



What's Inside

Undergraduates	2-3
Class of 2015	
UTRA students	
Undergraduate Awards	
University Awards	
WISE	
Rhodes Scholar	
DUG	
Graduate Students	4-7
Awards	
Master of Science Graduates	
PhD Graduates	
Physics Merit Fellowship	
Galkin Foundation Fellowship	
Deans' Faculty Fellowship	
Exploring Galaxies Far, Far Away	
Faculty Awards and Promotions	8
Philip J. Bray Teaching Award	
Savvas Koushiappas	
Jay Tang	
Faculty Research	9-15
Gamma rays from newly discovered dwarf galaxy	
Gold intensifies cancer-killing radiation	
LHC Restart	
Influence of feedback loops on ecosystems	
New evidence for exotic super conducting state	
DNA 'cage' could improve nanopore technology	
Paramecia need Newton for navigation	
Ladd Observatory	16
New Courses	17
Squishy Physics	
Physics for Non-physicists	
Computational Physics	
Events	17-20
A. O. Williams Lecture	
Houghton Conference	
Guralnik Symposium	
B&H 50 years	
Art Show	
John Hay Reading Room Dedication	

Greetings from the Chair

Welcome to the annual Physics Department newsletter! The 2014-15 academic year was interesting and rewarding in many ways. Physics at Brown is notable for the breadth of its program and the exciting research occurring in the department, which you can read about in the following pages. Efforts to secure research dollars paid off; faculty members were awarded nearly \$5M of research funds over the past year. Our cadre of PhD students is growing, and we will have over 30 candidates in our master's program this fall.

I am delighted to announce that we hired two new faculty members. JiJi Fan and Jonathan Pober will join us in the coming academic year as tenure-track assistant professors. JiJi, who earned her PhD in Theoretical Physics from Yale, works on proposing new high energy physics models with unexplored or less explored signatures, extracting the maximal information from current experiments, mapping out allowed parameter spaces of existing theories and perceiving unexplored regions in parameter space. Jonathan comes to us from the University of Washington. His research in observational cosmology currently focuses on imaging the hydrogen 21 cm line emission from the early universe. Jonathan holds a PhD from Berkeley.

We are particularly proud of the Class of 2015. Nearly half of this year's class, which included a Rhodes Scholar, graduated magna cum laude. Five of our PhD students were recognized for excellence as graduate teaching assistants and another five received honorable mention for their efforts.

Gifts from alumni and former colleagues help us to bring speakers to campus on a regular basis. We invite visitors every week during the academic year to give seminars, speak to journal clubs and present colloquia. In May, we had the pleasure of hosting a very successful Tony and

Pat Houghton Conference on Non-Equilibrium Statistical Mechanics. The two-day conference, organized by Professors Dima Feldman and Brad Marston, featured 17 speakers from around the world. The distinguished Rolf-Dieter Heuer, Director General of CERN since 2009, delivered the annual Arthur O. Williams Lecture.

Our historic Ladd Observatory continues its dynamic outreach programming. In order to provide some ongoing support for Ladd, the University sold property on Jerimoth Hill, the highest natural point in Rhode Island and a site of the university's astronomy program for stargazing away from city lights. We were also fortunate to receive a gift from an anonymous donor to partially underwrite the costs of programs and staffing during the coming year. On the National Register of Historic Places, Ladd is known internationally as a rare jewel of an observatory and houses an exceptional collection of antique instruments. We are grateful for the support to sustain this unique facility.

On June 4, we celebrated the 50th anniversary of the dedication of Barus & Holley. Spaces in the building will continue to change to adapt to the evolving needs of our expanding research programs. Construction of a new engineering research facility that will connect to Barus & Holley is underway and a new Applied Mathematics building, sited in our former parking lot on the corner of Hope and George Streets, will be completed this fall.

I look forward with enthusiasm to the coming year and hope to hear from some of you about your accomplishments and activities. You are always welcome to visit us!



Jim
James M. Valles, Jr.

Undergraduates

2015 Undergraduate Degree Recipients



Class of 2015

Christopher R. Bonadonna
Jeffrey D. Commons
Benjamin K. Chowdhury
Daniel J. DeCiccio
Nicholas M. Ebisu
Layne B. Frechette
Max J. Genecov
Nathan A. Johnson
Hannah R. Kolus
Abishek K. Kulshreshtha
Tae-Gone Lee
Alexander Meehan
Alexander G. Moskowitz
Jose F. Muci Lander
Richard A. Nally
Hojin Park
Daniel E. Parker
Andreas C. Pavlou
Sean N. Pike
Abigail Plummer
James B. Rattner
John S. Ribbans
Danielle D. Rothermel
Robert P. Schenck
Adam M. Scherlis
Jacob A. Seib
William T. Stephenson
Scott J. Underriner

2014 UTRA Students

Dominic Adams (*Mitrovic*)
Christopher Bonadonna (*Dell'Antonio*)
Nicholas Bower (*Stein*)
Samantha Dallas (*Dell'Antonio*)
Ellen Goldberg (*Stein*)
Evan Harris (*Dell'Antonio*)
Richard Nally (*Tan/Narain*)
Daniel Parker (*Volovich*)
Mansheej Paul (*Gaitskell*)
Adam Scherlis (*Spradlin*)
Devon Seymour (*Dell'Antonio*)
Sha Sha (*Tang*)
Charles Snider (*Cutts*)
Nathaniel Tarshish (*Koushiappas*)
Edward Williams (*Tucker*)

The UTRA program provides opportunities for collaboration between students and faculty and allows students to gain insights into the structure of academic work in a particular field.

Undergraduate Awards

R. BRUCE LINDSAY PRIZE
FOR EXCELLENCE IN PHYSICS

Richard Nally (*Tan/Narain*)
Dan Parker (*Volovich*)
Abigail Plummer (*Marston*)

MILDRED WIDGOFF PRIZE
FOR EXCELLENCE IN THESIS
PREPARATION

Hojin Park (*Jevicki*)
Adam Scherlis (*Spradlin*)

University Awards

ALFRED H. JOSLIN AWARD FOR
SIGNIFICANT CONTRIBUTION
TO THE QUALITY OF STUDENT
LIFE AT BROWN

Abishek Kulshreshtha (*Feldman*)

DISTINGUISHED SENIOR
THESIS PRIZE

Abigail Plummer (*Marston*)

Physics WiSE

Physics WiSE is the physics branch of the Women in Science and Engineering organization. The organization welcomes all genders, seeking to strengthen a supportive community within the Department of Physics (and the sciences in general). Their events, such as conversation groups, lunches with professors/alumni, and panel discussions create forums for constructive discourse about gender in the sciences, and strengthen relationships among students and faculty.

Their goal is to expand and inspire new generations of scientists with an outreach program, giving presentations at local

“Their goal is to expand and inspire new generations of scientists...”

schools about physics, astronomy, engineering, etc., in collaboration with other campus groups such as the Society of Women Engineers and CubeSat.

Physics WiSE organized multiple events during the 2014-2015 academic year. The group kicked off the year with a lunch and discussion with visiting alumnae, Juliet Blau Jenkins '85 and Janice Huxley Jens '84, who provided insight about careers in the physical sciences, and what role gender plays in the sciences, at university and in the workplace. At the end of the fall semester, WiSE hosted a social event that involved turning notes and problem sets into snowflakes that were hung up around the building. Over snacks and cocoa, the group engaged in conversation about classes and conflicts, and allowed members to get to know each other in a fun environment.

The spring semester began with an informal general body meeting to solicit ideas from members about events they would find most engaging and helpful. The discussion included some of the frustrations facing students, especially women and other underrepresented groups, studying physics at Brown. The meeting generated numerous ideas for social events and course-related support. As a result, the group hosted a study break for students to play board games, organized a Toastmasters public speaking workshop, and arranged lunches with physics faculty who are women. Conversations with Professors **Vesna Mitrovic**, **Meenakshi Narain** and **Anastasia Volovich** gave students the opportunity to ask questions, discuss the role of gender in physics careers and academia, and get advice in an informal setting.

Department Undergraduate Group (DUG)

Over the past year, the Physics DUG expanded and revamped their programming. At the beginning of the year, the group started a new, larger listserv and created a mentoring program between first-year students and older students, which they will expand in the fall.

Among the enjoyable events organized by the DUG included lunches, a movie screening and a Halloween pumpkin-carving activity, where people relieved midterm stress by chopping physics-themed images into pumpkins. The group also hosted a successful “How to Study for the Physics GRE” seminar, and they continue to gather advice from concentrators to provide to the incoming physics first-years in the fall. The DUG was especially glad to have opportunities to partner with the renewed Physics WiSE group this year and look forward to continuing the collaboration next year as well.

Rhodes Scholarship Recipient

Abi Kulshreshtha '15, a double concentrator in physics and economics, received one of this year's 32 Rhodes Scholarships, a highly selective honor that allows recipients to study for two or three years at Oxford.

Kulshreshtha said he appreciates the connections between the two disciplines. “Physics studies modeling the physical world, and economics studies modeling human behavior (and) the way we interact with scarce resources,” said Kulshreshtha, who will pursue a doctorate in theoretical physics at Oxford.

“The thing that excites me most is I'll get to interact with people on a regular basis who are studying a variety of other subjects,” he said. “The most important thing for me is that I make sure to apply my background in science and policy to larger problems that we see in our nation here. So I'm hoping that interaction with Rhodes scholars and education at Oxford will help me fulfill those goals.”

Graduate Students

Graduate Student Awards

BEYER AWARD FOR EXCELLENCE IN SCHOLARSHIP AND SERVICE

Alex Loosley (*Tang*)

ANTHONY HOUGHTON AWARD FOR EXCELLENCE IN SCHOLARSHIP AND SERVICE

John Golden (*Spradlin*)

Wanming Qi (*Marston*)

FORREST AWARD FOR EXCELLENT WORK RELATED TO EXPERIMENTAL APPARATUS

Qiang Hao (*Xiao*)

AWARD OF EXCELLENCE AS A GRADUATE TEACHING ASSISTANT

Rohitvarma Basavaraju

Jordan Bell

Joshua Kerrigan

Martin Kwok

Hyoun Ju Sohn

Honorable Mention:

Altan Allawalla

George Araujo

Matthew Huang

Wang Miao

William Taylor

SIGMA XI AWARD FOR EXCELLENCE IN RESEARCH IN PHYSICS

John Golden (*Spradlin*)

DISSERTATION FELLOWSHIP 2014-15

James Verbus (*Gaitskell*)

Lu Lu (*Mitrovic*)

The Physics Department recognizes

Jacqueline McCleary for her commitment to excellence in teaching through her association with the Sheridan Center as the department's Graduate Student Liaison.

Master of Science



Left to Right: **Maximilian King**, Master of Science, Master's Program; **Rizki Syarif**, Master of Science, Doctoral Program; **Jordan W. Bell**, Master of Science, Doctoral Program

Doctor of Philosophy



2015 PhD Recipients

Andrew S. Blaeser (*Nurmikko*)
Zeynep Demiragli (*Landsberg*)
John K. Golden (*Spradlin*)
Mingming Jiang (*Zia*)
Ilyong Jung (*Valles*)

Dongfang Li (*Zia*)
Alexander J. Loosley (*Tang*)
Xu Luo (*Ling*)
Angus J. McMullen (*Stein/Tang*)
Wang Miao (*Ling*)

Ryan J. Michney (*Dell'Antonio*)
Wanming Qi (*Marston*)
Tutanon Sinthuprasith (*Landsberg*)
Sheng Xie (*Pelcovits*)
LiChao Yu (*Ling*)

2014 – 2015 Physics Merit Fellowship Recipient: Angus McMullen

This year's Physics Merit Fellowship recipient, **Angus McMullen PhD'15**, studied the translocations of stiff filamentous viruses through solid-state nanopores. Solid-state nanopores are an important class of biosensor that can detect the presence of large biological molecules such as DNA. When a large biomolecule inserts inside the nanopore, it causes a corresponding blockage in the nanopore's ionic conductance. Applications of nanopores are varied and include the detection of DNA binding proteins, the convenient sizing of large segments of DNA, and the sequencing of DNA. Understanding is lacking in some fundamental areas of polymer translocation. For example, the translocation speed of a polymer still cannot be predicted. Angus's project, led by Professors **Jay Tang** and **Derek Stein**, used stiff filamentous viruses with variable properties to probe the physics of polymer translocation. Stiff filamentous viruses, like *fd* virus, are long, thin rod-like viruses that infect bacteria. Different viruses can have dif-

ferent properties — like stiffness or charge — that can be varied to probe the translocation process.

Experimental measurements of virus translocations were combined with simulations performed by Professor Hendrick de Haan at the University of Ontario Institute of Technology. Surprisingly, they found that the fluctuations in translocation speed of filamentous viruses increase with the applied voltage. This phenomenon was due in part to a dependence of the nanopore's pulling force on the axial position of the virus. They also compared experimental measurements of two filamentous viruses with different charge densities. Their results showed evidence of a molecular drag on counterions near the highly charged polyelectrolyte — a phenomenon recently observed in molecular dynamics simulations. This work helps to elucidate the physics behind a polymer's translocation speed.

2014 – 2015 Galkin Fellow: John Golden

Scattering Amplitudes are functions that describe what happens when subatomic particles, such as electrons and photons, interact. Starting in the 1940's, techniques for calculating scattering amplitudes were developed by Richard Feynman and others. In particular, the famous Feynman diagrams and Feynman rules effectively indicate how to calculate any amplitude one could ever want. The problem is that these calculations are enormously complicated, with even simple processes relevant to the LHC requiring supercomputers to calculate. However, something surprising keeps happening whenever physicists do these difficult and complicated Feynman calculations: the answers are remarkably simple. Over the last thirty years, physicists have studied these functions in the hope of finding simpler ways to calculate them.

John Golden PhD'15 and his collaborators, which included his advisor, Professor Marcus Spradlin, and Professor Anastasia Volovich, investigated some of these functions to try to uncover any underlying structure that might reveal more about the physics of scattering amplitudes. The amplitudes they worked with contain a class of functions known as polylogarithms, which have been studied by mathematicians for centuries. They were fortunate to collaborate with Yale's Alexander Goncharov who is one of the world's foremost experts on polylogarithms. His deep mathematical expertise, combined with new results and tools from physics, formed the core of the collaboration and led to some surprising results.

A basic problem is that polylogarithms are complex functions that satisfy many different identities, so there are many different ways of writing down the same thing. The group employed many mathematical tools to simplify the functions and were able to take expressions that were many pages long and reduce them to a single line. These simplifications required a lot of computational power, intuition, and time. The simplification was important not only because simpler is better, but also because the simple representations revealed structure that was originally hidden.

The core discovery in Golden's dissertation was that certain scattering amplitudes contain cluster algebraic structure. Cluster algebras are a relatively new area of mathematics, having been discovered in 2001. They have attracted a lot of attention in mathematics literature and are increasingly understood to play an important role in physics. Golden and his collaborators discovered that cluster algebras, which can be thought of as collections of special variables that have interesting relationships, are intimately connected to the polylogarithms they studied. Furthermore, the scattering amplitudes they examined could be "built" out of polylogarithms that depended on cluster algebras. This means that the complicated physics of scattering amplitudes is constrained by the relatively simple math of cluster algebras.



John Golden PhD'15

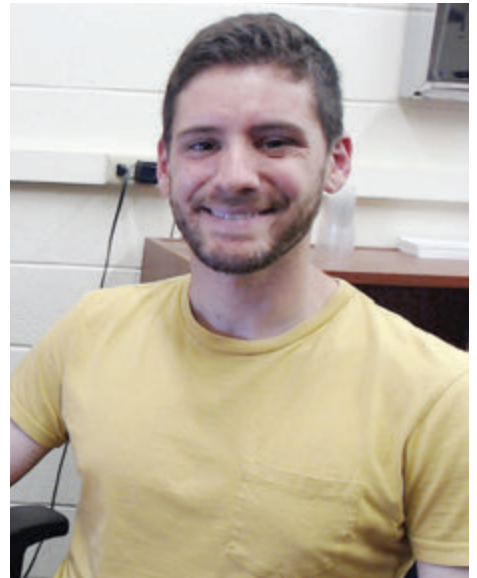
There is still much work left to do on this project. For example, the precise rules that govern how the cluster algebras group together to form amplitudes are not yet understood. More importantly, the story works only for a very special collection of amplitudes, and it is not yet known how to generalize the picture. However, the early results are very promising, and may point the way to a fundamentally new formulation of quantum field theory.

The early results are very promising, and may point the way to a fundamentally new formulation of quantum field theory.

Deans' Faculty Fellowship Recipient: Timothy Raben

Timothy Raben, a fifth year graduate student, is one of ten doctoral candidates at Brown to receive a Deans' Faculty Fellowship. Eligibility for the award requires the fifth year applicant 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. The DFFs are offered full fellowship support without any teaching responsibilities during the fall semester. In the spring semester, those who meet the thesis deadline are appointed as Visiting Assistant Professors with assignments to teach or co-teach a course in their areas of expertise.

Being able to apply during graduate school to teach a self-designed college course is rare, says Raben. Physics faculty members encouraged him to pursue the opportunity, and he will build on his experience as a TA in Physics, Sheridan Center liaison, and NSF Graduate STEM Fellow in K-12 Education. He sees the completion schedule as corresponding well with his plans to go on the job market for a postdoctoral appointment. "After one or two postdoc positions, I will seek a faculty position and I anticipate the DFF will be of great help," says Raben.



Timothy Raben

Exploring Galaxies Far, Far Away



Jacqueline McCleary

While taking an introductory course in cosmology during her senior year of college with astrophysicist Scott Dodelson, **Jacqueline McCleary** said she was so put off by some of the current theories in cosmology that she sent an email to Dodelson, saying she thought the concept of dark matter had been invented to explain aspects of the universe that scientists did not yet understand.

Dodelson called her and described in depth the evidence showing the existence of dark matter and the reasons why astrophysicists think 95 percent of the universe's mass energy is "dark." That phone call "was a transformative experience for me," McCleary said, adding that it inspired her to pursue cosmology research.

McCleary specifically researches "dark matter substructure in galaxy clusters. "Galaxies tend to be social animals, and they tend to hang

out in very large assemblies called clusters," McCleary said. These clusters are so large that they "bend space-time," and when light travels through the clusters, it bends too. When looking at a single galaxy, the bending effect is very small, but by looking at the distortions across a large number of galaxies, McCleary and other researchers can map the masses and locations of these clusters. "We know that most of the matter from clusters of galaxies is dark," McCleary said.

McCleary said her work aims to test the theory that dark matter clusters grow larger over time rather than starting big and fragmenting. Dark matter clusters are like cake batter, McCleary said. At first, they are very lumpy, but over time they become smooth. In her research, McCleary examines galaxy clusters at various distances from Earth. Because light takes a long time to travel, light emitted from clusters farther from Earth is older than that from closer clusters.

If dark matter does indeed grow larger over time, closer galaxy clusters should be smoother than ones farther away. Through examining photographs of galaxies, McCleary looks "at light to see whether it supports this paradigm," she said.

McCleary uses a telescope located at the Cerro Tololo Inter-American Observatory in La Serena, Chile, to acquire the super clear images she needs to conduct her work. McCleary visited the telescope last October to take photographs of nearby galaxy clusters. "It is a difficult process because if the weather isn't perfect, you have to wait for the sky conditions to be right." That time, she said, "They were right. It was awesome."

Excerpted from article by Isobel Heck, Brown Daily Herald

Faculty Awards and Promotions

Derek Stein receives Philip J. Bray Award for Teaching Excellence



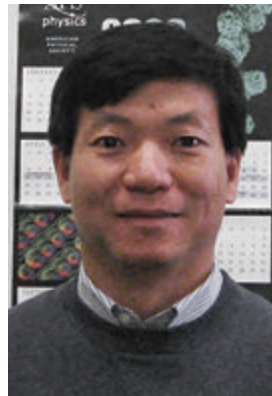
Dean of the Faculty Kevin McLaughlin (left) with Professor Derek Stein (right)

Promotions



Savvas Koushiappas, promoted to Associate Professor effective July 1, 2015, works in the interface between cosmology and particle physics. His work is predominantly in the area of dark matter physics and the search for the nature of the dark matter particle from an experimentally-motivated theoretical perspective. Professor Koushiappas is interested in the effects of the dark matter particle properties (mass, couplings) to the large-scale structure of the universe, the disentanglement of

diffuse high-energy astrophysical backgrounds in the context of dark matter searches, as well as new statistical approaches to a wide variety of problems. He also maintains interests in classical astrophysical problems and has made contributions to the fields of galaxy formation, gravitational lensing and gravitational waves. Prior to his arrival at Brown in 2008, Professor Koushiappas was a postdoctoral researcher in the Theoretical Division at Los Alamos National Laboratory, and before that he was a postdoctoral researcher in the Department of Physics at ETH-Zurich (Swiss Federal Institute of Technology). He received his PhD from The Ohio State University in 2004.



Effective July 1, 2015, **Jay X Tang** was promoted to Full Professor. After receiving his BS from Peking University and PhD of Physics from Brandeis University, Professor Tang completed postdoctoral training at Harvard Medical School. He was an assistant professor of physics at Indiana University for three years before coming to Brown in 2003.

Professor Tang's research area is experimental biophysics. His particular focus is on the self-assembly of protein filaments. The biological questions he addresses include morphology, pattern formation, force generation and motility of cells. He also holds a joint appointment with the School of Engineering.

Gamma Rays from Newly Discovered Dwarf Galaxy May Point to Dark Matter

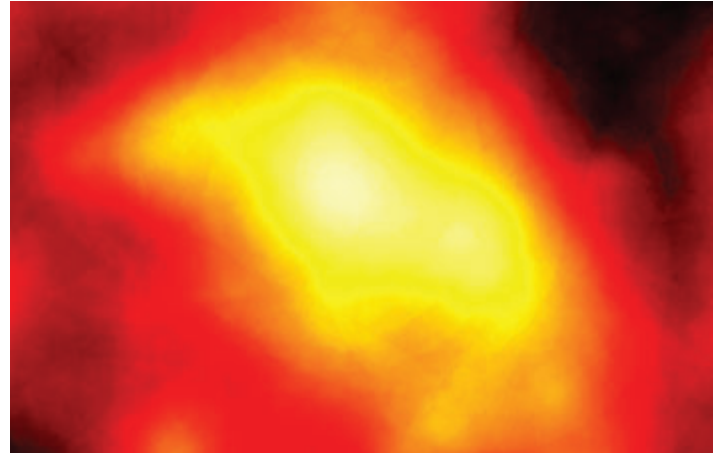
A newly discovered dwarf galaxy orbiting our own Milky Way has offered up a surprise — it appears to be radiating gamma rays, according to an analysis by physicists at Carnegie Mellon, Brown, and Cambridge universities. The exact source of this high-energy light is uncertain at this point, but it just might be a signal of dark matter lurking at the galaxy's center. "Something in the direction of this dwarf galaxy is emitting gamma rays," said **Alex Geringer-Sameth PhD'13**, a postdoctoral research associate in CMU's Department of Physics and the paper's lead author. "There's no conventional reason this galaxy should be giving off gamma rays, so it's potentially a signal for dark matter."

The galaxy, named Reticulum 2, was discovered recently in the data of the Dark Energy Survey, an experiment that maps the southern sky to understand the accelerated expansion of the universe. At approximately 98,000 light-years from Earth, Reticulum 2 is one of the nearest dwarf galaxies yet detected. Using publicly available data from NASA's Fermi Gamma-ray Space Telescope, CMU's Geringer-Sameth and Matthew Walker and Brown's **Savvas Koushiappas** have shown gamma rays coming from the direction of the galaxy in excess of what would be expected from normal background. "In the search for dark matter, gamma rays from a dwarf galaxy have long been considered a very strong signature," said Koushiappas, assistant professor of physics at Brown. "It seems like we may now be detecting such a thing for the first time."

"In the search for dark matter, gamma rays from a dwarf galaxy have long been considered a very strong signature,"

The researchers have submitted their analysis to the journal *Physical Review Letters* and posted it on arXiv. They caution that while these preliminary results are exciting, there is more work to be done to confirm a dark matter origin. "The gravitational detection of dark matter tells you very little about the particle behavior of the dark matter," said Matthew Walker, assistant professor of physics and a member of CMU's McWilliams Center for Cosmology. "But now we may have a non-gravitational detection that shows dark matter behaving like a particle, which is a holy grail of sorts."

A leading theory suggests that dark matter particles are WIMPs — Weakly Interacting Massive Particles. When pairs of WIMPs meet, they annihilate one another, giving off high-energy gamma rays. If that's true, then there should be a lot of gamma rays emanating from places where WIMPs are thought to be plentiful, like the dense centers of galaxies. The trouble is, the high-energy rays also originate



NASA/DOE/Fermi-LAT Collaboration/Geringer-Sameth & Walker/Carnegie Mellon University/Koushiappas/Brown University

from many other sources, including black holes and pulsars, which makes it difficult to untangle a dark matter signal from the background noise.

That's why dwarf galaxies are important in the hunt for the dark matter particle. Dwarfs are thought to lack other gamma-ray-producing sources, so a gamma ray flux from a dwarf galaxy would make a very strong case for dark matter. "They're basically very clean and quiet systems," Koushiappas said.

Scientists have been looking at them for signs of gamma rays for the last several years using NASA's Fermi Gamma-ray Space Telescope. There's never been a convincing signal until now. Over the last few years Geringer-Sameth, Koushiappas, and Walker have been developing an analysis technique that searches for weak signals in the gamma ray data that could be due to dark matter annihilation. With the discovery of Reticulum 2, Geringer-Sameth turned his attention to that part of the sky. He looked at all of the gamma rays coming from the direction of the dwarf galaxy as well as gamma rays coming from adjacent areas of the sky to provide a background level. Further study of this dwarf galaxy's attributes could reveal hidden sources that may be emitting gamma rays, but the researchers are cautiously optimistic.

"The fact that there are gamma rays and also a clump of dark matter in the same direction makes it quite interesting," Walker said.

Excerpted from article by Kevin Stacey, Brown News Service

The team was led by Prof. Koushiappas' former PhD student, Alex Geringer-Sameth PhD'13. Geringer-Sameth's PhD thesis work included the theory behind a novel statistical approach that combines large multiple independent data sets with applications to optimal dark matter searches.

Gold by Special Delivery Intensifies Cancer-Killing Radiation

Researchers from Brown University and the University of Rhode Island have demonstrated a promising new way to increase the effectiveness of radiation in killing cancer cells. The approach involves gold nanoparticles tethered to acid-seeking compounds called pHLIPs. The pHLIPs (pH low-insertion peptides) home in on high acidity of malignant cells, delivering their nanoparticle passengers straight to the cells' doorsteps. The nanoparticles then act as tiny antennas, focusing the energy of radiation in the area directly around the cancer cells.

In a paper published in the *Proceedings of the National Academy of Sciences*, the research team shows that the approach substantially increases the cancer-killing power of radiation in lab tests. "This study was a good proof of concept," said **Michael Antosh PhD'12** assistant professor (research) in Brown's Institute for Brain and Neural Systems and the paper's lead author. "We're encouraged by our initial results and we're excited to take the next step and test this in mice." The team is hopeful that the approach could ultimately improve radiation treatment for cancer patients. By increasing the effectiveness that a given dose of radiation has on cancer, the technique could reduce the overall radiation dose a patient requires, which would in turn reduce side effects. It could also increase the effectiveness of radiation at doses currently administered.

"We're encouraged by our initial results and we're excited to take the next step..."

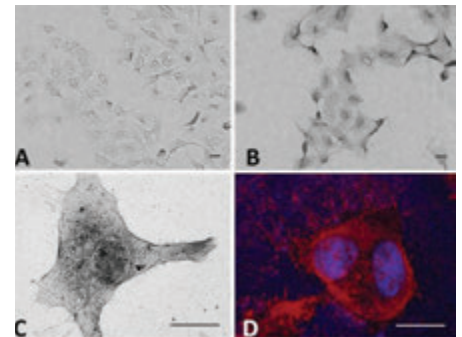
Both theoretical and experimental work had shown that gold nanoparticles could intensify the effect of radiation. The particles absorb up to 100 times more radiation than tissue. Radiation causes the particles to release a stream of electrons into the area around them. If the particles were in close

proximity to cancer cells, that stream of electrons would inflict damage on those cells.

"The idea here was to bring this all together, combining the nanoparticles with the delivery system and then irradiating them to see if it had the desired effect," said **Leon Cooper**, the Thomas J. Watson Sr. Professor of Science at Brown and one of the study's co-authors. Cooper, who shared the Nobel Prize in 1972 for explaining the behavior of electrons in superconductors, has been working for the last several years to better understand biological responses to radiation.

Gold is an especially good choice for amplifying radiation. When matter is hit by radiation at certain energies, electrons are released through a process known as the photoelectric effect. But gold has an additional source of electron emission, known as the Auger effect, that results from the particular arrangement of electrons orbiting gold atoms. It's the effect of the Auger electrons that the researchers were working to maximize. Working out the quantitative details of the process involved complex calculations and simulations, Cooper said.

Auger electrons are low-energy and travel only a very short distance. Their travel distance is so short, in fact, that the electrons may not escape the nanoparticle if the particle is too large. So the researchers had to make sure their particles were small enough to emit those electrons. The short travel distance also means that particles need to be delivered in very close proximity to the cancer cells in order to do damage, hence the need for the pHLIPs. Experiments showed that cancer cells irradiated in the presence of pHLIP-delivered gold had a 24-percent lower survival rate compared to those treated with radiation alone. The pHLIP samples had a 21-percent lower survival compared to irradiation with just gold but no pHLIPs. That suggests that the pHLIPs were effective in getting the gold close enough to the cells to do damage.



Cancer-seeking peptides — pHLIPs — find acidic tumor cells. By attaching gold nanoparticles to pHLIPs, cancer cells receive “antennas” for radiation therapy. Cancer cells (A) treated with gold alone (dark areas) take up far less gold than cells with gold delivered by pHLIPs (B). C and D are cellular close-up with pHLIP-delivered gold.

Images: Reshetnyak and Andreev/URI

The next step, the researchers say, is to test the approach in a rodent model, which the team is planning to do soon. “This work is a great example of successful collaboration between Brown and URI,” Andreev said. “We hope that the results of this research moving forward will lead to clinical application of pHLIP-based nanotechnology.”

Other authors on the study from URI were Dayanjali Wijesinghe, Samama Shrestha, and Natallia Katenka. Other authors from Brown were **Robert Lanou**, Yun Hu Huang, Nicola Neretti, Thomas Hasselbacker, David Fox, and Shouheng Sun. The work was supported by the National Institutes of Health.

Excerpted from article by Kevin Stacey, *Brown News Service*

LHC Restart

The Large Hadron Collider, which restarted in early April, will operate at nearly twice the energy of the previous run. Brown physicists and students will be working at the collider, looking for signs of additional Higgs bosons, heavy top quark cousins, long-lived particles and dark matter. Four Brown physicists, along with several postdoctoral researchers and graduate students, will continue to work at the LHC, which is headquartered in Geneva, Switzerland. Other group members will be connected over the net from Brown or from Fermilab, near Chicago. The Brown group is a member of CMS, one of the two large-scale experiments going on at the LHC.

“It’s a very exciting time because we’re crossing a new energy threshold,” said **Greg Landsberg**, who recently completed a term as physics coordinator for CMS. “We’re hopeful that at these higher energies we’ll see something spectacular in this next run.” The collider’s first run from 2010 to 2013 certainly didn’t lack spectacle. In 2012, the machine detected the elusive Higgs boson, the manifestation of an invisible field that gives some elementary particles their mass. The Higgs was the last missing piece of the standard model of particle physics, but its discovery also suggests that the standard model likely isn’t the end of the story. “Even though it completes the standard model, the Higgs also tells us that something else is out there,” said **Meenakshi Narain**.

In particular, the observed mass of the Higgs creates a sticky theoretical problem. According to theory, the Higgs should gain mass from its interactions with other particles — particularly the top quark, heaviest of the known quarks. At high energies, the Higgs’ interactions with the top quark should make its mass practically infinite. Yet when detected at the LHC, the Higgs tipped the scales at a rather svelte 125 gigaelectron volts (GeV). Explaining the lightweight Higgs in terms of the standard model requires some fancy mathematical footwork — too fancy for many physicists. That has fueled the search for explanations outside the standard model.

Narain and her students will be looking for signs of one such explanation — a heavy partner to the top quark. The heavy partner, if it exists, would counteract the top quark’s contribution to the Higgs’ mass and explain why the particle is so light. This next run may detect the heavy partner or rule it out. Narain, who is leading the LHC Physics Center at Fermilab, played a key role in the discovery of the top quark at the Tevatron collider in 1995. “It would be great if we were to discover its partner almost exactly 20 years later,” she said.

But the top quark partner isn’t the only possible explanation for the lightweight Higgs. Another is supersymmetry — the idea that all standard model particles have shadowy cousins with slightly different properties. Among the predictions made by supersymmetry is that there should be additional Higgs bosons hiding out there. **Ulrich Heintz**, along with a postdoctoral researcher and a student, will be looking for those. “If there were supersymmetry, there would have

to be more Higgs bosons,” Heintz said. “In supersymmetric theories, you end up with five different kinds of Higgs bosons, in the least.” It’s possible, Heintz says, that there’s a heavier Higgs with a mass of 300 GeV that decays into two standard 125 GeV Higgs particles. The higher-energy run should eventually create a few of these heavier Higgs bosons if they exist. “The higher energy gives us an increase in the number of heavy things we can make if they exist,” Heintz said. “That’s the real boost that we’re getting here. We may be able to access particles that were just out of range with the last run.” In addition to the heavy Higgs search, Heintz is also managing an upgrade to the readout electronics of the CMS detector. The upgrade will help the detector deal better with the higher frequency of collisions in the next run.

David Cutts and his graduate student have been looking for another potential manifestation of supersymmetry in the form of so-called long-lived particles. Most particles formed as a result of high-energy collision decay within microseconds. But some theories suggest that there should be heavy particles that survive much longer and travel farther from the site of the collision. “To find some of these long-lived particles would be an unambiguous sign of something new,” Cutts said. “For example, there are varieties of supersymmetry that would give rise to production of a heavy particle that would have a significant lifetime.” Cutts and his student are in the process of recalibrating their search for the next run. Collisions will happen more frequently in the higher-energy regime. Since their search is focused on the space between collisions, they must change their search parameters to account for the fact that collisions happen more frequently.

Landsberg will be looking for yet another particle outside the standard model — a dark matter particle. In particular, Landsberg’s search for dark matter will build on a potential discovery made by **Savvas Koushiappas**, another Brown physicist. Last month, Koushiappas and his colleagues detected a potential gamma ray signal coming from a dwarf galaxy, which could be due to dark matter particles at the galaxy’s center slamming into each other and annihilating into gamma rays and quarks. It might be possible, Landsberg said, to produce the same reaction at the LHC, only in reverse. “Instead of two dark matter particles annihilating to produce quarks, we might be able to take a pair of quarks and annihilate them to produce dark matter particles.”

The collider is scheduled to run nonstop throughout this year until a brief pause in December. The Brown physicists expect many of the questions they and other physicists are looking into will be answered this year. “The next run could be one in which we find all these new particles that send theorists back to the chalkboard to make sense of all of it,” Narain said. “It’s really a great time to be in particle physics.”

Excerpted from article by Kevin Stacey, Brown News Service

Influence of Feedback Loops on Ecosystems



Vegetation beginning to take hold 15 years after the extensive “Manter” fire in California’s Sierra Nevada mountains. The path in the foreground is the Pacific Crest Trail and the mountains beyond are part of the Domeland Wilderness. sky.

Merging physics and environmental science, an interdisciplinary team including **Brad Marston** recently published a paper examining how feedback loops influence ecosystem changes. The paper, published online March 30 in the journal *Trends in Ecology and Evolution*, discusses how feedback loops — cycles that output information that is put back into the starting point — interact in forests and savannas in relation to the alternative stable-state theory. This theory contends that feedback reinforces ecosystems and that the loss of a feedback loop can result in ecosystem change.

“The core of the climate model is all based on physics,” said Marston, professor of physics and co-author of the paper. Climate models depend on temperature, fluid dynamics and radiation, all of which can be modeled using concepts from physics, he said. Another lesson from physics is that “complex systems can react in unexpected ways,” Marston said. The climate is one such complex system.

In the paper, the researchers use forests and savannas as two examples of ecosystems that are maintained by feedback loops, and in which the loss of feedback loops effects change. Forests retain water, reducing the likelihood of fires, increasing nutrients in the soil and thus reinforcing the ecosystem. On the other hand, savannah grasslands are more flammable, increasing the likelihood of fires, decreasing nutrients in the soil and thus reinforcing the ecosystem. “You can reach a tipping point from forest to savannah and it’s hard to get back,” Marston said.

Disruption of these two feedback loops can lead to the destruction of both forest and savannah ecosystems. For example, in forest ecosystems, high rates of tree damage and loss can threaten the feedback loop, raising the risk of deforestation, Marston said. One example of a feedback loop that has led to environmental disruption involves climate change. Climate change involves ecosystems becoming drier and trees releasing more carbon dioxide, which in turn leads to greater climate change, Marston said. The alternative stable-state theory is more generally applicable to the consequences of climate change, Marston said. Deforestation occurred in the past in the Mediterranean and could occur in other places in the future, he said.

In addition to the factors the researchers identified, topography and elevation can also be significant factors in landscape changes, said Steven Archer, professor at the School of Natural Resources at the University of Arizona, who was not involved in the study. In North America, south-facing slopes receive more radiation and are warmer and drier, allowing for more rapid changes in the environment, Archer said.

Marston collaborated with David Bowman, professor of environmental change biology at the University of Tasmania and George Perry, associate professor at the School of Environment at the University of Auckland.

Excerpted from article in Brown Daily Herald by Steven Michael

New Evidence for Exotic Superconducting State

Superconductors and magnetic fields do not usually get along. But a research team led by Professor **Vesna Mitrovic** has produced new evidence for an exotic superconducting state, first predicted a half-century ago, that can indeed arise when a superconductor is exposed to a strong magnetic field. “It took 50 years to show that this phenomenon indeed happens,” said Mitrovic. “We have identified the microscopic nature of this exotic quantum state of matter.” The research was published in *Nature Physics*.

Superconductivity — the ability to conduct electric current without resistance — depends on the formation of electron twosomes known as Cooper pairs (named for **Leon Cooper**, a Brown University physicist who shared the Nobel Prize for identifying the phenomenon). In a normal conductor, electrons rattle around in the structure of the material, which creates resistance. But Cooper pairs move in concert

“The question is what happens when we have more electrons with one spin than the other.”

in a way that keeps them from rattling around, enabling them to travel without resistance. Magnetic fields are the enemy of Cooper pairs. In order to form a pair, electrons must be opposites in a property that physicists refer to as spin. Normally, a superconducting material has a roughly equal number of electrons with each spin, so nearly all electrons have a dance partner. But strong magnetic fields can flip “spin-down” electrons to “spin-up”, making the spin population in the material unequal.

“The question is what happens when we have more electrons with one spin than the other,” Mitrovic said. “What happens with the ones that don’t have pairs? Can we actually form superconducting states that way, and what would that state look like?”

In 1964, physicists predicted that superconductivity could indeed persist in certain kinds of materials amid a magnetic field. The prediction was that the unpaired electrons would gather together in discrete bands or stripes across the superconducting material. Those bands would conduct normally, while the rest of the material would be superconducting. This modulated superconductive state came to be known as the FFLO phase, named for theorists Peter Fulde, Richard Ferrell, Anatoly Larkin, and Yuri Ovchinniko, who predicted its existence. To investigate the phenomenon, Mitrovic and her team used an organic superconductor with the catchy name κ -(BEDT-TTF)₂Cu(NCS)₂. The material consists of ultra-thin sheets stacked on top of each other and is exactly the kind of material predicted to exhibit the FFLO state.

After applying an intense magnetic field to the material, Mitrovic and her collaborators from the French National High Magnetic Field Laboratory in Grenoble probed its properties using nuclear magnetic resonance (NMR). What they found were regions across the material where unpaired, spin-up electrons had congregated. These “polarized” electrons behave, “like little particles constrained in a box,” Mitrovic said, and they form what are known as Andreev bound states. “What is remarkable about these bound states is that they enable transport of supercurrents through non-superconducting regions,” Mitrovic said. “Thus, the current can travel without resistance throughout the entire material in this special superconducting state.”

Experimentalists have been trying for years to provide solid evidence that the FFLO state exists, but to little avail. Mitrovic and her colleagues took some counterintuitive measures to arrive at their findings. Specifically, they probed their material at a much higher temperature than might be expected for quantum experiments. “Normally to observe quantum states you want to be as cold as possible, to limit thermal motion,” Mitrovic said. “But by raising the temperature we increased the energy window of our NMR probe to detect the states we were looking for. That was a breakthrough.”

This new understanding of what happens when electron spin populations become unequal could have implications beyond superconductivity, according to Mitrovic. It might help astrophysicists to



Vesna Mitrovic

understand pulsars — densely packed neutron stars believed to harbor both superconductivity and strong magnetic fields. It could also be relevant to the field of spintronics, devices that operate based on electron spin rather than charge, made

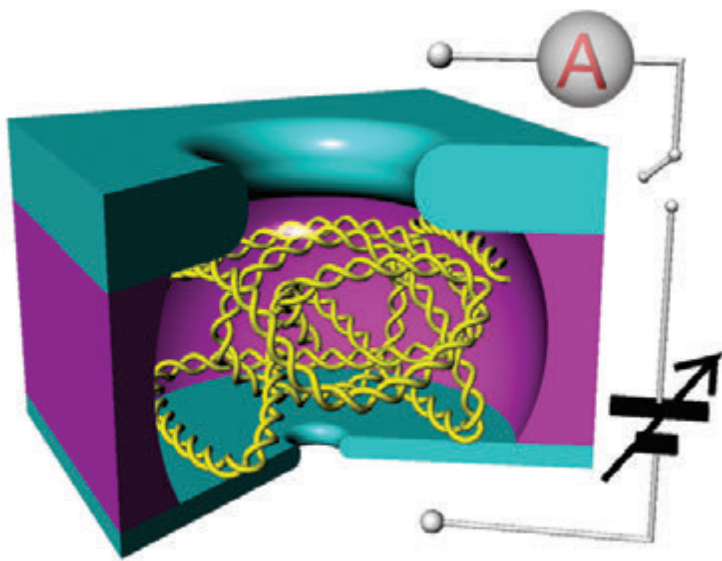
of layered ferromagnetic-superconducting structures. “This really goes beyond the problem of superconductivity,” Mitrovic said. “It has implications for explaining many other things in the universe, such as behavior of dense quarks, particles that make up atomic nuclei.”

This research was supported by the French ANR (grant:06-BLAN-0111), the Euro-MagNET II network (EU Contract No. 228043), and the visiting faculty program of Université Joseph Fourier, Grenoble.

Excerpted from article by Kevin Stacey, Brown News Service

DNA ‘Cage’ Could Improve Nanopore Technology

Despite having a diameter tens of thousands of times smaller than a human hair, nanopores could be the next big thing in DNA sequencing. By zipping DNA molecules through these tiny holes, scientists hope to one day read off genetic sequences in the blink of an eye. Now, researchers from Brown University have taken the potential of nanopore technology one step further. They have combined a nanopore with a tiny cage capable of trapping and holding a single DNA strand after it has been pulled through the pore. While caged, biochemical experiments can be performed on the strand, which can then be zipped back through the nanopore to look at how the strand has changed. “We see this as a very interesting enabling technique,” said **Derek Stein**, associate professor of physics and engineering at Brown, who helped develop the technology with his graduate students. “It allows you for the first time to look at the same molecule before and after any kind of chemical reaction that may have taken place.”



A NANOSCALE CAGE

An electrical field draws a strand of DNA in by the smaller hole, bottom, but the curled DNA cannot exit through the larger hole, top. After experimental procedures, a reversed electrical field draws the DNA strand back out of the lower hole, allowing before and after comparison.

Stein lab/Brown University

The device looks a bit like a miniscule hollowed-out hockey puck. On one flat side is a nanopore, and on the other side is a somewhat larger hole. When immersed in a solution containing DNA, an electric current across the nanopore grabs a single strand and pulls it into the hollow chamber. Once there, the strand has a natural tendency to curl into a tangled ball. That ball is too large to fit out of the hole on the other side, but that hole can be used to introduce additional molecules that might react with the trapped DNA. Once a reaction has

occurred, the electric current is reversed and the strand is sent back out through the pore, which can look for changes in the strand. “What we’ve made is basically a very small test tube,” said **Xu Liu PhD’14**, who led the work while he was a graduate student at Brown. “We can do biochemistry on the single strand in that very confined space.”

The key to the technology, Liu said, was making that test tube small, but not too small. If it were too small, the DNA wouldn’t have enough room to curl up, which would cause it to squirt out the hole at the top of the device. Using some theoretical calculations and a bit of trial and error, the researchers settled on a cage that’s about 1.5 micrometers square. Liu then tested the technology using what’s called a restriction enzyme, which cuts DNA molecules at particular sequences. After an intact DNA molecule was pulled through the pore into the cage, the researchers applied the enzyme through the hole in the top of the device. If all went as planned, the enzyme should have cut the strand into four pieces. When they pulled the molecule back through pore, they detected four distinct signals, indicating that the experiment had worked as expected.

The researchers say the device could be used for all kinds of experiments with DNA. For example, scientists use molecules called hybridization probes to look for specific sequences in a DNA molecule. The probes bind to target sequences, creating a bulge in the DNA strand that a nanopore could easily detect. “There was always a problem of knowing what the DNA looked like before the probe was applied,” Stein said. “This is a way of making sure you can measure the same molecule before anything is done to it, and then after. That wasn’t possible before with nanopores because the molecule would drift away.”

Liu is now working at a nanopore start-up company, where he plans to continue to develop the technology.

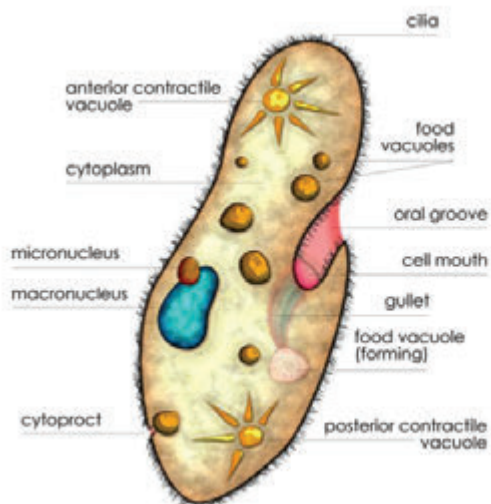
The research was supported by the National Science Foundation (CBET0846505) and by Oxford Nanopore Technologies Ltd. A paper describing the device is published in *Nature Communications*.

Excerpted from article by Kevin Stacey, Brown News Service

Paramecia Need Newton for Navigation

For such humble creatures, single-celled paramecia have remarkable sensory systems. Give them a sharp jab on the nose, they back up and swim away. Jab them in the behind, they speed up their swimming to escape. But according to new research, when paramecia encounter flat surfaces, they're at the mercy of the laws of physics. The findings, published in the journal *Physical Review Letters*, come from some surprising results in research performed in recent years by **James Valles**, professor and chair of the Physics Department, and his students. The group has been working to understand how paramecia react to changes in their buoyancy. The experiments are done by adding tiny magnetic particles to the water in which the creatures swim, and then applying a powerful magnet. When the water is pulled downward by the magnet, the paramecia become more buoyant and float more easily. Pull the water up, and the creatures become less buoyant. The initial research, published a few years ago, showed that paramecia have a remarkable ability to sense the changes in their buoyancy and adjust their swimming behavior accordingly.

"We found that if we made them sink more by making them less buoyant, they would try to swim harder against that sinking," Valles said. The effect was the same when the creatures were made more buoyant; they swam harder against the tendency to float. But over the course of the experiments, a strange thing happened. When their buoyancy was increased, meaning the paramecia should float more easily, the creatures would eventually get stuck to the lower surface of their enclosure. When the researchers reversed the experiment, making the paramecia less buoyant, they got stuck at the top. "It was so striking," said Valles, who performed the experiments with **Ilyong Jung PhD'15** and Karine Guevorkian of the Institut de Génétique et de Biologie Moléculaire et Cellulaire in France. "They looked like bats hanging from the top of a cave."



A Paramecium diagram (lucidhysteria.deviantart.com) along with its various components.

To understand this counterintuitive phenomenon, Valles and his colleagues watched paramecia swim into surfaces both under normal buoyancy as well as with buoyancy altered. Under normal circumstances, the paramecia skitter along the surface briefly before turning and swimming away. But when buoyancy was increased, they failed to complete the turn, leaving them stuck at an angle against the lower surface. The researchers determined that what they were seeing could be explained entirely by Newton's Third Law of Motion. When the creatures push against a surface, the surface pushes back with equal force. Under normal circumstances that force is enough to cause the creatures to turn, enabling them to swim away. But when their buoyancy is increased, paramecia don't hit the lower surface with as much force, which means the force applied back to them is also reduced.

"As they turn, that force of the wall acting on them gets smaller and smaller because they're swimming at an angle against the surface," Valles said. "It turns out that when buoyancy is altered, there's an angle at which that force goes to zero before they complete the turn." And so there they stay, stuck at that angle against the surface. The results are surprising, Valles said, because it implies that paramecia don't respond to contact with surfaces by actively changing their swimming behavior — even though they have the ability to respond actively when poked and prodded. "Paramecia are interesting to people because they're like swimming nerve cells — they have this surprisingly complex force-sensing network," Valles said. "But it appears as if it's not necessary for them to use it for simple navigation."

"Paramecia are interesting to people because they're like swimming nerve cells — they have this surprisingly complex force-sensing network,"

The findings raise some interesting evolutionary questions, Valles said. "Fish and other higher organisms actively navigate," he said. "But being passive apparently works just fine for paramecia; they're in every pond you come across. The question that's interesting to me is when in evolutionary history did a more active navigation become advantageous?"

Excerpted from article by Kevin Stacey, Brown News Service

Ladd Observatory



Time-lapse photo of Ladd Observatory showing motion of stars across the night sky. Photo by Scott MacNeill

Ladd offers a variety of academic enrichment programs. Curator **Michael Umbricht** presented curriculum specific programs for Brown/RISD Dual Degree students, the Brown architecture class taught by Professor Dietrich Neumann, and also RISD students from the Spatial Dynamics design class taught by Professor Deborah Coolidge. David Huestis, a long-time volunteer at Ladd, works with Bryant University astronomy class students. These programs have been very well received by faculty who appreciate the opportunity to use the resources at Ladd to engage students on diverse topics such as architecture, history, and design.

Professor **Ian Dell'Antonio** and curator Michael Umbricht continue to collaborate with the Providence Children's Museum. Their collaboration includes training Museum docents in teaching solar astronomy to kids in the local community centers and presenting programs for visitors to the Museum along with Brown astronomy TA students.

Michael Umbricht mentored Brown undergraduate Emma Jerzyk during the summer of 2014 to develop outreach resources to teach students in the local schools about space science. This effort is part of an ongoing collaboration between Ladd Observatory and the Brown CubeSat Team. The students are using the materials for after-school programs at D'Abate Elementary School and West Broadway Middle School. They have also helped with Ladd's visits to the Providence Children's Museum.

Exhibits at Ladd feature a display of antique celestial globes, an orrery, and star atlases from the 19th century. Ladd's outreach programs on Tuesday evenings have expanded to include a focus on the history of science and technology from a public humanities perspective. This approach involves presenting objects from our antique scientific instrument collection and storytelling about the scientists who used them to provide visitors with an understanding of the scientific work that has been conducted at Brown during the past century.

Ladd's following on Facebook has grown from 12,000 to 17,000 and our main Ladd Twitter account has grown from 800 to 1200, an increase of 40-50% over the past year. We have a second automated Twitter account that sends alerts for extreme weather events (heavy rain, high winds, low wind chill, etc.) which is used by the National Weather Service in Taunton and local weather forecasters Chelsea Priest and T. J. Del Santo of television stations ABC6, WPRI 12 and WNAC FOX. Ladd received a great deal of publicity during storm events over the recent harsh winter. Current conditions from Ladd's weather station are also included on the home page of the new mobile app <http://m.brown.edu> from Brown's Public Affairs and University Relations.

New Courses

PHYS 0113 – Squishy Physics

Squishy Physics is a freshman seminar designed by Professor **Jay Tang** to explore everyday applications of physics. The course offers project-based learning and involves hands-on experimentation, data analysis, and group presentation. It is designed for students interested in any field of science. It does not require any pre-requisite. Topics include motion, forces, flow, elasticity, polymers, gels, electricity, and energy. Students are guided to work on several projects over the semester and required to submit their work in brief written reports. The course concludes with students each making an oral presentation on the project of which they are most proud.

PHYS 2600 – Computational Physics

A new course designed by Professor **Meenakshi Narain**, provides students with an introduction to scientific computation at the graduate level, primarily as applied to physical science problems. The course assumes a basic knowledge of programming and focuses on how computational methods can be used to study physical systems complementing experimental and theoretical techniques.

PHYS 0180 – Physics for Non-Physicists



Michael Antosh PhD'12

Michael Antosh PhD'12, designed Physics for Non-Physicists: An Introduction to Classical and Modern Physics, which provides an introduction to many major concepts in physics. Antosh drew heavily on the materials used in Flat Earth to Quantum Uncertainty, a course created by Leon Cooper. The course is intended for a general audience, and calculus is not required. The question “what goes into making a scientific theory?” is examined, using the works

of Euclid, Galileo, Newton and others as examples. Concepts range historically from planetary motion (addressed at least as early as Ancient Greece) to modern physics topics that are still under debate today. These concepts include (but are not limited to) motion, forces, energy, electricity and magnetism, special relativity and quantum mechanics.

Events

Arthur O. Williams Lecture



This year's Arthur O. Williams Lecture, held on April 20, 2015, featured Rolf-Dieter Heuer, Director-General of European Organization for Nuclear Research (CERN). His talk, “Breaking the Wall of the Hidden universe: What the Discovery of the Higgs Boson Tells Us about Physics, Mankind and the Universe,” addressed the exciting prospects offered by the Large Hadron Collider (LHC) at CERN. Particle physics has entered a new era, and the LHC will provide a deeper understanding of the universe and the insights gained could change our view of the world. Dr. Heuer's talk, which discussed the recent discovery of the Higgs boson, presented a look forward to what the LHC is expected to yield in terms of insights into the origin of mass and the nature of dark matter as well as many other key questions.

Rolf-Dieter Heuer studied physics at the University of Stuttgart prior to earning his PhD at the University of Heidelberg. He took office as CERN's Director General in January 2009.

Events

Houghton Conference

The Tony and Pat Houghton Conference on Non-Equilibrium Statistical Mechanics, held on May 4-5, 2015, was organized by Professors **Dima Feldman** and **Brad Marston**. The conference promoted a broad discussion of current topics in Non-Equilibrium Statistical Mechanics. A roster of 17 speakers from universities in the United States, Switzerland, Israel, Finland, France and England gave presentations that focused on theoretical frameworks (or the desire for such) and on specific systems from wide-ranging fields such as astrophysics, atomic physics, biology, chemistry, climate physics, condensed matter, fluid mechanics, geophysics, and high-energy physics. The workshops and a poster session demonstrated a mix of experimental, computational, and theoretical perspectives. More than 50 people participated in the conference, which was made possible by a generous bequest from the estate of Tony and Pat Houghton. Tony was a theoretical condensed matter physicist who chaired the Brown University Department of Physics from 1992 to 1998.

Slides and video recordings of many of the talks are available at <https://icerm.brown.edu/events/nesm/> and https://icerm.brown.edu/video_archive/

Guralnik Symposium

On Friday, April 10, 2015, friends and colleagues of the late **Gerald S. Guralnik**, a faculty member of the Physics Department for nearly 50 years, gathered to present a series of scientific talks. Guralnik passed away suddenly last year, and the symposium, “The Value of Just Imagining”, was organized to honor his memory and reflect his passion for physics. A theoretical physicist, Guralnik was one of the six physicists to predict the existence of the Higgs boson. Two of his collaborators on that seminal paper, Carl Hagen of the University of Rochester and Imperial College’s Sir Thomas Kibble, gave presentations as well as former colleagues from Brown, Los Alamos National Lab, MIT, Lawrence Livermore National Lab and Washington University. Numerous former students were also in attendance.

A personable and caring individual, Guralnik set a new standard in how faculty could engage students. He was visionary in his ability to see the potential and importance of large-scale computation in fundamental research in physics, and was a pioneer in those efforts at Brown. A cocktail hour and dinner followed the symposium, where stories were shared and appreciated by all.

Barus & Holley – 50 Years

The dedication of Barus & Holley on June 4, 1965 was marked by an anniversary celebration on June 4, 2015. Professor **Bob Lanou** and Larry Larson, Dean of the School of Engineering, provided remarks to a crowd assembled in the lobby to mark the occasion. Lanou, who joined the Physics faculty in 1959, recalled how the day of the dedication was so hot that chairs set for the event in the parking lot began sinking into the tarmac. He also noted that the neighbors of Barus & Holley exerted a significant influence on the design of the building in terms of the window size (neighbors insisted on smaller windows), and the footprint and height of the building. After the speaking program, faculty, students and staff from the Physics Department and School of Engineering enjoyed mingling as they partook of coffee and three flavors of celebratory cake.



Left to right: Bob Lanou and Larry Larson

Physics Art Show

The November art show, held in the Barus & Holley lobby, exhibited entries from 22 students, faculty and staff. The range of art displayed included a diverse array of paintings, drawings, sculpture, and photography. Among the most unique entries was a large musical instrument constructed by graduate student Declan Oller who encouraged attendees to play it. The featured performance was a traditional Chinese dance performed by freshman Zheng Shi accompanied by music adapted from an ancient Chinese poem, "A Moonlight Night on the Spring River."



Amy Butcher



Alex Moskowitz



Atreya Chatterjee



Lauren Altman



Zheng Shi



Emily Toomey

Events

John Hay Library Main Reading Room Dedicated to a Physicist



Last fall, following a two-year hiatus for renovation, the John Hay Library reopened to much appreciative praise. Although the Hay is now primarily the site of Brown's Rare Books and Special Collections, many years ago the university's regular collection of physics materials was housed there. "Housed" is a generous word for it. The once-magnificent, spacious Main Reading Room had been carved up into much smaller poorly illuminated spaces. A happy outcome of the Hay renovation is that Physics will have a distinguished presence in the elegantly restored Main Reading Room of the Hay.

A generous gift from Brown parents, Catherine Willis (Class of 1985) and her husband, Ephraim F. Gildor, made the restoration of the Main Reading Room possible. Named in honor of Catherine's father, the physicist William J. Willis, it is now repurposed for University-wide general use. The Hay's reopening and the Willis Room dedication were held on October 25th in a ceremony. Professor **Bob Lanou**, a friend and former

colleague of W.J. Willis, spoke to the audience about Willis and his science.

William (Bill) Willis (1932-2012) was a distinguished elementary particle physicist with many original and important contributions to the field during its recent 50-year revolutionary era. That era also parallels the evolution of particle physics at Brown. Willis left a lasting influence on the scientific directions and policies of two of the world-leading labs, CERN and Brookhaven, where he did his research. He carried out crucial experiments, often with new discoveries, by inventing new instruments and methods, suggesting whole new research areas and providing organizational leadership on an international scale. He discovered the first definite evidence for something called "jets" in very high energy collisions of both protons and anti-protons. He foresaw the potential power of accelerating and colliding heavy ions in the lab as a different process for studying quarks and their interactions.

Willis led efforts at both US and European labs and through his work and that of many others, they discovered the existence of something named the "quark-gluon plasma" which provides a glimpse of an entirely new state of matter that likely existed at some period of our early universe. Some of his inventions in technology have enabled experiments, which were not possible previously. Of particular importance was his invention of the first precision, hermetic calorimeter for very high energy collisions. This technology was at the heart of the two experiments that recently discovered the Higgs boson (he was a leader in one of them). It also played a role in the earlier discovery of the predicted "top" quark and in the experimental confirmation of CP-non-conservation. His legacies in the advances of technology are still very much of the present practice world-wide.

The John Hay has a strong collection of rare works on astronomy, cosmology, mathematics, physics and related sciences, including first editions of Galileo (*Dialogo*, 1632), Newton (*Principia*, 1687) and Boyle (*Apparatus*, 1686) as well as additional works by them and other early giants. Earlier gifts from the Department of Physics facilitated a display of experimental devices from the Victorian and other eras. Benjamin West's telescope known for its early observation of the transit of Venus (1790) is there. These devices were researched and interpreted and are accompanied by printed labels explaining each device and what it is designed to do. Read more about the collection at <http://library.brown.edu/firstreading2009/HistoryOfScienceCollection.pdf>.

PHYSICS AT BROWN

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Thank you for your support.

