BROWN PHYSICS

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SUMMER 2016

What's Inside

Greetings from the Chair

The 2015-2016 academic year, my sixth and final year as chair, was a stimulating, eventful and productive time. As of July 1, my distinguished colleague, Gang Xiao, will assume the chairmanship. He is filled with enthusiasm and a vision for guiding the department in the coming years, and we look forward to his leadership.

Over the past year, three new faculty, Stephon Alexander, Jiji Fan and Jonathan Pober, joined the department. As you read about them in the following pages, you'll see they bring a host of new strengths to our teaching and research programs. In addition, the hiring of three staff members, Barbara Cole, Jessica Pontarelli, and Antonio Taylor, has enhanced the scope of our administrative operations.

It was my great pleasure to preside over an unusually large graduating class in May. Given the considerable number of graduates, we held consecutive ceremonies: one to recognize our PhD and Master's recipients and the other to celebrate our undergraduates. Our incoming class of graduate students is large as well; this fall, we will welcome 22 PhD and 17 master's candidates.

The prominent physicist S. James Gates, Jr. will begin a one-year visiting appointment at Brown University this summer. A member of President Obama's Council of Advisors on Science and Technology and recipient of numerous honors including the National Medal of Science, he will bring an exciting dimension to our department.

As most of you are likely aware, President Paxson has launched a University-wide effort to focus on the "pursuit of a fully diverse and inclusive community." As part of the initiative, each academic department was required to draft a working document to articulate recommendations and actions to address diversity and inclusion issues on a local level. Under the able guidance of Professor Ian Dell'Antonio and a committee of faculty, students and staff, a lengthy document was submitted that details an array of ideas including faculty initiatives, graduate recruitment, training programs, support structures for students, and enhancing our sense of community.

The Physics Department hosted a dynamic, engaging Degree Day program in April that brought 20 alumni back to campus to talk with our students. Two lively panel discussions were held. The alumni panel, facilitated by Bob Pelcovits, focused on career paths and choices and Meenakshi Narain lead a panel discussion by current students that examined issues related to diversity. Rick Gaitskell's research presentation and a dinner at the Faculty Club rounded out the event.

As always, the department supported numerous events this year to enrich our students and encourage collaborative research efforts. We were particularly pleased to have Nobel Prize winner, David Gross, deliver our annual A.O. Williams Lecture. Many interesting and distinguished speakers visit us throughout the year and alumni are always welcome at these talks.

As my term comes to an end, I want to reiterate the interest that the Physics Department maintains in all of you. We strive to remain accessible and available, and we particularly relish learning about your successes and endeavors. Please keep in touch!

Jim

James M. Valles, Jr.

2016 Undergraduate Degree Recipients

Class of 2016

Dominic T. Adams
Lauren E. Altman
Alexander M. Ashery
Källan M. Berglund
Lawrance W. Choi
London J. Cooper-Troendle
Samantha D. Dallas
Connor R. Flexman
Jahmour J. Givans
Yan Joe Lee
Alexander J. Levine
Paul E. Martin
Tomoya A. Mori
Kei Nishimura-Gasparian
Cameron L. Reid
Michael J. Scheer
Sana P. Siddiq
Charles A. Snider
Kate E. Storey-Fisher
Nathaniel E. Tarshish
Joseph F. van der List
Jamelle D. Watson-Daniels
Jack T. Wilson
Christopher F. Yee

2015 UTRA Students

Dominic Adams *(Mitrovic)*
Lauren Altman *(Spradlin)*
Artur Avkhadiev *(Dell'Antonio)*
Ittai Baum *(Volovich)*
Kallan Berglund *(Lowe)*
London Cooper-Troendle *(Mitrovic)*
Connor Flexman *(Gaitskell)*
Soumya Ghosh *(Dell'Antonio)*
Jahmour Givans *(Lowe)*
Steven Hines *(Tang)*
Oliver Isik *(Dell'Antonio)*
Nomin Khishigsuren *(Narain)*
Nguyen Le *(Oldenbourg)*
Alexander Levine *(Valles)*
Charles Snider *(Jevicki)*
Nathaniel Tarshish *(Pelcovits)*

Undergraduate Awards

R. BRUCE LINDSAY PRIZE FOR EXCELENCE IN PHYSICS

Lauren Altman
London Cooper-Troendle

MILDRED WIDGOFF PRIZE FOR EXCELLENCE IN THESIS PREPARATION

Dominic Adams
Nathaniel Tarshish
Jamelle Watson-Daniels

SMILEY PRIZE FOR EXCELLENT CONTRIBUTION TO THE ASTRONOMY PROGRAM

Källan Berglund

Physics WiSE and Diverse Individuals in Physics

Many types of systemic bias exist in our society, particularly in physics. Our department is no exception. But as a community, we are working to implement positive changes. One such change is the growth of student-organized groups addressing these inequalities one conversation at a time. The physics subgroup of Women in Science and Engineering (WiSE) has grown over the past three years, and is now expanding into two groups: Physics WiSE, absorbed into general WiSE and run through the Science Center, and Diverse Individuals in Physics (DIP), focusing on more diverse inclusivity and run within the Physics Department.

The Physics WiSE Founding Coordinators, Källan Berglund '16 and Elizabeth Gurin, and longstanding Co-Coordinator Samantha Dallas '16 have graduated. New leaders are stepping up. Blake DeVaney, Kara Hartig '18, and Sarah Blunt '19 will be coordinators of WiSE, representing the physical sciences and organizing Physics WiSE events. With the support of fellow students, Kairy Herrera will lead DIP to create space for additional voices to be heard: students struggling with physical and psychological challenges, students of different cultural and socio-economic backgrounds, LGBTQ+ individuals, and more.

Previously, Physics WiSE events included volunteer outreach, de-stress study-breaks, diversity panel conversations, and lunch discussions with guests sharing their experiences as women in physics. The primary goal of Physics WiSE has been to continue productive dialogue about systemic gender biases in the physics community, engaging as many people in the conversation as possible. These events will continue through Physics WiSE and DIP, with more conscious inclusion of individuals who may identify with multiple minority groups. Future DIP events might also include field trips, expanded outreach, and other community-building events.

These groups share a common goal: to foster community in the Physics Department and facilitate continued discourse about the hurdles faced by women and minorities in physics. We look forward to extensive collaboration between Physics WiSE and DIP, as well as the Physics DUG. The common question is, “How can we eliminate the biases that pervade our academic community?” The first step is to acknowledge that they exist, specifically, that they exist within us all. Physics WiSE and DIP invite all to join the conversation.

Contributed by Källan Berglund '16

Department Undergraduate Group (DUG)

Over the past year, the DUG continued its mission of improving and solidifying a sense of community among undergraduate students in the Physics Department. Various activities were organized including the annual Halloween pumpkin-carving event and an advising day specifically designed for sophomores. A new activity, DUG Discussions, was introduced. Students gathered to discuss and debate topics such as consciousness and quantum mechanics and the philosophical implications of special relativity. Given the success of these conversations, the DUG will continue to organize more discussions next semester.

During the creation of the department’s Diversity and Inclusion Action Plan (DIAP), the DUG hosted an undergraduate town hall that allowed students to voice their concerns surrounding issues of diversity and inclusion. Many of the suggestions that came out of the meeting were included in the plan, and the DUG appreciates all of the undergraduates who contributed to the conversation.

A new Physics DUG website will be launched in the fall.

Contributed by Amy Butcher '17

APS Award

Jovan Nelson '17 was awarded the Undergraduate Presentation Award from APS for his work at Fermilab. Jovan presented his work, "A Computer Program to Measure the Energy Spread in the Fermilab Booster at Injection" at the April 2016 Meeting in Salt Lake City, Utah.

Master of Science

Husain Alqattan
George Barbosa Araujo
Rohitvarma Basavaraju
Chung Chan
Atreya Chatterjee
Henoc Assefa Ejigu
David Jose Gabriel Maselli
Mary Hill Hadley
Guanyang He
Yehui He
Jun Kai Ho
Dongqing Huang
Shao Ran Huang
Joshua Ralph Kerrigan
Adam Eudene Lanman
Shing Chau Leung
Wenyang Li
Zidong Ma
Maria Eleni Moustaka
Rachel Aase Pedersen
Igor Prlina
Casey Alonso Rhyne
Joseph Michael Skitka
William Claiborne Taylor
Tung V. Tran
Minchao Wang
Christos Steven Zambas
Wenyu Zhang
Dewen Zhong
Zekun Zhuang
Michael Zlotnikov

ScM Student Awards

OUTSTANDING ACADEMIC ACCOMPLISHMENT

Zekun Zhuang

MASTER'S RESEARCH EXCELLENCE

Zidong Ma

ENGAGED CITIZENSHIP AND COMMUNITY SERVICE TO THE PHYSICS DEPARTMENT

Maria Eleni Moustaka
Rachel Pedersen

Doctor of Philosophy

2016 PhD Recipients

Juliette Alimena *(Cutts)*
Saptaparna Bhattacharya *(Landsberg)*
Ian Gordon Blackadder *(Koushiappas)*
Alex Edward Garabedian *(Narain)*
Xinjun Guo *(Mandre)*
Qiang Hao *(Xiao)*

Kyle Robert Helson *(Tucker)*
Liwei Jim Liu *(Maris)*
Pei Liu *(Pacifici)*
Lu Lu *(Mitrovic)*
Michael D. Morse *(Tang)*
Timothy G. Raben *(Tan)*

Kwangdong Roh *(Nurmikko)*
Ravi Shanker Singh *(Mandre)*
Peter Hing Bun Tsang *(Fried)*
James Richard Verbus *(Gatiskell)*
Lei Wang *(Marston)*
Zhuolin Xie *(Maris)*
Jung-gi Yoon *(Jevicki)*

PhD Student Awards

GALKIN FOUNDATION FELLOWSHIP AWARD

Jung-gi Yoon

ROBERT T. BEYER AWARD FOR EXCELLENCE IN SCHOLARSHIP AND SERVICE

Kyle Helson
Timothy Raben

ANTHONY HOUGHTON AWARD FOR EXCELLENCE IN THEORETICAL PHYSICS

Jung-gi Yoon

SIGMA XI AWARD FOR EXCELLENCE IN RESEARCH IN PHYSICS

James Verbus

FORREST AWARD FOR EXCELLENCE IN WORK RELATED TO EXPERIMENTAL APPARATUS

Michael Morse

AWARD OF EXCELLENCE AS A GRADUATE TEACHING ASSISTANT

Wencong Liu
David Lizarazo-Ferro
Igor Prlina
Eric Scotti

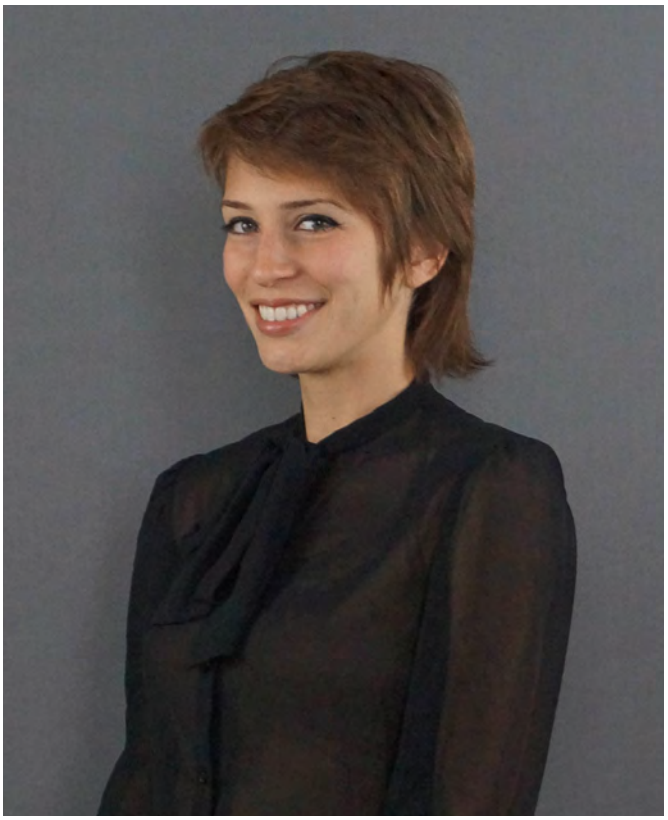
2015 – 2016 Physics Merit Fellowship Recipient: Jacqueline McCleary

This year's Physics Merit Fellowship recipient, Jacqueline McCleary, examined the dark matter substructure in low-redshift clusters of galaxies using weak gravitational lensing. Jacqueline's project, led by adviser Ian Dell'Antonio, targeting the highest mass clusters in the local Universe, as these have the strongest lensing signal and thus allow further reaches down the fractional scale of substructure.

Hierarchical formation of structure is one of the central predictions of the cold dark matter (CDM) paradigm. In this scenario, matter organizes itself from the bottom up, first collapsing into small structures that can overcome cosmological expansion, then continuing to merge into increasingly large halos. Because small collapsed objects often survive accretion onto a larger system to become sub-halos of their host, the CDM/hierarchical structure formation paradigm predicts that galaxy clusters should be rich in mass substructures. Jacqueline was able to make direct measurements of these cluster substructures through weak gravitational lensing analysis. This technique looks for coherence among the shapes of hundreds of thousands of galaxies behind the cluster of interest, which enables the reconstruction of the 2-D projection of cluster's mass distribution along the line of sight. A separate analysis can fit a physical mass to the same lensing signal.

The weak lensing analysis was undertaken using data from the Dark Energy Camera (DECam) at Cerro Tololo Inter-American Observatory in Chile. DECam's exceptionally wide field of view allows for the tracing of the dark matter distribution out to the virial radius of the clusters and hence efficient mapping of halo mass substructure. The depth and filter coverage of DECam imaging also allows for fitting observations with photometric redshifts, enabling the isolation of contaminating signal from high-redshift galaxy clusters. In total, Jacqueline analysed data on eleven low-redshift ($z \leq 0.12$) clusters. Jacqueline also collaborated with post-doc Anja von der Linden (now faculty at Stony Brook University) and P.I. Steve Allen of the X-ray and Observational Cosmology group at the Stanford Linear Accelerator facility in California. The team shared DECam data and a superior weak lensing analysis pipeline.

In and of themselves, the two-dimensional maps of projected mass enable a study of galaxy properties as a function of local substructure environment, and also of the DM substructures themselves: unlike canonical dark matter halos, DM in clusters is expected to show evidence for tidal stripping and truncation. This aspect of the PhD project is ongoing and will wrap up in the fall of 2016.



After Jacqueline's graduation, this work will also become the low-redshift anchor to a systematic observational measurement of the evolution of mass substructure in clusters of galaxies.

Such a study, the first of its kind, would deepen our understanding of how the first galaxies assembled themselves into clusters.

Deans' Faculty Fellowship Recipient: Philip Zucker

Fifth year physics doctoral student Philip Zucker is one of seven doctoral students at Brown to receive a Dean's Faculty Fellowship. A joint pilot initiative of Brown University's Graduate School and the Office of the Dean of the Faculty, the fellowships are designed to allow advanced graduate students to strengthen their teaching portfolios by developing their own courses in consultation with a faculty mentor. Eligibility for the award for the award requires the student to have a record of excellence in teaching and scholarship and commit to completing, defending and submitting the dissertation by January 15 of the sixth year. Those who meet the thesis deadline will be appointed as Visiting Assistant Professors with assignments to teach or co-teach a course in their areas of expertise.

IBES Graduate Fellowship Recipient: Joseph Skitka

Physics graduate student, Joseph Skitka, has been selected as a recipient of an IBES Graduate Fellowship for the 2016-2017 academic year. The Institute at Brown for Environment and Society has partnerships with fifteen University departments, providing graduate students with the flexibility to pursue a rigorous disciplinary education while simultaneously conducting valuable, stimulating multi-disciplinary research.

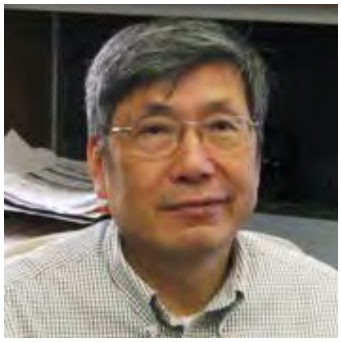
Students benefit from the interdisciplinary environment of the Institute while working under the direction of an IBES fellow within his or her home department. IBES supports its graduate students with a host of fellowship, research, and travel funding opportunities.

Faculty Awards and Promotions

APS Councilor

Professor Brad Marston was elected Councilor of the American Physical Society (APS) Division of Condensed Matter Physics (DCMP). His term, which began in January 2016, will run through the end of December 2019. The Divisional Councilor serves as a liaison between the APS Council and the Executive Committee of the Division, ensuring that interests of both the Division and the whole Society are protected by the Council and the Executive Board.

Fulbright Distinguished Chair Award



See-Chen Ying has been honored with the Fulbright Distinguished Chair Award. The Fulbright Distinguished Chair Awards comprise approximately forty distinguished lecturing, distinguished research and distinguished lecturing/ research awards. Fulbright Distinguished Chair Awards are viewed as among the most prestigious appointments in the Fulbright Scholar Program. His project, "Statics Dynamics of Overlayers Absorbed on Surfaces," will be hosted at Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research) in Brazil for three months.

Blavatnik Award

Professor Anastasia Volovich has been named a National Finalist of the 2016 Blavatnik National Laureates. The annual Blavatnik Awards, established by the Blavatnik Family Foundation in 2007 and administered by the New York Academy of Sciences, celebrate exceptional young researchers who drive the next generation of scientific innovation by answering the most complex scientific questions of today.

Promotion

Anastasia Volovich was promoted to Full Professor effective July 1. Professor Volovich received the M.A. in Physics with highest honors from Moscow State University in 1999 and the Ph.D. in Theoretical Physics from Harvard University in 2002. She came to Brown University as a Richard and Edna Salomon Assistant Professor in 2006 after her post-doctoral research at the Kavli Institute for Theoretical Physics in Santa Barbara and William D. Loughlin Membership at the Institute for Advanced Study in Princeton.

Recently named a National Finalist of the 2016 Blavatnik National Laureates, she is a recipient of an NSF CAREER Award, White House PECASE Award, DOE Early Career Research Award, Sloan Research Fellowship, Simons Investigator Award, Simons Fellowship in Theoretical Physics and other honors.

APS Fellow

Professor Vesna Mitrovic was elected as a Fellow of the American Physical Society for pioneering contributions to NMR study of low energy excitations in emergent quantum phases.

Stephon Alexander

Stephon Alexander has always been interested in finding answers to big questions. Fascinated as a youth by Einstein's theory of relativity, quantum theory, and string theory, Alexander is now a specialist in the field of string cosmology, where the physics of superstrings are applied to address longstanding questions in cosmology. An accomplished jazz musician, Alexander has been mentored by Ornette Coleman and Will Calhoun. He has combined his two great passions in a new book that explores the intersection between jazz and physics, The Jazz of Physics: The Secret Link Between Music and the Structure of the Universe. Alexander has also long been an advocate for historically underrepresented groups in the sciences.

Born in Trinidad, Alexander moved to the Bronx at age eight and discovered his passion for physics in High School. "My childhood was full of surprises…it taught me the idea of embracing the unknown. Our culture tells us to try and control situations. Instead, I've always coped with unexpected events by making up theories about why they may be happening." He earned an undergraduate degree at Haverford College, and later a Ph.D. in Physics from Brown University. He held postdoctoral fellowships at Imperial College, London and at The Stanford Linear Accelerator Center. He previously held faculty positions at Penn State, Haverford College, and Dartmouth College.

Alexander was the recipient of the 2013 American Physical Society Bouchet Award, "for his contributions to theoretical cosmology, in particular the interface between fundamental physics and early universe cosmology, that includes work in leptogenesis, and parity violating effects in quantum gravity, as well as for communicating many ideas of this field to the scientific community and the public."

Alexander continues to ask big questions in his research applying the physics of superstrings to questions of cosmology, in particular "What is behind the cosmic composition?" In his research Alexander asks, "how the world of particle physics and quantum gravity effects can be tested using measurements in cosmology... We know there is dark energy and dark matter out there, but we want to know what their identity is and what fundamental physics says about that."

"We know there is dark energy and dark matter out there, but we want to know what their identity is and what fundamental physics says about that."

While at Dartmouth Alexander headed the E.E. Just STEM Scholars Program to promote academic excellence and strategies for academic success among historically underrepresented groups in the sciences. The E.E. Just Program provides a supportive community of undergraduate, graduate student, and postdoctoral mentors that offer program scholars strategies for academic and research success. It comprises a national network of some of the world's leading scientists, with whom E.E. Just Scholars can interact and conduct research. The program successfully placed a number of its undergraduates in world-class research labs, including positions at Google, Rockefeller University, and Microsoft Research.

Alexander plans to continue his mission to promote diversity in the sciences at Brown through the newly created Cooper Scholars Program, named in honor of one of Alexander's graduate mentors at Brown, Leon N Cooper. "One of the biggest challenges facing African Americans in the sciences is the paucity of tenured and tenure-line faculty, especially in the physical sciences. As a tenured faculty member, I feel an obligation not only to recruit and individually mentor black and other minority group members, including female scientists, but also to help create institutional structures to implement these goals. Further, I believe that white and male students benefit when we incorporate into the sciences groups that have been excluded; it is important for them to experience a science education from a diverse faculty and with diverse peers."

Article by Pete Bilderback, Department of Physics

Jiji Fan

As a particle theorist, Jiji Fan is working to address some of the deepest questions in nature. "We have a theory called the standard model which pretty successfully describes most of the fundamental particles and how they interact in experiments, but it's not sufficient to address many fundamental questions about the universe," said Fan, assistant professor of physics. "So my research is to propose theories beyond the standard model to address those questions."

The Large Hadron Collider (LHC), the world's most powerful particle accelerator, restarted earlier this year at nearly twice the energy of its first run from 2010 to 2013. That first run turned up the elusive Higgs boson, the particle that gives mass to some elementary particles and the final missing piece of the standard model. The higher energy regime of this current LHC run will be better suited to peering behind the standard model's curtain.

"The discovery of the Higgs boson completes the standard model, but we know there has to be something else beyond the standard model."

For one thing, she says, the standard model fails to account for dark matter, which is thought to make up as much as 80 percent of the matter in the universe. Scientists know dark matter is there because they see its gravity affecting the rotation of galaxies and the way light travels through the universe. But no one has ever detected it directly, and the standard model has no candidate for what a dark matter particle might be.

The standard model also fails to adequately explain the mass of the Higgs boson. While the Higgs helps explain why the building blocks of matter (quarks and leptons) have mass, the Higgs' own mass is a conundrum. The Higgs should gain mass from all of the other particles with which it interacts. At high energies, that should make its mass practically infinite. Yet when detected at the LHC, its mass was 125 gigaelectronvolts (about 125 more massive than a proton).

Fan is particularly interested in supersymmetry, a theory that may help explain these questions and others. The idea behind supersymmetry is that the known particles each have shadowy, unseen cousins with slightly different properties. These "sparticles" partially cancel out the interaction of known particles with the Higgs, thus explaining its seemingly small mass. Supersymmetry also proposes candidates for a dark matter particle, and may help explain other fundamental questions, like why there's more matter in the universe than antimatter and why gravity is so weak compared to the other forces that govern the universe.

Fan's job as a theorist is to try to understand how these theoretical particles might manifest themselves at the LHC. "Supersymmetry is a good theoretical signature generator," she said. "Different supersymmetric scenarios could predict different experimental signatures. We think about how the supersymmetric particles would decay and what their final states might be. Then we think about how to search for them at the LHC."

Fan comes to Brown from Syracuse University, where she was an assistant professor. She has a Ph.D. from Yale and worked at Princeton and Harvard as a postdoctoral researcher.

Excerpted from article by Kevin Stacey, Brown News Service

Jonathan Pober

It is the ultimate research effort: trying to understand the origin of everything. Jonathan Pober examines the 14-billion-year history of the universe as we know it in the wavelength of hydrogen. Jonathan Pober looks back to the beginning of time for a living. It's amazing that astronomers have developed this capability, and at a pivotal point in his life, Pober was amazed to learn he could contribute to the effort.

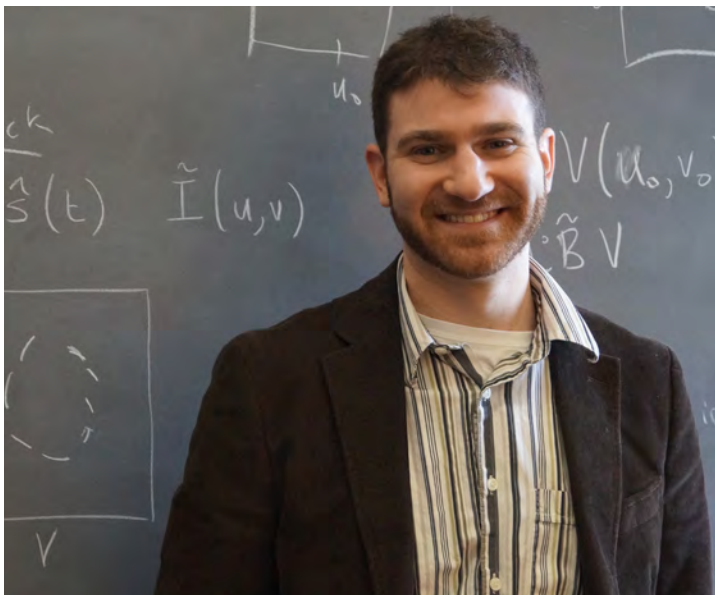
He was a pre-med undergraduate at Haverford College when he took a freshman seminar in astrophysics that future doctors could take to study physics in a way that might engage them more than sliding blocks on ramps, he said. "My interest in this field almost took me by surprise. It was honestly for me a 'People can actually study this?' moment. It wasn't just for Stephen Hawking and Albert Einstein. I sort of ran away with it from there."

He not only ended up making physics and astronomy two of his majors (he triple majored in philosophy), but also he joined a research lab studying the earliest structure of the universe based on data about the "Cosmic Microwave Background" (CMB). This is a pervasive emanation of electromagnetic radiation that gave astronomers their first picture of how matter was distributed around the cosmos only about 385,000 years after the Big Bang about 14 billion years ago.

The CMB surrounds us but is slightly stronger from some directions than others — some call it "lumpy" or "anisotropic." That's important because even faintly apparent clumps of matter back then could serve as centers of gravitational attraction that eventually would coalesce into clusters of galaxies and stars. "They are sort of the seeds of structure in the universe," Pober said. Pober got right to work on helping develop ways to find more and finer detail of these variances in the CMB signal. The smaller the details astronomers seek, the better they must become at filtering out all the other signals in the foreground that might interfere and blur the picture.

After graduation in 2007, Pober went to the University of Cambridge for a year to continue his studies and to earn a master's degree in physics. From there he went to the University of California–Berkeley, where he earned a second masters and his Ph.D. in astronomy.

At Berkeley, Pober found the wavelength he's been tuned to ever since: the signature radio wave emitted by plain old, neutral hydrogen, the most abundant and simplest element. While the CMB reveals a single moment in time, tracking hydrogen's radiation allows astronomers to look at a range of times in the history of the universe. The wavelength emitted by hydrogen is 21 centimeters, but because the universe has been expanding since the Big Bang, that wavelength appears to us to be proportionally shifted longer and



longer the farther away and therefore older the hydrogen is. So if Pober wants to see what the distribution of hydrogen looked like, say, 500 million years after the Big Bang, he can look for hydrogen whose wavelength has been shifted to about two meters. Tuning to a different wavelength would give him a glimpse at hydrogen of a different vintage.

So while the CMB provides a snapshot, 21 cm hydrogen provides more of a movie of the universe's evolution since.

> "Understanding how we get the diversity of galaxies and structure we see in the universe today is something we are looking to do."

The trick remains, however, developing the instrumentation and analytical methods to filter out all the noise and interference in the foreground that could intervene.

Since finishing at Berkeley in 2013, Pober was a post-doc at the University of Washington. Coming to Brown provides him the chance to strike a happy balance between his research and teaching interests. "I'm really excited to be at a place where undergraduates are spending time with professors," he said.

Excerpted from article by David Orenstein, Brown News Service

LUX Celebrates 300 Live Days

Amid streamers, a piñata and paper unicorns, LUX researchers celebrated the 300-live-day run of their dark matter detector. "I would describe the mood as exciting, joyous and electric," said Mark Hanhardt, Sanford Lab support scientist. Why unicorns? For LUX researchers, they symbolize the search for the elusive WIMP, or weakly interacting massive particle, the leading contender in the dark matter search.

LUX consists of one third-of-a-ton of liquid xenon inside a titanium vessel. Researchers hope to identify the very rare occasions when a dark matter particle collides with a xenon atom inside the detector. When that happens, the xenon atom will recoil and emit a tiny ash of light, which will be detected by sensitive light detectors.

In October 2013, after a 90-live-day run, LUX announced it was the most sensitive dark matter detector in the world. "LUX was so much larger than existing detectors that within a few weeks of starting its first run in 2013, it had surpassed all previous direct detection experiments," said Richard Gaitskell, co-spokesperson for LUX.

A reanalysis of the 2013 data, released by LUX in December, discussed new calibration techniques that allowed for even greater sensitivity. Those techniques, which included the use of tritiated methane, krypton-83 and a neutron generator, were used in the most recent run; however, results will not be available before the end of 2016.

The 300-day run began in November 2014 and the detector has been in WIMP search mode or calibration mode since. But it has not been without its challenges, Gaitskell said. "During any dark matter search, we must ensure the detector is taking data in a completely stable mode in which the operating conditions are clearly understood," he said. "This means we monitor the detector health continually and occasionally we have to react to any apparent issues that have developed."

At regular intervals throughout the new run, calibrations were carried out for two weeks every four months to ensure a high level of accuracy in measuring responses to backgrounds and potential dark matter signals, he added. After 19 months, the run officially ended on May 2 at 1 p.m. "That's a long time to operate a detector without a significant break," said Simon Fiorucci, LUX science operations manager. "But it was critical to demonstrate our ability to do so as we prepare to run LZ for more than three years."

Later this year, LUX will be decommissioned to make way for a new, much larger xenon detector, known as LUX-ZEPLIN, or LZ. This second- generation dark matter detector will have a 10-ton liquid xenon target and be up to 100 times more sensitive. "The tremendous success of LUX paved the way for LZ," said Murdock Gilchriese, LBNL (Lawrence Berkeley National Laboratory) operations manager for LUX and LZ project director. LZ will be located inside the same 72,000-gallon water tank that currently shields LUX.

"Sanford Lab will continue to play a global role in the search for dark matter," said Jaret Heise, science director at Sanford Lab. "We're looking forward to working with the expanded collaboration, which will include 31 institutions and about 200 scientists."

In the meantime, LUX researchers are continuing their work, including testing several new calibration techniques that will be used in LZ. The team has come a long way and made significant progress. "We are all proud to have made it this far," Fiorucci said.

Reprinted with permission from Constance Walter, Sanford Underground Research Facility

"LUX was so much larger than existing detectors that within a few weeks of starting its first run in 2013, it had surpassed all previous direct detection experiments."

Statistical Technique to Enhance Accuracy of Climate Models

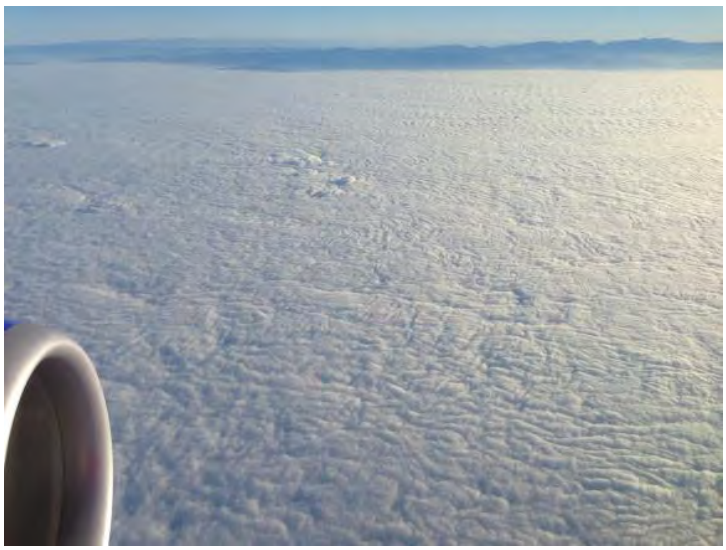
A team of physicists and mathematicians has come up with a statistical technique that puts the fine details back into computer simulations of large-scale phenomena like air circulation in the atmosphere and currents in the ocean. Computer models are generally good at capturing the big picture, but they are often forced to ignore things that happen at small scales. For example, models of a planet's atmosphere capture the large-scale dynamics of jets and airflows, but they don't include small-scale dynamics created by things like clouds and localized turbulence, despite the fact that those dynamics can often influence the larger scales. "There are simply too many numbers for the computer to simulate it at a reasonable speed," said Professor Brad Marston. "It might take years to simulate a day of the atmosphere, which wouldn't be good."

The traditional approach to dealing with the problem is to simply lop the small scales off of the simulation. A few ad hoc ways of putting some of that information back in exist, but they tend not to be mathematically rigorous. "These schemes have always suffered from the criticism that they lack predictive power," Marston said. "You have to make a lot of decisions that you really shouldn't have to make but you're forced to make."

In a paper published in the journal Physical Review Letters, Marston and his colleagues show a method of averaging out those small-scale dynamics in a way that is computationally tractable, which allows those dynamics to be simulated and their effects to be captured in a rigorous way. "We're retaining the degrees of freedom at the small scale, but treating them in a different way," Marston said. "We don't have to simulate all the little swirls, so to speak. We treat them by using their averages and the sizes of their fluctuations. It allows us to capture the contributions of these small-scale dynamics that would normally not be included."

In their paper, the researchers used the technique to model air jets forming on a round surface. They showed that the method produces results similar to brute-force numerical simulations of the same jets. There have been prior attempts to treat small-scale disturbances statistically, Marston said, but those haven't fared very well. Prior attempts have treated disturbances as being homogeneous and assumed they were not traveling in any one particular direction. "But that almost never happens in nature," Marston said. "Turbulence almost always has some directionality to it. That directionality is what makes these kinds of approximations work. It makes these approximations tenable."

The researchers hope that the method might make for more accurate simulations of a wide variety of natural phenomena, from how the churning interiors of planets create magnetic fields to



how air flows across the surfaces of cars or airplanes. The method could be particularly useful in modeling Earth's changing climate because the technique can more rigorously capture the influence of cloud formation.

The method could be particularly useful in modeling Earth's changing climate because the technique can more rigorously capture the influence of cloud formation.

"Cloud formation is seen as the largest source of uncertainty in climate models right now," Marston said. "There are famous examples where different climate models that have different ways of dealing with the clouds give you qualitatively different results. In a warming world, one model might produce more clouds and another might produce fewer."

By averaging those cloud dynamics and then simulating them in the models, it might be possible to reduce some of that uncertainty, Marston said. The team has already started working to incorporate the method in climate simulations, as well as simulations of ocean currents and problems in astrophysics dealing with the behavior of plasmas. "There are a whole bunch of problems out there where we feel this could be helpful," Marston said.

Excerpted from article by Kevin Stacey, Brown News Service

New Courses

PHYS 1970F – Quantum Information

Timothy Raben, PhD'16, recipient of a 2015 Deans' Faculty Fellowship, which appointed him as a visiting assistant professor for the Spring 2016 term, designed this course. Quantum information is the modern study of how to encode and transmit information on the quantum scale--in many ways fundamentally different from classical information. The course connects a standard treatment of quantum mechanics with information theory. Some topics overlap with PHYS1410, but information will be presented from a different viewpoint and with new applications. Topics include measurement, quantum states, bits, density of states, entanglement, quantum information processing, computing, and some special topics. An end of term project is required for successful completion of the course.

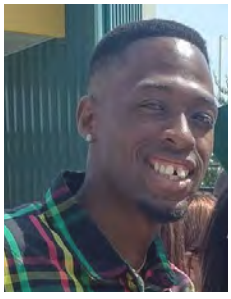
PHYS 2610G – Special Topics in Particle Physics: The Standard Model and Beyond

Designed by Professor Jiji Fan, the course explains the theoretical basics of the Standard Model and some of the experimental evidence that has established it. It examines how recent data from the Large Hadron Collider has established the existence of the Higgs boson, as well as the theoretical implications of this discovery, which is used to synthesize many ideas learned in the course. The course also addresses some candidate theories beyond the Standard Model including supersymmetry and dark matter models.

Staff

Barbara Cole joined the Physics Department as our primary financial coordinator. Barbara, who graduated magna cum laude from Stonehill College with a bachelor's degree in social science, brought with her a wealth of experience from her time in the Advancement Office of Wheaton College and as a financial manager at Verizon.

Communications Coordinator Jessica Pontarelli manages our website and social media, and provides technical support and graphic design services for the Physics Department. Jessica completed a bachelor's degree in communications from Rhode Island College and earned a graduate certificate in graphic design from Rhode Island School of Design. Her experience includes supervision of a design and production department and teaching in the Rhode Island School of Design's continuing education program.



Antonio Taylor, our newest staff member, has a bachelor's degree in sociology from San Francisco State University and a master's degree in higher education and student affairs from the University of San Francisco. In addition to a variety of administrative responsibilities, he manages all activities related to undergraduate student affairs. While earning his degrees, Antonio amassed extensive experience as a counselor and tutor.

Staff members Kathy Brobisky and Jean Miller at the Annual Physics Spring Picnic

Conferences

Annual New England String Meeting

The Physics Department's high energy theory group hosted the seventh New England String Meeting on November 6, 2015. These quasi-regular meetings serve the regional theoretical physics community and have been held at Brown since 2006. The meetings consistently attract around 75 participants for a day of enjoyable and informative lectures.

This year's meeting featured talks by Thomas Hartman (Cornell), Daniel Jafferis (Harvard), Igor Klebanov (Princeton), Gregory Moore (Rutgers), David Poland (Yale), and Cumrun Vafa (Harvard) on a variety of topics from the fractional quantum hall effect to conformal field theories with higher spin symmetries.

Support for the meeting was provided by Professor Anastasia Volovich's Simons Investigator Award.

http://www.het.brown.edu/~strings/

14 Workshop on Non-Perturbative Quantum Chromodynamics

The 14th Workshop on Non-Perturbative Quantum Chromodynamics, June 13-16, 2016, co-directed by Professors Herb Fried and Chung-I Tan along with Duke University's Berndt Mueller, was held at the Institute for Astrophysics of Paris, France, As in the past, the emphasis continued to be on current research activities relating to aspects of non-perturbative Quantum Field Theories relating to QCD. Each participant was provided with ample time to present and discuss his/her current research projects and their future promise.

During the four-day workshop, highlights included strong dynamics for addressing beyond the Standard Model via conformal limit and potential lattice approach. Various modern approaches to holography were discussed. Another key area of focus was on integrability and quantum spectral curves, an approach that led to a deeper understanding of high energy scattering via string/guage duality. In addition, talks were also presented on future LHC physics relevant to non-perturbative QCD. A specific focus was on LHC experiments in the gluon-rich region, with glueball and other non-standard particle production.

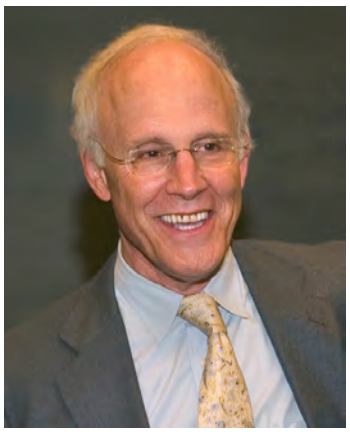
7th International Workshop on Materials Analysis & Processing in Magnetic Fields

Organized by Professor Jim Valles and Noriyuki Hirota (National Institute for Materials Science, Tsukuba, JAPAN) with the assistance of Mary Ann Rotondo, the four-day workshop was the seventh in a series that focuses on the use of magnetic fields in the processing, probing and manipulation of materials. The 35 researchers, who came from seven different countries, described a very interdisciplinary body of work.

The presentations touched on a wide range of materials from the very soft, like biomatter, to the very hard, like ceramics, and on a plethora of goals like creating more ordered structures or probing phase transitions. They included descriptions of novel modalities for industrial waste remediation and some of the most advanced magnetic field based techniques for elucidating the microscopic properties of matter. Some specific highlights: Chinedum Osuji (Yale) showed how his group was controlling the alignment of nanopores that grow in soft materials for the development of advanced filters. Peter Christianen (Nijmegen, The Netherlands) described a proof of principle for a novel drug delivery concept using magnetic fields to actuate the release of nano-particles from polymer "nano-stomachs". Jun Wang (NPU China) presented on experiments probing a liquid-liquid structure transition using magnetization that he performed in collaboration with Eric Beaugnon (Grenoble, France). Richard Hill (Nottingham, UK) has levitated droplets for fundamental studies of spinning induced fragmentation. Katherine Mirica (Dartmouth) has developed table top magnetic levitation to a high art for a range of chemical and physical assays. Noriyuki Hirota described his group's state of the art advances in in situ imaging of magnetic field effects on materials and processes.

The workshop also showed off Rhode Island. The sunny and clear weather set the stage for a fantastic conference excursion to Beavertail and Newport. The follow-up New England Clambake on the Main Green in front of University Hall introduced participants to some of our finest fare!

Arthur O. Williams Lecture



David Gross, Chancellor's Chair Professor of Theoretical Physics and former Director of the Kavli Institute for Theoretical Physics at UCSB, delivered the 2016 Arthur O. Williams Lecture. A central figure in particle physics and string theory, Dr. Gross's discovery, with his student Frank Wilczek, of asymptotic freedom—the primary feature of non-Abelian gauge theories—led them to the formulation of Quantum Chromodynamics, the theory of the strong nuclear force. This completed the Standard Model, which details the three basic forces of particle physics--the electromagnetic force, the weak force, and the strong force. Dr. Gross was awarded the 2004 Nobel Prize in Physics, with David Politzer and Frank Wilczek, for this discovery. He has also made seminal contributions to the theory of Superstrings, a burgeoning enterprise that brings gravity into the quantum framework.

In addition to the Nobel Prize, Dr. Gross's awards include the Sakurai Prize, MacArthur Prize, Dirac Medal, Oscar Klein Medal, Harvey Prize, the EPS Particle Physics Prize, the Grande Medaille d'Or and the Nobel Prize in Physics in 2004. He holds honorary degrees from universities in the US, Britain, France, Israel, Brazil, Belgium and China. He is a member of the US National Academy of Science, the American Academy of Arts and Sciences, the American Philosophical Society, the Indian Academy of Science and the Chinese Academy of Science.

He received his Ph.D. in 1966 at UC Berkeley and was previously Thomas Jones Professor of Mathematical Physics at Princeton University.

Celebration of Service

Incoming chair Gang Xiao (right) addresses the department as he presents a gift to outgoing chair Jim Valles (left).

Physics Art Show

This year's well-attended art show featured a wide array of visual and interactive art by faculty, post-docs, staff and students. Creativity and imagination abounded in the annual exhibition that included ceramics, photographs, drawings and installations.

The performance component of the show highlighted physics concentrators Ricky Oliver '17 and Eliott Rosenberg '17 who performed a movement from Handel's Concerto in G minor (arranged for piano and trumpet).

Ricky Oliver and Eliott Rosenberg

Maria Eleni Moustaka

Josh Kerrigan

Prerit Jaiswal

Degree Day

The Department of Physics hosted a well-attended Degree Day program on Saturday, April 30. Twenty alumni returned to campus on a beautiful spring day to network with students and engage in conversations on a variety of topics. Professor Bob Pelcovits facilitated an alumni panel discussion that explored the many different directions one can successfully follow after earning a degree in physics. The five panelists represented a range of pursuits including the professoriate, environmental policy, biomedical research and nuclear détente. Samantha Dallas '16 introduced the second panel, which consisted of three PhD candidates, Samuel Chan, Brian Kilpatrick and Jacqueline McCleary, and two undergraduates, Amy Butcher '17 and Jahmour Givans '16. Moderated by Professor Meenakshi Narain, the panelists engaged in a lively discussion with audience members about issues of diversity and inclusion.

The afternoon ended with a presentation about the search for dark matter by Professor Rick Gaitskell, and was followed by a cocktail hour and dinner at the Faculty Club.

Left to Right: Professor Bob Pelcovits (standing), Hossein Khiabanian, PhD'07, Mirna Mihovilovic Skanata, PhD'14, Shawna Hollen, PhD'12, Nick Hagerty, ScB'10, Charles Powell, ScB'13

Ladd Observatory

Photo by Tracy Prell

For the past five years, the Ladd Observatory has collaborated with the Providence Children's Museum. During the summer of 2015, programming was expanded to complement a major exhibit called My Sky to teach children about the moon and stars. The programs involved portable telescopes on the sidewalk as well as indoor science programs. Undergraduate students from the Department of Physics and the Brown CubeSat Team presented many of the programs. In recognition of service to the community, the Museum presented an Excellence Award to Professor Ian Dell'Antonio and Ladd Observatory's curator, Michael Umbricht, at the Museum's annual meeting this spring.

Ladd continues to offer a broad range of academic enrichment programs for classes at Brown, RISD, Bryant, the Tougaloo College Partnership, and other institutions. Programming includes tours of the building and demonstrations using Ladd's historic scientific instrument collection. Ladd also provides resources for students who are working on special projects, including a student who did a senior thesis in Science and Technology Studies at Brown and an architecture student at RISD.

The public open nights continue to increase in popularity, and many regular visitors return to learn about the sky from Ladd's staff and the students who assist. One notable event was the observations of the transit of Mercury on May 9th. Portable solar telescopes on the lawn provided a safe view of the planet passing in front of the sun.

In October of 2016, the Observatory will celebrate 125 years of astronomy and public science education. A new blog has been created to document the rich history of science at Brown University. It describes the scientific work and Ladd's engagement with the community to enhance the public understanding of science. http://blogs.brown.edu/ladd/category/history/

A variety of special programs and exhibits were designed to complement the blog. In February, Professor Dell'Antonio and Michael Umbricht presented the astrophysics and history of Nova Persei 1901 at the John Hay Library along with Holly Snyder, Curator of the history of science collection. They offered a demonstration of the Brashear astronomical spectroscope alongside Prof. Winslow Upton's notebooks describing his observations of the nova of 1901. The Observatory loaned a telegraph clock dial to the Providence Public Library for an exhibit on time called Portals. Observatory Astronomer Francine Jackson and Michael Umbricht presented programs on the timekeeping service that Ladd provided to the community starting in the 1890s. The anniversary programs will continue through the summer and conclude with an exhibit at the Brown Library and a variety of lectures and demonstrations in the fall.

Article by Michael Umbricht, Department of Physics

Warren Galkin (far right), Class of '51

Professor Sean Ling, Alex Meehan '15, and Abigail Plummer '15 at the Presidential Palace of the Republic of China, Nanjing, China.

Li Wie Liu, PhD'16, making ice cream at the Spring Picnic

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