the origin and evolution of the universe. Over 270 scientists, engineers and technologists from over 35 institutions around the world are contributing to the project, making it the world's largest cosmology collaboration.

In addition to his academic pursuits, Keating hosts the popular, long-running "Into The Impossible With Brian Keating" podcast that covers the latest research in cosmology. He is also the author of the bestselling books, "Losing the Nobel Prize," "Think Like A Nobel Prize Winner!" and "Galileo's Dialogue on Two World Systems." He gave a commencement talk entitled "Think Like Galileo Galilei: How to Remain Relevant for Half a Millennium."

"I was always curious, even as a kid I would break stuff apart, blow stuff up, and mull things over in my mind," said Keating. "That tradition continued as an undergraduate. But it wasn't until I came to Brown that my abilities were marshaled and properly stewarded into a productive direction allowing me to really become a scientist."

"My upbringing made me curious. My education at Brown made me a scholar. In particular, my development was driven by my mentors; my Ph.D. adviser Peter Timbie; my beloved Professors Gerald Guralnik, J. Michael Kosterlitz, Frank Levin, Gang Xiao, James Valles Jr. and Leon N Cooper. From day one, I made lifelong friends, including my colleague and best man at my wedding, Stephon Alexander. Coming back to Brown to accept the Horace Mann Medal, in front of my wife and kids, was surreal. It represented a culmination of a dream established nearly 30 years ago—to become a scholar worthy of the accolade 'Brown Ph.D.'"

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PHOTO: DONOVAN DAVINO/BROWN UNIVERSITY

Brown Physics Ph.D. student Donovan Davino created this image of the night-time sky over the South Window Arch in Arches National Park, Utah. It is a combination of 60 stacked images, taken with a Canon EOS Ra camera using a Meike 50 mm F1.8 lens. All of the image stacking and post processing was done in Photoshop.

BROWN TOGETHER

For all Department of Physics gifts and contributions, please contact

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TABLE OF CONTENTS