BROWN PHYSICS

imagine

AY 2017-2018

BROWN

On the cover: PhD student Shayan Lame

STUDENTS

FACULTY RESEARCH

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A note from the chair...

As the current academic year draws to an end, I'm happy to report that the Physics Department has had an exciting and productive year. At this year's Commencement, the department awarded thirty five undergraduate degrees (ScB and AB), twenty two Master's degrees, and ten Ph.D. degrees. It is always gratifying for me to congratulate our graduates and meet their families at the graduation ceremony. This year, the University also awarded my colleague, Professor J. Michael Kosterlitz, an honorary degree for his achievement in the research of low-dimensional phase transitions. Well deserved, Michael!

Our faculty and students continue to generate cutting-edge scholarships. Some of their exciting research are highlighted in this magazine and have been published in high impact journals. I encourage you to learn about these and future works by watching the department YouTube channel or reading faculty's original publications. Because of their excellent work, many of our undergraduate and graduate students have received prestigious awards both from Brown and externally. As Chair, I feel proud every time I hear good news from our students, ranging from receiving the NSF Graduate Fellowship to a successful defense of thier senior thesis or a PhD project. Our students are extremely capable and resourceful.

We have expanded the number of faculty with new recruitment in condensed matter physics. Assistant Professor Kemp Plumb joined the faculty last year and two new assistant professors will arrive in the upcoming academic year. Also this year, Professor See-chen Ying will retire after decades of productive teaching and research. We wish him well!

The Department is in the process of establishing two new centers, one in theory and the other in astrophysics. The goal of these centers are to enhance collaboration among stakeholders and raising the department profile in these two key areas. These centers will provide excellent teaching and research platforms to our students and postdocs. Additionally, I am happy to report that we have established two prestigious postdoc fellowships, the Leon Cooper Postdoctoral Fellowship and the Michael Kosterlitz Postdoctoral Fellowship.

I have been very pleased to have met some of our alumni this past year. I am grateful for their interest in our department and their generous support to our students and research. Please visit the department when you can to tell us more about your work and career development. We always love hearing from you.

Happy reading,

Gang Xiao

Gang Xiao,
Department Chair
Professor of Physics & Engineering

CLASS OF 2018

Jacob D. Adelberg
Artur Avkhadiev
Mason E. Bartle
Jack Butler
Zoë R. Canaras
Rebecca H. Cheng
Evan A. Coleman
Emanuel R. Dallas
Nathaniel E. Dick
Matthew J. Dudak
David J. Engel
Joseph Fichera
Joshua C. Greene
Cory S. Greer
Kara A. Hartig
Alexander S. Hirsch
Oliver G. Isik
Josephine Issenman
Luke W. Johns
Lucas S. Kang
Anand V. Lalwani
Sarah R. Lamacchia
Yinan E. Liu
Andrew S. Marmor
Drew B. Meldrum
Michelle Miller
Marlene Ortega
Giovanni Pittalis
Keegan W. Quigley
Adarsh Sridhar Narayanan
Nicholas Z. Stern
Dara J. Storer
Matthew Tan
Adrian Constantin T. Wedekind
Emily M. Yaruss

UNDERGRADUATE AWARDS

R. BRUCE LINDSAY PRIZE *for Excellence in Physics*
Artur Avkhadiev
Evan Coleman
Kara Hartig

MILDRED WIDGOFF PRIZE *for Excellence in Thesis Preparation*
Zoë Canaras
Keegan Quigley

SMILEY PRIZE *for Excellent Contribution to the Astronomy Program*
Nicholas Stern

CHAIR'S AWARD *for Excellence in Scholarship and Service to the Physics Department*
Marlene Ortega

PAUL C. CROSS PRIZE *for Extraordinary potential for achievement in the field of physical chemistry. Presented by the Department of Chemistry.*
Artur Avkhadiev

UTRA: Undergraduate Teaching and Research Awards

2018 UTRA STUDENTS

Gabriel Altopp *(Heintz)*
Jason Chan *(Stein)*
Ciaran Godfrey *(Landsberg)*
Gabriel Hannon *(Tan)*
Kaushik Srinivasan Harith *(Heintz)*
Jonathan Hess *(Plumb)*
Matthew Ishimaru *(Maris)*
Jacob Jackson *(Landsberg)*
Elizabeth Kimmel *(Xiao)*
Alexander Lawson *(Plumb)*
Diego Rodriguez *(Narain)*
Devansh Saluja *(Jevicki)*
Hannah Szapary *(Stein)*
Adam Tropper *(Fan)*
Joy Zheng *(Tang)*

SUMMER UTRA EXPERIENCE

JOY ZHENG '21 PHYSICS/COMPUTER SCIENCE

I am working on a UTRA research project this summer at Professor Tang's Biophysics Lab. My research project is Measuring the Strength of Tethering of Caulobacter crescentus to Solid Surfaces by Applying an Electric Field to the Environment.

As a prospective physics science concentrator, I value the impact of scientific research. It's the generations of dedicated researchers and scientists that bring us closer to the truth of the universe. I've always wanted to conduct a scientific research on my own. The Undergraduate
Research and Teaching Award at Brown provides a valuable platform for us to experience the research life and it's one of the reasons why I decided to study physics at Brown.

Last fall, my mentor Artur, a senior physics concentrator, suggested that I should talk to different physics professors to get a sense of the undergraduate research experience. I met with several professors and they were all very encouraging and they talked about their research projects and expectations for undergraduate researchers. I found Professor Tang's biophysics research in bacteria mobility very interesting. Professor Tang is very welcoming and invited me to attend his regular lab meetings with his graduate students and suggested me learn the fundamental experimental procedures from his PhD candidate George. During the winter break, Professor Tang recommended several research papers to me and encouraged me to think about the subject I'd like to work on. Throughout the spring semester, I attended the lab meetings and volunteered at the lab to learn the experimental procedures.

After several further discussions, Professor Tang and I decided that I can work on bacteria tethering effect, a sub problem of the lab's research. I did more background research and decided on studying the tethering effect of Caulobacter Crescentus to solid surfaces. With professor Tang's help, I received the UTRA project.

During the summer, I worked closely with the PhD student George in the lab. George guided me step by step and I learned how to nurture bacteria, how to make solvents, how to observe
the bacteria motion under a microscope, how to apply electric field to the environment, etc. With George's guidance, I was able to conduct different experiments, collect data and analyze data on my own. Meanwhile, Professor Tang would check in with me every week and discuss the progress of my research. He would also host weekly lab meetings to discuss my project and other students in the lab also helped me a lot. I did most experiments and collected many movies of the bacteria tethering effects during June. During July, I would focus on the theoretical side and analyze the data.

From designing the research project to working with other graduate students in the lab to talking to Professor Tang, the UTRA project experience offers me much insight of scientific research. It's my first research experience and I truly enjoy the hands-on experience. I would love to continue doing research in our physics department and help unravel the truth of our universe.

Don't turn your back

Evan Coleman (Sc.B Mathematical Physics '18) is an aspiring scientist pursuing a career in High Energy Physics. In his time at Brown, he worked on the CMS Experiment at CERN, and performed one of the first measurements of the top quark lifetime which used data from the Large Hadron Collider. He has also published peer-reviewed research in particle phenomenology, and wrote his thesis on modern topics in string theory. He is a Goldwater and Astronaut Scholar, and will begin his doctoral studies as an NSF Fellow at Stanford in September of 2018.

In my time at Brown as an undergraduate specializing in particle physics, I have been honored to meet two different US Secretaries of Energy: Dr. Ernest Moniz of the Obama Administration and Rick Perry of the Trump Administration. The attitudes that these officials demonstrated toward basic research could hardly have differed more. After all, President Trump intends to run the government like a business. It makes sense for him to invest in the projects which his shareholders -- supposedly, the American people -- would find worthy of resources.

That such a large portion of the general public agrees with the drastic cuts to basic research funding underscores a major issue in the American scientific community which scientists and science students must not ignore. After all, if the average citizen shared our appetite for physics, we would have greater political leverage. We have instead fallen prey to a feedback loop: as physics becomes more abstract, challenging, and expensive, it also becomes more difficult to explain. Funding grows scarce, and scientists are pressed to focus on their research. They spend less time participating in outreach and science activism. Their research goes largely unnoticed by a public which becomes increasingly suspicious of the size of science budgets. Rinse and repeat. (In case you think I'm exaggerating, ask the next high school student you meet what a Hydrogen nucleus is made of. The basic answer has been known since the quark model was verified in the 1960's, yet a shocking number of young students have not learned that the proton is composed of more fundamental particles.)

In the twentieth century, some of the greatest physicists in history worked as "silent hands," using their technical expertise to influence political discourse and even bridge differences in values between cultures. American-British collaboration in the development of centimetric radar and in the Manhattan Project was crucial to the Allied victory in World War II. The invention of nuclear weaponry forced the nations of the world to work together to prevent further nuclear conflict. The formation of the European Centre for Nuclear Research (CERN) has brought scientists together from all over the world, where to this day they collaborate despite political conflicts at home. But while crises in the 1900's were relatively visible and tangible, the conflicts we face today lie well-beneath the surface of our political discourse. Soldiers wage war from desk chairs. Misinformation and propaganda spread through the internet like wildfire. Gradually, the countries of the West are closing themselves off, and the United States risks estranging itself from the rest of the world.

To the current generation of Brown students, both graduate and undergraduate, I urge you: Don't turn your back on physics. Maybe a degree in the natural sciences appeals to you, but another career path offers better job prospects. Maybe you don't enjoy scientific research. These are perfectly fair considerations. But if you do have an interest in physical thinking -- especially if you believe you're not good at it, or you don't fit into the physics mold -- you should study as much as you can, and share your knowledge as often as is reasonable. Now more than ever is a time for you to be a bastion of the logical, principles-focused reasoning that we celebrate in physics.

To today's Brown physics alumni, be they career physicists or not, I would like to present a charge: Don't turn your back on the rest of the world. Brown is an amazing institution, full of ambitious and intelligent people, but these are people who to some degree understand their talents and abilities. Our world is full to the brim of untapped intellectual potential. We must abandon the dogmatic statement that science is foreign and abstruse because it is more difficult than any other subject. It is precisely the belief that science is impossibly convoluted which convinces the general public to spend their mental energy elsewhere. Attention is one of the most potent human currencies; if you invest yours in others, they might just return the favor. By sharing our passion with those around us, we can together work toward a science-literate society.

As I now become a Brown alumnus, I am grateful for the quality of training I've received and for the improvements which the talented faculty, staff, and students in the physics department have worked hard to achieve in my time here. In a period of history which is exceptionally politically polarized and at times confusingly heinous, Brown has remained stalwart to its scholarly endeavors. Nevertheless, there is much work to be done, and many improvements to make both inside and outside of Brunonia. I won't turn my back, and neither should you.

—Evan Coleman '18

MASTERS OF SCIENCE

William Brockmueller
Ian Everbach
Isaac Fugate
Hanzhi Jiang
Ashwini Kannan
Runxuan Liu
Conghuan Luo
Jan Makkinje
Tyler Morrison
Daniel Norman
Angela Pizzuto
Juhi Rajhans
Katherine Taylor
Haobei Wang
Yang Wang
Chunshu Wu
Liangtai Xing
Yiming Xing
Weilin Yao
Madelaine Zaleski
Fan Zhang
Tianyi Zhou

ScM STUDENT AWARDS

OUTSTANDING ACADEMIC ACCOMPLISHMENT
Hanzhi Jiang

MASTER'S RESEARCH EXCELLENCE
William Brockmueller

ENGAGED CITIZENSHIP AND COMMUNITY SERVICE TO THE PHYSICS DEPARTMENT
Athira Sanal

DOCTOR OF PHILOSOPHY

Altan Allawala *(Advisor: Brad Marston)*

Atreya Chatterjee *(Advisor: David Lowe)*

Wencong Liu *(Advisor: Vesna Mitrovic)*

William Maulbetsch *(Advisor: Derek Stein)*

Jacqueline McCleary *(Advisor: Ian Dell'Antonio)*

Declan Oller *(Advisor: Jimmy Xu)*

Yang Song *(Advisor: Alexander Zaslavsky, David Paine)*

Kenta Suzuki *(Advisor: Antal Jevicki)*

Shu Wang *(Advisor: Gang Xiao)*

Michael Zlotnikov *(Advisor: Anastasia Volovich)*

PhD STUDENT AWARDS

DISSERTATION FELLOWSHIP AWARD 2017 - 2018
Rizki Syarif

PHYSICS MERIT DISSERTATION FELLOWSHIP 2017 - 2018
Atreya Chatterjee
Michael Zlotnikov

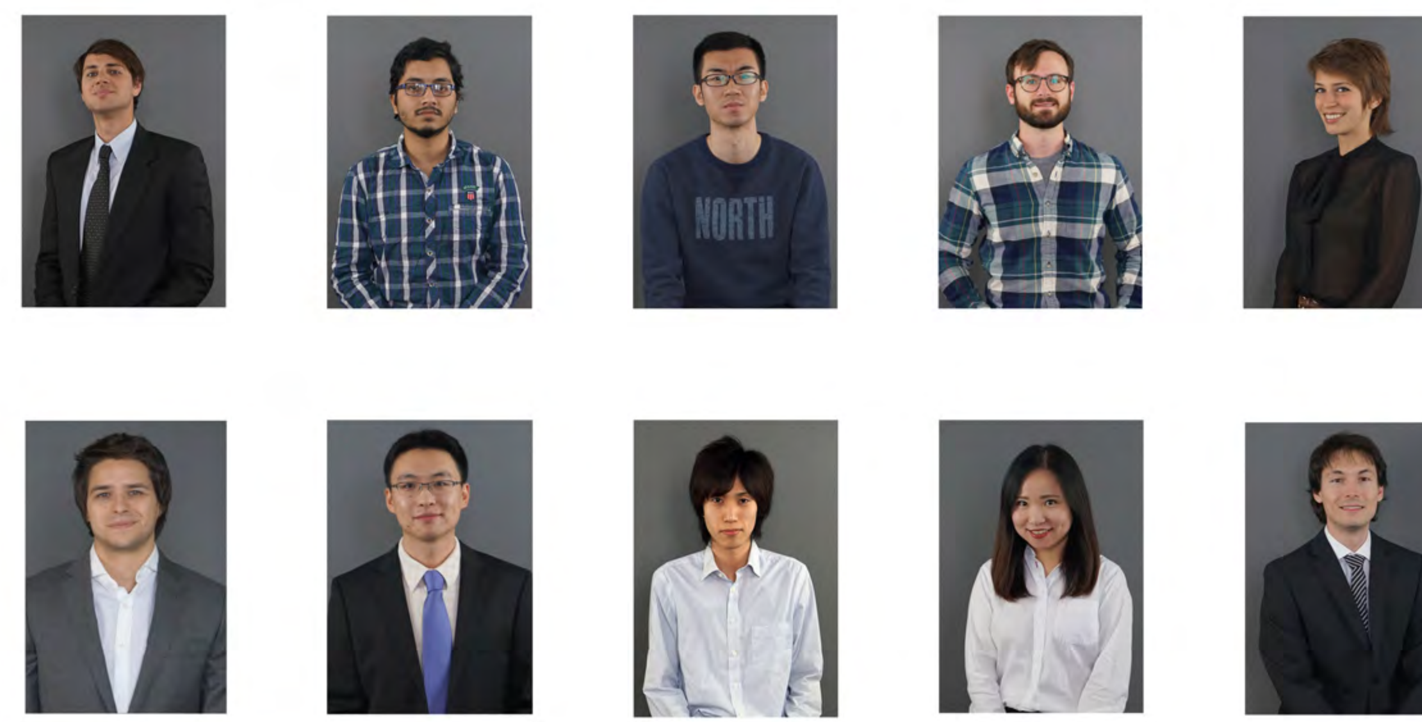
GALKIN FOUNDATION FELLOWSHIP AWARD 2017 - 2018
Kenta Suzuki

ANTHONY HOUGHTON AWARD *(Excellence in Theoretical Physics)*
Kenta Suzuki

FORREST AWARD *(Excellence in Work Related to Experimental Apparatus)*
Guanyang He

AWARD OF EXCELLENCE AS A GRADUATE TEACHING ASSISTANT
Bjorn Burkle
Haobei Wang

SIGMA XI AWARD
Altan Allawala



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SERVING AS A SCIENCE CONSULTANT ON A HOLLYWOOD MOTION PICTURE

When director Ava DuVernay set out to adapt the sci-fi classic “A Wrinkle in Time” for the silver screen, she turned to Brown University physicist **Stephon Alexander** for help in melding fantasy with physics.

As science advisor for the film, Alexander’s job was to help DuVernay’s creative team “stay true to the physics and at the same time make sure these wonderful fantasy elements [from the book] are retained,” he said. “That was a big part of the joy and the challenge of working with Ava and the creative team in making that happen.”

Alexander is no stranger to the intersection of art and science. An accomplished jazz saxophonist, he wrote a widely lauded book called “The Jazz of Physics,” which explores the links between musical improvisation and theoretical physics. Alexander’s research in cosmology, particle physics and quantum gravity touches on the Einsteinian ideas that play a central role in the film.

As in Madeleine L’Engle’s novel, the film’s teenage hero, Meg Murry, and her companions travel the universe in search of Meg’s father. They reach distant stars and exotic planets using ripples — or wrinkles — in the fabric of space-time. The idea that grows out of Einstein’s theory of relativity.

© Disney

“The idea here is that energy and matter can actually bend or warp the space-time fabric,” Alexander said. “Depending on how the space-time fabric is warped, it’s possible to travel very far distances instantaneously.”

In the film, Meg’s father, physics professor Alex Murry, creates a machine that enables this kind of interstellar travel. Alexander needed to imagine, using real concepts in physics, how such a machine might work.

The idea that he and the creative team settled upon was one that exploits something of a loophole in Einstein’s axiom that nothing can travel faster than the speed of light. “The real statement is that nothing within space and time can travel faster than the speed of light,” Alexander said. “But nothing restricts space itself from traveling faster than the speed of light.”

So in the film, Murry’s machine uses light energy to bend space-time into a bubble, the frontier of which is able to travel faster than light. By encapsulating himself in that bubble, the professor travels with along with it.

In keeping with some of the concepts in his own book, Alexander wanted the light energy used to create the bubble is generated through a phenomenon called sonoluminescence, in which sound waves in certain types of fluids create light energy.

“I’m guilty of trying to connect sound and music to interesting things in physics,” Alexander said. DuVernay and her creative team liked the idea too, and it stayed in the movie.

Ari Daniel for NPR

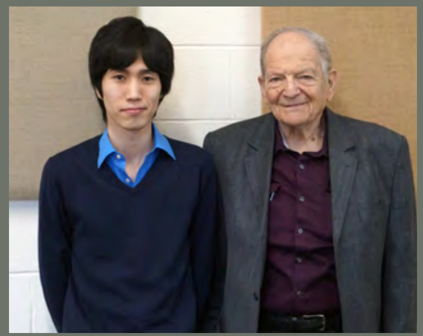
As with Alexander’s other work melding art and science, he said he found the experience deeply rewarding and believes his work on the film will inform the work he does in physics going forward. “I learned a lot actually,” he said. “It forced me to stretch my imagination.”

—KEVIN STACEY

2017 – 2018 GALKIN FELLOWSHIP RECIPIENT

The Sachdev-Ye-Kitaev (SYK) model is a quantum mechanical many body system with random all-to-all interactions on fermionic N sites (N>>1). This model was shown to saturate the known maximal chaos bound of many body system together with large ground state entropy. Based on these observations and from the fact that black holes are the fastest scramblers in the nature with large ground state entropy, the model is conjectured to be dual to a quantum black hole in the sense of the AdS/CFT correspondence. In contrast to other examples of the AdS/CFT correspondence, the simple structure and solvability of the SYK model is expected to lead us to deeper understanding of holography and quantum gravity theories.

Kenta Suzuki, the 2017-2018 Galkin Foundation Fellow, with his advisor, Professor Antal Jevicki, developed a systematic description of large N physics of the SYK model by a single bi-local field. In the strong coupling limit, the model exhibits an emergent conformal reparametrization symmetry of time and triggers a divergent contribution in the propagator of the bi-local field. This symmetry corresponds to the general coordinate transformation symmetry in the dual AdS gravity theory. Once we slightly deviate from the strong coupling limit, the breaking of the conformal symmetry is captured by an effective action given by the Schwarzian derivative. They developed a non-linear-level derivation of this zero modes effective action for finite reparametrization symmetry, which describes the physical degrees of freedom in the gravity sector of the dual theory.



Kenta Suzuki and Warren Galkin '51

Besides the symmetry modes, which correspond to the dilaton-gravity sector in the dual AdS theory, poles appearing in the propagator of the bi-local field in the SYK model also predicts an infinite tower of matter fields in the dual AdS_2 space-time. Suzuki and his collaborators proposed a systematic mechanism which nicely packages this infinite spectrum into a single field in 3-dimensional space-time. Through Kaluza–Klein reduction down to two dimensional AdS space, it recovers the entire spectrum.

Finally, there is one more important question for identifying the dual space-time of the SYK model: the signature of emergent space-time of the Euclidean SYK model. In Suzuki's dissertation, it is explained the need for non-local (Radon-type) transformations on external legs of n-point Green's functions. This results in a dual theory with Euclidean AdS signature with additional leg-factors. It is speculated that these factors incorporate the coupling of additional bulk gauge degrees of freedom similar to the discrete states of 2D string theory.

—KENTA SUZUKI, PhD '18

Fellow Travelers

On October 4, 1957 the Soviet Union launched the first artificial Earth satellite which was called Sputnik I. The word Sputnik simply means "satellite" or, more generally, "fellow traveler." The quotes from Professor **Charles Smiley**, director of **Ladd Observatory**, are from a report published in The Hinterlands, the Bulletin of the Western Rhode Island Civic Historical Society. He describes how Sputnik I could be seen from all parts of the Earth and reports on the local observations of it: "In Rhode Island, between October 12 and November 27, it was observed at Ladd Observatory of Brown University on 13 different passages for a total of 33.2 minutes." The observed positions and motion were plotted on a star map.

The satellite itself was only 22 inches in diameter and would have been difficult to see from the ground. Instead, they were observing the rocket that launched the satellite which also entered orbit. The second stage of the rocket was 92 feet long and 9.7 feet in diameter. Sunlight reflecting off the rocket body was much easier to see. Notice that observers in Providence RI, Nantucket MA, and Mansfield CT saw the rocket in a slightly different position against the background stars due to parallax.

The next satellite launched was Sputnik II on November 3, 1957. *"Sputnik II was observed visually at Ladd Observatory of Brown University on 14 passages for a total of 54 minutes."* In the photograph there are two subtle streaks from upper right to lower left showing the trail of the rocket. As it tumbled it would appear brighter or darker as the rocket body reflected more or less sunlight.

Professor Smiley demonstrating a quartz frequency standard to students at Ladd Observatory.

Both Sputnik I and II carried radio transmitters to send status information to the ground. They operated at 20.005 and 40.002 MHz which could be received using a shortwave radio.

Charles Newton Kraus, Brown University class of 1931, was an experienced amateur radio operator. He was president of the Brown Radio Club while he was a student in the late 1920s. He demonstrated the reception of a television transmission in 1928. His "ham" radio license was 1BCR (then W1BCR after 1928.) He operated an experimental station W1XE and was also issued an experimental license for a police car radio in 1937. According to an obituary in the February 1974 issue of Brown Alumni Monthly: *"In 1956, he established contact with Seabee units manning Operation Deep Freeze in the Antarctic and arranged telephone hookups with families in Rhode Island, who were able to talk directly with Seabee husbands and sons."* In his 1958 report Smiley describes how Kraus recorded the signals from the Sputnik satellites using his amateur radio equipment.

A five minute time exposure showing the trail of Sputnik II. December 18, 1957 at 9:21 GMT.

The Soviet Union then launced Sputnik III on May 15, 1958. It was observed visually and the radio transmissions were recorded at Ladd Observatory as Smiley reported:

"The launching rocket for Sputnik III also went into orbit and was easily followed visually. Its brightness varied in a period of about 8 seconds, probably due to tumbling of the rocket in space. At its brightest, the rocket was about as bright as Venus; at its faintest, it was lost to sight even with field glasses. The satellite was somewhat fainter, about as bright as a first magnitude star, but without the vigorous up-and-down in brightness of the rocket"

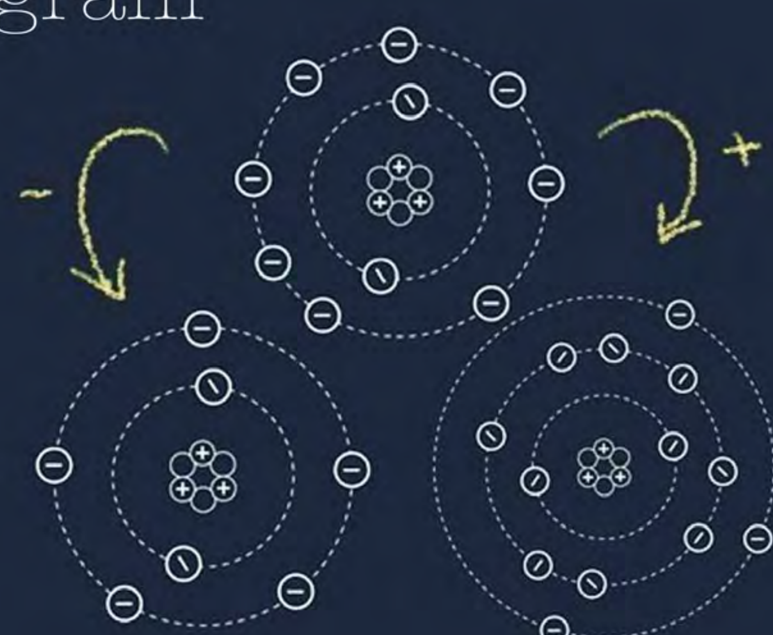
"The radio transmitter of Sputnik III satellite was strong enough so its signals could be picked up with an inexpensive short-wave set. At Ladd Observatory of Brown University, more than 100 of the first 1000 revolutions of Sputnik III were recorded; some 65 of them were recorded on magnetic tape, covering a total of four and one half hours of signals. In addition, the rocket and satellite were followed visually whenever possible."

In August 1958 Smiley traveled behind the "Iron Curtain" to attend the Tenth General Assembly of the International Astronomical Union in Moscow. He described the experience in a lecture entitled "The Inside of the Iron Curtain." This description of his presentation was published in the February 1959 Hinterlands bulletin: *"Professor Smiley said that he envied only three things in the Soviet Union: the turbo-jet passenger planes, the Russian ability to launch large satellites, and some excellent red seedless grapes grown in Uzbekistan. He said that a color photograph of his 1957 Chevrolet Bel Air V-8 was all that was need to convince the Russians that American scientists do not lead a hard life,"* a quote that foreshadows the "Kitchen Debate" between then U.S. Vice President Richard Nixon and Soviet Premier Nikita Khrushchev in July of 1959.

—MICHAEL UMBRICHT

This article is an example from the Ladd Observatory History of Science and Technology Blog. To read more stories from their long history of science education and service to the community, visit blogs.brown.edu/ladd

The Evolution and Impact of the Brown University Science Cartoons "SciToons" Program



The path from conducting cutting-edge research in physics to producing informative, animated science videos with students in an iterative learning process to increase their knowledge and interests in STEM fields was a logical progression of my professional work as a scientist.

This effort has evolved into a new experimental approach towards communicating scientific concepts, and in 2011, I formally established the Science Cartoons (SciToons) program. The program involves STEM and non-STEM students and faculty in the creation of the SciToons videos. The first video, published in fall 2011, told the formation story of a coarse-grained metamorphic rock called Schist that was on display in Brown's Science Center. I collaborated on this project with students Jinaabah Showa '11 and Pierce Shipp '15, and Professors Jan Tullis and David Targan. Since that time the program has produced more than 20 videos.

The SciToons production process is guided by the Multimedia learning theoretical framework [1] which focuses on understanding the background of problem solvers (novices and experts) and approaches for engaging them in the metacognition process. One of the outputs of this framework is the SciToons model. The SciToons model [2,3] engages both new learners (novices) and experts through an iterative feedback process in the development of narratives, storyboards, animatics and animations. The iterative feedback process allows all participants which includes STEM and non-STEM students, and faculty, to understand the basicunderpinnings of scientific research or concepts that are being communicated, and how to develop the appropriate narratives and animatics for a given SciToons project. Also, this iterative feedback helps to reduce the use of jargon and technical terms in the final script.

The production group, called the SciToons Creation Group (SCG), started with two students and a faculty member, and its growth rate is staggering. Overall, 80 students and 16 faculty have been part of the program since its inception. Each semester, an SCG is comprised of 20 to 30 students and faculty content experts working together on developing several video projects. The group decides which stories it wants to tell. Over the course of a project's development, members of the SCG work on tasks such as writing and editing scripts, gathering feedback on storyboards, or critiquing voiceover recordings until the final product is approved for publication.

The impact of SciToons on SCG members is significant, as it makes them better able to communicate science and improves their ability to learn about science concepts outside of their fields of interests. This is especially true for our non-STEM members who are exposed to new scientific research and concepts for the first time. For example, Rachel Gutman '17 (a comparative literature and linguistics concentrator) was the lead script-writer for the SciToons video titled "Phase Diagrams: Triple Points, Critical Points and Supercritical Fluids", which was based on the research of Professor Humphrey Maris. She had no background in critical opalescence, but learned enough about the phenomenon through the iterative feedback sessions with the SCG team: Professor Maris, Yiming Yang (a physics graduate student in Professor Maris' group), Kairy Herrera '18 (a physics and literary art concentrator), David Charatan '22

(an undergraduate) and me.

SCG members develop new transferable skills and some have gone on to become editors and producers at major organizations such as the Atlantic and TED-ED. A former student who now works for TED-Ed wrote recently "SciToons was my first experience with this kind of work, and I'll always feel very lucky and grateful to have had that opportunity as an undergraduate. So, THANK YOU!"

The evidence of impacts on viewers can be inferred from the primarily positive comments they volunteered. For instance, "It was so easily explained. Wonderful, if things are taught in college in this way scenario [then things] would be different in [our country]." (*Conductive polymer*) Really straightforward and clear! (*Phase diagram*) WOW! Very informative and easy to understand!!!! (*What is solar energy?*)

Oludurotimi Adetunji is Associate Dean for Undergraduate Research and Inclusive Science, Adjunct Professor of Physics, Director of the Undergraduate Teacher Awards (UTRA), Director of Research Impact, and Executive Producer of SciTooons.

The four to five-minute SciToons videos are very compelling and accessible to non-technical audiences. We cover a wide range of topics, including phase diagrams, climate models, graphene, solar cells, solar energy, conductive polymers, echolocation and crispr-cas9. Collectively these videos have been viewed more than 400,000 times and their popularity continues to grow via YouTube (SciToons), Twitter (@Sci_Toons), Instagram (@Sci_Toons), and other social media outlets. Currently, there are several physics themed videos in the production pipeline, including the Cosmic Microwave Background (CMB) with content expert Professor Ian Dell'Antonio and Dark Matter (DM) with content expert Professor Derek Stein.

We have made some significant strides to broaden interest in the SciToons program, so I believe we are uniquely positioned to expand our collaborations to include partners beyond the boundaries of the campus. And we look forward to connecting with our alumni community and the science community at large on future works.

Finally, I would be remiss not to mention the broader impact of SciToons in the national science research community. Our videos have also been featured nationally on the social media platforms of the Fermilab, the National Oceanic and Atmospheric Administration (NOAA) and the National Institutes of Health (NIH) National DNA Day.The SciToons program has been presented or featured at national and international conferences such as the Material Research Society, the National Alliance for Broader Impacts and American Geological Union and the University Research Magazine Association. In May 2018, the program was highlighted in the compendium of the National Academies of Sciences, Engineering and Medicine report which focused on the integration of the Humanities and Arts with Sciences, Engineering and Medicine in Higher Education [4].

—Oludurotimi Adetunji

FACULTY

BROWN HONORARY DOCTORATE

At its 250th Commencement on Sunday, May 27, Brown University conferred honorary doctorates on seven candidates, including Nobel Laureate and Harrison E Farnsworth Professor of Physics, **J. Michael Kosterlitz**.

NEW DEAN OF THE COLLEGE

Rashid Zia, a Brown University alumnus, and Associate Professor of Engineering and Physics was named the University's new dean of the college.

The dean of the college is Brown's senior undergraduate academic officer, whose responsibilities include overseeing Brown's student-centered Open Curriculum, academic advising, international study programs and classroom instruction. The dean reports directly to the provost and is a member of the president's cabinet and the executive committee.

Professor Zia's work combines electrical engineering, materials science, optical physics and physical chemistry to study the interaction of light and matter. He has been the recipient of a National Science Foundation CAREER Award and a Presidential Early Career Award for Scientists and Engineers (PECASE), the highest honor bestowed by the United States government for young researchers, as well as a Fellow of both the Optical Society of America and the National Forum on the Future of Liberal Education.

BREAKTHROUGH PRIZE IN FUNDAMENTAL PHYSICS

The 2018 Breakthrough Prize in Fundamental Physics was awarded to a team of researchers who helped shape our understanding of the origin, evolution, and nature of the cosmos. NASA's WMAP space mission was led by Charles L. Bennett (Johns Hopkins University), Gary Hinshaw (University of British Columbia), Norman Jarosik (Princeton University), Lyman Page Jr. (Princeton University), David N. Spergel (Princeton University). There are 22 other members of the mission's team, including Brown Physics Professor, **Greg Tucker**.

Launched in 2012 by Yuri Milner, a Silicon Valley tech investor, the Breakthrough Prize is also backed by Mark Zuckerberg of Facebook and his wife Priscilla Chan, Anne Wojcicki from the DNA testing company 23andMe, and Google's Sergey Brin.

FACULTY PROMOTIONS

Dmitri E. Feldman was promoted to Full Professor effective July 1. Professor Feldman graduated from Moscow Institute of Physics Technology in 1995 with honors and received his Ph.D. from Landau Institute for Theoretical Physics in 1998. He came to Brown in 2003 after postdoctoral positions at Weizmann Institute of Science and Argonne National Laboratory. Professor Feldman is a recipient of a Koshland Scholar Award and a CAREER Award from the National Science Foundation. His research interests include topological matter and statistical mechanics.

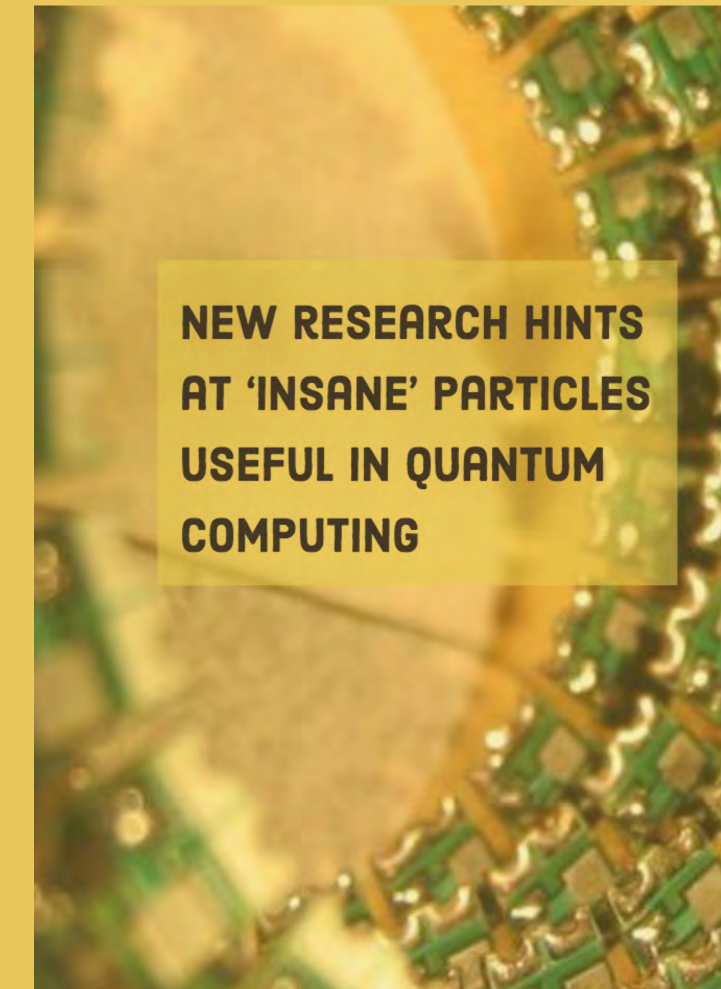
Vesna Mitrović was promoted to Full Professor effective July 1. Professor Mitrović graduated from Illinois Institute of Technology in 1995 and received her Ph.D. in experimental condensed matter physics from Northwestern University in 2001. She came to Brown in 2004 after a post-doctoral position at Grenoble National High Magnetic Field Laboratory. Professor Mitrović is a recipient of the CAREER award from the National Science Foundation and has been named an A.P. Sloan Fellow in 2007. In 2015 she became a Fellow of the American Physical Society for "pioneering contributions to NMR study of low energy excitations."

Last year, the Department of Physics welcomed new faculty member, **Kemp Plumb**, to its Experimental Condensed Matter Group.

Professor Plumb's lab will focus on exotic magnets in order to better understand the organizing principles that govern the collective behavior of electrons in quantum materials. "The way that I approach research is like an explorer," Plumb explains, "I use neutron and x-ray spectroscopy to explore the little worlds that are realized inside different materials."

Plumb explores these microscopic worlds by bombarding these exotic magnets with either neutrons or x-rays to see how the electrons that are responsible for the magnetism collectively respond. While the worlds he observes may be little, the work can only be done at some of the largest facilities in the United States including Argonne, Brookhaven, and Oak Ridge National Laboratories.

Before joining Brown's Department of Physics, Plumb received his Ph.D. from the University of Toronto, followed by a postdoctoral appointment at Johns Hopkins University. "One thing that really stood out to me about Brown was that the community of the department is welcoming."



NEW RESEARCH HINTS AT 'INSANE' PARTICLES USEFUL IN QUANTUM COMPUTING

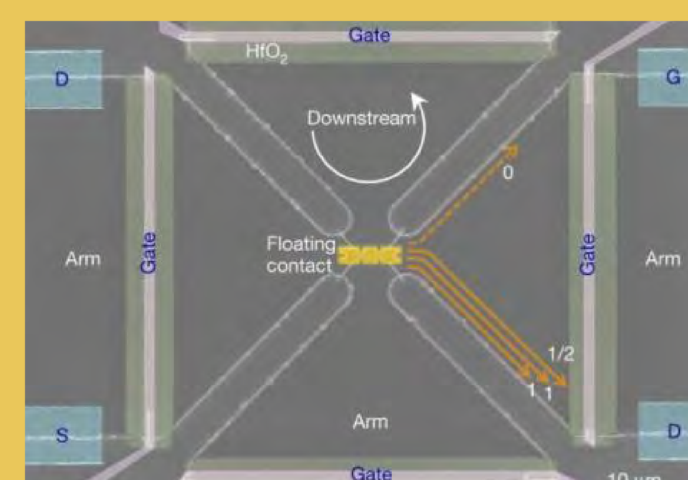
In a paper published this week in early June in Nature, a research team including a Brown University physicist has characterized how heat is conducted in a matter state known as a quantum Hall liquid, in which electrons are confined to two dimensions. The findings suggest the presence of non-Abelian anyons, quantum quasi-particles that retain a "memory" of their relative positions in the past. Theorists have suggested that the ability of these particles to retain information could be useful in developing ultra-fast quantum computing systems that don't require error correction, which is a major stumbling block in the development of quantum computers.

The research was led by an experimental group at the Weizmann Institute of Science in Rehovot, Israel. **Dmitri Feldman**, a professor of physics at Brown, was part of the research group. He discussed the findings in an interview.

Q: Could you explain more about what you and your colleagues found?
A: We were looking at thermal conductance — which simply means the flow of heat from a higher temperature to a lower temperature — in what's known as a 5/2 quantum Hall liquid. Quantum Hall liquids are not 'liquids' in the conventional sense of the word. The term refers to the behavior of electrons inside certain materials when the electrons become confined in two dimensions in a strong magnetic field.

What we found was that the quantized heat conductance — meaning a fundamental unit of conductance — in this system is fractional. In other words, the value was not an integer, and that has interesting implications for what's happening in the system. When the quantum thermal conductance is not an integer, it means that quasi-particles known as non-Abelian anyons are present in this system.

Q: Can you explain more about non-Abelian anyons?
A: In the Standard Model of particle physics, there are only two categories of particles: fermions and bosons. That's all there is in the world we experience on a daily basis. But in two-dimensional systems like quantum Hall liquids, there can be other types of particles known as anyons. Generally speaking, there are two types of anyons: Abelian anyons and non-Abelian anyons. Abelian anyons behave more or less like conventional fermions, but non-Abelian anyons are, for lack of a better way of saying it, completely insane. They have very strange properties that could be used in quantum computing, or more specifically, for what's known as topological quantum memory.



Q: What's the connection between non-Abelian anyons and quantum computing?
A: A regular quantum computer — one without non-Abelian anyons — would require error correction. For one useful quantum bit of information, you need multiple additional quantum bits to correct errors that arise from random fluctuations in the system. That's extremely demanding and a big problem in quantum computing. But topological quantum computing — which requires the presence of non-Abelian anyons — is unique in that it doesn't need error correction to make the quantum bits useful. That's because in a non-Abelian system, you can produce states that are completely indistinguishable locally, but globally the states are completely different. So you can have random perturbations of these local quantum numbers, but it won't change the global quantum numbers, which means the information is safe.

Q: Where does this line of research go from here?
A: This work suggests that a particular entity known as a Majorana particle is at work in the particular system that we studied. And that suggests that a Majorana-based quantum computer is possible. But an even more powerful computational platform would come from what's known as parafermions, which have been theorized but not yet shown to exist. Perhaps their existence could also be proven with similar experimental tools in the future.

—KEVIN STACEY

AT A GLANCE

AS OF JULY, 2018

55 JUNIORS & SENIORS

84 PHD STUDENTS

53 MASTER STUDENTS

30 FULL TIME PROFESSORS

10 EMERITUS FACULTY

2 NOBEL LAUREATES

LEON COOPER, 1972
J. MICHAEL KOSTERLITZ, 2016

15 POSTDOCS

31 JOINT, AFFILIATED, & ADJUNCT PROFESSORS

1 NATIONAL MEDAL OF SCIENCE RECIPIENT

S. JAMES GATES, 2011

WHAT EARTH'S CLIMATE SYSTEM & TOPOLOGICAL INSULATORS HAVE IN COMMON

Topological insulators, materials that insulate on the inside but conduct electricity along their outer edges, have created quite a buzz in condensed matter physics. Now a new study in the journal Science shows that the same topological behavior that governs these exotic materials also drives equatorial waves — pulses of warm ocean water that play a major role in regulating the Earth's climate, including the El Niño-Southern Oscillation.

"These waves were discovered by geophysicists in the 1960s, but they lacked a deep understanding of why they existed,"

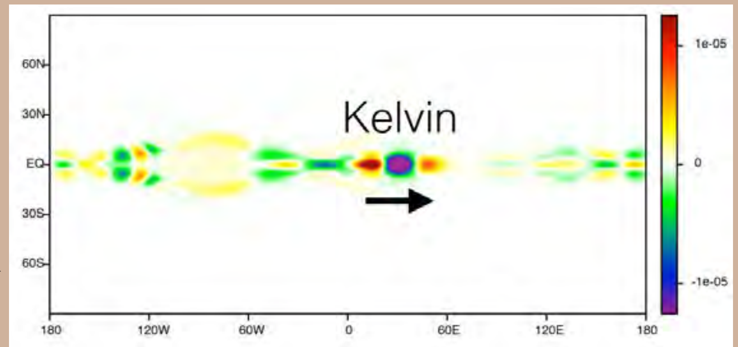
said **Brad Marston**, a physics professor at Brown University and coauthor of the new study. "What we've shown is that they have the same origin as the waves that are important in solid state physics — the waves of electrons that travel around the edges of topological insulators."

The research was inspired by a special type of topological insulator that exhibits what's known as the quantum Hall effect, which was discovered in 1980. The topology plays an essential role in the quantum Hall effect was recognized by the 2016 Nobel Prize in physics that was awarded to trio of physicists, including Brown University's Michael Kosterlitz.

In the quantum Hall effect, a magnetic field causes electrons inside a semiconducting material to travel in circles called cyclotron orbits. That circular movement prevents a flow of electrons — a current — from moving across the material, except at the material's outer edges. There, electrons can only complete a half-circle before running out of real estate and banging against the edge. Because all of the electrons on a given edge execute their movement in the same direction, all those half-circles can link up and form an edge current. Thus, topological insulators conduct on the outside and insulate on the inside.

Marston and his collaborators, Pierre Delplace and Antoine Venaille from the University of Lyon in France, showed that analogous dynamics are at play with Earth's equatorial waves. In the case of the Earth, the role of the magnetic field is played by the Coriolis effect — an apparent force caused by the planet's rotation. It's what causes hurricanes to spin in opposite directions in the Northern and Southern hemispheres. The role of the edge is played by the equator, where the Coriolis force breaks down.

"In each of the two hemispheres, you have the Coriolis force pushing in opposite directions," Marston said. "That traps the waves at the equator in a way that's very similar to how the current in a topological insulator is trapped at its edges. While the Earth doesn't have an 'edge' per se, the equator is essentially the edges of the two hemispheres stuck together."



The mathematics behind the two phenomena, Marston and his colleagues showed, is essentially identical.

"If you look in recent solid state physics papers at diagrams that describe the dispersion of electrons in a topological insulator, the plots looks exactly like the diagram in a geophysics textbook that depicts the dispersion of equatorial waves," Marston said. "When topological insulators were discovered a decade ago it was new physics, but to our surprise the Earth has been doing it all along."

The research helps to explain the existence of several types of equatorial waves. One of them, known as the equatorial Kelvin wave, delivers periodic pulses of warm water to the coast of South America, which is the El Niño oscillation. The findings also explain how these waves persist despite being battered by storms and shifting wind, and how they pass straight by islands that might be expected to cause the waves to scatter.

"In topological insulators, the current is able to move right through impurities in the material as if they weren't there," Marston said. "That's because of their topological nature, and it helps us understand why equatorial waves and the El Niño oscillation persist despite being jostled around by weather and other obstacles."

In addition to helping explain the persistence of El Niño cycles, Marston says these same dynamics are likely happening elsewhere in the climate system — in the upper atmosphere, for example. Recognizing the topological nature of these phenomena could help deepen scientists' understanding of how they work, Marston says.

"As a practical matter, this will give us new ways to identify these kinds of climate dynamics by looking at the topology," he said. "We might be able to find and understand topological structures that may have been missed before."

—KEVIN STACEY

Gravitational ***waves*** could shed light on the origin of black holes

A new study published in *Physical Review Letters* outlines how scientists could use gravitational wave experiments to test the existence of primordial black holes, gravity wells formed just moments after the Big Bang that some scientists have posited could be an explanation for dark matter.

"We know very well that black holes can be formed by the collapse of large stars, or as we have seen recently, the merger of two neutron stars," said **Savvas Koushiappas**, an associate professor of physics at Brown University and coauthor of the study with Avi Loeb from Harvard University. "But it's been hypothesized that there could be black holes that formed in the very early universe before stars existed at all. That's what we're addressing with this work."

The idea is that shortly after the Big Bang, quantum mechanical fluctuations led to the density distribution of matter that we observe today in the expanding universe. It's been suggested that some of those density fluctuations might have been large enough to result in black holes peppered throughout the universe. These so-called primordial black holes were first proposed in the early 1970s by Stephen Hawking and collaborators but have never been detected — it's still not clear if they exist at all.

The ability to detect gravitational waves, as demonstrated recently by the Laser Interferometer Gravitational-Wave Observatory (LIGO), has the potential to shed new light on the issue. Such experiments detect ripples in the fabric of spacetime associated with giant astronomical events like the collision of two black holes. LIGO has already detected several black hole mergers, and future experiments will be able to detect events that happened much further back in time.

"The idea is very simple," Koushiappas said. "With future gravitational wave experiments, we'll be able to look back to a time before the formation of the first stars. So if we see black hole merger events before stars existed, then we'll know that those black holes are not of stellar origin."

Cosmologists measure how far back in time an event occurred using redshift — the stretching of the wavelength of light associated with the expansion of the universe. Events further back in time are associated with larger redshifts. For this study, Koushiappas and Loeb calculated the redshift at which black hole mergers should no longer be detected assuming only stellar origin.

They show that at a redshift of 40, which equates to about 65 million years after the Big Bang, merger events should be detected at a rate of no more than one per year, assuming stellar origin. At redshifts greater than 40, events should disappear altogether.

"That's really the drop-dead point," Koushiappas said. "In reality, we expect merger events to stop well before that point, but a redshift of 40 or so is the absolute hardest bound or cutoff point."

A redshift of 40 should be within reach of several proposed gravitational wave experiments. And if they detect merger events beyond that, it means one of two things, Koushiappas and Loeb say: Either primordial black holes exist, or the early universe evolved in a way that's very different from the standard cosmological model. Either would be very important discoveries, the researchers say.

For example, primordial black holes fall into a category of entities known as MACHOs, or Massive Compact Halo Objects. Some scientists have proposed that dark matter — the unseen stuff that is thought to comprise most of the mass of the universe — may be made of MACHOs in the form of primordial black holes. A detection of primordial black holes would bolster that idea, while a non-detection would cast doubt upon it.

The only other possible explanation for black hole mergers at redshifts greater than 40 is that the universe is "non-Gaussian." In the standard cosmological model, matter fluctuations in the early universe are described by a Gaussian probability distribution. A merger detection could mean matter fluctuations deviate from a Gaussian distribution.

"Evidence for non-Gaussianity would require new physics to explain the origin of these fluctuations, which would be a big deal," Loeb said.

The rate at which detections are made past a redshift of 40 — if indeed such detections are made — should indicate whether they're a sign of primordial black holes or evidence for non-Gaussianity. But a non-detection would present a strong challenge to those ideas.

—KEVIN STACEY

TECHNIQUE MAKES NMR MORE USEFUL FOR NANOMATERIALS, EXOTIC MATTER RESEARCH

Nuclear magnetic resonance (NMR) is a powerful scientific tool used in medical imaging and in probing the chemical structure of molecules and compounds. New research from Brown University shows a technique that helps adapt NMR to study the physical properties of thin films, two-dimensional nanomaterials and exotic states of matter.

NMR involves applying a strong magnetic field to sample and then zapping it with pulses of radio waves. The magnetic field aligns the magnetic moments, or "spins," of atomic nuclei within the sample. The radio waves will flip the spins of certain nuclei in the opposite direction, depending on the frequency of the waves. Scientists can use the signal associated of spin flips at different frequencies to create images or to determine a sample's molecular structure.

"NMR is a very useful technique, but the signal you get is very weak," said **Vesna Mitrović**, an associate professor of physics and the senior author of the research, which is published in Review of Scientific Instruments. "To get a usable signal, you need to detect a lot of spins, which means you need a lot of material, relatively speaking. So much of the work we're doing now in physics is with thin films that are part of small devices or materials that have tiny crystals with odd shapes, and it's really difficult to get an NMR signal in those cases."

Part of the problem has to do with the geometry of the probe used to deliver the radio pulses and detect the associated signal. It's usually a solenoid, a cylindrical coil of wire inside of which the sample is placed. The NMR signal is strongest when a sample takes up most of the space available inside the cylinder. But if the sample is small compared to the volume of the cylinder — as thin films and nanomaterials would be — the signal weakens to nearly nothing.

But for the past few years, Mitrovic's lab at Brown hasbeen using flat NMR coils for a variety of experiments aimed at exploring exotic materials and strange states of matter. Flat coils can be placed directly on or very close to a sample, and as a result they don't suffer from the signal loss of a solenoid. These types of NMR coils have been around for years and used for some specific applications in NMR imaging, Mitrovic says, but they've not been used in quite the same way as her lab has been using them.

For this latest research, Mitrovic and her colleagues showed that flat coils are not only useful in boosting NMR signal, but that different geometries of flat coils can maximize signal for samples of different shapes and in different types of experiments.

For instance, in experiments using thin-films of the semiconductor indium phosphate, the researchers showed that very small samples yield the most signal when placed at the center of flat, circular coil. For larger samples, and for experiments in which it is important to vary the orientation of the external magnetic field, a meander-line shape (a line that makes a series of right-angle turns) worked best.

The ability to get a signal at varying magnetic field orientations is important, Mitrovic says. "There are exotic materials and interesting physical states that can only be probed with certain magnetic field orientations," she said. "So knowing how to optimize our probe for that is really helpful."

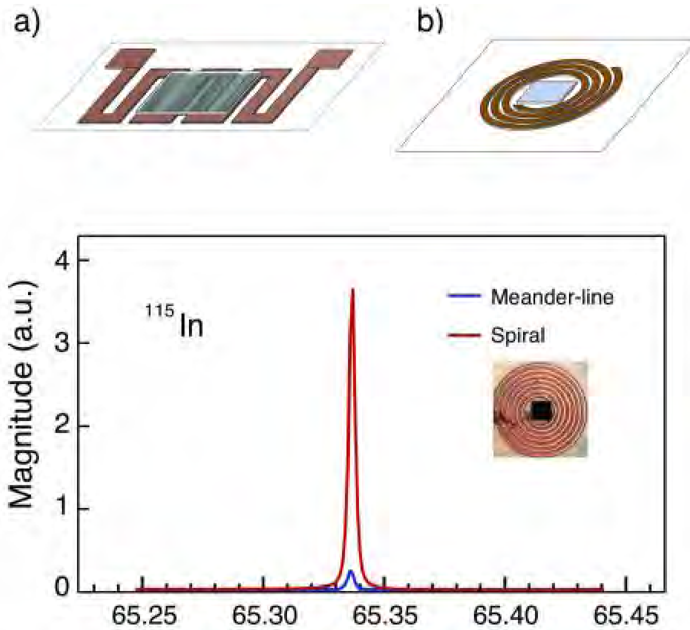
Another advantage to flat coils is it gives experimenters access to their sample, as opposed to having it caged inside a solenoid.

"Many of the states we're interested in are induced by manipulating the sample — applying an electric current to it or applying a stress to it," Mitrovic said. "The flat coils make it much easier to be able to do those manipulations."

Mitrovic hopes the guidance this research provides in how to optimize flat coils will be useful to other physicists interested in using NMR to investigate exotic materials and states of matter.

Mitrovic's co-authors were Wencong Liu and Lu Lu, both from the Brown. The research was supported by a grant from the National Science Foundation (DMR-1608760).

—KEVIN STACEY



NMR in flatland
Researchers have shown how flat NMR probes, as apposed to cylindrical ones, can be made useful in studying the properties of nanomaterials.
Mitrovic lab / Brown University

US CMS BOARD CHAIR ELECTION

Brown Physics Professor **Meenakshi Narain** has been elected for a 2 year term as Chair of the Collaboration Board of U.S. institutions in the Compact Muon Solenoid (CMS) Collaboration. In this capacity she will represent the U.S. institutions to the management of the international CMS Collaboration at CERN and to the U.S. funding agencies. The Chair of the Collaboration Board plays a key role in shaping the vision and direction of the U.S. CMS collaboration within international CMS. The U.S. CMS Collaboration is supported by the Department of Energy and the National Science Foundation and consists of over 1200 scientists, including physicists, students, engineers, and technicians, making it the largest national group in the international CMS Collaboration. The percentage of females in the collaboration is around 27%.

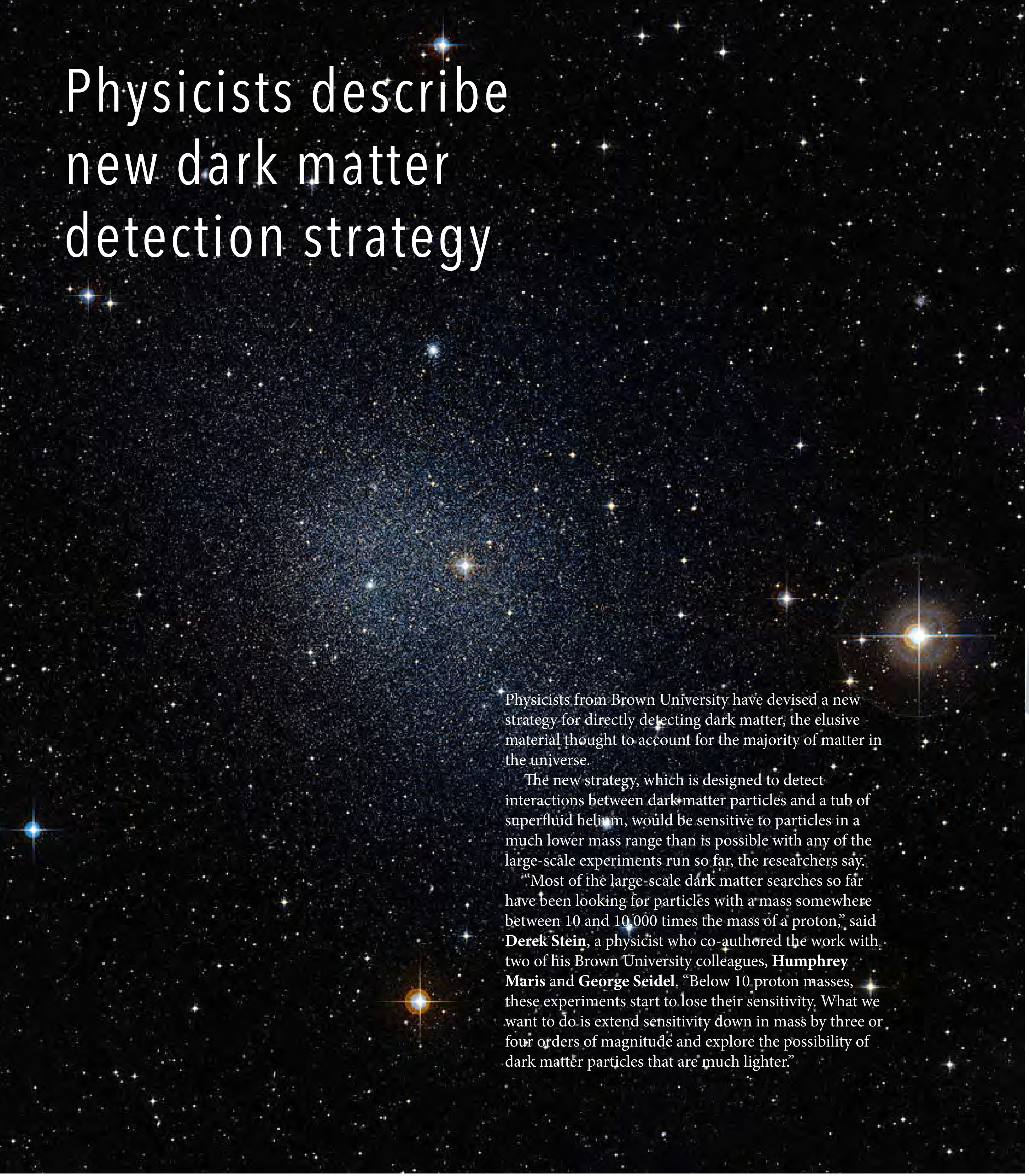
Discoveries from CMS experiment at the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland, are revolutionizing our understanding of the universe. The U.S. CMS Collaboration is making significant contributions to nearly every aspect of the detector, including construction, installation, and data-taking. U.S. CMS also plays a major role in the construction and operation of the experiment's computing facilities and software that is used to analyze the unprecedented amount of data that CMS generates. These highly sophisticated computing tools allow physicists to operate the CMS detector, reconstruct the data, analyze it and, ultimately, make discoveries.

NEWTON'S APPLE TREE

In March, Brown Physics' descendant of the apple tree that sparked Isaac Newton's principle of universal gravity was transplanted to its new, permanent home on campus.

Professor **Humphrey Maris** acquired part of this tree for Brown's physics department and it was planted behind the Barus and Holley building in 2000. Isaac Newton, the English mathematician, astronomer, theologian, author, and physicist is widely known as a crucial figure in the scientific revolution, crediting his work to the apple tree that has lied in the orchard at Woolsthorpe Manor for around 400 years. For at least 240 years, this tree has been referred to as the 'gravity tree.' After observing an apple fall from the tree, Newton questioned why the apples always fall straight to the ground. He began to consider and ponder why all things fall to the ground, rather than going un in the air or off to the side. He reasoned that there must be a power that causes this to happen, thus beginning his research on gravitational force.

Construction of the new Applied Math building in 2014 temporarily necessitated the tree be moved temporarily in front of the Italian House on Hope Street. The famous tree can now be found at its new home in front of the Engineering Research Center. This tree serves as inspiration to the students and symbolizes curiosity, creativity, and innovation.



Physicists describe new dark matter detection strategy

Physicists from Brown University have devised a new strategy for directly detecting dark matter, the elusive material thought to account for the majority of matter in the universe.

The new strategy, which is designed to detect interactions between dark matter particles and a tub of superfluid helium, would be sensitive to particles in a much lower mass range than is possible with any of the large-scale experiments run so far, the researchers say.

"Most of the large-scale dark matter searches so far have been looking for particles with a mass somewhere between 10 and 10,000 times the mass of a proton," said **Derek Stein**, a physicist who co-authored the work with two of his Brown University colleagues, **Humphrey Maris** and **George Seidel**. "Below 10 proton masses, these experiments start to lose their sensitivity. What we want to do is extend sensitivity down in mass by three or four orders of magnitude and explore the possibility of dark matter particles that are much lighter."

NASA
ESO/Digital Sky Survey 2

Missing matter

Though it has not yet been detected directly, physicists are fairly certain that dark matter must exist in some form. The way in which galaxies rotate and the degree to which light bends as it travels through the universe suggest that there's some kind of unseen stuff throwing its gravity around.

The leading idea for the nature of dark matter is that it's some kind of particle, albeit one that interacts very rarely with ordinary matter. But nobody is quite sure what a dark matter particle's properties might be because nobody has yet recorded one of those rare interactions.

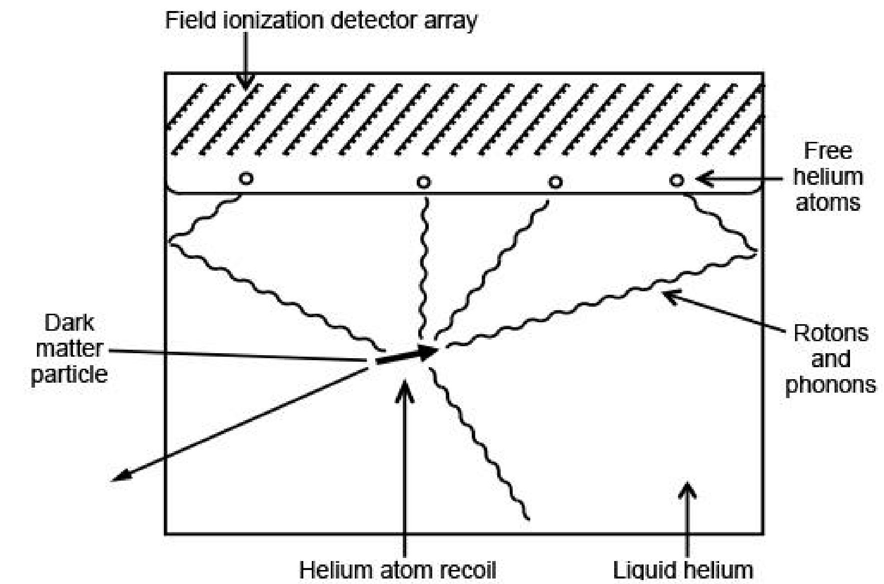
There's been good reason, Stein says, to search in the mass range where most dark matter experiments have focused thus far. A particle in that mass range would tie up a lot of loose theoretical ends. For example, the theory of supersymmetry — the idea that all the common particles we know and love have hidden partner particles — predicts dark matter candidates of the order of hundreds of proton masses.

But the no-show of those particles in experiments so far has some physicists thinking about how to look elsewhere. This has led theorists to propose models in which dark matter would have much lower mass.

A new approach

The detection strategy that the Brown researchers have come up with involves a tub of superfluid helium. The idea is that dark matter particles passing through the tub should, on very rare occasions, smack into the nucleus of a helium atom. That collision would produce phonons and rotons — tiny excitations roughly similar to sound waves — which propagate with no loss of kinetic energy inside the superfluid. When those excitations reach the surface of the fluid, they'll cause helium atoms to be released into a vacuum space above the surface. The detection of those released atoms would be the signal that a dark matter interaction has taken place in the tub.

"The last bit is the tricky part," said Maris, who has worked on similar helium-based detection schemes for other particles like solar neutrinos. The collision of a low-mass dark matter particle might result in only a single atom being released from the surface. That single atom would carry only about one milli-electron volt of energy, making it virtually impossible to detect through any traditional means. The novelty of this new detection scheme is a means to amplify that tiny, single-atom energy signature.



Superfluid dark matter catcher
A proposed dark matter detector using superfluid helium might detect particles with much lower mass than most current detectors.
Maris/Seidel/Stein/Brown University

It works by generating an electric field in the vacuum space above the liquid using an array of small, positively charged metal pins. As an atom released from the helium surface draws close to a pin, the positively charged tip will steal an electron from it, creating a positively charged helium ion. That newly created positive ion would be in close proximity to the positively charged pin, and because like charges repel each other, the ion will fly off with enough energy to be easily detectable by a standard calorimeter, a device that detects a temperature change when a particle runs into it.

"If we put 10,000 volts on those little pins, then that ion going is going to fly away with 10,000 volts on it," Maris said. "So it's this ionization feature that gives us a new way to detect just the single helium atom that could be associated with a dark matter interaction."

Sensitive at low mass

This new kind of detector wouldn't be the first to use the tub-of-liquid-gas idea. The recently completed Large Underground Xenon (LUX) experiment and its successor, LUX-ZEPLIN, both use tubs of xenon gas. Using helium instead provides an important advantage in looking for particles with lower mass, the researchers say.

For a collision to be detectable, the incoming particle and the target atomic nuclei must be of compatible mass. If the incoming particle is much smaller in mass than the target nuclei, any collision would result in the particle simply bouncing off without leaving a trace. Since LUX and L-Z are intended for the detection of particles with mass greater than five times that of a proton, they used xenon, which has a nucleus of around 100 proton masses. Helium has a nuclear mass only four times that of a proton, making a more compatible target for particles with much less mass.

But even more important than the light target, the researchers say, is the ability of the new scheme to detect only a single atom evaporated from the helium surface. That kind of sensitivity would enable the device to detect the tiny amounts of energy deposited in the detector by particles with very small masses. The Brown team thinks its device would be sensitive to masses down to about twice the mass of an electron, roughly 1,000 to 10,000 times lighter than the particles detectable in large-scale dark matter experiments so far.

Stein says that the first steps in actually making such a detector a reality will be fundamental experiments to better understand aspects of what's happening in the superfluid helium and the precise dynamics of the ionization scheme.

"From those fundamental experiments," Stein says, "we would craft designs for a bigger and more complete dark matter experiment."

The research was funded in part by the National Science Foundation (DMR-1505044).

—KEVIN STACEY

UNTANGLING THE FABRIC OF THE UNIVERSE

When **Sarah Bawabe** arrived at Brown as a first-year student in fall 2017, she hadn't given much thought to a physics as a potential concentration. That was before she took an introductory physics seminar called "Flat Earth to Quantum Uncertainty" with Brown physicist **S. James Gates Jr.**

"I vividly remember showing up to class and thinking that Professor Gates was the coolest person alive," Bawabe said of the renowned theoretical physicist and National Medal of Science winner. "When I was a kid, I wanted to be an astronaut… so I had physics in the back of mind. But coming here, taking Professor Gates' class and getting to see what physics was all about really solidified things."

As a result of the class, which was originally created by Brown professor and Nobel Laureate Leon Cooper, Bawabe promptly declared a concentration in mathematical physics and asked Gates if he might have any summer research opportunities for her. As it turned out, he did.

For the past 19 years, Gates has led a program called the Summer Student Theoretical Physics Research Session (SSTPRS). For its 20th year, SSTPRS moved to Brown from Gates' former academic home at the University of Maryland. The program gives undergraduates a chance to work side-by-side with him on big questions in theoretical physics. The ultimate goal is for students to eventually be co-authors with Gates on peer-reviewed journal papers — a major leg up for students thinking about graduate school.

Every weekday this past June, Bawabe and 19 other SSTPRS students from colleges around the country (and one student from Hong Kong) met in Barus and Holley, where Gates brought the group up to speed on his current research projects. Since 2004, he has been studying graphical representations of the mathematics underlying supersymmetry, a theory that helps to unite the fundamental forces that govern the universe. Those graphical representations, which Gates and his colleagues call adinkras, are pictures that encode the mathematics of how supersymmetric particles interact. The hope is that adinkras can provide scientists with a deeper and more intuitive understanding of the universe than equations alone.

Professor Jim Gates and Sarah Bawabe (l)

But before that can happen, Gates needs to prove that adinkras are properly encoding the underlying math, and that's what the SSTPRS students are working on. The work involves performing complex calculations — with pencil and paper as well as with the help of computers.

Bawabe admits that working with such arcane and occasionally dizzying math was a bit daunting for someone just finishing her first undergraduate year.

"You open one of these research papers and you see all these weird symbols and you just have to wonder what's going on," she said. "But after a few weeks I could start to decode it, and that was really satisfying."

Over the course of the month, Bawabe said she became fluent in two mathematical coding languages and learned a range of new mathematical techniques. But more importantly, she says, she formed a new group of like-minded undergrads with whom she'll continue to work. Now that they've completed the classroom portion of SSTPRS, the students will continue to collaborate and work toward publishing their work in a peer-reviewed journal.

"I learned so much from SSTPRS, not just about specific concepts, but also about what it's like to really 'do physics' out in the world," Bawabe said. "It was incredible being able to learn under Professor Gates and all of his collaborators. It's especially rare that such knowledgeable people in the physics world take the time to teach us, work with us and truly have faith that even we undergraduates can contribute to their work."

Bawabe said she would encourage other students with a love of physics to participate if they have the chance.

"This program changed my outlook on the world of physics," she said. "Being a girl and often feeling intimidated by this male-dominated field, having the confidence to know I, too, can make it is a powerful and motivating feeling. I started in June feeling terrified about what I had gotten myself into, but at the end I walked away feeling like I was capable of more than I had given myself credit for."

—KEVIN STACEY

ALUMNI NEWS

Shawna Hollen, Brown Physics PhD'13, and University of New Hampshire, Assistant Professor of Physics, will be a Member-at-Large for the Division of Condensed Matter Physics, an election by the American Physical Society (APS). Members-at-Large serve on the Executive Committee that oversees the activities of this more than 10,000 member strong division.

A student of Professor **Jim Valles**, Professor Hollen joined the faculty at UNH in 2015 following a postdoc at The Ohio State University. She has set up a lab for novel experiments on 2D, graphene-like materials that have exceptional technological promise. Her group's scanning probe and unique Ultra High Vacuum electronic transport apparatus' enable them to explore directly how microscopic defects and surface adsorbates influence their electronic properties.

Dhani Harrison

Musician and designer Dhani Harrison, son of The Beatles' George Harrison, studied physics at Brown. In November, he debuted his solo album, "In//Parallel."

At the 4th annual Brown University Graduate Student Career Options Conference, one of the alumni invited to speak about their post-Brown career path was **Sheng Xie**, who earned his PhD in Physics in 2015.

Sheng worked with Professor **Bob Pelcovits** on numerical studies of soft matter. After graduation, he worked at Capital One for nearly two years as a quantitative analyst in credit risk management. His responsibilities involved data mining and creating robust statistical driven models to manage credit risks for corporate loans. Now, he is at Barclays Investment Bank as a desk quant for Credit Trading Products. On a daily basis, he maintains quantitative models of credit derivatives products and support traders with providing daily reports on markets movements, position exposures, and investment strategies.

Q: Your first position after graduate school:
A: Quantitative analytics at Capital One.

Q: Career skills graduate students should develop for careers in your field:
A: My field is technology for development. A key skill is strong communications and math, programming, finance.

Q: Advice for graduate students seeking careers in your field:
A: Prepare early, talk to people from the field.

Keep in touch!

We would love to hear from you. Please send any news, updates, address changes, comments, or recommendations to physics@brown.edu or to department manager, Douglas Wilkie, at douglas_wilkie@brown.edu.

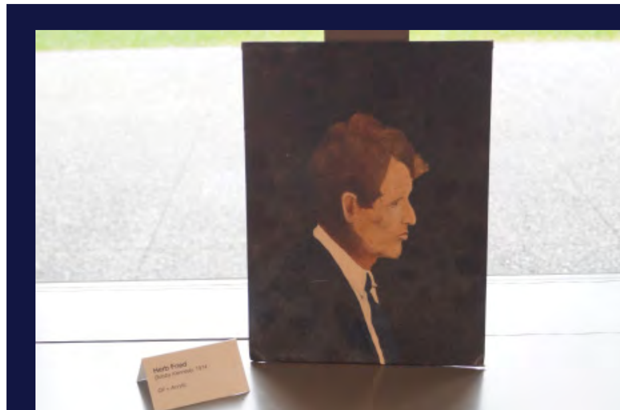
AY 2017 - 2018 Physics Events

Michelle Miller '18, 8th Annual Art Show

PhD students David Osterman (l) and Bjorn Burkle (r) preparing to make ice cream with liquid nitrogen at this year's annual physics spring picnic.

Physics students playing an impromptu game of soccer at Barus & Holley Gardens

Professor Philip Nelson from the University of Pennsylvania gave this year's Arthur O. Williams Lecture,"Physics of Human and Superhuman Vision."



At this year's 8th annual physics art show, a particular painting by Emeritus Professor Herb Fried was on display. Marking 50 years since the assasination of Robert F. Kennedy, the oil and acrylic painting by Professor Fried, titled "Bobby Kennedy" was painted after the politician's death in 1968.

REMEMBERING CHARLES ELBAUM, PROFESSOR EMERITUS

This year, the Department of Physics mourned the loss of our beloved colleague and friend **Charles Elbaum**, who passed away on March 4, 2018. Elbaum joined Brown's Physics Department in 1959 as Assistant Professor of Applied Physics, served as chair of the department from 1980 to 1986, and was appointed the Hazard Professor of Physics in 1991.

Charles was a beloved teacher and mentor to countless students and a valued colleague and leader to the faculty and staff in the Department of Physics and the larger Physics community. During his distinguished career, he made many important contributions to the field of condensed matter physics, particularly, at very low temperatures. He was a leading expert in the properties of quantum solids and liquid helium, crystal defects and their interactions, diffusion in solids, ultrasonic waves and acoustics in solids, metallurgy, superconductivity, and vortex dynamics near the superconducting phase transition. He was a prolific author of many highly-cited scientific papers, books, and book chapters, as well as the owner of eight patents. In addition to his work in physics, Elbaum made key contributions to the areas of neural networks and synaptic plasticity. In 1975 Elbaum, along with Professor Leon N Cooper, founded Nestor Inc., a company dedicated to finding commercial applications for neural networks. Nestor's impressive list of customers included General Electric, Ford Motor, Chemical Bank, Hughes Aircraft, Lockheed, Morgan Stanley, and Salomon Bros.

Because of his slight build and easy going demeanor many were shocked to learn what an outstanding, highly competitive athlete Charles was. His exploits on the slopes of Mt. Washington's treacherous Tuckerman Ravine are the stuff of legend. Professor Bob Lanou remembers, "No matter what Charles chose for a run the reward of watching him do it was a joy. With consummate grace and sure grip with his edges in series after series of linked turns under full speed, he would [complete the run] more than 95% of the time with no emergency stop or tumble… he was the picture of high speed grace under full control… he would urge us to do as many runs as we could manage, and still have enough energy to hike and ski back to our hut or lodge at the bottom." Knee problems eventually forced Charles to give up skiing, but did not prevent him from being active, "he immediately took up windsurfing, and stuck with it through two knee replacements," according to his son Michael, "he didn't stop windsurfing until he turned 81."

Charles was as beloved by Physics staff as he was by his fellow faculty members. His cheerful demeanor and philosophical quips brightened many a day. He was kind and took a genuine interest in the lives of people around him. Assistant Financial/Operations Administrator Jean Miller remembers, "Professor Elbaum was a gentleman, he was polite, considerate, very intelligent, warm and humorous. No matter where you saw him, inside or outside of Brown, he was always engaging and happy that he saw you. It is very sad for me, I came here when I was in my 20's, a lot of great people who were members of this department are no longer with us."

Before coming to Brown, Charles received both his Masters and Ph.D. degrees from the University of Toronto in 1954. He later served as a Research Fellow at the University of Toronto and Harvard University. He carried on research at the University of Paris, and at various government and industrial research laboratories during his long, distinguished career. A Fellow of the American Physical Society, he officially retired from his tenured position in 2001 but remained active as a Professor of Physics (Research) for many years.

Professor Leon N Cooper shares the sentiments of many when he says, "Charlie was a great colleague and a great friend. I will miss him." Our continued deepest condolences to Professor Elbaum's family, friends, and colleagues.

—PETE BILDERBACK

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2017 annual poster session brought together undergraduates, graduate students, and faculty to discuss current research in the department.