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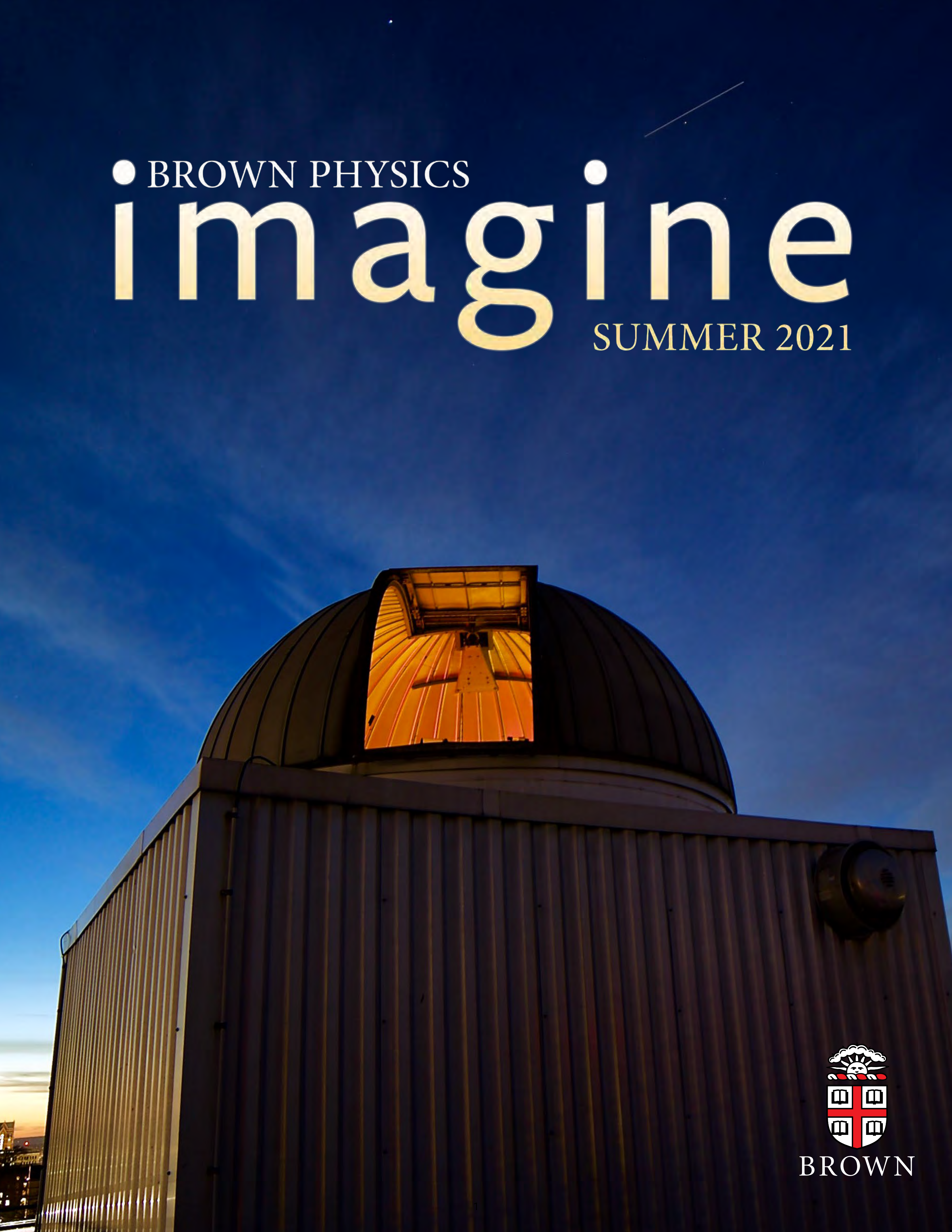

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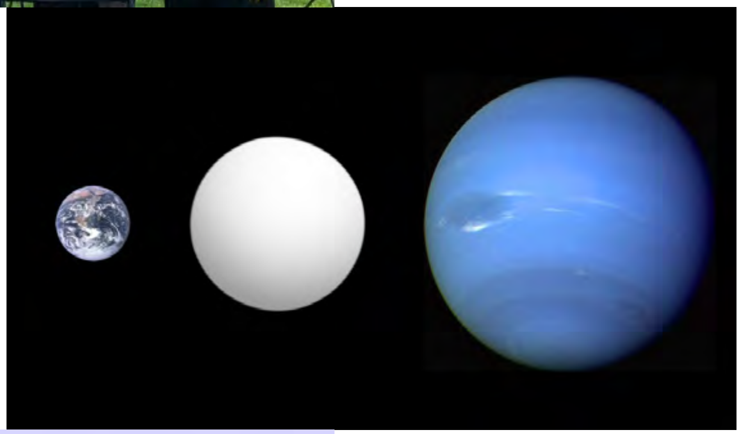

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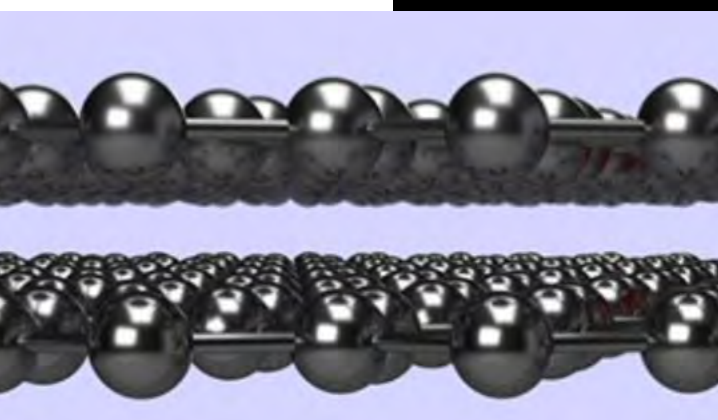

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imagine

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On the cover:
Barus & Holley rooftop observatory with International Space Station passing overhead.
ROBERT HORTON/BROWN UNIVERSITY

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BROWN TOGETHER

For all Department of Physics gifts and contributions, please contact

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MAKE A GIFT

GREETINGS FROM THE CHAIR...

Greetings from Brown Physics! Normally, "Imagine" magazine is published at the end of each academic year. But the current academic year is not yet over, as remote and hybrid teaching continues during the summertime for our first-year undergraduates. It has been a tumultuous year, full of uncertainty and challenges. The pandemic has fundamentally changed the modality of instruction, research, and operation of our department, and technologies such as Zoom and cloud computing have helped bring cohesion to our community. But what has sustained the department most of all is the dedication, commitment, and perseverance of our students, faculty, and staff.

In this issue of "Imagine," we celebrate the achievements of our students, who have overcome mental stress and limited access to physical resources and close personal interaction. They refused to let the upheaval of the pandemic define their experience, and have strived more than previous generations to reach all their academic milestones. As you will see, many of them have received prestigious awards and fellowships as a result of their accomplishments.

I am grateful to the Brown Physics faculty for their great contributions to this department and the University. They did not lower their standards in education or research under very difficult circumstances. On the contrary, they showed great care with our students, and have generated record amounts of scholarship and external funding. At the same time, more of our faculty have become leaders in professional societies and organizations. Professor S. James Gates Jr. currently serves as President of the American Physical Society, Professor Stephon Alexander serves as President of the National Society of Black Physicists, and Professor Meenakshi Narain serves as Co-Convener of the Energy Frontier of the Particle Physics Community Planning Exercise. We have many stories in this issue that demonstrate how the Brown Physics community refused to accept setbacks as inevitable, and instead embraced the crisis as a vehicle for change and advancement.

I want to thank our professional staff for their strong dedication and services to the department. The pandemic created a huge turnover on our staff. We welcome our new staff as we bid farewell to those who have chosen to retire or to change jobs.

More than ever, I appreciate and am heartened by the support of our alumni. Their generosity is incredibly valuable to our mission and operation. As we move forward to face the "new normal," we will continue striving to make the department more diverse, equitable, and friendly to all. Happy reading!

Gang Xiao
Department Chair

AN UPDATE FROM LADD OBSERVATORY

When Ladd Observatory was dedicated in 1891, then Director Winslow Upton declared that, in addition to the education of the Brown University community, the doors would also be open to the general public, as they, too, needed to be aware of the wonders of the sky. That tradition has continued since that day – until now. With the introduction of the total lockdown created by the COVID-19 crisis, Brown, along with the rest of the world, suddenly found itself unable to offer anyone, including its students, the education it is so known for. And, with that directive, the historic Ladd Observatory found itself closed, not only to the university but also to the public at large.

Ladd Observatory is a jewel among buildings. Having received its status as a historic structure, it is home to machines reaching back to the 19th century. Its museum feel, including its necessity as the timekeeping center for the community, takes the visitor back to the age when clocks were not as accurate as today when having a 12:00 siren was necessary for setting the tone of the afternoon's workday.

The building is empty of patrons now, but the staff has continued to bring Ladd to life without actually being there. The Ladd notes, conceived by previous Director Hendrik Gerritsen, have been a staple of the Observatory for over 16 years, continuing to inform the public about the night sky and other fascinating trivia concerning the sky, even through the pandemic crisis. Although the note cannot share with the public the wonder of looking through the magnificent 12-inch refracting telescope, it can guide the observer to what can be seen from a backyard. And, despite Ladd being unavailable to the public, its subscriber list during this time has actually grown.

During last year's closure, Astrophysics Professor Ian Dell'Antonio suggested creating videos on varied astronomical themes. With images mainly from Robert Horton, and text from Francine Jackson, who also narrated the four-to six-minute videos, topics ranged from the Night Sky to our Moon, and our daytime star, the Sun. Others had been planned, but, with the start of virtual astronomical classes, it was necessary for the staff to concentrate on students, although it is still hoped to continue the videos at a later date, as they had been enjoyed by members of the public.

Ladd has been a part of the Brown community for over a century. It has been visited by many people, young, as well as old, from the infamous (such as horror writer H.P. Lovecraft – see the Griffith Observer's article "Lovecraft at Ladd," October 2020) to neighbors curious about the "different" building on the top of the hill. Its antique equipment lends a charm not often discovered by a building by the side of a city street. It has seen the beginning of amateur astronomy organizations, including Skyscrapers, Inc., now housed at its own beautiful facility, in North Scituate, Rhode Island, and it has been the stepping stone for many students unsure of their future, who realized the incredible variety of topics available in astronomy.

What the staff has learned during this time is that, although Ladd has been closed for over a year, people still have the facility on their minds. Every week, with the receipt of the Ladd note, someone will write to the staff, wondering when the public will once again be able to pass through its doors and be thrilled by the sight of Saturn, or Venus, or a double star system, through the 12-inch refractor. We also are looking forward to that day.

Francine Jackson
Staff Astronomer at Ladd Observatory

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CELEBRATING OUR GRADUATES!

"This course really opened my eyes because it showed me what important roles that thermodynamics, statistical mechanics, and electrostatics play in living systems."

COURTESY WEIJIE CHEN

WEIJIE CHEN

Ph.D. Physics

What was your favorite physics course (and why)?

My favorite physics course is PHYS 2630, Biological Physics, taught by Prof. Jay Tang. Physical laws deal with small things like particles or large objects such as the galaxies, but one thing that can easily be overlooked that the physical laws also govern "lives," from DNA replication to fish swarming. This course really opened my eyes because it showed me what important roles that thermodynamics, statistical mechanics, and electrostatics play in living systems.

DEVEN CARMICHAEL

Sc.B. Physics

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

From research meetings to late-night homework discussions to quick chats in line for coffee, I felt that everyone was excited to help me work on challenging problems. I got to know so many wonderful friends and mentors because of this culture of communally figuring things out.

COURTESY DEVEN CARMICHAEL

"I got to know so many wonderful friends and mentors because of this culture of communally figuring things out."

"I got to learn about a subject, plasma physics, that I think is the coolest thing ever..."

COURTESY GRANT RUTHERFORD

GRANT RUTHERFORD

Sc.B. Physics

What was your favorite physics course (and why)?

My favorite physics classes were a tie between my two independent studies (PHYS1980) and writing my thesis (PHYS1990). In my independent studies, I got to learn about a subject, plasma physics, that I think is the coolest thing ever and would not have gotten exposure to otherwise. Additionally, I grew a lot as a student by having to teach myself an entirely new area. And I really enjoyed writing my thesis because I got to put everything I learned in those independent studies together with the research I'd conducted to produce a piece of work that I am very happy with.

ELLIOTT LEHRER

Sc.B. Physics/Philosophy and Mathematics

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

I came into Brown Physics enormously overconfident. For the start of my physics classes I never picked up good study habits or made the learning decisions that would pay off in the long term since I thought everything would always be easy. This meant that when I did reach the classes that were really hard for me, I suffered enormously more than I should have—creating one of my most academically and emotionally difficult semesters at Brown.

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

Never be afraid to ask for help.

What's next for you?

I will be pursuing a Math Ph.D. at the University of Maryland, College Park. In the long term I'd love to become either a math or physics

COURTESY ELLIOT LEHRER

"Never be afraid to ask for help."

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“The first step on the path to wisdom is to say ‘I don’t know.’”

IDA ALARCON/BROWN UNIVERSITY

ANDERS SCHREIBER

Ph.D. Physics

Do you have any advice for new physics students?

Make sure to have a good work-life balance. I’ve enjoyed competing in powerlifting during my Ph.D., which was a great way to break up studying.

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

My many chats with the administrative staff! Everyone was super friendly and always made me feel so welcome in the department!

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

The biggest lesson can probably be summarized in a quote by Professor Spradlin when teaching PHYS2320 (I am paraphrasing here): “The first step on the path to wisdom is to say ‘I don’t know.’” We often want to seem like we know all the answers, but it is always better to answer “I don’t know” to a question when we don’t know the answer!

ANNA ZUCKERMAN

Sc.B. Physics/Mathematics and Geology

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

I will remember late nights spent in empty classrooms with a group of my peers, staring at the blackboards as we tried to solve problem sets. The sense of camaraderie and community was strongest when we all struggled together.

What’s next for you?

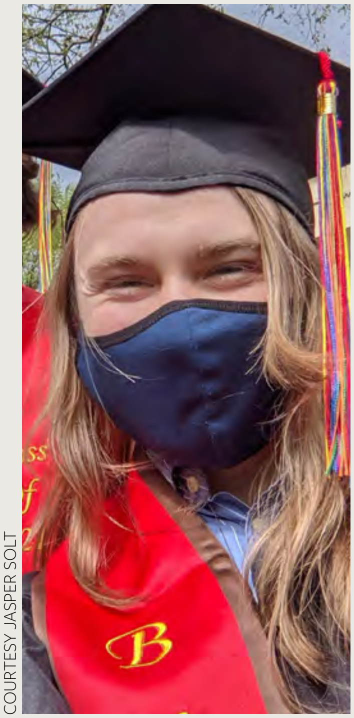
I will be working in a year long research position for the coming year, then beginning a Ph.D. program next Fall.

MAUREEN DEVLIN

Anna (bottom) pictured with her twin sister Leah, also Sc.B. Physics/Mathematics and Geology ’21.

“The sense of camaraderie and community was strongest when we all struggled together.”

“Statistical mechanics made me see the world in a different way.”



COURTESY JASPER SOLT

JASPER SOLT

Sc.B. Physics and Computer Science

What was your favorite physics course (and why)?

Statistical mechanics made me see the world in a different way. Looking at how the behavior of individual actors can be abstracted into movements and phenomena not only explains the natural world, but also the social and political world.

Do you have any advice for new physics students?

Everyone who is arrogant and everyone who seems further ahead in their studies than you, don’t matter. It’s more important to find your niche than to be the best at everything.

What’s next for you?

I’m staying here! I’ll be a Brown physics Ph.D. student starting this fall. So, new physics students, let’s chat!

JAE JONG OH

Sc.M. Physics

Do you have any advice for new physics students?

Don’t be afraid to talk to people! Go to graduate student coffee hour and undergraduate hot chocolate and chat with your fellow physics students! If you see some professors walking their dogs outside, go say hi to them! Talking to many physicists in different stages of their lives really helped me to figure out what I want to do in future.

What’s next for you?

I’ll be studying super-conducting qubits as a Ph.D. student at University of Waterloo.

COURTESY JAE JONG OH

“Anyone can do physics! Don’t worry if you are smart enough to be a physicist.”

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Jacob J. Jackson
Thomas Raliegh Jenkins
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Pablo F. Legorreta Caso
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Harlan Samuel Oaks-Leaf
Dante Rousseve
Natalie Jane Rugg
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Allison Taylor Saltz
Marianna Grace Scott
Jasper Solt
Asutosh Swain
Adam Antoine George Tropper
Justin Avery Voelker
Angela Jane White
Zhaoyi Zheng
Anna Devlin Zuckerman
Leah Devlin Zuckerman

STUDENT AWARDS

R. Bruce Lindsay Prize for Excellence in Physics

Adam Tropper

Mildred Widgoff Prize for Excellence in Thesis Preparation

Grant Rutherford

Chair's Award for Excellence in Scholarship & Service to the Physics Department

Natalie Rugg

Smiley Prize for Excellent Contribution to the Astronomy Program

Jasper Solt, Anna Zuckerman, Leah Zuckerman

MASTERS OF SCIENCE

Calvin C. Bales
Eric Brewster Barrett
Aaron Paul Baumgart
Sizhe Cheng
Andrew Joseph Fanning
Joseph Hunter Fichera
Zhenxiang Gao
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Joseph Frank Plumitallo
Brandon Matthew Pugnet
Timothy Rehm
Farrah Medi Simpson

STUDENT AWARDS

Master's Research Excellence
Aaron Baumgart

Outstanding Academic Accomplishment in Master's Program
Eric Barrett

Engaged Citizenship and Community Service to the Physics Department
Jae Jong Oh

DOCTOR OF PHILOSOPHY

Jatan Buch, *Adviser: JiJi Fan*

Weijie Chen, *Adviser: Jay Tang*

Guanyang He, *Adviser: Gang Xiao*

Ka Hei (Martin) Kwok, *Adviser: Greg Landsberg*

Lijuan Qian, *Adviser: Gang Xiao*

Kwok Wai (Ken) Ma, *Adviser: Dmitri Feldman*

Saloni Saxena, *Adviser: J. Michael Kosterlitz*

Anders Schreiber, *Adviser: Anastasia Volovich*

Kyriakos Vattis, *Adviser: Savvas Koushiappas*

STUDENT AWARDS

Galkin Foundation Fellowship Award 2020-2021
Rong Cong

Physics Merit Dissertation Fellowship 2020-2021
Anders Schreiber

Anthony Houghton Award for Excellence in Theoretical Physics
Kyriakos Vattis

Forrest Award for Excellence in Work Related to Experimental Apparatus
Weijie Chen and Michael Lukasik

Award for Excellence as a Graduate Teaching Assistant
Isabelle Goldstein, Annalies Kleyheeg, Tatsuya Daniel, Vineetha Bheemarasetty, Alejandra Rosselli, Rutendo Jakachira, Nikolas Pervan

Beyer Award for Excellence in Scholarship & Service
Anders Schreiber

2020 - 2021 GALKIN FELLOW RONG CONG

STUDENT SPOTLIGHT

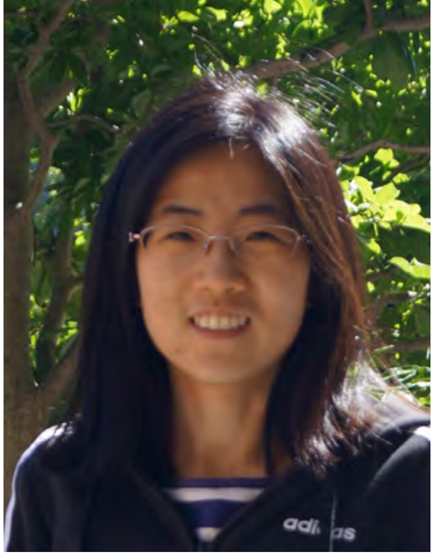
By Pete Bilderback

Every academic year Brown Physics awards the Galkin Foundation Fellowship to one outstanding senior graduate student in the Department of Physics. The Galkin Foundation Fellowship is made possible by the generosity of Warren Galkin '51, a Rhode Island native who received an Sc.B. in Physics at Brown. This year's Fellowship recipient, Rong Cong, impressed those who attended her virtual presentation, "Structural and magnetic properties of 5d double perovskites probed by nuclear magnetic resonance." Cong's Fellowship project was supervised by Brown Professor of Physics Vesna Mitrović who noted that her colleagues joked afterward that Cong's presentation "resembled a defense of three separate Ph.D. theses, two in experimental physics, and one in theoretical physics."

According to Cong, receiving the Fellowship offered, "encouragement for me to continue doing my research." She adds, "I feel honored to have this award and it will definitely stimulate me to work harder on the research that I am doing." She describes the research as "using NMR [Nuclear Magnetic Resonance spectroscopy] technique to study the magnetic and structural properties of quantum magnets with strong spin-orbit-coupling." Cong describes these materials as having, "electron correlation with strong spin-orbit coupling. Theory has indicated that there are multi-polar spin interactions in these 5d compounds which are more often seen for f-electron system. We used NMR as a probe to study them."

NMR spectroscopy is a spectroscopic technique that is used to observe the magnetic fields around atomic nuclei. It's a powerful tool that can give access to the structure of a molecule and its electronic signature and is considered the definitive method for identifying organic compounds in modern organic chemistry. It is also useful in determining the spin properties of sub-atomic particles.

Cong notes that the magnetic materials she was studying are particularly interesting because, "currently, the complex interplay among spin, orbital and charge degrees of freedom has been a prime focus of strongly correlated materials research and the spin-orbital-lattice entangled states presents difficulty both in understanding it experimentally and describing it theoretically," which is the reason she needed to approach the project from both an experimental and computational perspective.



Work had already begun on the project when Cong joined Mitrović's lab, "I continued research on these 5d1 to 5d2 magnetic Mott insulators based on work done by earlier graduate students." Cong found Mitrović helpful and easy to work with for the project, "[she] has a very flexible style. We [lab members] have a lot of freedom to explore in terms of the projects we want to do. I could reach out to her whenever I had any questions or concerns. She has been very helpful in connecting me with other collaborators."

Brown Physics remains deeply grateful to Warren Galkin '51 for his generosity in supporting cutting-edge physics research. Said Department Chair Gang Xiao, "Warren Galkin's donations to the Physics Department have supported more than 20 Ph.D. students, many of them highly successful in their professional careers. We are grateful to Warren for his generosity and strong support of STEM programs." Xiao added, "Because of the Galkin Fellowship, Cong was empowered to develop an insightful understanding of a new class of quantum materials. Her achievement exemplifies the excellence of our graduate students and their dedication to cutting-edge research."

STUDENT SPOTLIGHT

ADAM FURMAN EARNS NASA FELLOWSHIP

By Pete Bilderback

Brown Physics undergraduate Adam Furman was awarded a NASA Student Airborne Research Program (SARP) internship for the Summer of 2021. SARP is a highly selective eight-week summer internship program that offers rising senior undergraduate students and graduate students the opportunity to acquire hands-on research experience in all aspects of a scientific campaign.

In an ordinary year student interns would use one or more of NASA's Airborne Science Program flying science laboratories to study Earth system processes. But, as Furman explains, the pandemic necessitated a number of changes to this summer's program which included interns working remotely from their homes.

One advantage of having interns work remotely is that data can be collected from different locations. Furman says, "they [NASA] sent us air quality measurement instruments to take samples wherever we [student interns] are across the country and then in December we'll all get to go to California for a week and still fly some missions." Furman has been analyzing air quality samples collected by canisters distributed to last summer's interns who also worked remotely. According to Furman, "we found some really interesting data that might indicate that perhaps some air quality guidelines are not being followed as strictly as they should be." Furman's canister is currently collecting data from the roof of the Barus and Holley building. Data from this canister is yet to be analyzed, Furman says it will likely be studied by next year's internship group.

Student interns across the country are also working on other projects this summer, Furman explains, "there are 28 interns divided across four different NASA research groups that focus on different Earth science-related disciplines." Furman has been contributing to the research done by a group that is taking ocean-related measurements using his expertise in computational physics. He has spent the summer constructing a mathematical model that can analyze organic matter in the oceans.

Furman explains, "there's something called color dissolved organic matter which is an interesting kind of biomarker. It's a measurement that you want to be able to get if you're analyzing the health of an ecosystem." A key measure of ecosystem health is how much phytoplankton (tiny photosynthetic organisms that form the foundation of the food web for most marine life) is present in any given area. It's difficult to directly measure phytoplankton levels across the globe, but Furman explains "there are well-understood models for how this color dissolved organic matter will absorb light, so you can plot a theoretical spectrum to predict how it will behave." So phytoplankton levels can be indicted measured via satellite by analyzing the optical properties of the water.

Furman has found working on projects remotely both rewarding and challenging. "I think they've done a lot to make it more manageable. The program is only four days a week, but you still need to be on Zoom a lot which can be difficult. It's just not the same as interacting with people in real life." On the other hand, Furman believes the remote set-up has also offered him the opportunity to focus on his computational modeling work. "They [NASA] really care a lot about our well-being and tried to make sure that the activities and lectures are interesting. I've gotten a lot out of [the program], and I think I had the best possible experience I could have had under the circumstances."

STUDENT SPOTLIGHT

NICHOLAS DRACHMAN AWARDED GRADUATE FELLOWSHIP FOR STEM DIVERSITY

By Pete Bilderback

Brown Physics Ph.D. student Nicholas Drachman has been awarded a Graduate Fellowship for STEM Diversity (GFSD). GFSD is a partnership between government agencies and laboratories, industry, and higher education whose goal is to increase the number of American citizens with graduate degrees in STEM fields while emphasizing the recruitment of a diverse applicant pool.

For the Fellowship Drachman will work at the National Institute of Standards and Technology (NIST) on a device that can improve the measurement of nanoflow rates. According to Drachman, the group he will be working with at NIST, "has developed devices that can measure… the flow of liquid in a tiny channel very accurately down to very low values." Drachman hopes this "NIST on a chip" technology, which can be used to measure fluid flow on the scale of nanoliters per minute, can be adapted to measure the flow rate in a novel nanopore ion source for mass spectrometry created in Professor Derek Stein's laboratory.

The ion source resembles a very sharp needle that is narrow enough to restrict the flow of liquids to the point that single ions can be emitted directly from the liquid into a high vacuum, bypassing the inefficient electrospray process used by more conventional ion sources. The NIST device would potentially allow direct measurement of the flow rate in these ion sources and validate the proposed ion emission mechanism.

Future potential uses for the device include single-molecule protein sequencing. Current technology allows for the relatively cheap sequencing of single DNA molecules, and Stein and his collaborators hope to create a device that can do the same for single protein molecules. Drachman says, "what we want to do is use their [NIST's] devices...to focus a UV light source down onto a very thin tube of liquid and potentially break up the molecules in that liquid." This would enable the device to break off the amino acids from the protein one at a time and then emit them directly to a detector that would enable the sequencing of single protein molecules.

STUDENT SPOTLIGHT

NAIYUAN (JAMES) ZHANG AWARDED FIRST JUN QI AND CHRISTINE GENG FELLOWSHIP

By Pete Bilderback

Naiyuan (James) Zhang was the first student to be awarded the Jun Qi '03 Ph.D. and Christine Geng Graduate Fellowship in Condensed Matter Experimental Physics. The Fellowship allowed Zhang to focus his attention on cutting-edge research in condensed matter physics with his advisor, Professor Jia (Leo) Li.

Zhang says the support allowed him to work on several projects simultaneously. These projects included one aiming to "experimentally validate fractional quantum Hall effect in graphene double-layer samples with non-Abelian wavefunctions." According to Zhang, "the idea is to develop nano-scaled structures capable of detecting how heat flows in a 2D plane, which will provide insight into the quantum statistics associated with the electronic wavefunction."

The Fellowship also allowed Zhang time to design a unique experiment meant to examine potential anisotropy quantum transport behavior in "magic-angle" twisted graphene, which Zhang describes as consisting of "two or three graphene layers stacked together with rotational misalignment in order to study how quantum phenomena behave under a low-dimensional confinement in an extreme quantum limit (ultra-low temperature and high magnetic field)."

To accomplish these goals, Zhang needed to utilize a range of state-of-the-art techniques to fabricate nanometer-scale, atomic-layer-thin electronic devices. Zhang says, "with the support of the fellowship, not only was I able to become proficient with all these techniques, I pushed the boundary of 2D material manipulation and fabrication a bit further, and was able to fabricate a few samples of complex design and high quality. I am in the process of cooling these samples down to as low as 20mK, which is deep in the quantum regime." The structure required the production of atomic-layer-thin components and was assembled in the nano-fabrication facility at Brown (IMNI clean room).

In the coming weeks, the team will be performing exciting experiments on these samples, which provide a glimpse into the quantum world that has never before been observed.

The work could have significant implications on quantum computing. Current quantum computers such as the ones built by Google are very sensitive to noise and need to expend a tremendous amount of computational power just to correct errors caused by noise. According to Zhang, the potential benefit of building a quantum computer with non-Abelians is that "information is not stored locally, and hence is very robust to these local noises. By making the quantum computer immune to noises, we can increase the efficiency of qubit usage and therefore greatly increase computational power."

Additionally, Zhang notes that "tri-layer graphene, like its bi-layer counterpart, displays superconductivity when twisted at a small magic angle. By probing its potential anisotropic electronic behavior, we expect to discover more about the mechanism behind superconductivity." Zhang says next steps in the project include, "performing the measurements for the samples I made so far" as well as working on two more projects that include, "coupling a twisted tri-layer graphene with a plain quadra-layer graphene," and another utilizing twisted quadra-layer graphene.

Zhang expressed gratitude to Jun Qi and Christine Geng, saying "I was happy to dive into this research and learn so much, and I am honored to have been rewarded with this fellowship." Department Chair Gang Xiao likewise expressed his appreciation, "the financial support from Jun Qi and Christine Geng has been valuable and timely in supporting our graduate student research in one of the most exciting areas of condensed matter physics, two-dimensional electronic solids. We are grateful to Jun and Christine for their generosity and their interest in our quantum materials research."

GET TO KNOW THE CLASS OF 2021

ADAM TROPPER

Sc.B. Physics and Mathematics

What was your favorite physics course (and why)?

Marcus Spradlin's Quantum Field Theory II course (taught during the pandemic no less), was an expertly taught tour de force of String Theory. It was the final physics course I took at Brown and bookended my degree in a really engaging way. Indeed, I found myself having to use equations and ideas from virtually every physics course that I had taken previously, and it was similarly eye-opening to see the deep connections that theoretical physics has to sophisticated mathematical concepts in algebraic geometry, number theory, representation theory, and so forth.

Do you have any advice for new physics students?

Do not be apprehensive about starting research, even as a young student! I began my research experience by reading textbooks and doing numerical linear algebra (no inherent physics content) on Python. I spent months without having a single interesting insight, but theoretical physics is often like that. Not two years later, and I was a published author who could speak fluently about how one might leverage Anderson localization in certain random matrix models to generate exponential hierarchies in particle physics while being cognizant of naturalness prescriptions (a sentence that would have been gibberish to me at the start). Everyone whom I've spoken with has had a similar journey in their research endeavors. At the beginning, the journey looks so long and daunting, but before you know it, you're cresting the peak and asking yourself "how did I get here so fast?" Even as a young student, you're already far more capable than you think and should be bold in beginning this intellectual climb.

What impact did the pandemic have on your studies?

Fortunately, as my interests in physics are more theoretically inclined, the pandemic had a very minimal impact on the quality of my education (if anything, I probably went to more seminars now that I could attend in pajamas versus having to walk through the Providence rain). My instructors made tremendous efforts to transition their courses to an engaging on-line format and, in spite of the inherent difficulties, it was nice to spend quality time with family for more than a few weeks.

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

My time at Brown helped me appreciate the importance of grit. Being persistent in your efforts is so central to studying physics, a discipline where homework problems can take days to finish, concepts can take months to understand, and projects can take years to complete. Having the mental fortitude to press on when a breakthrough is nowhere in sight was an attitude that the Physics Department helped me cultivate; it's also one that promises to serve me well for the rest of my life.

What's next for you?

In the fall, I'm off to Boston where I intend to continue studying high energy theoretical physics (particle physics, string theory, and the like) in Harvard's Ph.D. program.

"My time at Brown helped me appreciate the importance of grit. Being persistent in your efforts is so central to studying physics..."

COURTESY CADENCE LEE PHOTOGRAPHY

“Physics stretched me, and for that, I am immensely grateful.”

MARIANNA SCOTT

A.B. Physics/Philosophy

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

Things that are truly difficult are never pleasant. I can say without an ounce of hesitation that the physics department was responsible for supplying the greatest number of my unpleasant moments at Brown. But somehow, paradoxically, with hindsight, those intensely unpleasant moments have come to seem like the most fulfilling. And this struggle is doubly fulfilling when you manage to do it alongside other people—cramming into a tiny B&H classroom the night before a midterm, painting a mural of differential equations in an Andrews whiteboard room, the sheer joy of cracking a problem alongside someone who will eventually become one of your best friends. Physics stretched me, and for that, I am immensely grateful.

Do you have any advice for new physics students?

Find people. Find people. Find people. Make friends with your TAs. Make a Facebook group chat for your class. Go to office hours and hound your professors. Physics is much more fun when it isn’t a solo mission.

COURTESY MARIANNA SCOTT

COURTESY SARAH BAWABE

SARAH BAWABE

Sc.B. Physics and Computer Science

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

I will never forget my final semester when I researched and wrote my thesis with Dr. Stephon Alexander as my advisor. I will never forget all of the curiosity, exploration, deadlines, Zoom meetings, and yet incomparable zen that accompanied it all. Writing and finishing my thesis was one of my proudest accomplishments during my time at Brown, and hearing all of the physics professors say their congratulations, well wishes, and heartfelt goodbyes during the virtual graduation ceremony reminded me not only of where it all began, but also just how far I had come to be standing there that day as an alumna.

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

No question is a dumb question. (In fact, my whole thesis began with me daring to ask a “dumb curiosity question” to the lab group.)

“Writing and finishing my thesis was one of my proudest accomplishments during my time at Brown...”

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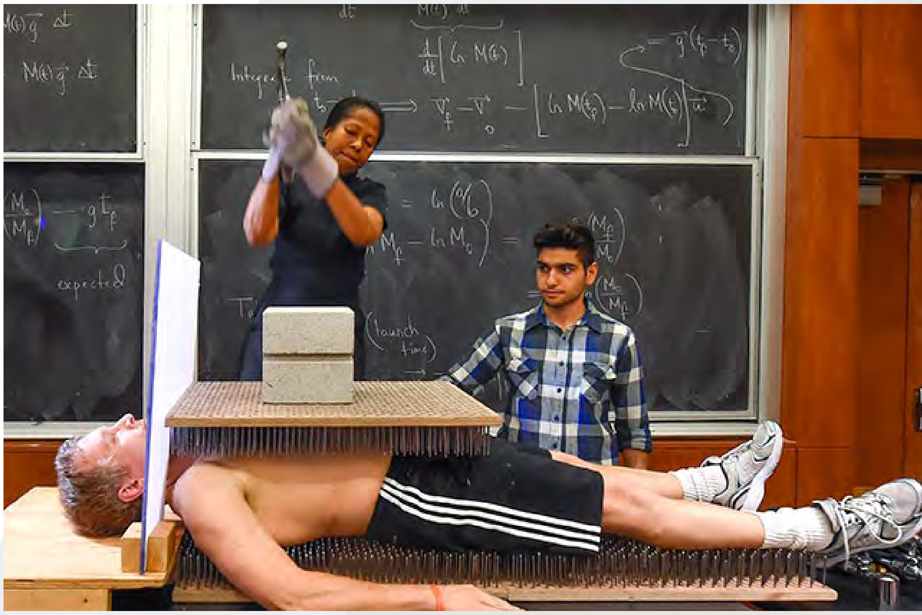
BROWN PHYSICS WELCOMES NEW DEMONSTRATIONS MANAGER ANGELLA JOHNSON



COURTESY USC DEPARTMENT OF PHYSICS

The Physics Department welcomes a new Demonstrations Manager, Angella Johnson. Angella graduated with a Bachelor's degree in physics from Temple University and a Master's degree in Building Science-Architectural Studies from the University of Southern California. She joins us from USC where she worked as the Lecture Support Lab Manager for fourteen years.

What influenced you to choose this career path?

So honestly I didn't even know a job like this existed. What got me interested in physics was optics and lasers when I took a class with my first female physics professor and it was just so interesting. It really grabbed my attention. I figured I would want to work in academia but I wasn't sure of what I would do. I stumbled upon this career while I was at UCLA and I knew I wanted to stay in academia. As a physics grad student I remembered being a TA and thought it can't be that much different. But now that I've done it for so many years, I think physics demonstrations are really great. It's wonderful for students who can't grasp certain concepts to actually see it since we all retain information differently. Some of us are visual, some are auditory and some are tactile learners. Demonstrations are a combination of things. You can write an equation but if you can actually see the physics, hear, or touch it, that makes the learning experience more profound.

What made you want to study physics?

I was at Temple University and unsure about what I wanted to do. I thought about speech pathology and audiology and in order to complete that program, I had to take a class in acoustics which was in the physics department. I remember going into an anechoic chamber and I thought it was really cool. I had started to stray away from audiology and pathology. I realize that I did not want to do it for the rest of my life. At that time, I met Professor Marjatta Lyyra, who encouraged me to pursue physics. Professor Lyyra was the first female professor in the department, and her research was in experimental atomic, molecular and optical physics. She encouraged me to take her course in optics and invited me to work in her undergraduate lab. That's how it all started. From speech pathology and audiology to acoustics then optics. I was sold!

That seems to be a valuable encounter and a life changing experience. Can you share more about your undergraduate experience?

Everything changed for me after that. I thought, wow the things you can do with lasers! Surgery, military purposes, just amazing. At that time there was a lot of attention around Professor Lyyra and I was really drawn to her. I took a lot of classes where I was the only female and many times the only minority. I actually had a professor tell me that you are a double minority, you're either going to make it work for you or it's going to work against you. Being a double minority gave me the fuel I needed and the boost to continue moving forward. It wasn't until I attended an event held by the National Society of Black Physicists that I saw a place for someone like me in science.

What are you looking forward to working at Brown?

The very first day I got a tour, and this may sound geekish, but [Manager of Astronomy Labs and Ladd Observatory] Bob Horton showed me so many cool labs. I'm looking forward to getting to learn more about the research happening in the department and diving more into the instructional labs. Also, the campus is so beautiful, I'm looking out the window now and it's just gorgeous. It's so different from Los Angeles but at this point in my life, this is what I need.

COVID has obviously disrupted a lot of what you would have come into during a normal academic year. Are there things that you think will be challenging for you in the next few months, especially in the spring semester?

I have some big shoes to fill. Before me, it was Jerry Zani, and before that it was Dean Hudek. I think it's good and it's challenging, there are pluses and minuses. I expect the spring will be some sort of hybrid situation. The whole instructional lab here works differently from where I'm coming from, it's much more team-oriented. I'll have to figure out who will request demos, when they will request them and what are their favorites. That's going to take time to understand. With COVID it's going to be a challenge, I would just ask that professors be patient with us as we figure it out.

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LABORATORY PHYSICIST DEAN HUDEK RETIRES AFTER 31 YEARS OF SERVICE TO THE DEPARTMENT OF PHYSICS

By Pete Bilderback

COURTESY DEAN HUDEK

Dean Hudek (left) with Nobel Laureate William D. Phillips.

Brown Physics Laboratory Physicist, Dean Hudek, elected to retire this year after thirty-one years of service to the department. The position was an ideal fit for Hudek who recalls that even as a young child he loved to take things apart to see how they worked and says he "felt like I had won the lottery on my first day of work on the last day of June 1989."

At the time Hudek was hired, the department's demonstrations and labs had fallen into what he categorized as a "state of disrepair," and he was charged with upgrading and developing all instructional facilities and resources. His first order of business was to organize and upgrade the department's demos. "I spent that first summer going through piles of equipment, identifying, organizing, putting things into categories, and placing them on shelves." Bob Lanou [the Department Chair at the time] would come down periodically and apologize for making me do all this, but I was actually having a good time."

Over time, Hudek's responsibilities expanded and he hired Kevin McCabe to run class demos so that he could focus his attention on upgrading the physics laboratories and the lab experience for students. Gerald Zani replaced McCabe as Manager of the Physics Demonstration Laboratory in 1995 and held the position until 2020 when he took a job as Senior Engineering Technician in Brown University's School of Engineering.

Hudek says he enjoyed the opportunity to work with leaders in the field of physics, including two Nobel Laureates, Leon N Cooper and J. Michael Kosterlitz, who he recalled as being unassuming in class. "He [Kosterlitz] was so humble, and he seemed so intimidated by the equipment, I've always had a place in my heart for him." He says he also particularly enjoyed working with Gregory Tucker, Greg Lansberg, and Phil Bray, among others, as well as doing demo shows for Providence area school children as part of the University's public outreach.

For Hudek, one of the most enjoyable aspects of the position was the opportunity to work directly with Brown students. "I particularly enjoyed working on PHYS2010 [Techniques in Experimental Physics] labs helping students learn what they needed to learn and hearing the appreciation they had." He embraced the challenge of keeping up with the latest technologies as the field changed. "I enjoyed running the advanced labs, and always trying to make them newer and better as technology changed."

Hudek says he has fond memories of working with Greg Landsberg on PHYS2010 labs. "At one point Greg asked me the difference in price between liquid nitrogen and liquid helium. I told him liquid nitrogen costs about the same as milk and liquid helium costs about the same as good whiskey...on my last day at Brown Greg presented me with a fine bottle of scotch, and I was very touched by that."

Retirement plans include spending more time with his wife and former Brown Physics Department Manager Phyllis Hudek at their home on Johnson's Pond in Coventry, RI. The couple has many travel plans including a trip to Italy to visit sites featured in "The DaVinci Code" that was delayed by the pandemic. Hudek admits stepping away from the department, especially during a pandemic, was difficult, but is gratified to have seen all the improvements to demos and labs that were made during his tenure. "Realizing all the improvements that occurred, knowing what it was like when I got there and then seeing what it was like when I left. That's something that's important to me."

BROWN PHYSICS WELCOMES NEW LABORATORY PHYSICIST SARA MUELLER

By Pete Bilderback

COURTESY SARA MUELLER

Brown Physics welcomes Sara Mueller, the department's new Laboratory Physicist. Mueller graduated with a Ph.D. in Physics from The Ohio State University in December of 2019, which she categorizes as "the least fortuitous moment to graduate with a Ph.D." She notes, "I had a few postdoc offers pending, and then the pandemic hit and they all got canceled. All of a sudden I had no offers, which was wild." Mueller had been working at a postdoctoral position at City College of New York (CUNY) for eight months when she was advised to apply for the position of Laboratory Physicist by a Brown Physics alumni, "one of my mentors from graduate school, Shawna Hollen [Ph.D. '13], sent me the job listing."

Mueller was intrigued by the position, "it's a really unique opportunity because a lot of places don't have someone who coordinates all the instructional labs...I thought it was really exciting." Mueller was also drawn to the Providence area for family reasons, "my wife's family is from the area and we moved to Providence before I found out about my postdoc offer [at CUNY]." Mueller says she always loved running physics experiments and believes the job is a perfect fit for her, "the thing that I find very cool about this job is that I get to do all of the things I really enjoyed doing as a graduate student and none of the things I didn't enjoy doing like writing grant proposals."

Mueller says she is also favorably impressed by the department's commitment to diversity, inclusion, and equity. "It feels good to be in a place where I know that the battles that I have been fighting my whole career are different, and I don't have to feel like I'm just spinning my wheels. I don't feel like I have to justify my own humanity as a queer woman [at Brown]." She says she is also, "really impressed with the staff, everyone is so helpful it's almost ridiculous."

Mueller confesses there is one additional thing that attracted her to Brown, "I'm not going to lie, there's a little part of me, young Sara, whose dreams have come true because I'm now in the same building as Leon Cooper. I did superconductivity research early in my career and he was an inspiration."

Jia (Leo) Li

FACULTY RESEARCH

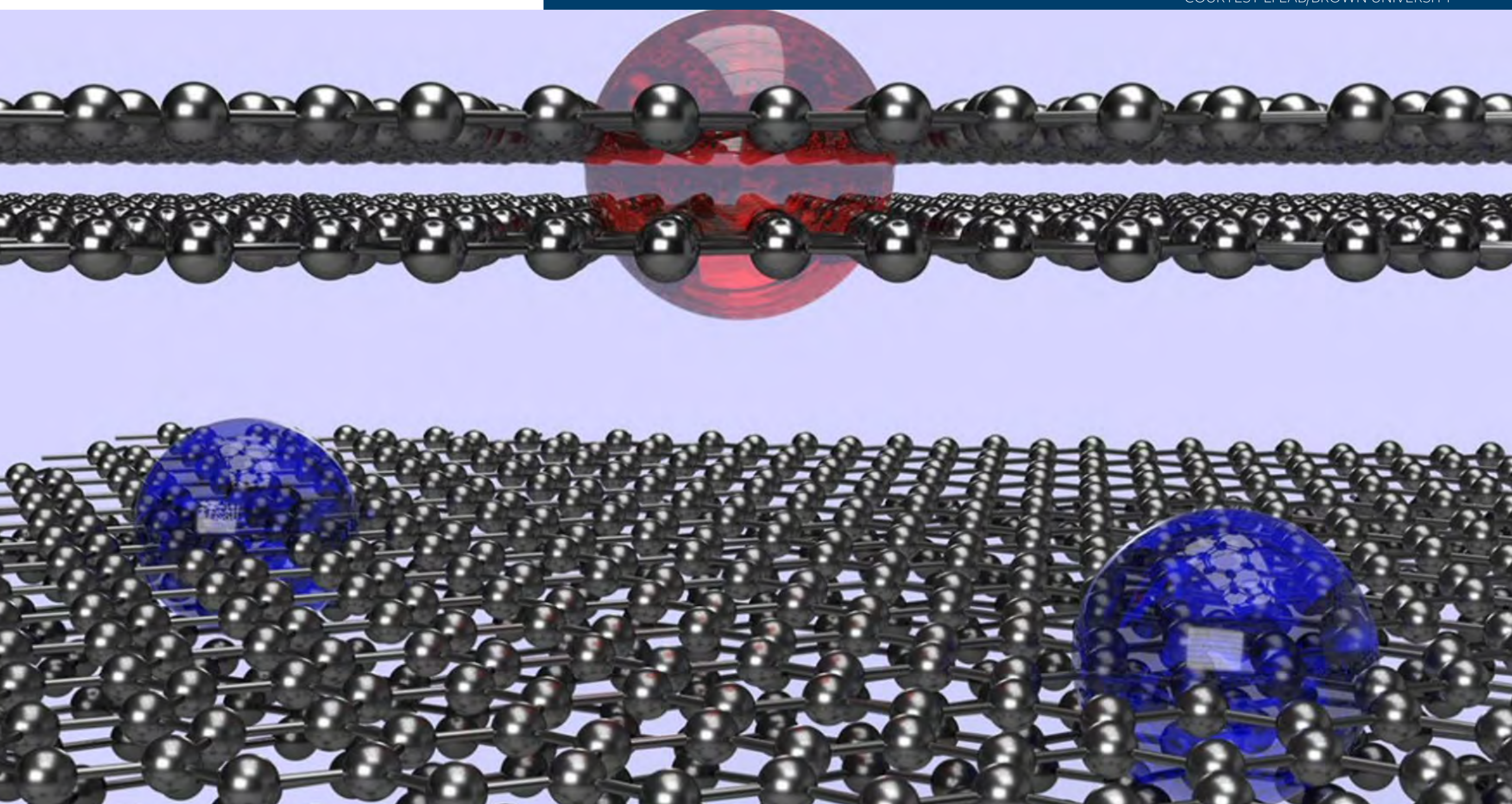
LI LAB FINDS SURPRISING ELECTRON INTERACTION IN "MAGIC-ANGLE" GRAPHENE

By Kevin Stacey

Physicists have long searched for ordered condensed-matter systems that can transition to exotic states like superconductivity at higher temperatures. In a paper published in Nature, Brown University Assistant Professor of Physics Jia (Leo) Li and his colleagues find evidence of a Pomeranchuk-type mechanism in which the liquid ground state freezes upon increasing the temperature in twisted bilayer graphene and related systems. They describe a technique that weakens the repulsive force between electrons in "magic-angle" graphene superconductors, providing physicists with exciting new details about this strange state of matter.

In 2018, physicists showed that something interesting happens when two sheets of the nanomaterial graphene are placed on top of each other. When one layer is rotated to a "magic angle" of around 1.1 degrees with respect to the other, the system becomes a superconductor — meaning it conducts electricity with zero resistance. Even more exciting, there was evidence that it was an unconventional form of superconductivity — a type that can happen at temperatures well above absolute zero, where most superconducting materials function.

COURTESY LI LAB/BROWN UNIVERSITY



Researchers have discovered a way to manipulate the repulsive force between electrons in "magic-angle" graphene, which provides new insight into how this material is able to conduct electricity with zero resistance.

Since the initial discovery, researchers have been working to understand this exotic state of matter. Now, a research team led by Brown University physicists has found a new way to precisely probe the nature of the superconducting state in magic-angle graphene. The technique enables researchers to manipulate the repulsive force between electrons — the Coulomb interaction — in the system. In a study published in the journal Science, the researchers show that magic-angle superconductivity grows more robust when Coulomb interaction is reduced, an important piece of information in understanding how this superconductor works.

"This is the first time anyone has demonstrated that you can directly manipulate the strength of Coulomb interaction in a strongly correlated electronic system," said Jia Li, an assistant professor of physics at Brown and corresponding author of the research. "Superconductivity is driven by the interactions between electrons, so when we can manipulate that interaction, it tells us something really important about that system. In this case, demonstrating that weaker Coulomb interaction strengthens superconductivity provides an important new theoretical constraint on this system."

The original 2018 finding of potentially unconventional superconductivity in magic-angle graphene generated significant interest in the physics community. Graphene — one-atom-thick sheets of carbon — is a relatively simple material. If it did indeed support unconventional superconductivity, graphene's simplicity would make it an ideal place to explore how the phenomenon works, Li says.

"Unconventional superconductors are exciting because of their high transition temperature and potential applications in quantum computers, lossless power grids and elsewhere," Li said. "But we still don't have a microscopic theory for how they work. That's why everybody was so excited when something that looked like unconventional superconductivity was happening in magic-angle graphene. Its simple chemical composition and tunability in twist angle promise a clearer picture."

Conventional superconductivity was first explained in the 1950s by a group of physicists that included longtime Brown professor and Nobel Prize winner Leon Cooper. They showed that electrons in a superconductor distort the atomic lattice of a material in a way that causes electrons to form quantum duos called Cooper pairs, which are able to move through that material unimpeded. In unconventional superconductors, electron pairs form in a way that is thought to be a bit different from the Cooper mechanism, but scientists don't yet know what that mechanism is.

For this new study, Li and his colleagues came up with a way to use Coulomb interaction to probe electron pairing in magic-angle graphene. Cooper pairing locks electrons together at a specific distance from each other. That pairing competes with the Coulomb interaction, which is trying to push the electrons apart. If it were possible to weaken the Coulomb interaction, Cooper pairs should in theory become more strongly coupled, making the superconducting state more robust. That would provide clues about whether the Cooper mechanism was happening in the system.

To manipulate the Coulomb interaction for this study, the researchers built a device that brings a sheet of magic-angle graphene in very close proximity to another type of graphene sheet called a Bernal bilayer. Because the two layers are so thin and so close together, electrons in the magic-angle sample become ever so slightly attracted to positively charged regions in the Bernal layer. That attraction between layers effectively weakens the Coulomb interaction felt between electrons within the magic-angle sample, a phenomenon the researchers call Coulomb screening.

One attribute of the Bernal layer made it particularly useful in this research. The Bernal layer can be switched between a conductor to insulator by altering a voltage applied perpendicularly to the layer. The Coulomb screening effect only happens when the Bernal layer is in the conducting phase. So by switching between conducting and insulating and observing corresponding changes in superconductivity, the researchers could ensure what they were seeing was due to Coulomb screening.

The work showed that the superconducting phase became stronger when Coulomb interaction was weakened. The temperature at which the phase broke down became higher, and was more robust to magnetic fields, which disrupt superconductors.

"To see this Coulomb effect in this material was a bit surprising," Li said. "We'd expect to see this happen in a conventional superconductor, yet there's lots of evidence suggesting that magic-angle graphene is an unconventional superconductor. So any microscopic theory of this superconducting phase will have to take this information into account."

Li said the results are a credit to Xiaoxue Liu, a postdoctoral researcher at Brown and the study's lead author, who built the device that made the findings possible.

"Nobody has ever built anything like this before," Li said. "Everything had to be incredibly precise down to the nanometer scale, from the twist angle of the graphene to the spacing between layers. Xiaoxue really did an amazing job. We also benefited from the theoretical guidance of Oskar Vafek, a theoretical physicist from Florida State University."

While this study provides a critical new piece of information about magic-angle graphene, there's much more that the technique could reveal. For example, this first study only looked at one part of the phase space for magic-angle superconductivity. It's possible, Li says, that the behavior of the superconducting phase varies in different parts of the phase space, and further research will unveil it.

The ability to screen the Coulomb interaction gives us a new experimental knob to turn in helping to understand these quantum phenomena," Li said. "This method can be used with any two-dimensional material, so I think this method will be useful in helping to engineer new types of materials."

Other authors of the study were Zhi Wang, K. Watanabe and T. Taniguchi. The research was supported by Brown University and its Institute for Molecular and Nanoscale Innovation.

"This is the first time anyone has demonstrated that you can directly manipulate the strength of Coulomb interaction in a strongly correlated electronic system."

-JIA (LEO) LI

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Stephon Alexander

FACULTY RESEARCH

SIMONS FOUNDATION GRANT WILL SUPPORT RESEARCH THAT COULD UPDATE EINSTEIN'S THEORY OF GRAVITY

By Kevin Stacey

Einstein's theory of general relativity is one of the most successful theories in all of science. It posits that massive objects warp the very fabric of space and time, giving rise to the gravitational force that holds the universe together. The theory's predictions have been tested to remarkable precision, and it has passed every test so far.

But for all that success, there are things about the universe that the theory fails to explain, and areas where it appears to break down altogether. With a $1 million grant from the Simons Foundation, Brown physics professor Stephon Alexander will work on a new tweak to the theory, which may help explain puzzling aspects of the universe.

"General relativity works really well in terms of predicting the expansion of the universe, the existence of black holes and the existence of gravitational waves, just to name a few things," Alexander said. "But there are things that it fails to deal with, like dark matter and dark energy. And it produces infinities or singularities in the solutions for black holes and the big bang, which tells us that the theory is breaking down in those cases."

To help address the questions that general relativity leaves unanswered, Alexander is working to adapt a mathematical theory originally developed by Shiing-Shen Chern and James Simons. Alexander started the work more than a decade ago, publishing an influential study in 2009 that introduced what he calls "dynamical Chern-Simons gravity." With this new grant, Alexander plans to continue those efforts with Brown graduate student Leah Jenks.

"This is a modification to general relativity that makes a series of very sharp predictions," Alexander said. "What we want to do is continue to develop this theory and see if we can reconcile it with some of the areas where Einstein's theory runs into trouble."

Early indications, Alexander said, suggest that the modified theory may offer explanations for dark matter, the elusive stuff thought to account for the majority of the mass in the universe, and dark energy, the force driving the universe's ever-accelerating expansion. It could also shed light on black hole singularities, points at which Einstein's theory predicts an infinite curvature of time and space.

Alexander's work will also yield experimental approaches to testing whether dynamical Chern-Simons gravity is on the right track. For example, the theory could make some very specific predictions about the nature of gravitational waves — ripples in spacetime produced by ultra-high-energy events like the merger of two black holes or the Big Bang itself. Einstein predicted their existence in 1916, and they were finally observed in 2015. Alexander says that if his theory is correct, then those waves should have a peculiar — and detectable — property in the way they spin.

"If you could somehow see a gravitational wave propagating toward you, you'd see it undulating up and down as it moved," Alexander said. "But it could also have a kind of spin, a little like a football spiraling as it moves through the air. Our version of this theory suggests that there should be an asymmetry in the spins of gravitational waves, with more waves spinning in one direction than the other. We could look for that asymmetry, which would give us some validation for this theory."

Making those measurements will require a precise calculation of spin properties, Alexander says. He and Jenks will work to refine the theory to make sure they have the best predictions possible.

The grant from the Simons Foundation awards cutting-edge theoretical work with the potential for redrawing the boundaries of scientific knowledge. Alexander says he's thrilled about the foundation's investment in this new theory.

"It's great to have the support of such a prestigious organization for myself and my students," Alexander said. "I'm looking forward to getting started."

With a $1 million grant from the Simons Foundation, Brown physicist Stephon Alexander will look to expand Einstein's theory of gravity to explain cosmic mysteries like dark matter and black hole singularities.

COURTESY OF THE EVENT HORIZON TELESCOPE COLLABORATION

In 2019, scientists took the very first picture of a black hole, but what happens at its center, called the singularity, remains a mystery. Research by Brown physicist Stephon Alexander could help in unraveling that mystery.


June 10, 2021 partial solar eclipse over the Narragansett Bay as photographed by Brown Professor of Physics Savvas Koushiappas.

SAVVAS KOUSHIAPPAS/BROWN UNIVERSITY

J. Michael Kosterlitz

FACULTY RESEARCH

A NOVEL THEORETICAL FRAMEWORK FOR UNDERSTANDING DISORDERED SYSTEMS

By Pete Bilderback

Brown University's Harrison E. Farnsworth Professor of Physics, J. Michael Kosterlitz, recently published his first paper in the Proceedings of the National Academy of Sciences of the United States of America (PNAS) since becoming a member of the National Academy in April of 2017.

Kosterlitz's article, "Global potential, topology, and pattern selection in a noisy stabilized Kuramoto–Sivashinsky equation" authored with collaborators from the Shanghai Center for Quantitative Life Sciences, Yong-Cong Chen, Chunxiao Shi, Xiaomei Zhu and Ping Ao, posits a novel theoretical framework for understanding how the transition from a disordered to an ordered state complex system proceeds through nonlinear steps.

In 2016, Kosterlitz, along with David J. Thouless and F. Duncan M. Haldane, received the Nobel Prize in Physics for work using the mathematical field of topology to examine phase transitions in exotic states of matter. In this paper, Kosterlitz and his collaborators utilize topology to investigate systems that are out of equilibrium.

Kosterlitz describes the equilibrium state as the final, or "boring" state of a system, but notes that, "systems that are out of equilibrium are much harder to deal with because you have to discuss them in terms of the dynamics of their evolution towards some equitable state, assuming you know what that is." He notes that, "in the real world, most systems are out of equilibrium, systems are constantly evolving towards some equilibrium state."

Kosterlitz was particularly interested in certain experimental systems that "appear to come eventually to some stationary time-independent state." He clarifies, "it's not equilibrium, it's a driven-out-of-equilibrium state, but it seems to be time-independent." He wondered if, "maybe the same thing happens in these driven-out of-equilibrium systems when they come to a unique final stationary state."

Working with Brown Physics graduate student Saloni Saxena Ph.D. '21, Kosterlitz wanted to test his hypothesis out on a simple model system to see if this speculation could be right. "There's no reason for it to be right, it's just that in some experiments it seems to happen, and I just wanted to test it out, and it seemed to work for a very simple system."

In discussions with his collaborators at the Shanghai Center for Quantitative Life Sciences, Kosterlitz learned, "they had some clever analytical methods of dealing with the same type of problem but in much simpler systems with only a few variables." Kosterlitz, "wanted to see if the same thing happened for more complex systems."

To do so, Kosterlitz insisted on incorporating stochastic, or random, noise to mimic real-life systems. "Every real system is subject to some random perturbation whether it's fluctuations in temperature or a truck driving by the laboratory." By way of example, Kosterlitz notes how if you have a slightly sticky ball that slides down a hill, "it will get stuck in the first local minimum it gets to." To get it out of that state, "you need some random noise or fluctuations. It's like if you shake the system eventually it will jiggle out of it and end up in the deepest minimum. But it won't stay there forever because with some new fluctuation it gets excited out of that state."

Kosterlitz was curious if it was possible to show that a system would spend most of its time in a particular state. Along with his collaborators, he managed to construct a formula that put that into a mathematical language, and in the particular system they looked at "it happened to fit." For future work, Kosterlitz would like to see if the same holds true for more complicated systems that do come to a stationary state.

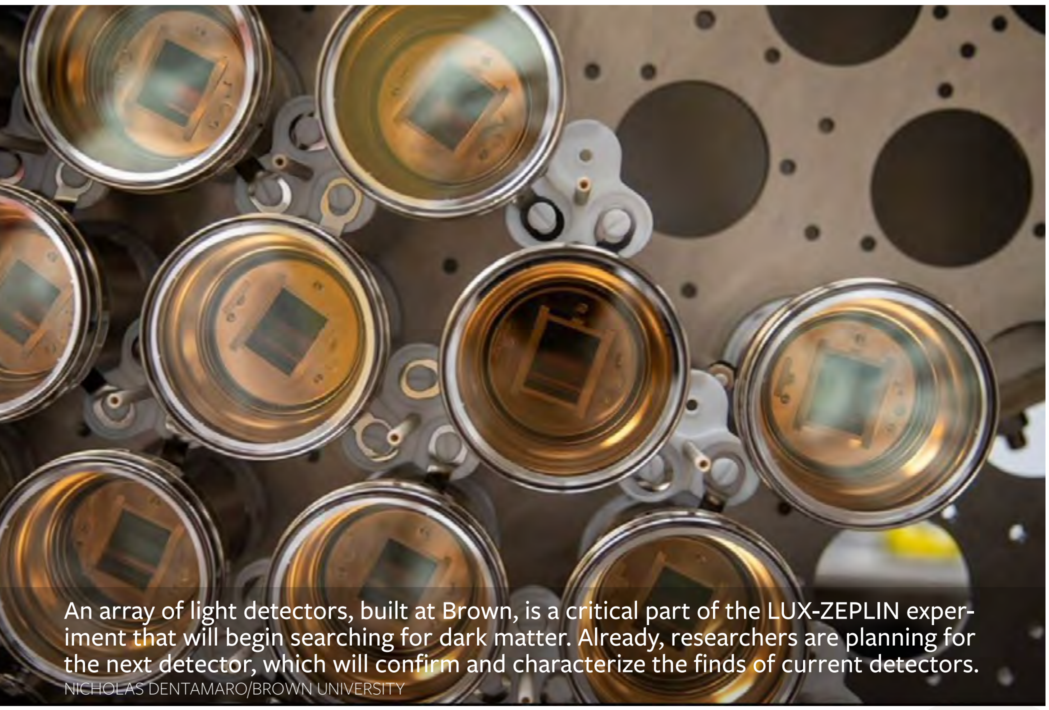
Richard Gaitskell

FACULTY RESEARCH

LEADING XENON RESEARCHERS UNITE TO BUILD NEXT-GENERATION DARK MATTER DETECTOR

By Kevin Stacey

Even as two powerful dark matter detectors are set to switch on later this year, scientists including a Brown professor are already planning a new experiment aimed at mysterious dark matter particles.



An array of light detectors, built at Brown, is a critical part of the LUX-ZEPLIN experiment that will begin searching for dark matter. Already, researchers are planning for the next detector, which will confirm and characterize the finds of current detectors.
NICHOLAS DENTAMARO/BROWN UNIVERSITY

A Brown University physicist will play a key role in a future experiment aimed at detecting and characterizing dark matter, the mysterious stuff thought to account for most of the matter in the universe.

The XENON/DARWIN and LUX-ZEPLIN collaborations — which operate two current and ongoing dark matter experiments — have now joined forces to work together on the design, construction and operation of a new multi-ton-scale xenon observatory to explore dark matter. Xenon experiments have proven to be the most sensitive dark matter detection systems in the world over the last 20 years, says Richard Gaitskell, a physics professor at Brown who will participate in the new experiment. The primary science goal of the new joint observatory is to reach a sensitivity for detecting dark matter in the Earth's galaxy by at least a factor of 10 beyond that of the current generation of detectors.

"Nature has presented us with an enormous challenge in identifying the dominant form of matter in our universe," said Gaitskell, who is currently a member of the LUX-ZEPLIN research team. "The dark matter reacts so weakly with conventional material that we have to build massive detectors in order to potentially collect only a handful of identifiable interactions a year. The larger the detector, the greater the chance of seeing an interaction."

Dark matter makes up 85% of the matter in the universe, but its nature remains a mystery. Scientists can see the effects of its gravity in the rotation of galaxies and in the way light bends as it travels across the universe, but no one has directly detected a dark matter particle. The direct identification of the dark matter particle is among the highest priorities in science and also one of the most challenging.

The current xenon-based experiments XENONnT and LUX-ZEPLIN will start their first science runs in 2021. The experiments employ 5.9 and 7.0 tons of liquid xenon for the search, respectively. Both research teams are hopeful that one or both of these experiments will make the world's first direct detection of a dark matter particle. But whatever the outcome, Gaitskell says that the new detector is necessary to confirm or clarify those results.

"If we see a dark matter signal using our 10-ton detectors, we will then need a much larger detector to accurately determine the properties of that elusive dark matter," he said. "If we see nothing over the next few years with the 10-ton detectors, we will need the much larger detector to probe additional hiding places of the dark matter. The work on the research and design for the new even more massive next-generation detector has begun."

Beyond its sensitivity to dark matter, the new detector's large mass and low level of background interference will also enable world-leading searches for additional signatures of physics beyond the Standard Model of particle physics, collaboration scientists say. In particular, the secondary science goal will be the search for neutrinoless double-beta decay in xenon, shedding light on the nature of the neutrino and the imbalance of matter and antimatter in the universe. The observatory will also perform searches for other rare processes and particles such as axions, hypothetical particles that might be emitted from the sun. It will also measure neutrinos created in the sun, the Earth's atmosphere, and potentially those from Galactic supernovae.

The current LUX-ZEPLIN experiment operates at the Sanford Underground Research Facility in South Dakota. The XENONnT experiment is located at the INFN Gran Sasso Laboratory in Italy. DARWIN is the evolution of the XENON program and includes additional groups, focusing on several research and development aspects required for the much larger detector. The new multi-ton liquid xenon detector will combine the most successful technologies employed in rare-event searches with xenon detectors, including those developed for XENONnT and LUX-ZEPLIN, and from targeted research and development including work supported under DARWIN.

After a joint workshop in April 2021, 104 research group leaders from 16 countries have signed a memorandum of understanding to work together on the design, construction and

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Gregory Tucker

FACULTY RESEARCH

BROWN RESEARCHERS TO HELP BUILD TELESCOPE TO STUDY EXOPLANET ATMOSPHERES

By Kevin Stacey

CCO PUBLIC DOMAIN

With a new grant from NASA, Brown physicist Gregory Tucker and a team of students will help to build a telescope that can study the atmospheres of distant planets.

A Brown University professor and his students will play key roles in building and operating a new telescope designed to unlock the secrets of planets orbiting distant stars.

Gregory Tucker, a professor of physics, received a $2.5 million grant from NASA to build components for the Exoplanet Climate Infrared TElescope (EXCITE). The instrument, which is designed to fly suspended from a high-altitude balloon, combines a powerful telescope with a spectrometer capable of probing the atmospheric characteristics of exoplanets. In particular, EXCITE will study hot Jupiters, planets that are about the size of the largest denizen of the Earth's solar system but orbit surprisingly close to their host stars.

"When people were first searching for exoplanets, nobody expected hot Jupiters to exist because it's not clear how they would form," Tucker said. "But they turn out to be quite common, and because of their size we can measure the properties of their atmospheres and get an understanding of their atmospheric dynamics."

The EXCITE instrument is designed specifically to do just that. The project is led by Peter Nagler, a researcher at NASA's Goddard Space Flight Center who helped to develop the idea for the instrument while a Ph.D. student at Brown working with Tucker.

Tucker says that EXCITE will have some distinct advantages over space telescopes and other large-scale instruments when it comes to studying atmospheres. Observation time on space telescopes is precious, meaning they generally take relatively quick looks at lots of different targets. EXCITE, on the other hand, will be able to stare at individual planets for days at a time as they orbit their host stars.

Hot Jupiters have short orbital periods of less than 10 days, which means EXCITE can gather continuous data from a planet throughout its orbital cycle. That can provide detailed information about the composition of an atmosphere as well as to track key dynamics driven by temperature and pressure.

For example, Tucker says that EXCITE could potentially determine wind speeds on a planet by studying its substellar point — the spot closest to a host star.

"You'd expect this closest point to be the hottest spot on the planet because it's constantly heated by the star, but in fact we tend to see a small eastward shift," Tucker said. "That's because the atmosphere is redistributing that heat, and we can use that shift to determine wind speed."

To get these kinds of observations, EXCITE will fly 25 miles up in the skies above Antarctica. That altitude removes interference from much of the Earth's atmosphere, which over Antarctica is already clear, dry and optimal for telescope viewing. To reach that altitude, the SUV-sized EXCITE instrument will be tethered to a balloon about the size of a football stadium when fully inflated.

Among the components to be developed at Brown is a cryogenic system for the instrument's spectrometer. Interference generated by the optics inside the spectrometer itself could obscure the signals that the researchers are trying to detect. By cooling the optics down, the team can minimize that interference.

"We're basically putting it in a big Thermos bottle with a mechanical cooler," Tucker said.

Tucker's team will also help with integration and assembly of the full instrument. When EXCITE is ready to fly, Tucker and his students will provide flight support and aid in data analysis. The team hopes to start building components next year and begin flights sometime in the next few years.

Ultimately, Tucker hopes that EXCITE will provide data on exoplanet atmospheres that other instruments can't capture — information that could help scientists better understand how solar systems form and evolve. And the technical insights provided by EXCITE could push the study of exoplanet atmospheres forward even further.

"Eventually we'd like to be able to study the atmospheres of smaller Earth-size exoplanets, but the technology isn't quite there yet," Tucker said. "I think this could be a good path to getting toward the study of these more Earth-size planets."

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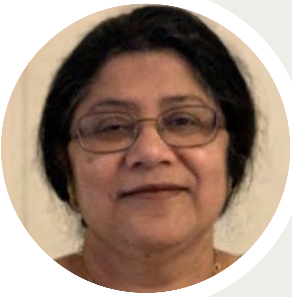


MEENAKSHI NARAIN CONTINUES AS CO-CONVENER OF THE ENERGY FRONTIER OF SNOWMASS

By Pete Bilderback

Professor Meenakshi Narain will continue as the co-convener of the "Energy Frontier" group of the Particle Physics Community Planning Exercise (a.k.a. "Snowmass") organized by the Division of Particles and Fields of the American Physical Society, Narain's appointment, since January 2020, puts her in the forefront of developing the 20-year global strategic vision of the high energy physics community and U.S. participation in the next future collider project sited in either Europe, China, Japan or the U.S.

Narain and her team will identify some of the most inspiring and grand questions the universe can pose. Hundreds of particle physicists will conduct detailed studies of the proposed future accelerators and experiments that could answer them. The report generated from this study, expected by December 2022, will be reviewed by the Particle Physics Project Prioritization Panel, which will identify and prioritize the most valuable areas of particle physics study in the years to come. This report will be used for deciding U.S. investment in research and development and construction of the next big particle collider being discussed for 2045.

Narain says, "we're pushing the edges of technology in every way, so we have to come up with the detector concepts, the accelerator concepts, and then come up with a price tag apart from understanding what physics we can do." Future particle colliders will need to have the potential to discover new particles and perform precision measurements of the properties of already known particles, as the high energy physics community grapples with the need to test hypothesized physics beyond the standard model of particle physics.

These large-scale international collaborations require massive budgets and careful, detailed long-term planning. Narain notes, "accelerators are really expensive…and while one country leads a project, the funding comes from many countries. And in order to get that funding, we have to be able to justify and explain our vision." The results of the Snowmass study will be submitted to the Department of Energy (DOE) and the National Science Foundation (NSF).

Making the case for the funding of fundamental science can be difficult because many of the economic benefits are in the future and unpredictable. Narain maintains that part of making the case to government agencies involves convincing them of the need for a highly-skilled workforce. "We need to demonstrate that by doing this cutting-edge research, we develop logical thinkers who are very creative, and as they enter the workforce they can lead many of these new initiatives that will help the country grow in various directions." "Students who are trained in this way," she adds, "are highly employable in industry as well as in academia...We try to explain to them not only the necessity of doing basic science but also a highly-skilled workforce which has an immediate impact on the economy."

Politicians and funding agencies also need to be convinced that fundamental research will reap tangible benefits in the future. According to Narain, "the future value of fundamental physics comes from the technology we develop right now. Today we use particle beam accelerators to treat cancer that were developed to do fundamental science." She adds, "there are many other applications used in medical imaging. For instance, [particle accelerators] are used in pattern imaging right now, and that started in fundamental particle physics. It takes a while for them to see practical applications, but we do see them in time."

Narain notes the Snowmass study was delayed due to COVID, "we had a hiatus of about six months because people were really stressed, and everything was happening remotely. We plan to have a big workshop to really restart things in August." She notes that while some things can be done remotely, others require face-to-face contact, "if you cannot sit next to each other and talk and brainstorm, it's very difficult to understand what [other people] are doing and to find where they are stuck and how to get unstuck."

"We are at an important juncture in high energy physics today. We are developing a vision for the field to discover new physics and explore uncharted territory beyond the Large Hadron Collider. This will form the basis for formulating the strategy that DOE and NSF will try to implement. We will outline the potential of the different possible experiments and particle colliders, and boldly go where no one has gone before!"

Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois is the kind of investment in particle physics research that requires enormous amounts of capital from governments. MAREK ŚLUSARCZYK/WIKIMEDIA

ROBERT HORTON/BROWN UNIVERSITY

The sun as photographed from Ladd Observatory.

Jiji Fan

FACULTY RESEARCH

JIJI FAN DISCUSSES FERMILAB MUON G-FACTOR EXPERIMENTAL RESULTS

By Pete Bilderback

One of the biggest stories in physics this year involves the results of an experiment by a group of scientists at Fermilab that measured the g-factor of the muon. In a paper published in Physical Review Letters, the group found that measurements of the magnetic moment of the muon in Fermilab's particle accelerator differed from what is predicted by the standard model of particle physics. The group's results mirror those obtained in an experiment done twenty years ago at Brookhaven National Laboratory. Both experiments found the measured value of the magnetic moment of the muon disagreed with calculations based on the standard model. Combining both measurements, the tension between experiment and theory is at 4.2 standard deviations, a significant difference.

By way of contrast, the standard model predicts the magnetic moment of the electron in agreement with experimental findings out to 13 decimal places. The anomalous magnetic moment, a small departure of the magnetic moment from the value of 2, is the most accurately computed and measured quantity in all of physics. It is an open question why the standard model prediction of the magnetic moment agrees well with the experiments for the electron but not for the muon.

The Fermilab group's anomalous findings sparked some breathless speculation in the press. Business Insider declared, "A new experiment has broken the known rules of physics, hinting at a mysterious, unknown force that has shaped our universe." The New York Times trumpeted, "A Tiny Particle's Wobble Could Upend the Known Laws of Physics." Those following the story as it was covered in the press might reasonably conclude that the standard model of physics is irretrievably broken and we need an entirely new physics to describe how our universe works from the smallest particles to the largest objects in the cosmos.

Brown University Professor of Physics JiJi Fan, who specializes in physics beyond the standard model, was notably more cautious in her assessment of the result. "Clearly this result is very important. The results should motivate the particle physics community to look deeper into the calculation related to the magnetic moment of the muon." As to whether the findings show the standard model to be broken, Fan said, "the result is not conclusive. At the moment it's probably best described as a possible hint for deviations from the standard model, but it's definitely not confirmed. A lot more work needs to be done."

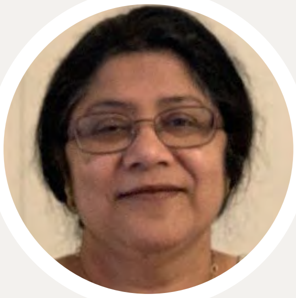
Fan explains that there are different opinions in the particle physics community on what the standard model predicts. One key part of the theoretical prediction is the effects of hadron particles. Last year a group of more than 120 theoretical physicists published a consensus value for the muon's magnetic moment. The value was based on the hadronic contribution obtained by a data-driven approach and it disagrees with the Fermilab results. But there is another type of theoretical calculation for the hadronic contribution that utilizes what is called lattice quantum chromodynamics. A paper using this calculation method was published in Nature on the same day the Fermilab group released their results. According to Fan, the results reported in this paper "are actually in agreement with the latest experimental results." Fan says it's "mysterious" as to why these two methods deliver such different results, and much more work remains to be done before we can arrive at definitive conclusions.

It may be too soon to discard the standard model of particle physics altogether, but as Fan notes, "we definitely knew the standard model cannot be the complete story from very early on, well before this result." "We already know, for example, that the standard model cannot describe dark matter or dark energy." Fan praises the Fermilab group's work, "it is definitely a remarkable experimental achievement. It's very difficult to produce such high-precision measurements. That's a huge achievement," but she cautions, "how we should interpret the results theoretically actually requires much more work."

FACULTY NEWS

GREG LANDSBERG AND COLLEAGUES TO USE AI TO SEARCH FOR UNUSUAL PATTERNS IN EXPERIMENTS

Professor Greg Landsberg and department colleagues have been awarded a 2021 Seed Research Award for a project entitled, "Using Artificial Intelligence to Search for New Physics Underground, on the Ground, and in the Sky." The team proposes to utilize advanced artificial intelligence (AI) methods and a combination of supervised and unsupervised machine learning algorithms to look for unusual patterns in data of experiments underground, on the surface of the Earth, and in the sky. The group seeks to leverage significant developments over the past few years in high-power, massively parallel computing made possible in part by the advancement of fast GPUs, FPGAs, and specialized processors which have taken AI to a qualitatively new level, making it a valuable tool for scientific research. Landsberg will be joined in the project by his Department of Physics colleagues Hazard Professor of Physics Richard Gaitskell and Associate Professor of Physics Savvas Koushiappas.



MEENAKSHI NARAIN EARNS DISTINGUISHED ALUMNI AWARD

Professor Meenakshi Narain was awarded the Distinguished Alumni Award from the Indian Institute of Technology for her outstanding contributions to the field of particle physics. Narain has served as chair of the US Compact Muon Solenoid (CMS) Collaboration Board since 2018 and is co-convener of the Energy Frontier of the Particle Physics Community Planning Exercise organized by the Division of Particles and Fields of the American Physical Society.

ANDREY GROMOV EARNS NSF CAREER AWARD

Professor Andrey Gromov has been awarded a National Science Foundation (NSF) Faculty Early Career Development Program (CAREER) Award. The CAREER Program offers the NSF's most prestigious awards in support of "early-career faculty who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization."

Gromov's proposed interdisciplinary research program will contribute to the development of new ideas and challenge the foundations of condensed matter physics, and if successful will play a crucial role in the design of future quantum information storage devices as well as quantum information processing protocols.

Gromov also plans to do outreach to underrepresented groups and K-12 schools with the aim of increasing diversity and inclusion in physics. To achieve those goals, he has partnered with The Leadership Alliance and the Summer Research – Early Identification Program (SR-EIP) Program. Among other outreach initiatives, Gromov will use NSF funding to sponsor a URM student for summer on-campus research at Brown each year, to show what a real research environment is like and motivate students to pursue graduate degrees in STEM.

IAN DELL'ANTONIO AWARDED PRESIDENT'S AWARD FOR EXCELLENCE IN FACULTY GOVERNANCE

Brown President Christina Paxson awarded Professor Ian Dell'Antonio the 2021 President's Award for Excellence in Faculty Governance. Dell'Antonio has served on a number of university committees including the Library Advisory Board (2012-2014), Research Computing Committee (2012-2016), Committee on Medical School Faculty Appointments (2015-2018), the NEASC Re-accreditation Committee (2016-2018), the Tenure, Promotion and Appointments Committee (2018-2021) and the University Safety Committee (2020-2021).

STEPHON ALEXANDER AND COLLEAGUES EARN INTERPRETABLE MACHINE LEARNING SEED AWARD

Professor Stephon Alexander and other colleagues at Brown have been awarded a 2021 Seed Research Award for a project entitled, "Finding the Physics that Matters in Astrophysical and Astro-Particle Analyses with Interpretable Machine Learning." The group proposes to use interpretable machine learning to create a software framework for identifying and understanding the biases induced in the models scientists utilize by the training data they use. Scientists are often presented with a trade-off between abundant but low-resolution data, and scarce high-resolution data. The aim of the project is to correct the biases in the abundant low-resolution data so that it is more like the scarce high-resolution data in the ways that affect the predictions of the machine learning models trained on that data. If successful, scientists would have access to higher quality, abundant data. Assistant Professor of Computer Science Stephen Bach, Professor of Physics Ian Dell'Antonio, Hazard Professor of Physics Richard Gaitskell, and Assistant Professor of Physics Jonathan Pober will serve as Co-PI's on the project.

S. JAMES GATES JR. MAKES HISTORY AS APS PRESIDENT

Ford Foundation Professor of Physics and Director of the Brown Theoretical Physics Center S. James Gates Jr. became the first Black theoretical physicist to become President of the American Physical Society (APS). Gates had the following to say about his tenure, "During my service as the President of the American Physical Society for the year 2021, we have overcome several challenges, a number of them relating to the COVID pandemic and the political turmoil that we saw in our nation. As we open back up during the partial recovery thanks to the vaccines, the environment continues to be challenging. The APS is evolving to meet these challenges, and I'm confident that as an organization we will continue to improve the culture of physics."

Gates was also recently named a Fellow of the South African Institute of Physics in recognition both for his scientific achievements and his contributions to South African science policy.

VESNA MITROVIĆ AND COLLEAGUES SEARCH FOR QUANTUM INFORMATION PROCESSING IN THE BRAIN

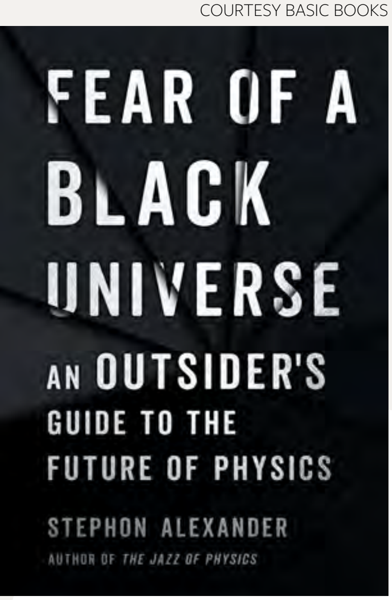
Professor Vesna Mitrović and Brown colleagues have been awarded a 2021 Seed Research Award for a project entitled, "Reverse Engineering the Synaptic Cleft - the Search for Quantum Information Processing in the Brain." The interdisciplinary team assembled by Professor Mitrović proposes to test theoretical physicist M. Fisher's theory that the fundamental principle of complex brain operation is quantum processing involving nuclear spins of phosphorus as a neural qubit. Fisher identified a hypothetical "Posner molecule" as one that can protect neural qubits very long times and thereby serve as a working quantum memory.

The group's novel approach involves harnessing the properties of nuclear spins to study quantum information processing (QIS) in the brain by reverse-engineering specific polymers and biomolecules to provide sufficiently long coherence times required for quantum processing. This is orthogonal to Fisher's approach which focuses on the search for the Posner molecule. Team members include Tayhas Palmore, the Elaine I. Savage Professor of Engineering and Professor of Chemistry, as well as Assistant Professor of Neuroscience Edward Walsh. Palmore plans to synthesize polymer-based bio-materials with appropriate nuclear spin species, while Mitrović and Walsh will use the nuclear magnetic resonance (NMR) technique to test possible coherence propagation and test whether such bio-materials can be used as a quantum register to process information.

The group's long-term goal is to identify essential bio-material properties required for QIS and quantum signal transmission using nuclear spins of phosphorus with an ultimate goal of synthesizing artificial neural synapses and memory registers.

STEPHON ALEXANDER PUBLISHES "FEAR OF A BLACK UNIVERSE"

COURTESY BASIC BOOKS



Stephon Alexander will publish his second book, "Fear of a Black Universe," a follow-up to the best-selling "The Jazz of Physics" with Basic Books on August 31. In the book, Alexander argues that physics must embrace the excluded, listen to the unheard, and be unafraid of being wrong.

In "Fear of a Black Universe," Alexander shows that great physics requires us to think outside the mainstream — to improvise and rely on intuition. Drawing on historical anecdotes and data from the social sciences, Alexander emphasizes how the outsider's perspective is often the key to catalyzing breakthroughs in physics. Alexander takes forays into physics' dark realm, muses over a theory of consciousness, the origins of the quantum universe, a new link between the big bang and the origin of life, and what we need from a theory of quantum gravity to finally grasp the invisible forces that shape our universe.

Alexander says, "We find ourselves in a very strange universe, where most of the matter and energy around us is invisible yet essential to the fabric of our very existence. The nature of the so-called dark sector and other anomalies are forcing physicists to venture into unchartered and risky territories." He continues, "In 'Fear of a Black Universe,' I investigate these profound mysteries physicists face and their overlap with other fields, such as neuroscience, biology, and artificial intelligence. To do this, I show how the 'genetic code' of modern physics consists of three fundamental building blocks: superposition, invariance, and emergent principles. Along the way, I not only interrogate the deep questions of physics but questions about how new physics emerge. Who will be the Einstein of this new frontier? Who will shine a light on the dark sector? Does the fear of failure, the mysterious, the invisible, the ignored, the stigmatized — things often associated with Blackness — prevent us from unlocking the secrets of the universe?" Alexander also notes that in writing the book he was "inspired by the creative genius and scientific courage" of his mentor and advisor at Brown, Nobel Laureate Leon N Cooper.

The book has received excellent advanced reviews. Publisher's Weekly named "Fear of a Black Universe" one of its top 10 science books of the year and calls it, "both an excellent work of advocacy and a welcoming introduction to physics." Kirkus Reviews calls the book "lush with ideas and bold in its analysis of the status quo," and credits the book with "reorient[ing] our view of science and the universe." David Spergel, the winner of the 2018 Breakthrough Prize in Fundamental Physics, compares the book to Stephen Hawking's "A Brief History of Time," calling it, "very brief and very ambitious." Spergel says, "it covers an enormous amount of material and offers insights not only into physics but how we do physics and who we are as physicists."

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BROWN PHYSICS INSTRUCTIONAL STAFF AND FACULTY INNOVATE DURING PANDEMIC

By Pete Bilderback

In 1667 when Sir Isaac Newton emerged from his family farm after more than a year of social isolation due to the Great Plague of London, he had developed his theory of universal gravitation, created calculus, and set the blueprint for all physics that would follow. While much myth-making surrounds Newton's "annus mirabilis" at Woolsthorpe Manor and it is unrealistic to expect any of us to achieve what Newton was able to do, it is also true that crises can create opportunities to rethink old ways of doing things and lead to new and better processes. Necessity, as they say, really can be the mother of invention, but good preparation and forward-thinking are the necessary groundwork needed to turn crises into opportunities for advancement. As the instructional staff and faculty of Brown University's Department of Physics move toward a post-pandemic "new normal" they find themselves armed with new insights and tools that will affect how Brown students learn physics for decades to come.

When Brown University sent employees home on March 13, 2020, due to the rapidly deteriorating COVID-19 situation, Bob Horton, the Manager of Astronomy Labs and the Ladd Observatory, had never heard of Zoom. But he was keenly aware that new tools and methods of teaching physics were needed. "Our astronomy courses had become more popular over the last several years, particularly PHYS0220 [Astronomy], which during the spring of 2020 was at an all-time high, with an enrollment of over 220 students," says Horton. "Our rooftop observatory, with a 16" telescope and camera had served us well when courses typically had 50 or fewer students enrolled, but with a limited number of clear nights and limited facilities, the increase in enrollment over the last several years was already presenting a logistical challenge."

Plans to make changes were already underway. In the Fall of 2019, Horton met with faculty and the Ladd Observatory staff to discuss ideas about how the department might better meet the needs of astronomy classes with large enrollments. According to Horton, in preparation for accommodating larger numbers of students, "we had purchased several new telescopes and cameras during the winter break to supplement our main telescope and related equipment in the observatory." Horton continues, "additionally, we decided to make greater use of Ladd Observatory, which had been primarily used for public outreach, but would now also be used to support some of our astronomy labs."

Instead of being limited to only using the 16" telescope in the Barus and Holley rooftop observatory, students would also have access to portable, 8" reflecting telescopes on the rooftop. The new telescopes have computerized tracking mounts with built-in GPS and wifi and, as would later prove critical, can be controlled with apps on a tablet or phone, allowing students to explore the sky by simply locating interesting objects on a sky map, and tapping on the screen to command the telescope to position to that object.

Canon cameras that are designed specifically for taking astronomical images were also installed. These cameras can likewise be remotely controlled with smartphones or tablets, and the images taken can be directly downloaded to these devices. Horton says students were making excellent progress in these labs, "when taking astronomical images, such as galaxies, nebulae, and star clusters, we typically collect up to ten or more images of each object, and then, later on, using image-processing software, stack the images and make enhancements to bring out all of the detail." Meanwhile, at Ladd Observatory students took high-resolution images of the moon using the 12" refracting telescope that was built in 1891. These labs were conducted by Ladd staff members Scott MacNeill and Michael Umbricht.

No amount of advanced planning could prepare the department for what happened on March 13, 2020, when the university directed all staff, faculty, and students to leave campus, but fortunately, the groundwork needed for successful remote labs was already in place. Horton says, "we were aware the COVID-19 pandemic was spreading globally, but at the start of the semester, it still seemed far enough away, or perhaps we did not fully appreciate the danger of it yet." But as the semester continued into late winter, and the number of cases in the United States increased, so too did concern that the pandemic might prove to be seriously disruptive to learning at Brown. Horton says when the university instructed everyone to leave the campus, "I'm pretty sure my only concern at that point was staying healthy, and the instructions for everyone to leave the campus seemed ominous. Teaching was totally disrupted. I went home wondering what would happen next."

By late March of 2020 classes were being held via Zoom, but

Astronomy instruction team in front of the Barus and Holley rooftop observatory (l-r) Ian Dell'Antonio, Robert Horton, David Cutts. ROBERT HORTON/BROWN UNIVERSITY

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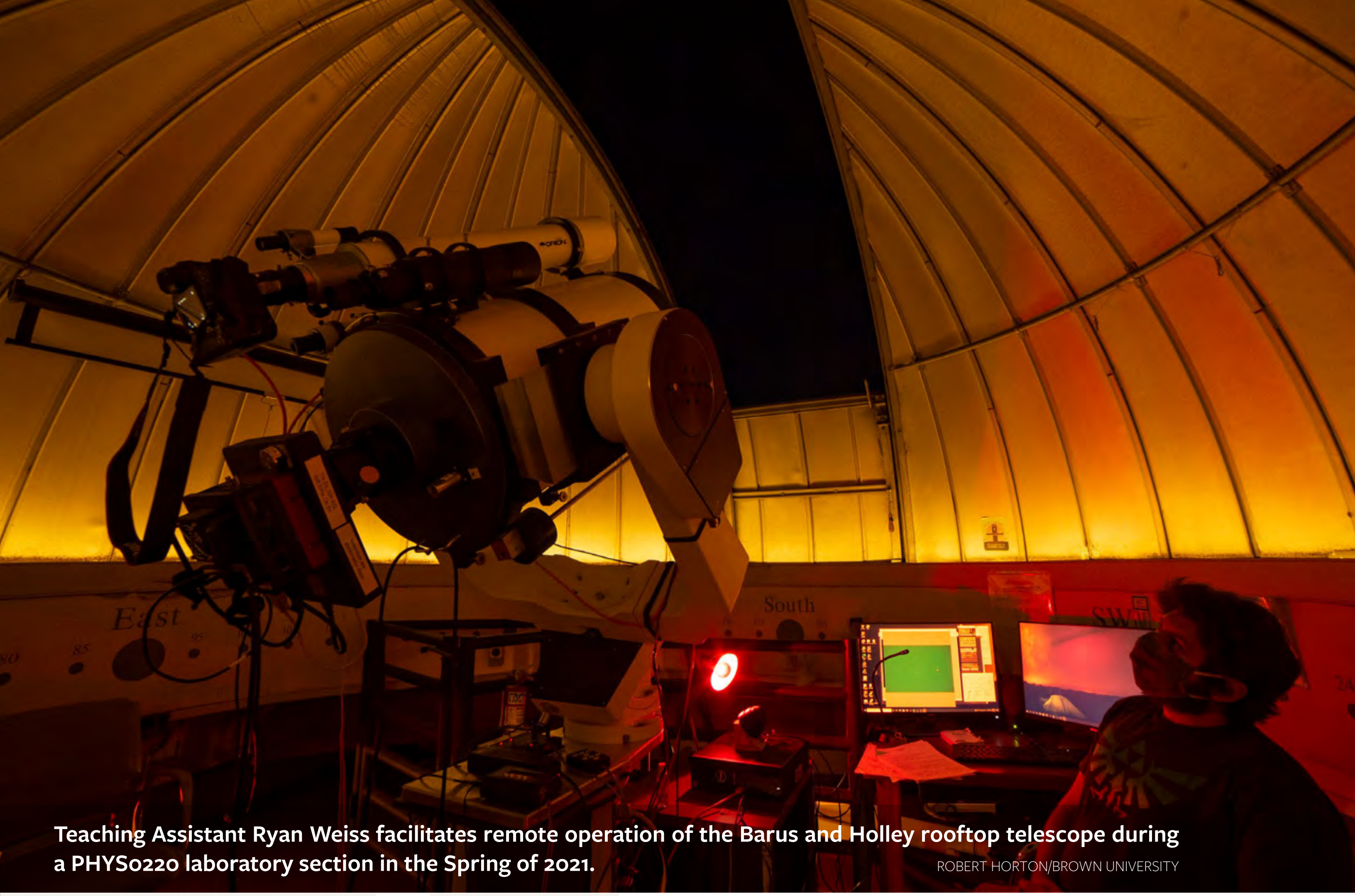

Teaching Assistant Ryan Weiss facilitates remote operation of the Barus and Holley rooftop telescope during a PHYS0220 laboratory section in the Spring of 2021. ROBERT HORTON/BROWN UNIVERSITY

labs were still in limbo. According to Horton, "our lab structure had always been completely dependent on students being present to operate the equipment." And at this time only a quarter of the class had attended an outdoor astronomy lab and taken images with the telescopes, and even fewer students had been able to do any image processing. It was clear that labs had to resume in some form, so the team decided to provide students with unprocessed images that they had taken before the shutdown and instructed them how to do the image processing from home using free software that they could install on their computers.

In order to expand the collection of images, Horton used his backyard observatory to continue taking additional images and uploaded the files to Google Drive for students to process. Horton also worked with Scott MacNeill to develop a new planetary image-processing lab, and Scott, using his telescope, took images of the planet Venus with specialized filters, which were later used by students to create some images of cloud patterns on Venus. These efforts got the team through the Spring semester, allowing students to complete their lab work while also keeping the instructional team intact and involved.

Preparation for the Fall 2020 semester began shortly after the Spring semester wrapped up, and this time the team knew that everything would have to be done remotely from the start. Horton assigns much of the credit for the successful transition to Professor David Cutts, "Dave was instrumental in getting some special funding, which was critical in making our project a success, he deserves a huge amount of credit for his foresight and efforts." Horton continues, "Personally, having never even heard of Zoom prior to March of 2020, I had my doubts this was going to work out, but Dave never did. I really appreciated Dave's determination and positive attitude embracing new ways of teaching." He also credits Professor Ian Dell'Antonio, "Ian was always willing to put in as much time as needed, and more, to resolve software issues and work with me at all hours." Despite being physically distanced, Horton found working remotely with his colleagues rewarding, "this was such an incredible team effort from all involved including Dave, Ian, several students, and myself."

As the Spring 2020 semester was wrapping up, Cutts was looking forward to teaching PHYS0270, "Astronomy and Astrophysics," a more advanced introduction than PHYS0220. It would be the last class he would teach before retirement at the end of the 2020-2021 academic year. According to Cutts, "students in this relatively small class of about twenty are highly talkative and interactive as we discuss astronomy together in our small lecture room." Cutts found teaching this course particularly enjoyable, but it was clear to him much work needed to be done before the class could be successfully offered in the Fall of 2020.

While lectures could be moved online with relative ease, it was not a simple matter to simulate a laboratory experience in which small groups of students gathered around a 16" telescope on the roof of Barus and Holley. Cutts characterized hands-on telescope experience as "a vital component

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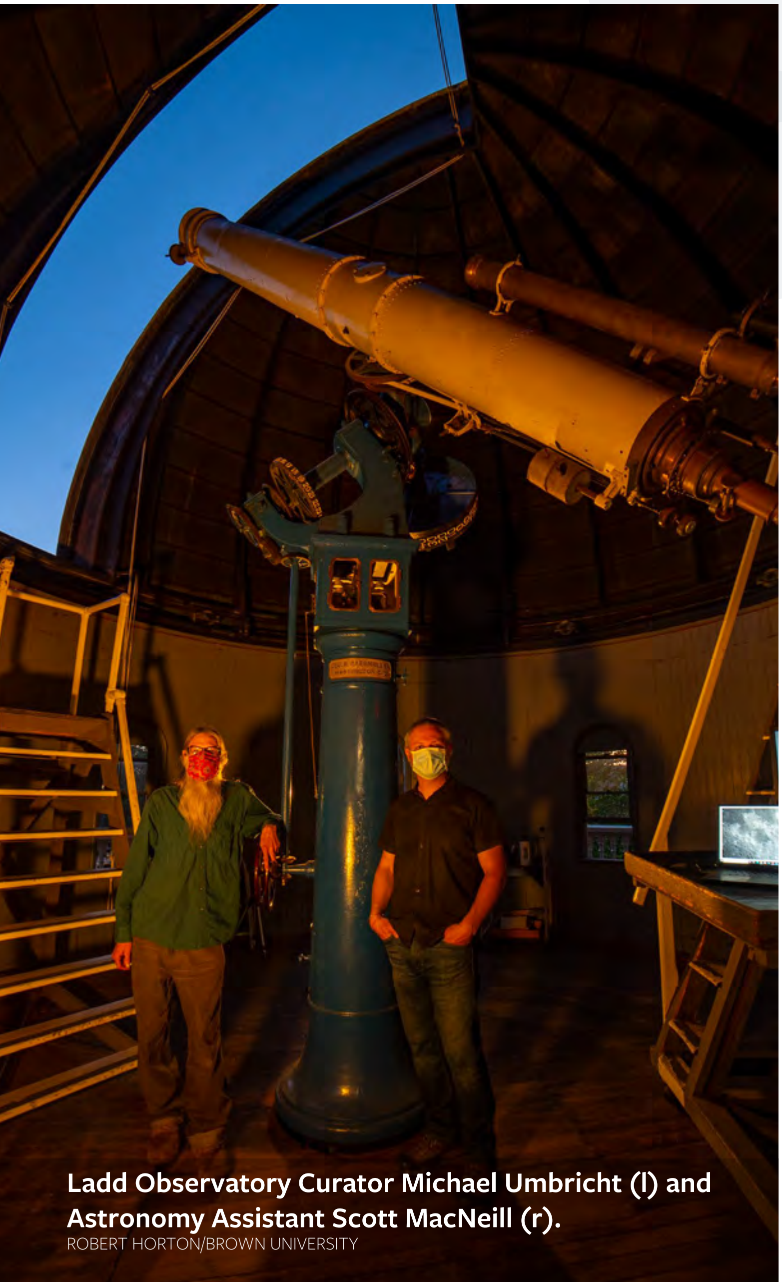
of the course." Cutts says, "it was clear we needed to upgrade the Barus and Holley rooftop observatory so the telescope and associated camera(s) could be operated remotely, with the students directly controlling the instruments and seeing the data collected, in real-time."

Cutts took a leadership role in exploring what options were available and recognized that Zoom was more than just a video-conferencing application and could also be used to remotely share software being run on a host computer. Together with Dell'Antonio and Horton, Cutts obtained a SPRINT grant from the University to hire former PHYS0270 students Rachel Hemmer and Edgar Villegas to assist with the transition to remote learning.

Given the high degree of reliability and accuracy necessary to operate a telescope remotely, Cutts recognized the need for "a more powerful computer as well as upgraded control software for the telescope and the camera." In the past, an onsite teaching assistant allowed for a certain amount of imprecision, but the logistics were considerably more complicated when working remotely. Cutts says, "we had to point accurately and to use software that allowed fine-tuning of positions, as well as of telescope focusing, to be done online by a remote observer." Everyone involved understood that getting everything working would require an astronomical level of effort.



Ladd Observatory Curator Michael Umbricht (l) and Astronomy Assistant Scott MacNeill (r).
ROBERT HORTON/BROWN UNIVERSITY

The group also decided that it would be necessary to install web cameras inside the observatory so that students could see the telescope via their computers. In addition, they needed to find a way to focus the telescope, operate a CCD camera and spectrograph, and control the tracking system that guides the telescope, all remotely. Using the funding he secured from the university, Cutts purchased a powerful new desktop computer for the observatory, along with control software that interfaced with all of the hardware including the telescope, CCD cameras, filter wheel, spectrograph, electric focuser, and a new guiding camera. The team worked quickly to iron out the bugs that inevitably accompany such a major technological upgrade.

Extensive work was necessary to prepare the observatory for remote laboratories. According to PHYS0220 instructor Ian Dell'Antonio, "we had to install and test new software and observing modes. Bob and I took the lead on the software installation and testing. First, we installed a new computer in the dome. Working with the software developer, we upgraded the telescope control software to make sure it would connect to the new camera acquisition software."

In the process, Dell'Antonio discovered there were some real advantages to the new system. "We also installed a second CCD camera on a 4" telescope piggy-backed onto our 16" to serve as a guide camera and tested using it as a guide camera, operating both with the MaximDL software package. This auto-guiding setup turns out to be much more effective and easily operated than our previous guiding solution." According to Dell'Antonio, "it is now possible to take long exposures without the stars trailing. And the auto-focusing functions sped up setup and allowed the telescope focus to be controlled via the computer."

According to Dell'Antonio, another important improvement is that using Zoom's "allow control of this computer" function remote users can "point the telescope, set up the guider, and take pictures with the camera, all with a single person in the dome who is needed to rotate the dome and ensure the safety of the equipment."

New hardware was needed in addition to new software and Dave Cutts took the lead by purchasing and installing three new cameras: two to provide images of the telescope itself and a third to make sure the telescope is pointed through the dome opening. According to Dell'Antonio, "these cameras have turned out to be extremely useful. Originally, they were envisioned as tools for the students to see the observing stations, and they've served well in that role. However, the cameras have also been invaluable in allowing us to diagnose problems remotely, allowing the department staff to assist TAs and get labs back on track without requiring us to drive back to Brown."

Cutts also tested out any procedures the group came up with, improving and streamlining them, and then updating instruction manuals for both imaging and spectroscopic observations. He also worked with Hemmer and Villegas to test the manuals and run practice laboratories.

With the needed hardware and software arriving by early summer, Cutts, Dell'Antonio and Horton took turns working in the observatory alone while the other two joined via Zoom. As the team learned to use the new software they took ample notes that would be needed to re-write all of the laboratory manuals to in-

High resolution image of the Moon's Tycho crater as photographed by the Ladd Observatory 12" refracting telescope that was built in 1891. SCOTT MACNEILL/BROWN UNIVERSITY

clude instructions for remote operation. The team spent extensive hours working to iron out software bugs so that students could have the full lab experience from a remote location anywhere in the world. By the end of the Summer, they were satisfied that the groundwork had been laid for a successful Fall semester, and the team set about training the course's teaching assistants how to operate the new equipment and software. Cutts, Dell'Antonio, and Horton credit undergraduate students Rachel Hemmer and Edgar Villegas, as well as graduate students Donovan Davino, Zacharias Escalante, and Nicole Ozdowski with help fine-tuning the system and for outstanding work as remote teaching assistants.

The first lab session of the Fall semester was attended by two students with a single teaching assistant physically present in the observatory providing instructions over Zoom. The students themselves were far from the darkness shrouded Barus and Holley observatory and were still bathed in West Coast sunshine in Portland, OR, and Los Angeles respectively. Horton also attended the session via Zoom and characterized the experience as "really cool." "It was great to see everything go according to plan and to watch the two students having so much fun commanding the telescope to a slew of galaxies, nebulae, and star clusters while using the remote cameras to take images of them."

In parallel to the effort at Barus and Holley, in preparation for PHYS0220 in the Winter and Summer 2021 terms the Ladd Observatory telescope was also upgraded. Scott MacNeill and Ladd Observatory Curator Michael Umbricht played critical roles in the project. MacNeill is an expert in image processing techniques and wrote a guide for students on how to use Photoshop to process raw camera images, and also recorded video tutorials to assist students working from home. Umbricht worked with Brown's Computing and Information Services Department (CIS) to upgrade the internet at Ladd Observatory and made recommendations for video and lighting equipment that greatly improved remote labs.

Dell'Antonio says that "although the installation of computer-controlled guiding and focusing were driven by the needs of the pandemic, they will improve the laboratory experience going forward. This represents a major increase in the capability of the telescope—we can now pursue fainter objects than ever before." Cutts agrees that, "what resulted was a wonderful improvement in the laboratory facility, one that will benefit our teaching for years to come."

As the instructional team prepares for the Fall 2021 semester, which will once again be in-person, they find themselves with a bevy of new lab techniques they could scarcely have imagined prior to the pandemic.

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BROWN PROFESSORS AND STUDENTS MAKE THE CASE FOR DIVERSITY

In the wake of George Floyd's brutal murder, physicists and students from Brown took to the web to discuss strategies for increasing diversity and inclusion in the physics community

By Kevin Stacey

One night in 1982, S. James Gates Jr., then a young postdoctoral researcher in physics at the California Institute of Technology, sat in a car with a friend outside his apartment. As the two discussed the finer points of a bowling match they had just completed, a bright light suddenly flashed through the rear window.

It was the spotlight on a police cruiser.

"Someone had called the police about these two suspicious black men in the neighborhood," Gates recalled. "I guess we were in one of those places where African Americans weren't supposed to be."

It was Gates' second encounter with law enforcement during his time in California, and he was angry about once again being targeted by police despite doing nothing wrong. He stepped out of the car and quickly found himself staring down the barrel of a gun.

"He had drawn his gun and was ready to pull the trigger," Gates said. "All of a sudden, a couple of thoughts occurred to me. One of them was that I could die right now. Another was that there would be no consequences at all for this policeman if that happened. And my final thought was, this is quite a statement about how much my life is worth in the country of my birth."

Tensions eased, however, and Gates did not die that night. He would go on to become one of America's most renowned and decorated physicists, receiving the country's top scientific award, the National Medal of Science, in 2011.

Gates, now a professor at Brown, shared a bit of this story in late June with hundreds of physicists, students and others as part of a webinar sponsored by the American Physical Society (APS). The goals of the webinar were to harness the sharpened awareness of racial injustice, stirred by the killing of George Floyd, Breonna Taylor, and others at the hands of law enforcement, to improve diversity and equity in the physics community.

"With the death of George Floyd, we witnessed a globally broadcast extra-judicial execution in real time, and I think it outraged the moral sense of so many people not just in this country, but around the world," Gates said. "It has prompted people to look at some things that are very difficult to talk about and do, and yet it seems to be a time pregnant with opportunity. And so that's part of the reason why we felt that it was time to discuss this while we're in this elevated environment."

The webinar grew out of conversations between Gates, Harvard physicist Lisa Randall and Stephon Alexander, a physics professor at Brown and President of the National Society of Black Physicists. Once the three had discussed what form the program

IDALINA ALARCON/BROWN UNIVERSITY

Farrah Simpson is a Ph.D. student at Brown and student board member of the National Society of Black Physicists.

"When I first met Professor Gates and Professor Alexander that was the first time I was able to see mentors who looked like me."

-FARRAH SIMPSON

S. JAMES GATES JR/BROWN UNIVERSITY

S. James Gates Jr. talks about diversity and inclusion in physics during a recent webinar.

> **"I'm actually confident that we will continue to make progress. I think that is part of the character of this country."**
> **-S. JAMES GATES JR.**

might take, Gates, who is president-elect of APS, was able to pull the event under the APS umbrella. Gates says that around 2,700 people worldwide watched the live broadcast on June 24.

As one of five panelists who gave remarks during the event, Gates told the virtual attendees that now is the time for action to advance diversity and inclusion, both in physics and well beyond.

"We need your energy," he said in his opening remarks. "We need your passion. We need your involvement."

He went on to cite several programs and initiatives put in the motion several years ago by the APS and encouraged attendees to get involved. Among those are the APS National Mentoring Community, which matches undergraduate students from historically underrepresented groups with faculty mentors, and APS-IDEA (Inclusion, Diversity and Equity Alliance), which provides academic departments and labs with strategies for creating more inclusive and equitable communities.

Another key initiative is the APS Bridge program, which aims to increase the number of people from historically underrepresented groups who earn doctoral degrees in physics, creating structures at institutions across the country to support underrepresented students at each stage of the road toward a Ph.D. — a similar goal to that of the Brown-based Leadership Alliance, which works across a wide range of academic disciplines.

The need to increase diversity among faculty was echoed by another webinar panelist, Farrah Simpson, a current graduate student at Brown who serves as student member on the board of the National Society of Black Physicists. Simpson said she knew from her first year as an undergraduate that she wanted to pursue a physics Ph.D. But it wasn't until she started graduate school at Brown that she actually started to believe that her dream could be a reality.

"When I first met Professor Gates and Professor Alexander [at Brown], that was the first time I was able to see mentors who looked like me," Simpson said. "Before that, every lecture hall that I entered was a white man. And that's what we see in media; that's what we see on TV — that a physicist is a white man. But having someone who looks like me doing something that I someday wanted to do had a profound impact."

She urged those watching to hire more Black professors and postdocs and to recruit more Black students, and to take steps to make sure those people are properly supported and encouraged.

"I hope we as a community can work actively and consistently toward change," she concluded.

"I thought what Farrah had to say was really powerful," Alexander said. "She cut to the heart of the issue and showed what representation can mean in helping a student flourish. That's a huge benefit of diversity. Some people see it as a zero-sum game — that if we change the way things are now, we're sacrificing something. That's not true. When we diversify, it enhances."

Gates echoed Simpson's sentiment that hard, consistent work is required to make progress.

"That's part of the message I tried to deliver — if you want to make a difference, it's got to be a commitment for decades," Gates said after the webinar. "But if you make that commitment, you can make a difference."

Gates said that last month's webinar was a first step toward capturing the energy of this moment to make a positive difference in physics and beyond. He and his colleagues have already started thinking about how they plan to follow the event up with new activities and programs.

And while the killing of George Floyd was a tragic reminder that racial inequities are persistent, Gates points out that there has been progress in the 40 years since his own terrifying encounter with police.

"Not to blow my own horn, but one metric that I can give to people is that in 2013 — 150 years after President Lincoln established the National Academy of Sciences — I was elected to that organization as its first African American theoretical physicist," he said. "No one like me existed when I was a postdoc at Caltech facing the possibility of the end of my life. So there's been progress. I'm actually confident that we will continue to make progress. I think that is part of the character of this country."

UPDATE FROM THE DIRECTOR OF THE BTPC (Brown Theoretical Physics Center)

The Brown Theoretical Physics Center (BTPC) aims to stimulate collaborative research across the boundaries between astrophysics/cosmology, condensed matter and high energy theoretical physics, and supports interdisciplinary cross-departmental research with other STEM disciplines. BTPC faculty are engaged in research in strongly correlated matter; interdisciplinary studies of cosmology, astrophysics and condensed matter physics; quantum information science; climate and environmental physics; theoretical particle physics, quantum field theory, and mathematical foundations and symmetries.

The center has hosted a bi-weekly "IDEA" (InterDisciplinary made EAsy) lunchtime seminar aimed at students and postdocs. The layout of the Barus building invites collaborative discussions, and (until the pandemic stopped physical gatherings) several groups met regularly in the first floor Physics Commons area.

Over the next three years, BTCP members will focus on three areas we regard as highly promising research avenues: Quantum computing, the physics of machine learning, and the physics of climate systems.

The quantum computing effort, which has already begun, will build upon the center's existing strengths in quantum materials. Members of the BTPC currently participate in several grants led by our experimental colleagues. As quantum computing will likely remain a national priority, BTPC faculty will take the lead in writing proposals in this area.

The physics of machine learning is a recent interest of center member Andrey Gromov, who has adopted the novel perspective of viewing deep learning networks as a form of condensed matter. Other faculty, including our colleagues in the Center for the Fundamental Physics of the Universe, are already using machine learning as a tool. S. James Gates Jr. has also completed, along with affiliate member Caroline Klivans, an initial foray into the exploration of machine learning as a tool for "supersymmetric field" theories.

The work on the physics of climate systems builds upon existing strengths and connections with the Department of Earth, Environment, and Planetary Science (DEEPS). Brad Marston collaborates with Baylor Fox-Kemper and Jung-Eun Lee on research, workshop organizing, and grant proposal writing. The Biden Administration has indicated that climate change will be a top priority, and we expect significant increases in funding for climate science.

We note with pleasure that Andrey Gromov received a CAREER award based in part upon research supported in part by collaboration with BTCP postdoc Dung Nguyen.

The Summer Student Theoretical Physics Research Session (SSTPRS) led by Jim Gates has been held at Brown since 2017. The 2020 program, which was virtual, is described elsewhere in this issue. SSTPRS is growing the pipeline of physicists from underrepresented groups. For example, student Deven Bristow, who is Black, recently co-authored a paper with Jim Gates.

Members of the Center have authored more than ninety papers from the inception of the Center to the end of 2020. Additional papers have already been written in 2021 with many more to come. BTPC faculty gave more than one hundred invited external scientific talks since 2017, and have also presented many public talks.

The BTPC counts among its faculty a number of members of underrepresented groups.

There are two Black faculty, one female faculty member, and one female research faculty member. Two of the four Affiliate faculty members are female. One of the current postdocs is a member of an underrepresented group, and five of the seventeen graduate students are female.

All BTPC seminars have been on-line-only since March 2020. The pandemic has had more subtle effects in reducing informal contacts between members that we believe are crucial for advancing the BTPC mission. We look forward to the resumption of in-person meetings and seminars in the fall.

S. James Gates Jr.
Director, Brown Theoretical Physics Center

Associate Director: Brad Marston
Faculty: Stephon Alexander, JiJi Fan, Dmitri Feldman, Andrey Gromov, Antal Jevicki, J. Michael Kosterlitz, Savvas Koushiappas, David Lowe, Robert Pelcovits, Marcus Spradlin, Chung-I Tan
Research Faculty: Kory Stiffler, Natalia Vladimirova
Affiliated Faculty: Baylor Fox-Kemper (DEEPS), Caroline Klivans (Applied Math), Tom Powers (Engineering), Brenda Rubenstein (Chemistry)
Emeritus Faculty: Leon N Cooper

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

The Center for the Fundamental Properties of the Universe (CFPU) has been very productive in a number of its core mission to enhance and increase research collaboration and research output amongst its members over the past year. We look forward to being able to expand once in-person initiatives and collaborations in the coming year as pandemic restrictions are lifted.

A primary area of focus has been the CFPU Student Machine Learning Initiative (SMLI) which seeks to provide opportunities for physics undergraduates, graduate students and postdocs to participate in interactive seminars and workshops on machine learning (ML) and artificial intelligence (AI) in order to encourage them to further exploit these techniques to create future research opportunities and publications. SMLI seminars occurred once every two weeks in 2020 and 2021. Seminars were held virtually over Zoom and were well attended. We are now planning a further expansion of SMLI events with an even larger undergraduate participation through new-format machine learning competitions. This work continues to be a bountiful source of new ideas and subsequent proposal submissions.

The rhythm of visitors to the CFPU was profoundly interrupted by COVID restrictions, nevertheless, the CFPU maintained a strong seminar program in 2020 and 2021. These seminars provide a good opportunity to identifying new interdisciplinary research opportunities. They also ensure that our undergraduate, graduate and postdoc members are being directly exposed to many of the latest developments in cosmology, astrophysics and particle physics.

As you can read elsewhere in this issue, stakeholder Gregory Tucker has had significant success with the new EXoplanet Climate Infrared TElescope (EXCITE) program and has collaborated with CFPU affiliates Stephen Parman and Alexander Evans from the Department of Earth, Environmental, and Planetary Sciences (DEEPS) on exoplanets.

Graduate students Kyriakos Vattis, Michael W. Toomey and stakeholder Savvas M. Koushiappas published new research findings on the application of deep learning to the astrometric signatures of dark matter substructure. Stakeholders Koushiappas, Jiji Fan, and Ian Dell'Antonio are also now collaborating on new research that focuses on interpreting dark matter signatures relating to a recent dwarf galaxy image.

Stakeholders Stephon Alexander, Dell'Antonio, Gaitskell, Jonathan Pober and affiliate stakeholder Stephen Bach (Computer Science) were awarded a 2021 Seed Research Award for a project entitled, "Finding the Physics that Matters in Astrophysical and Astro-Particle Analyses with Interpretable Machine Learning." The group proposes to use interpretable machine learning to create a software framework for identifying and understanding the biases induced in the models scientists utilize by the training data they use. A second Seed Award was given to stakeholders Landsberg, Gaitskell and Koushiappas for further AI-focused research, "Using Artificial Intelligence to Search for New Physics Underground, on the Ground, and in the Sky."

The CFPU is also supporting the American Physical Society (APS) Conference for Undergraduate Women in Physics (CUWiP). The conference has been organized by Jiji Fan who is a CFPU stakeholder (as well as Meenakshi Narain, Vesna Mitrović, and Anastasia Volovich who are faculty in Physics). This meeting was originally scheduled for 2020 and has now been moved to January 2022.

In addition, CFPU stakeholder Stephon Alexander has been serving as President of the National Society of Black Physicists (NSBP) since 2019. The CFPU is working directly with him and David Spergel, President of the Simons Foundation, to establish a new program in 2021 to support new opportunities for up to six Black and/or African American faculty to work on new research projects with Brown CFPU and Brown Theoretical Physics Center (BTPC) faculty where clear research overlaps are identified.

Moving forward, the CFPU aims to continue significantly elevated levels of proposal submission with a goal of 25 proposals per year across the stakeholders. We also set an aggressive target of increasing the value of successful proposals to a further $1 million per year above the increased levels we previously established. We also intend to use our established goal of 15 joint papers coming from CFPU initiatives as an appropriate goal for the next 3 years. We will continue to strongly support initiatives and proposals relating to AI/ML, given how successful this has been. We will build on the successful areas in which CFPU stakeholders and their teams have applied AI/ML to areas of interdisciplinary physics research with the goal of delivering further successful research proposals and papers.

Richard Gaitskell
Director, Brown Center for the Fundamental Properties of the Universe

Center Stakeholders: Stephon Alexander, David Cutts, Ian Dell'Antonio, JiJi Fan, Ulrich Heintz, Savvas Koushiappas, Greg Landsberg, Jonathan Pober, Gregory Tucker
Center Affiliate Stakeholders: Stephan Bach (Computer Science), Alexander Evans (Earth, Environmental and Planetary Sciences),Stephen Parman (Earth, Environmental, and Planetary Sciences)

SOCIETY OF PHYSICS 2020 ZONE MEETING

The Physics DUG, in collaboration with Yale's Society of Physics Students, co-hosted Brown's first Society of Physics Students Zone Meeting from October 23-24, 2020. The virtual event attracted undergraduates studying physics and related fields throughout the Northeast area. Over 80 students from 15 institutions attended. The event was led by Natalie Rugg '21, the Associate Zone Councilor from Brown, as well as the Physics DUG coordinators and Yale SPS board members. The zone meeting included both social and academic events, from Physics Jeopardy to student research presentations to a faculty panel discussion. The keynote speaker was Brown's Ford Foundation Professor of Physics S. James Gates Jr., who spoke about his involvement in public policy and answered questions about his multifaceted career. A central theme of the meeting was diversity and inclusion, with faculty panelists from both Brown and Yale addressing the current state of the physics community.

BROWN PHYSICS CELEBRATES INTERNATIONAL WOMEN'S DAY

The Brown University Department of Physics recognized International Women's Day 2021 with a variety of events including an on-line talk featuring Brown Physics Professors JiJi Fan, Vesna Mitrović, Meenakshi Narain and Anastasia Volovich. Each professor discussed how she had overcome obstacles and biases as a woman in a male-dominated discipline, addressed what challenges they continue to face, and offered potential solutions to obstacles still encountered by women in the field of physics to this day.

Brown Physics WiSE (Women in Science and Engineering) also co-sponsored an on-line games night that was open to all gender identities to celebrate the date and recognize the many under-appreciated contributions of women to science. In addition, Professor Stephon Alexander delivered a remote talk hosted by the Aspire Artemis Foundation and Partners entitled "Creating Impact and Change Through Storytelling and the Application of Equalizing Technology: Remote Learning and Community Storytelling for Underrepresented and Disadvantaged Groups."

BROWN PHYSICS MOURNS LOSS OF COLLEAGUE

By Pete Bilderback

ALBERT EINSTEIN COLLEGE OF MEDICINE POST-DOC PASSES FROM COVID

The Brown Physics community was deeply saddened to learn of the passing of Dr. Arpan De, a recent postdoctoral fellow in Medicine and Molecular Pharmacology at the Albert Einstein College of Medicine, and collaborator with Professor Jay Tang's laboratory at Brown due to complications from a COVID-19 infection. Tang issued the following statement:

"I wish to share the sad experience of a collaborator who recently died of COVID: This was Dr. Arpan De, a 34-year-old postdoc from India, who worked at Albert Einstein College of Medicine (AECM). Arpan returned to India in March and got married in April, and unfortunately caught COVID at the end of April. Prior to his return, he worked as a postdoctoral fellow at AECM in my collaborator's lab. I knew him well through collaboration and in fact, asked him about his COVID vaccination status during our farewell Zoom meeting in late February. He could have gotten vaccinated back in January (he worked in a hospital-based laboratory). He chose not to, fearing that it might lead to a positive antibody test result that would affect his travel plans. It is utterly tragic that such a talented scientist and a dear colleague lost his young life to COVID. I am not a specialist on infectious diseases, but I know enough of the basic scientific facts to advocate strongly for a forcible vaccination guideline and yes, requirement, as legally possible, to organizations and friends around me. The painful loss of a young collaborator reinforced that desire to share my experience and conviction as broadly as I can."

Dr. De is the lead author on a new paper co-authored with Tang's group entitled "Bacterial Swarmers Enriched During Intestinal Stress Ameliorate Damage" that is available on-line ahead of print in the journal Gastroenterology. Professor Tang's graduate student Weijie Chen '21 Ph.D. also made significant contributions to the paper and worked closely with De at AECM in the laboratory of Dr. Sridhar Mani, who is the corresponding PI.

By all accounts, De had an extremely promising career ahead of him. Tang characterized the Gastroenterology article, with De being the lead author, as a "very, very significant" contribution to the study of the role of bacterial swarmers in the amelioration of various types of intestinal stress in humans. The authors found that the presence of bacterial swarmers is highly predictive of intestinal stress, but that counter-intuitively these bacteria act to heal intestinal inflammation. Dr. De had been collaborating with Tang's lab for the past three years and Tang said he had "two or three face-to-face meetings with him" over the years. While most of their recent interactions were via Zoom, Tang indicated De "took huge pride in the work" they had done together.

De's post-doctoral supervisor, Dr. Sridhar Mani, stated that De was, "instrumental in developing and publishing new ideas in the field of microbes and intestinal inflammation," and characterized him as "an exacting scientist [who] believed that one day he could help humanity through his science." Weijie Chen '21 Ph.D., De's primary collaborator at Brown agreed, "Arpan was one of the most talented, skillful, and hardworking scientists I've ever worked with. There's no doubt that he was going to be a very successful PI in the near future." He added that he found De very easy to work with, "Arpan taught me many experimental skills in microbiology, and he was so nice and patient when he worked with me and other lab mates." He added, "Arpan's passing is a tragedy for his family as well as a huge loss for the science community. He will be remembered for all his achievements and kindness. He will forever remain alive in our hearts and memories."

JAMES VALLES ADVANCES ANTI-RACIST FIRST YEAR PHYSICS CURRICULUM

By Pete Bilderback

Brown Professor of Physics Jim Valles didn't think there was anything particularly wrong with the way he was teaching PHYS0070, "Analytical Mechanics," a mathematically rigorous introduction to Newtonian mechanics when a group of students who had taken the course proposed a Group Independent Study Project (GISP) focusing on race and gender in the scientific community. The results of the students' study convinced him otherwise. He discussed the journey that changed the way he thought he should teach physics in a recent talk entitled, "Towards Anti-Racist Pedagogy in 1st Semester Physics."

The students' presentations brought Valles' attention to what they perceived as a problem with the overall atmosphere of the class. They had found studies that clearly indicated that the under participation in physics of women and people from underrepresented groups could not be traced to ability or interest. Instead, their review of social psychology concepts, such as stereotype threat, in the context of their own experiences pointed them to consider what could be done to improve the learning climate for all. "The students were feeling and experiencing things that as the instructor I could not see." Valles continues, "I thought we were doing marvelous things, but there were dynamics and approaches that I was taking in the classroom I wasn't aware of that made the class less inclusive than it could have been."

The primary inhibiting factor that the students identified was a hyper-competitive atmosphere between students that discouraged collaboration and left some students feeling excluded. "Students found the environment, even around solving problems, really difficult, and they didn't feel like it was helping them be their best, and they didn't feel like they could bring their best or most personal self to this space."

Spurred on by Professor Meenakshi Narain and other members of the Departmental Diversity and Inclusion Action Plan (DDIAP) Committee, Valles successfully lobbied to make PHYS0070 a mandatory S/NC course in which students do not receive letter grades. Response to the change was overwhelmingly positive with 69% of students who took the course maintaining that the mandatory S/NC structure of the class enhanced their learning. In course feedback, one student noted, "it is much easier to learn when I can relax a little bit about how a problem will be graded and think more slowly and deliberately about how I can understand it and solve it."

More recently Valles has come to believe that these and other pedagogical changes that benefit all learners can also be powerful tools for anti-racism. Valles, following the work of Kyoko Kishimoto, identifies four characteristics of anti-racist pedagogy: providing context on the development of a discipline so students understand it is as not ahistorical and neutral, embedding learners so that they see themselves as part of the topics being discussed, decentering authority in the classroom, and building community by creating a trusting space where students are invested in learning together.

Valles maintains that mandatory S/NC grading meets three of the four criteria: embedding learners, decentering authority, and building community. Other pedagogical approaches that Valles identifies as anti-racist include introducing scaffolded exercises that have rich context and include self-assessment, transparent syllabus design that is learner-centered, as well as polling in class and during exams and assignments.

Valles questions the received wisdom that what happens in science classrooms has nothing to do with race. "If you look at the numbers, it's obvious there is a problem, and we need to listen to the stories and pay attention, and then figure out how to make those numbers better and those stories better."

Valles says that it can be "scary" putting the word "racist" in a talk title but that, "one of the things that I find really very important to keep in mind is that the opposite of 'racist' is not 'not racist' but 'anti-racist.'" Valles continues, "and so with anti-racism, if you try to practice it, you see places where there are equity disparities, and once you see them, being anti-racist means you try to fix them, dismantle them and make it better."

Valles admits, "it's true that in our discipline it's hard to see how F=ma or Schrödinger's equation could be racist." "But that's not the point. It's important to contextualize that what we're learning comes largely from a majority white, male culture. And when you talk about the great Nobel laureates in physics it's important to remind everybody how many people weren't allowed to participate in the process. Everyone in the classroom needs to be reminded that you are capable of doing this, you are capable of learning this material and becoming a great physicist if that's what you want to be. The history of physics has been dominated by white males, but that has nothing to do with abilities across genders and across races."

Valles says that coming to terms with these things and making pedagogical changes has not come easily to him. "Making changes amounts to deviating from how I remember the classes that educated me and the way I taught for many years. How could those ways be wrong? What could I have not seen in my classes over the years?" Valles continues, "For motivation, I recall the lessons from the GISP group and other Brown students who have felt on the margins in physics. I reflect on and try to listen to more stories from colleagues, articles, and books. To take steps, I turn to best practices that research has validated and wonderful colleagues have shared with me. And I strive to maintain a growth mindset as I admit the need to commit to changes."

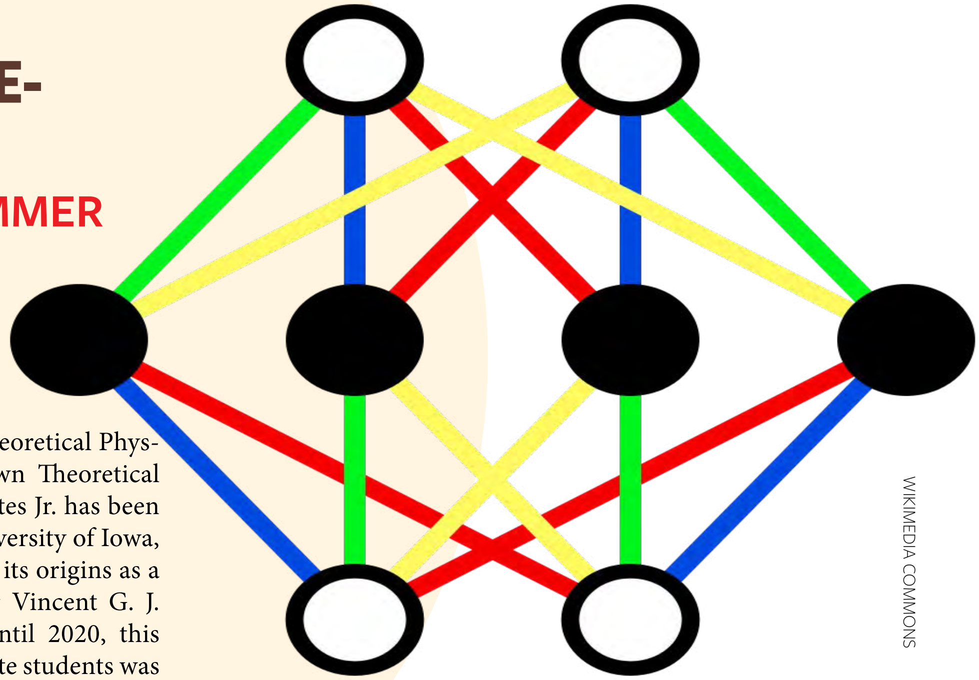
An exciting development for Valles over the past year has been the development of a Sheridan Center Workshop that has broadened discussions of and efforts to employ anti-racist pedagogy in other disciplines. Envisioning the changes made to PHYS0070 through the lens of anti-racist pedagogy came to him as the result of discussions with colleagues as he worked on and facilitated START (Seminar for Transformation Around Anti-Racist Teaching). "Conversations with Monica Linden in Neuroscience, Patricia Sobral in Portuguese and Brazilian Studies, and Sheridan Center Director Mary Wright and her colleagues Stacey Lawrence and Eric Kaldor broadened my perspective on what contributes to a significant learning experience for our very diverse student body." More conversations are in store as the instructor teams from seven different departments work on their pedagogy. "It has been inspiring," says Valles.

SSTPRS CONTINUES DESPITE PANDEMIC

A VIRTUAL SPIN ON A SUMMER PROGRAM CONNECTS STUDENTS FROM AFAR

By Victoria Kabakian

In its 21-year history, the Summer Student Theoretical Physics Research Session (SSTPRS) led by Brown Theoretical Physics Center (BTPC) Director S. James Gates Jr. has been held at either the University of Maryland, the University of Iowa, and since 2017, at Brown University. SSTPRS had its origins as a joint collaboration between Gates and Professor Vincent G. J. Rodgers (University of Iowa). Every year up until 2020, this unique opportunity for undergraduate and graduate students was held in person.



WIKIMEDIA COMMONS

An adinkra similar to the ones produced during the SSTPRS sessions.

In the past, the program brought students to campus for an intensive four-week program, and personal face-to-face interactions were a critical component of its success. The COVID-19 outbreak required various adjustments including lengthening the program and making it completely virtual on Zoom. "We ran the program five weeks as we felt it necessary to get the students to the usual point of readiness to engage authentic research that has been our tradition," said Gates. In addition to the extra days on the calendar, the daily schedules were adjusted to reduce the amount of on-line instruction to 12 hours per week, compared to 20 to 25 hours per week of in-person instruction in previous years.

While the in-person component was missed, there were advantages to the switch. In his 48 consecutive years of teaching, Gates never imagined having such a diverse group of students in his program. Participants in 2020 included three from Brown University, three from Caltech, three from the Chinese University of Hong Kong, a participant in Abu Dhabi, one from University of California, Davis, and the remainder from the University of Maryland. This was possible because of the technology of Zoom.

The 2020 program was Assistant Professor Kory Stiffler's eighth year participating in the SSTPRS, and his fifth as an instructor. He discussed some of the challenges and resulting achievements of this new model. "The instructors had to be more efficient, and we were able to cover nearly as much material as the typical in-person sessions of the past. The students' attentiveness and hard work was crucial in these successes." Stiffler added, "They were truly a remarkable group of students and were able to successfully meet all of the challenges along with the instructors."

Communicating real-time long and detailed calculations to students was one obstacle to overcome. The instructors were able to use writing tablets to solve this problem. They then had the students take still pictures of their handwritten calculations and use the share screen feature of Zoom.

From the perspective of the 22 students in this year's program, this new virtual model for the SSTPRS was also a win. Brown University junior Laurel McIntyre had no previous experience with physics research. She applied to the program because she wanted to expand her skills and begin deciding which area of physics she would like to pursue. McIntyre notes, "I think the mentors handled the transition to virtual well. They often put us in Zoom breakout rooms and encouraged us to communicate with each other because collaboration is important in research." As a student without research experience, this was a great platform for McIntyre and others to build a foundation for future research opportunities.

In the previous semester, third-year Brown Ph.D. student Aleksander Cianciara attended Professor Gates' research group meetings to learn more about supersymmetry and adinkras, pictures that encode the mathematics of how supersymmetric particles interact. His interest in adinkras inspired him to apply for the SSTPRS program this summer. "I was really impressed by how the mentors were able to create and facilitate an effective curriculum to take students with ranging knowledge of physics and get them up to speed with the essentials necessary for research in theoretical physics," shares Cianciara. "I think it's a powerful testament that physics isn't about memorizing pages of equations and facts, but rather about learning to think through an idea logically and rigorously from start to finish. As the frontiers of knowledge continue to expand, I wonder if this program is perhaps providing a new paradigm for how physics could be taught in the future."

Although it was an unexpected change to a summer program with two decades of in-person instruction under its belt, the adaptation to virtual was a success. When asked whether he thought future programs would be better in-person or virtual, Stiffler concluded, "I do see a hybrid of in-person events with virtual components added as a future possibility."

Along with Gates and Stiffler, SSTPRS instructors were Professor Kevin Iga (Pepperdine University), Konstantinos Koutrolikos (Brown), Yangrui Hu (Brown) and Sze-Ning Mak (Brown). Andrew Dewald (University of Iowa) worked as a Teaching Assistant, and Pete Bilderback and Mary Sutton served as Administrative Assistants. The program will continue in a fully virtual format during the Summer of 2021.

STUDENT SPOTLIGHT

ADAM TROPPER EARNS NSF FELLOWSHIP

By Pete Bilderback

COURTESY ADAM TROPPER

Adam Tropper '21 was awarded a prestigious fellowship through the National Science Foundation's (NSF) Graduate Research Fellowship Program (GRFP). The NSF GRFP recognizes and supports outstanding graduate students in STEM disciplines who are pursuing research-based masters and doctoral degrees in the United States. The five-year fellowship includes three years of financial support including an annual stipend of $34,000 and a cost of education allowance of $12,000 to the institution. Tropper says the award will allow him to continue his studies at Harvard University where he will enter the Physics Ph.D. program in the Fall with significantly lighter teaching requirements.

Tropper intends to use the funding to do research in string cosmology, "I plan to study the cosmology of the very, very early universe, moments after the Big Bang within the framework of string theory." According to Tropper, "this [string theory perspective] is relevant because in those early moments, there were very high energy processes going on that are well beyond what we could hope to study with something like the Large Hadron Collider. To calculate cosmological observables, we need a theory that can reasonably describe these high energies; the leading candidate is string theory."

Tropper believes the education he received as an undergraduate at Brown has prepared him well for graduate studies because it allowed him to do serious research as an undergraduate. "I think Brown's open curriculum really served me well, and the reason for this is it's often difficult to do research in theoretical physics without specific course prerequisites," he continues, "for example, one needs quantum mechanics to do pretty much anything in particle physics. Brown's open curriculum and flexibility allowed me to take those courses ahead of schedule and construct my curricular trajectory to fit my research interests."

He also credits the level of instruction and attention he was able to receive from professors at Brown, "I really have Brown and the wonderful professors, to thank for setting me up on this trajectory." He particularly praised Professors JiJi Fan and Marcus Spradlin for guiding his undergraduate education and research interests. "I think Brown really fostered an environment where I could succeed, both in coursework and research. The faculty here were tremendously invested in my development and have played a pivotal role in my recent accomplishments."

Tropper also says Brown helped instill the sense of "grit" necessary for success in a difficult research field. "While doing research you'll find yourself getting stalled out; you'll pursue a different approach to tackling a challenging problem every day for weeks on end, and, ultimately, they might all fail." Tropper says it can be "difficult on your psyche" to spend so much time researching something without positive results to show for it. "But of course you learn something from these failed attempts. I think that's where the importance of grit really lies."

ISABELLE GOLDSTEIN EARNS RI SPACE GRANT

STUDENT SPOTLIGHT

By Pete Bilderback

Brown University Department of Physics Ph.D. candidate Isabelle Goldstein has been awarded a NASA Rhode Island Space Grant. Goldstein is working to solve a set of theoretical problems related to the construction of the ESA lead highly-ambitious Laser Interferometer Space Antenna (LISA) which has been proposed to measure a new regime of gravitational waves than is possible with the earth-bound Laser Interferometer Gravitational-Wave Observatory (LIGO).

Gravitational waves are tiny ripples in the spacetime that were predicted by Einstein's theory of general relativity over a century ago, but could not be verified experimentally until 2017 when the Nobel Prize in Physics was awarded to Rainer Weiss, Kip Thorne and Barry C. Barish "for decisive contributions to the LIGO detector and the observation of gravitational waves." It is that interplay between theory and experiment that Goldstein says attracted her to the LISA project, "it's an exciting opportunity. I love these kinds of projects where you can really see how theory and experiment interact."

LIGO, consisting of observatories that use mirrors spaced two and a half miles apart that are capable of detecting a change of less than one ten-thousandth the charge diameter of a proton is perhaps the most ambitious experimental physics apparatus built to date, but LISA is an order of magnitude larger and more ambitious. Goldstein says LISA's detectors will be placed in space in orbit around the sun, "in a triangle formation with each of them separated by millions of miles, it will be quite a bit bigger than LIGO." The larger apparatus will be able to, "see much longer wavelength gravitational waves [than LIGO]."

Goldstein says the theoretical groundwork that needs to be laid for an experiment on this scale is substantial, "theorists have to do a lot to prepare for that kind of big experiment. Some of the things to consider are how much noise are we going to see coming from small unresolvable events in the universe? And we'd like to know if we can learn anything by studying that noise, which is like TV static in the background." Goldstein adds, "there are other questions we can ask, such as if we find a maximum redshift for a black hole merger, then what will that tell us about the formation of structure in the universe? Or if we can study the neutron star and white dwarf mergers and find how many of them we see per year, what will that tell us about the enrichment of metals in the universe?"

The time-scale for such an ambitious project is large as well, according to Goldstein, "the main project hasn't started to be built yet because it won't launch until the 2030s. This could be an entirely career-spanning project." Goldstein says, "I'm extremely excited to be working on the LISA project. In the past, a lot of my work focused on dark matter and galaxy formation, but gravitational waves are such a new field. LISA will give us a completely different perspective on the universe. It's a really fascinating field, not only for the new information it will provide but also because the field is so young and there's so much work left to be done and so many questions left to answer."

COURTESY ISABELLE GOLDSTEIN

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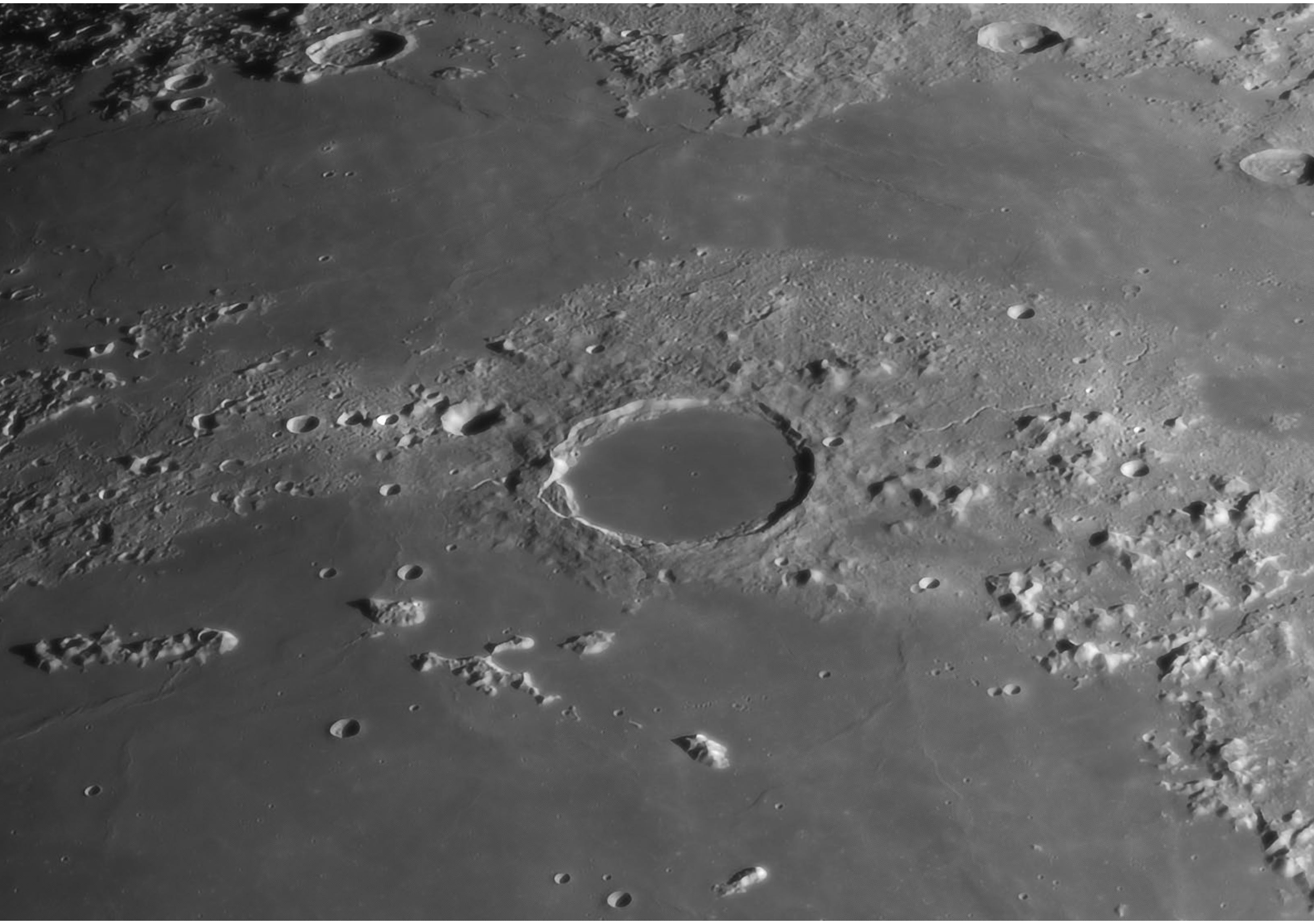

Frosty Drew Observatory Director Scott MacNeill took the high resolution image of the Moon's Plato crater above at Brown Universtity's Ladd Observatory. Plato is about 68 miles in diameter with a depth of 4,816 feet.

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For all Department of Physics gifts and contributions, please contact

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