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Annual Newsletter 2012

What's Inside

Greetings from the Chair

Two of our most significant events in 2012 were the selection of Brown's 19th president, Christina Paxson, and the discovery of a new particle by the Large Hadron Collider. I am proud to say that the Physics Department played key roles in both of these activities. Chung-I Tan chaired the academic search committee for the new president. Gerald Guralnik was one of six physicists to predict the existence of the Higgs boson fifty years ago, and Dave Cutts, Ulrich Heintz, Greg Landsberg and Meenakshi Narain were all involved in the hunt for the new particle.

Our faculty are engaged in a slew of exciting projects. The Large Underground Xenon detector (LUX), located in an old gold mine shaft in South Dakota, is nearly ready to commence its search for dark matter. Rick Gaitskell is co-leading the LUX collaboration; stay tuned for results! Greg Tucker's group and collaborators went to Antarctica in the fall to launch two experiments that promise new insights into the origins of the universe. Derek Stein's group's ability to nanocontrol the nominally flipping and flopping DNA molecule promises future advanced sequencing possibilities. These are but three examples of our ongoing innovative research.

The Department is looking toward the future with a search for a junior condensed matter experimentalist. Gang Xiao is directing the search committee's review of many outstanding candidates from a large pool of applicants. Our goal is to fill the position by the start of the next academic year.

After much discussion, our department has created a dedicated master's degree program. The curriculum includes professional development components in addition to the current core graduate curriculum. Thus far, seven students have been accepted into the program, which is directed by Jay Tang.

Faculty and student involvement in community outreach activities over the past year was robust. Our students have taught lessons at the elementary and secondary levels in Providence's public schools. Ian Dell'Antonio organized multiple events at museums, ran a workshop for teachers and worked with Americorps to make telescopes available to Boys and Girls Clubs. Ladd Observatory's expanded programming and events associated with the Transit of Venus attracted more than 3,000 visitors.

The Department hosted the fourth Degree Day program in April. Our students seized the opportunity to forge professional relationships and learn about what alumni do after Brown. More than one student has noted that the program helped them to decide to concentrate in physics. We appreciate the generosity of our alumni who participate in the program and look forward to welcoming many of you back to campus for the next Physics Degree Day in 2014.

The first Houghton Lecture series was held in October. Esteemed visitors, former students, post-docs and collaborators from around the world came for a day full of talks and reminiscences. Leon Cooper topped off the day by vocalizing his concerns about Schrödinger's cat. Supported by a generous bequest from the late Tony Houghton and his wife, Pat, the lecture series bearing their name was an excellent way to commemorate our former chair's contributions. We eagerly anticipate many more of these stimulating lectures in his honor.

Shortly after taking office, President Paxson visited the Physics Department. Her vision for growing Brown is not simply for the sake of expansion but in a way that will remove constraints and allow us to flourish at what we do best: teaching and research. We look forward to supporting her vision in 2013!

Jim

James M. Valles, Jr.

Undergraduates

2012 Undergraduate Degree Recipients

Back row: Adam M. Coogan, Matthew Dodelson, Michael H. Weissman, Minjae Cho, Luis L. Lazo del Sol, Natalie E. Bodington **Middle row:** Michael L. Wagman, Thomas P. Iadecola, Real R. Provencher, Jacob D. Isbell, Mark A. Nagy, Kate D. Alexander, Marianna H. Neubauer, Arthur D. Adams **Front row:** Marie Atterbury, Harry F. Mickalide **Not present in photo:** James A. Bensson, Anand J. Desai, William P. Hicks, Ryan D. Lester, Benjamin A. Lichtner, Vaibhav Mathur, Mathew A. Reiss, Thomas M. Weinreich

2012 UTRA Students

Alexander Berg
Caitlin Carpenter
Urmila Chadayammuri
Karri DiPetrillo
Layne Frechette
Yukun Gao
Soumya Ghosh
Ryan Handoko
Laura Kulowski
Marc Langer
Jaeyoon Lee
Nakul Luthra
Eva Lyubich
Alexander Moskowitz
Jordi Negron
Wei Jie Jason Poh
Deivid Ribeiro
Geoffrey Sedor
Nora Shipp
Cole van Krieken
Nathan Weinberger
Zachary Winoker

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 Prizes for Excellence in Physics
Minjae Cho
Matthew Dodelson

Mildred Widgoff Prizes for Excellence in Thesis Preparation
William P. Hicks
Marianna H. Naubauer
Michael L. Wagman

Smiley Prize for Excellent Contribution to the Astronomy Program
Kate Alexander

Clapp Prize (Best Undergraduate Thesis) and **Cross Award in Chemical Physics**
Thomas M. Weinreich

Department Undergraduate Group (DUG)

Co-chaired by **Abi Kulshreshtha**'15, **Alex Meehan**'15 and **Michael-Patrick English**'14, the Brown Physics DUG focused on hosting events to help guide students to a variety of physics opportunities. The group organized a particularly successful event prior to the annual poster session. Students and several faculty members gathered to discuss how to maximize the opportunity to talk with professors during the poster session. Another successful event was organized in conjunction with Brown's Office of International Program, to provide information about the possibilities of studying physics abroad.

The student organization also arranged events to specifically provide guidance to freshman, and reported that the Physics faculty did a wonderful job of helping them to explore various avenues of research. Plans are in the works for more activities in 2013 to bring faculty and students together.

Graduate Students

Graduate Student Awards

Galkin Foundation Fellowship Award
Wenzhe Zhang, 2011-2012
Alex Geringer-Sameth 2012-2013

Beyer Award for Excellence in Scholarship and Service
Richard I. Cook
Helen A. Hanson

Anthony Houghton Award for Excellence in Theoretical Physics
Chenjie Wang
Congkao Wen

Forrest Award for Excellent Work Related to Experimental Apparatus
Thomas J. Grimsley

Dissertation Fellowship Award
Chenjie Wang

Physics Merit Dissertation Fellowship Award
Vivek Parahar

Award of Excellence as a Graduate Teaching Assistant
Michael P. Antosh
Jonnathan A. Kurvits
Wang Miao
Peter C. Nagler
Matthew S. Rosenfeld
David M. Tersegno

Honorable Mention:
Yana Cheng
Jacqueline E. McCleary
Mai Tran

Teaching Assistant (TA) Training Program

The student-run TA training program is working harder than ever. In conjunction with Professor **Dave Cutts**, TA Chair, the TA training program has not only offered an intensive introduction before the start of school, but is now organizing a series of activities throughout the academic year. TA's, both new and experienced, are participating in enrichment activities over the course of the year in order to improve the quality of undergraduate instruction.

Community Mentor Program

The community mentor program has continued to have a strong presence in the Physics Department. Incoming students are paired with more senior graduate students to help with peer advice, i.e., finding a research group, how to manage homework time, where to find a good slice of pizza, etc. Graduates and their mentors meet informally during the school year to give new students a perspective on acclimating to graduate life.

Graduate Student Coffee Hour

Student coffee hours are held weekly in the faculty lounge throughout the year to allow graduate students a chance to meet and chat about physics and life over cookies and coffee. The coffee hour also provides the opportunity to learn about what other students are doing in the department, discuss post graduation careers with invited speakers, and reach out to graduate student representatives about student issues.

Back Row: Chenjie Wang, Wenzhe Zhang, Dafei Jin, Xi Wang, Jing Wang
Front Row: Thomas Grimsley, Wanchun Wei, Sungcheol Kim, Pengyu Liu, Richard Cook, Steven Palefsky, Michael Antosh
Not present in photo: Aram Avetisyan, Helen Hanson, Hyeyun Jung, Nhiem Tran, Congkao Wen

Honors and Awards

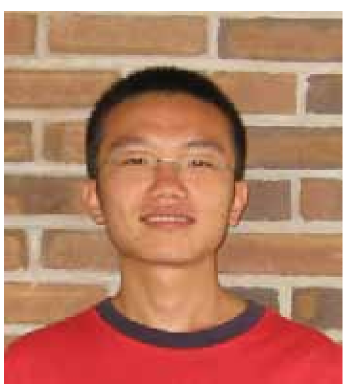
Ladd Commendations

Michael Umbricht, David Targan, and Francine Jackson

Photo of Transit Room circa 1895 held against current image of room.

The city of Providence and the state of Rhode Island each chose to recognize the historical significance of Ladd and the recently completed work to preserve and conserve the Transit Room. The Providence Preservation Society awarded Ladd its Historic Preservation Award at a ceremony in Providence last May. In October, two organizations, Preserve Rhode Island and the Rhode Island Historical Preservation and Heritage Commission, honored the Ladd staff in a program held at Rosecliff, one of the Newport mansions. Associate Dean **David Targan**, director of Ladd Observatory, accepted the prestigious Rhody Award on behalf of the staff.

2012-2013 Physics Merit Fellowship Recipient



Hao Tu

Under the supervision of Professor **Robert Pelcovits**, Physics Merit Fellowship recipient **Hao Tu**'s dissertation focused on theoretical models for the free energy of self-assembled smectic-A liquid crystalline monolayer membranes. Tu's work was done in collaboration with the experimental groups of Professors Dogic and Meyer at Brandeis University.

The presence of liquid crystalline order is common in many biological membrane systems such as lipid bilayers where the orientations of the constituent rod-like units exhibit long-range order. Understanding the basic principles governing the combined effects of liquid crystalline order and membrane geometry is an important step toward fully understanding the nature of these membranes including possible technological applications.

The Brandeis groups use rod-like fd viruses in aqueous solutions to form various self-assembled structures with the aid of an attractive force produced by a polymer depletant added to the solution. Among these structures, smectic-A monolayer membranes have attracted much attention due to their ability to form a variety of novel structures. For example, twisted ribbons are observed when the viruses are chiral, while mostly flat disks with "crenellated" edges are seen for effectively achiral membranes made from mixture of viruses with opposite handedness. Phase transitions between membranes with different shapes are observed when the strength of the depletion force or the temperature is tuned. The goal of Tu and Professor Pelcovits was to establish a general theoretical model for the free energy of these smectic-A monolayer membranes.

Their theoretical free energy model utilized well-known theories for liquid crystalline order and membrane elasticity, supplemented by a simple edge energy corresponding to the strength of depletion force in the experiments. They exploited analytical and numerical methods including Monte Carlo simulations to minimize the energy of membranes with prescribed geometry. Their theoretical model has enhanced the understanding of liquid crystalline monolayer membranes and may give guidance to the search for applications of these membranes in the future.

Gruber Cosmology Prize

Professor **Greg Tucker** is a member of the Wilkinson Microwave Anisotropy Probe (WMAP) team awarded the 2012 Gruber Cosmology Prize at the International Astronomical Union meeting in Beijing last August. Charles Bennett, professor of physics and astronomy at Johns Hopkins University and principal investigator of WMAP accepted the $500,000 prize, which was shared by the team, and a gold medal. Bennett emphasized the collaboration's team effort, saying "There are so many heroes who stand up at just the right time and make something happen, and they all deserve credit for that."

The citation reads "The Gruber Foundation proudly presents the 2012 Cosmology Prize to Charles Bennett and the Wilkinson Microwave Anisotropy Probe team for their exquisite measurements of anisotropies in the relic radiation from the Big Bang---the Cosmic Microwave Background. These measurements have helped to secure rigorous constraints on the origin, content, age, and geometry of the Universe, transforming our current paradigm of structure formation from appealing scenario into precise science."

A rare site, BLAST-Pol (left) and EBEX (right) outside for testing at the same time. The launch vehicle (aka The Boss), is attached to BLAST-Pol in preparation for testing.

Guralnik Receives Medal

Last October, Professor **Gerald Guralnik** traveled to the Czech Republic to accept the Commemorative medal of the Faculty from Charles University, an ancient University in Prague founded by Bohemian King Charles IV in 1348. The medal was awarded to Guralnik in appreciation of his "long and fruitful scientific career in the physics of quantum fields, spanning from the theory to the computational methods."

While in Prague to receive the award, Guralnik gave two talks. One was an open public lecture held in a huge and beautiful centuries old lecture hall, which was very well attended by an inquisitive crowd. The second talk was sponsored by the Czech National Academy of Sciences and held at their main building. The latter talk was part of a day-long series of talks in celebration of 20 years of membership of the Czech Republic in CERN. There were a number of CERN scientists present including the Scientific Director of CERN and various experiment spokespeople. Guralnik, the only speaker from the United States, gave the main theory talk.

B.E.A.R. Day Honor

The Brown Employee Appreciation and recognition (B.E.A.R.) Day is a long-standing event to celebrate years of service and performance excellence. The program, hosted by President Christina Paxson, added a new feature this year to recognize the staff of individual departments. Physics was selected as the first department to be honored in this way.

Graduate Student Research

2012-2013 Galkin Fellow

Alex Geringer-Sameth, the 2012-2013 Galkin Foundation Fellow, works on exploring the nature of the dark matter in the Universe through astrophysical probes. Over the past three years he has worked in close collaboration with his advisor Professor **Savvas Koushiappas** and plans to complete his Ph.D. in May 2013.

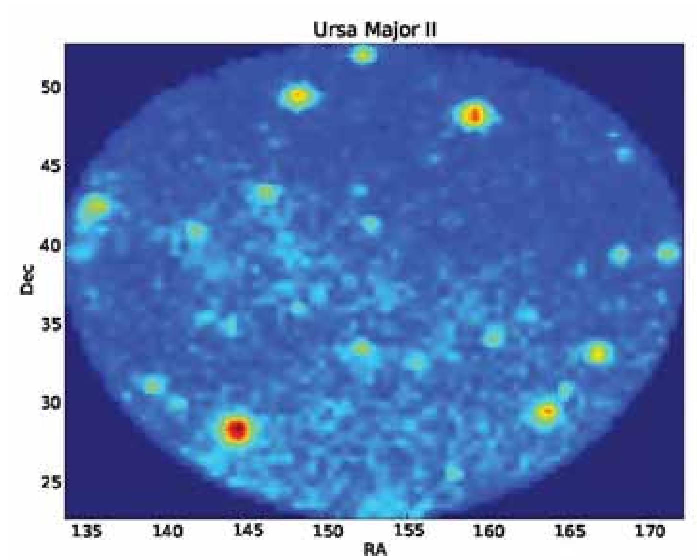
The world we see around us is composed of protons, neutrons, and electrons and yet these particles make up only 17% of all the matter in the Universe. Dark matter constitutes the other 83% and is an essential ingredient in our modern understanding of the history of the Universe from the Big Bang and the cosmic microwave background to the evolution of the large scale structures that host the galaxies and galaxy clusters we observe today.

Dark matter's fundamental role in cosmology is matched only by its conspicuous absence from the very successful Standard Model of particle physics. Any explanation of the nature of dark matter will require new physics beyond the Standard Model. What sort of particle is the dark matter and how does it interact with the particles of the Standard Model? These central questions, lying at the boundary of astrophysics and particle physics, are being tackled by several groups here at Brown.

Alex's research explores what we can learn about dark matter by searching for evidence of its annihilation in the Milky Way, part of a field known as indirect detection. The annihilation of weakly interacting dark matter in the early Universe explains its observed present-day abundance. This motivates the search for such annihilation occurring in our galaxy today. The annihilation of two dark matter particles into Standard Model particles generically entails the emission of high energy photons. As part of his thesis Alex developed a statistical formalism that can be applied to any set of measurements to search for such emission.

Using data from NASA's Fermi Gamma-ray Space Telescope, Alex performed the most sensitive search for annihilating dark matter to date. The analysis, published in Physical Review Letters, severely constrains the permitted mass of the dark matter particle. A followup Rapid Communication in Physical Review D constrains dark matter annihilation directly into a two-photon final state, testing a recent tentative claim of such a signal originating from the Galactic Center. In ongoing work with the VERITAS collaboration, Alex is applying these techniques to data from the ground-based VERITAS telescope to search for dark matter particles of higher masses.

All such searches must contend with the diffuse gamma-ray background generated, in part, by populations of unresolved sources. As part of his thesis work Alex introduced two novel techniques, published in the Monthly Notices of the Royal Astronomical Society, that are based on the statistical properties of the gamma-ray background over large areas of the sky. The first is a spacetime correlation function which is sensitive to a population of extremely faint moving sources, such as asteroids or other solar system debris. The second makes use of time series analyses in untangling the emission from unresolved galactic pulsars. In both cases, the new techniques are designed to discover and characterize an entire population of sources even when the individual members remain undetectable.



A view of the Ursa Major II dwarf galaxy in gamma-rays detected by the Fermi Gamma-ray Space Telescope. The dwarf galaxy, located at the center of the field of view, is embedded in a concentrated halo of dark matter. Nearby sources such as supernova remnants and pulsars as well as distant active galaxies can be seen as bright spots in the image.

Image Credit: NASA/DOE/Fermi-LAT Collaboration Geringer-Sameth and Koushiappas/Brown University.

The Galkin Foundation Fellowships are funded through a generous donation by Warren Galkin, Class of '51. The Fellowship recognizes exceptional promise and achievement in physics by a senior graduate student.

The Higgs Boson: Found at Last

The year 2012 was a momentous year for Particle Physics and the Brown CMS Group, led by Professors **David Cutts**, **Ulrich Heintz**, **Greg Landsberg,** and **Meenakshi Narain**. On July 4, 2012 the ATLAS and CMS experiments announced the discovery of a new particle with a mass of 125 GeV. The properties of the new particle were consistent with expectations for the long sought Higgs boson, the only particle of the standard model that had not yet been observed. Brown Physicists who are part of the CMS Collaboration played important roles in this discovery.

The idea of the Higgs boson arose in the 1960s when theorists struggled with creating a theoretical framework to understand the interactions of elementary particles. The masses of elementary particles posed a particular problem. The theory naturally described interactions of massless particles but some of the particles had to be quite massive, such as the W and Z bosons which mediate the weak nuclear interaction which is responsible for example for the processes that make the Sun shine. In 1964, papers were published by three different groups of theorists that had independently found a solution to this problem. One of these was co-authored by Brown Physics Professor **Gerald Guralnik**. Guralnik and his colleagues showed that if they hypothesized the existence of a new particle with very specific properties they could describe massive W and Z bosons. This new particle is the Higgs boson. Its invention provided a theory that could describe all aspects of fundamental particles and their interactions that experiments have observed since, and that we therefore have come to call the standard model. But does it give the correct description? Until 2012 no experiment had observed the Higgs boson.

The world's largest scientific instrument, the Large Hadron Collider (LHC), was conceived to settle this question. It accelerates proton beams to such large energies that the fireball that ensues when the beams collide would sometimes, about once in every 2 billion collisions, produce a Higgs boson – if it existed. The Higgs boson would immediately decay into pairs of other particles – a consequence of the interactions needed to impart these particles with mass. Cathedral-sized cameras, the ATLAS and CMS detectors were built to capture the image of the fleeting Higgs bosons. Physicists at Brown University are part of the team that built and operates the CMS detector.

Most of the particles the Higgs boson can decay into are difficult to isolate from the background but sometimes – about once in 500 decays – the Higgs boson decays to two photons. Their energies can be precisely measured by the detectors and therefore the mass of the particle that produced them can be measured. If there was a Higgs boson then the experiments should observe an excess of photon pairs at a particular mass value on top of the background of photons from other sources. Both the ATLAS and CMS Collaborations scoured the data that their detectors delivered for such a signal. CERN announced a seminar to release the results for 10am on July 4, 2012. The experiments carefully guarded their results and worked feverishly to carry out cross checks to make sure that

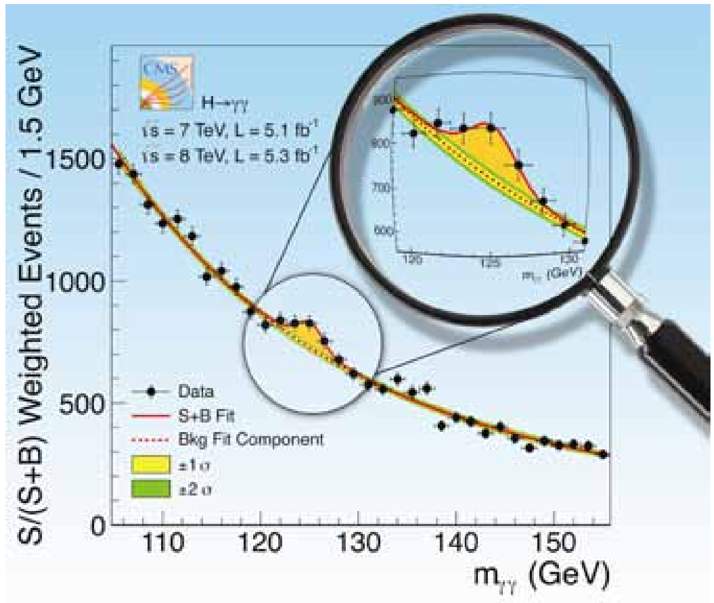


Figure 1: Mass spectrum of photon pairs observed by the CMS Collaboration. The enlarged portion shows the enhancement from the Higgs boson signal in the data over the smooth background indicated by the dashed line.

there was no mistake. By the time of the seminar, long lines had formed in front of the auditorium. Some students had even camped out over night in front of the doors in order to ensure a seat in the auditorium. The two experiments announced their findings to the roaring applause of the audience. Both the ATLAS and CMS Collaborations observed such an excess around a mass of 125 GeV. The mass spectrum of photon pairs observed by the CMS Collaboration is shown in Figure 1. Figure 2 shows a graphic representation of an event in which two photons were observed that could have originated from a Higgs boson decay. In addition there also was evidence that this particle decayed to two Z bosons, another way that the Higgs boson was predicted to decay.

Members of the Brown CMS group played important roles in the discovery. Research Professor **Thomas Speer**, postdocs **Grant Christopher**, **Alexey Ferapontov**, **Alexandra Junkes**, **Gena Kukartsev**, **Edward Laird**, and graduate students **Juliette Alimena**, **Saptaparna Bhattacharya**, **Zeynep Demiragli**, **Alex Garabedian**, **Michael Luk**, **Zaixing Mao**, **Michael Segala**, **Tutanon Sinthuprasith**, and **Stephen Sirisky**. The Brown group contributed to construction and operation of the CMS detector. Professor Greg Landsberg and his group took part in the construction of the part of the detector that traces the paths of charged particles to measure the direction in which they are emitted and their momentum. Professor Meenakshi Narain led the group that developed the reconstruction algorithm that would identify a particular type of quarks, bottom quarks, in the images of particle collisions. The Higgs boson is predicted to decay into pairs of bottom quarks. Narain also participated in the analysis of the data to search for Higgs boson

Higgs Boson continued on p. 20. . .

Research in the Antarctic

Greg Tucker

Professor **Greg Tucker**, senior research associate **Andrei Korotkov** and graduate student **Kyle Helson** spent much of the fall semester at the NASA Long Duration Balloon (LDB) facility on the coast of the Antarctic. They were there to work on two balloon-borne experiments.

The Balloon-borne Large Aperture Submillimeter Telescope with Polarization (BLAST-Pol) will help us to understand the first stages of star formation. Protostars appear to collapse more slowly than would be expected from gravity alone. Magnetic fields in these regions may provide the braking mechanism that slows the collapse of protostars. BLAST-Pol, a 2.5 m diameter telescope, which was making its fifth and final flight, was successfully launched on December 25 to begin its approximately two-week long flight at an altitude of 125,000 ft. (38 km).

The E and B EXperiment (EBEX) is an instrument to help reveal what happened at the time of inflation during the first fraction of a second after the Big Bang. Gravitational waves generated by inflation produce a polarization signature in the cosmic microwave background (CMB), which is light "left over" from the Big Bang.

Kyle Helson

Andrei Korotkov

By measuring this polarization signature, EBEX should help us understand the physics of the early universe. The 8000 lb. (3600 kg) EBEX instrument was successfully launched on December 28 on a 34 million cubic foot balloon.

The group is looking forward to analyzing the data from both BLAST-Pol and EBEX. For both BLAST-Pol and EBEX, the Brown group designed and built much of the receiver systems as well as part of the telescope pointing systems.

The LDB facility is near the United States Antarctic Program McMurdo station, which is run by the National Science Foundation. Videos of the launches are available at:

http://www.youtube.com/watch?v-Es95ac0qVJE and
http://www.youtube.com/watch?v=f-_2ESkCf94

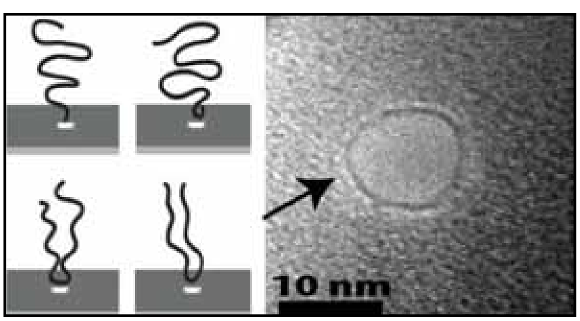
Near the end of inflation EBEX launch
Photo credit: Dr. Asad Aboobaker, University of Minnesota

DNA's preference for Diving Head First

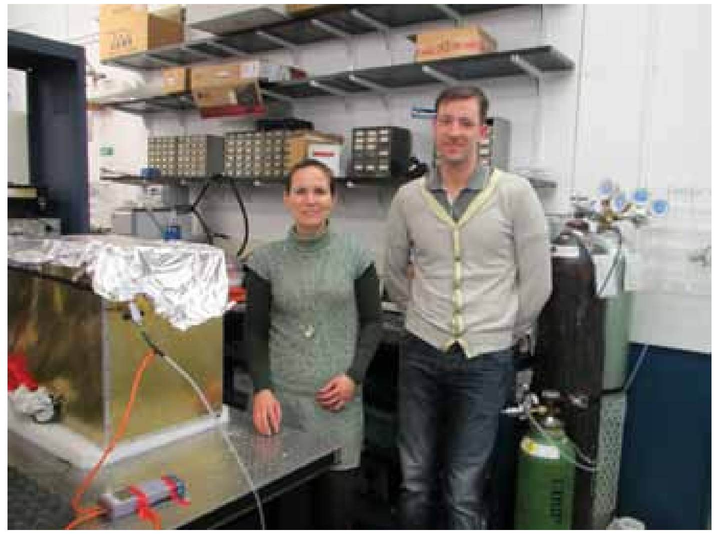
Recent research published in the journal *Physical Review Letters* looks at the dynamics of how DNA molecules are captured by solid-state nanopores, tiny holes that soon may help sequence DNA at lightning speed. The study found that when a DNA strand is captured and pulled through a nanopore, it's much more likely to start the journey at one of its ends, rather than being grabbed somewhere in the middle and pulled through in a folded configuration. "We think this is an important advance for understanding how DNA molecules interact with these nanopores," said Professor **Derek Stein**, who performed the research with graduate student **Mirna Mihovilovic** and undergraduate **Nick Hagerty**. "If you want to do sequencing or some other analysis, you want the molecule going through the pore head to tail."

Research into DNA sequencing with nanopores started a little over 15 years ago. The concept is fairly simple. A little hole, a few billionths of a meter across, is poked in a barrier separating two pools of salt water. An electric current is applied across the hole, which occasionally attracts a DNA molecule floating in the water. When that happens, the molecule is whipped through the pore in a fraction of a second. Scientists can then use sensors on the pore or other means to identify nucleotide bases, the building blocks of the genetic code. The technology is advancing quickly, and the first nanopore sequencing devices are expected to be on the market very soon. But there are still basic questions about how molecules behave at the moment they're captured and before.

"What the molecules were doing before they're captured was a mystery and a matter of speculation," Stein said. "And we'd like to know because if you're trying to engineer something to control that molecule — to get it to do what you want it to do — you need to know what it's up to." To find out, the researchers carefully tracked over 1,000 instances of a molecule zipping through a nanopore. The study found that molecules are several times more likely to be captured at or very near an end than at any other single point along the molecule. "What we found was that ends are special places," Stein said. "The middle is different from an end, and that has a consequence for the likelihood a molecule starts its journey from the end or the middle."



When a DNA strand is captured and pulled through a nanopore, it's much more likely to start the joiurney at one of its ends (top left) rather than being grabbed somewhere in the middle and pulled through in a folded configuration. Credit. Stein Lab/Brown University



Mirna Mihovilovic and Derek Stein

As it turns out, there's an old theory that that explains these new experimental results quite well. It's the theory of Jell-O. Jell-O is a polymer network — a mass of squiggly polymer strands that attach to each other at random junctions to make Jell-O a jiggly, semi-solid. The way in which the polymer strands connect to each other is not unlike the way a DNA strand connects to a nanopore in the instant it is captured. When applied to DNA, the Jell-O theory predicts that if you were to count up all the possible configurations of a DNA strand at the moment of capture, you would find that there are more configurations in which it is captured by its end, compared to other points along the strand. It's a bit like the odds of getting a pair in poker compared to the odds of getting three of a kind. You're more likely to get a pair simply because there are more pairs in the deck than there are triples. This measure of all the possible configurations is all that's needed to explain why DNA tends to go head first. As Stein puts it, "The number of ways that a molecule can find itself with its head sticking in the pore is simply larger than the number of ways it can find itself with the middle touching the pore."

These theories of polymer networks have been around for a while. They were first proposed by the late Nobel laureate Pierre-Gilles de Gennes in the 1960s, and Bertrand Duplantier made key advances in the 1980s. Mihovilovic, Stein's graduate student and the lead author of this study, says this is one of the first lab tests of those theories. "They couldn't be tested until now, when we can actually do single molecule measurements," she said. "[De Gennes] postulated that one day it would be possible to test this. I think he would have been very excited to see it happen."

From article by Kevin Stacey, Brown News Service

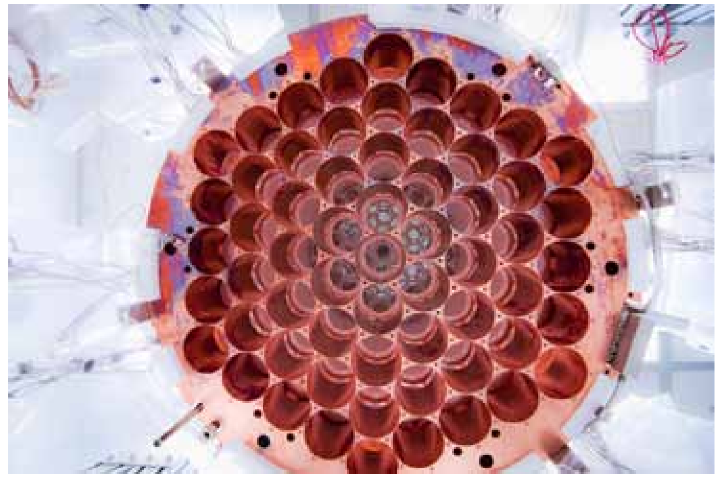
Dark Matter Hunting

An experiment to look for one of nature's most elusive subatomic particles is finally underwater — in a stainless steel tank nearly a mile underground beneath the Black Hills of South Dakota. The Large Underground Xenon experiment — LUX — will be the most sensitive device yet to look for dark matter. Thought to comprise more than 80 percent of the mass of the universe, dark matter has so far eluded direct detection. The LUX detector, under construction for more than three years in South Dakota, was installed underground in a protective tank in July. "We're nearly ready to switch on," said Professor **Rick Gaitskell**, one of the founding investigators on the experiment. "Once it's running, the LUX detector offers our best chance yet of directly detecting dark matter."

Dark matter particles are neutral and they don't emit light, so LUX scientists will look for evidence of collisions between dark matter particles - called weakly interacting massive particles (WIMPs) - and xenon atoms inside the LUX detector. "We're basically using a bucket of xenon - albeit a very carefully instrumented one - to capture the signature of particles as they pass through it," Gaitskell said. "If WIMPs are among those particles, we should be able to detect them."

LUX requires a very quiet environment. The experiment was installed 4,850 feet underground in the Sanford Lab, where it is protected from the cosmic radiation that constantly bombards the surface of the earth. LUX also must be protected from the small amounts of natural radiation from the surrounding rock. That's why the detector was lowered into a stainless steel tank 20 feet tall and 25 feet in diameter. The tank, filled with more than 70,000 gallons of ultrapure de-ionized water that will shield the detector from gamma radiation and stray neutrons, is lined with 20 devices called photomultiplier tubes, or PMTs, each capable of detecting a single photon of light. Very occasionally, a high-energy particle caused by cosmic radiation will penetrate the earth all the way down to the LUX experiment. If that happens, the resulting tiny flash of light in the water will alert researchers that a corresponding signal in the detector was not caused by dark matter.

The Lux detector, hanging at the center of its 25 feet diameter water tank, which serves as a radiation shield and is itself instrumented as a Cherenkov light detector. The tank was filled with water in September 2012, one of the few last steps needed toward getting ready to turn the experiment on for dark matter hunting.



Inside view of the LUX detector, before installation of the bottom array of photomultiplier tubes (PMTs) in their copper honeycomb support. The top array PMTs are visible though the holes in the bottom, about 2 feet away. The responsibility for PMTs installation and testing rested with the group at Brown University.

The detector itself is a double-walled titanium cylinder about six and a half feet tall and three feet in diameter. The cylinder is a vacuum thermos — or "cryostat" — that holds about a third of a ton of xenon, cooled to a liquid state at –160 degrees Fahrenheit. Inside the cryostat, 122 smaller PMTs will detect when a WIMP bumps into a xenon atom. The collision will produce two flashes of light—one at the point of impact and a second flash in a thin layer of xenon gas at the top of the detector. Electrons released during the collision and drawn upwards by a strong electrical field inside the detector will cause the second stronger flash. Researchers will compare data from the two flashes to determine whether dark matter has been discovered.

The search for dark matter represents the next great frontier in physics Gaitskell said. "On the cosmological scale, it's mostly dark matter out there," he said. "Visible forms of matter are just the flotsam and jetsam on the surface. So we really are looking to discover something fundamental about the nature of the universe." The LUX scientific collaboration includes dozens of scientists from 17 research universities and national laboratories in the United States and Europe. Brown's group, led by Gaitskell, consists of senior research associate **Simon Fiorucci** and postdoctoral research associate **Monica Pangilinan**, along with graduate students **Carlos Faham**, **Jeremy Chapman**, **David Malling**, **James Verbus**, **Samuel Chan** and **Dongqing Huang**.

The Sanford Lab, located in the former Homestake gold mine, is owned and operated by the South Dakota Science and Technology Authority, with support from the Department of Energy and oversight by DOE's Lawrence Berkeley National Laboratory. Read more: www.luxdarkmatter.org

From article by Kevin Stacey, Brown News Service

Notable Papers

Probing the Possible Supersolidity of Helium

During the last eight years, there has been much interest in the possibility that solid helium may enter a superfluid state ("supersolid") below a temperature of 0.2 K. Most of the experimental evidence supporting this comes from torsion oscillator experiments, which are able to detect very small changes in the moment of inertia of a solid sample. In a paper published as an editor's choice article in *Physical Review B*, "Effect of elasticity on torsional oscillator experiments probing the possible supersolidity of helium", Professor **Humphrey Maris** was able to show that the observed changes may, in fact, be due to a change in the elastic properties of the solid, rather than a transition to the supersolid state. In December, *Physics Today* published a paper acknowledging that Maris was able to explain away original evidence of supersolidity in helium-4.

Non-Abelian Anyons

One of Professor **Dima Feldman**'s papers, Hanbury Brown–Twiss Interference of Anyons,was featured by *Physics*: *Spotlighting Exceptional Research*. The paper, which appeared in *Physical Review Letters*, proposes an experiment to probe the existence of non-Abelian anyons. These are, arguably, the smallest particles in the Universe: their charges are one quarter of the electron charge and lower. Their statistics, in contradiction with elementary quantum mechanics textbooks, is neither Fermi nor Bose. The idea is to consider two-particle interference. This will allow one to see signatures of both exchange and exclusion statistics [the latter is the anyonic analogue of the Pauli principle].

BCM Theory at 30

"The BCM theory of synapse modification at 30: interaction of theory with experiment" by Professor **Leon N Cooper** and Adjunct Professor (Research) **Mark Bear**, published in *Nature Reviews Neuroscience* in November of 2012, chronicles 30 years of the BCM (Bienenstock, Cooper, Munro) theory of synaptic plasticity. The authors detail how over the past 30 years BCM theory has suggested experiments, how its postulates and some of it consequences have been confirmed by experiment, how the experiments have led to further refinement of the theory, as well as the discovery of important new phenomena. The authors suggest BCM theory as a good model for the successful interaction between theory and experiment in neuroscience.

Precision Cosmology

Two papers by Professor **Greg Tucker**, "Nine-year Wilkinson Microwave Anisotropy Probe WMAP Observations: Final Maps and Results" and "Nine-year Wilkinson Microwave Anisotropy Probe WMAP Observations: Cosmological Parameter Results" were submitted to the *Astrophysical Journal Supplement* in 2012. The WMAP science team has determined, to a high degree of accuracy and precision, not only the age of the universe, but also the density of atoms; the density of all other non-atomic matter; the epoch when the first stars started to shine; the "lumpiness" of the universe, and how that "lumpiness" depends on scale size. In short, when used alone (with no other measurements), WMAP observations have improved knowledge of these six numbers by a *total factor of 68,000*, thereby converting cosmology from a field of wild speculation to a precision science.

From National Aeronautics and Space Administration website

In 2012, *ScienceWatch Newsletter* reported that three earlier WMAP papers were among the "hottest" of 2011. One of the papers, cited more than 500 times before the end of its first year of publication, delivered the "cosmological interpretations" of the WMAP seven-year data. The papers offer significant insight into the past and present universe.

Causality and Chirality

Causality is one of the basic laws of Nature. It states that only the past can affect the future but the future has no effect on the past. In some topological states of matter, known as chiral systems, the causality principle is greatly enhanced: in addition to the past-future asymmetry, the left has no effect on what happens on the right. Another paper by Professor **Dima Feldman**, "Chirality, Causality, and Fluctuation-Dissipation Theorems in Nonequilibrium Steady States", appeared in *Physical Review Letters*, examines this causality from chirality, which has dramatic consequences for the statistical mechanics in topological states of matter. He and his co-author, **Chenjie Wang**, PhD'12 found that the fluctuation-dissipation theorem applies even beyond thermal equilibrium. This is very different from the usual fluctuation-dissipation theorems, such as the Einstein relations and the Nyquist formula, and provides a convenient way to probe chirality in experiment. Wang, Feldman's former student, received the Houghton Award in part for his research that contributed to this paper.

New Courses

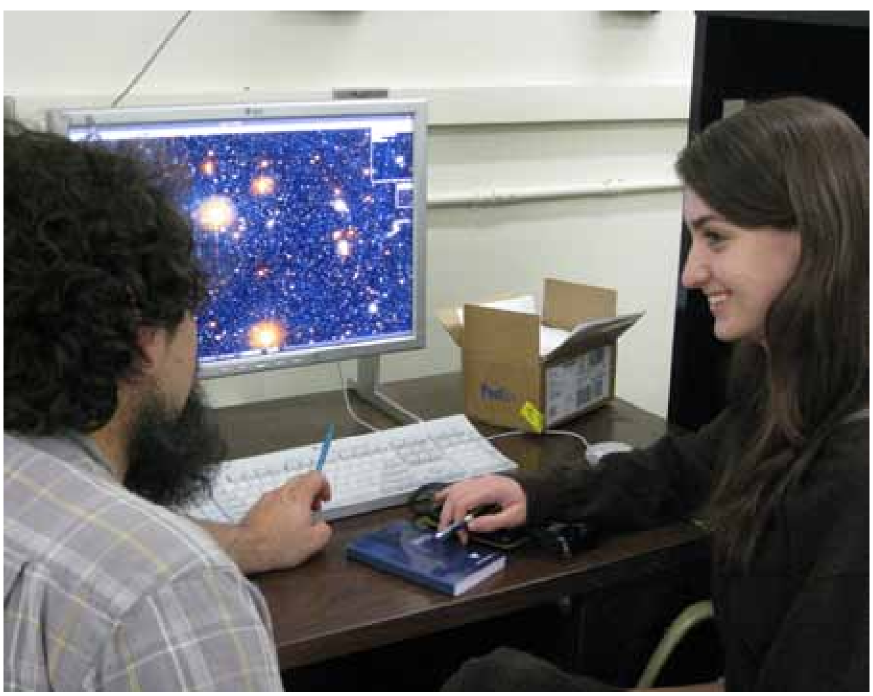
PHYS 1970 Physics of Energy

Professor **Derek Stein** designed an introductory course to the fundamental laws that govern energy and its use. Fundamental concepts are analyzed quantitatively in the context of important applications of energy. Mechanical energy, thermodynamics, the Carnot cycle, electricity and magnetism, quantum mechanics, nuclear physics, and photosynthesis are among the examined concepts. The technologies covered include wind, hydro, and geothermal energy, engines and fuels, electrical energy transmission and storage, solar energy and photovoltaics, nuclear reactors and biomass.

Society's use of energy underlies improvements in the living standard.   The consequences of energy use are having a significant impact on the Earth's climate, and its scarcity in certain forms is a source of insecurity and political conflict. Undergraduate students at Brown appreciate these facts and are increasingly interested in energy. This course is intended for undergraduates interested in energy science, regardless of whether that interest stems from a desire to develop new technologies, a concern for the environment, a desire to participate effectively in the energy policy debate, or simply curiosity about the fundamental physics.

PHYS 0112 Alien Worlds: The Search for and Properties of Extra-Solar Planets

Our understanding of planets has been revolutionized over the last 25 years. With the discovery of an ever-growing number of planets and planetary systems, it is now possible to take a population approach to answering the question of how planets form and how they arrange themselves. Recent discoveries show that many of the things taken for granted when there was only the solar system to describe are not true. This course developed by Professor **Ian Dell'Antonio** will introduce these new findings and explore how our understanding of planets, habitable worlds, and the search for life in the Universe has changed as a result of this avalanche of discoveries. Professor **Greg Tucker**, who will teach the course this spring, has modified it to include more about the search for life in the Universe.



Professor Ian Dell'Antonio with summer research student Nora Shipp

International Activities

Hanoi University of Science

As part of the Physics Department's ongoing relationship with the Hanoi University of Science, Professor **Vesna Mitrovic** traveled there in December. She delivered 12 hours of lectures over the course of four days about various topics, including Quantum transport in Low Dimensional systems, Spectroscopic techniques (STM, AFM, NMR), Superconductivity, and quantum devices. She said her time in Hanoi was exhausting but really fun interacting with students and colleagues there. She found the students to be very enthusiastic and approachable. Vietnam fosters a culture of great respect and regard for professors, and Professor Mitrovic said she was treated royally during her 6-day visit.

Each fall for the past five years, Brown has hosted visiting faculty from HUS to observe classes and learn about the department's teaching methods. In 2012, two visitors, Dr. Nguyen Anh Tuan and Dr. Le Tuan Tu, spent September and October observing classes taught by Professor **Derek Stein** and Dr. **Miquel Dorca** on advanced electromagnetic theory and thermodynamics and statistical mechanics.

Vesna Mitrovic with students at the Hanoi University of Science

Alumni in Taiwan

While on sabbatical during the fall, Professor **Chung-I Tan** spent a month in Taiwan visiting the Physics Department and the National Center for Theoretical Physics at National Chiao-Tong University. While in Taiwan, he had a reunion lunch in Hsingchu with three Brown physics alumni. Hsingchu is a town located about thirty minutes outside of Taipei, and it is considered the "Silicon Valley" of Taiwan because of the many high-tech companies located there. It is also the home of National Chiao-Tung University and National Tsing Hua University. These two universities, together with National Taiwan University, are three top universities in Taiwan.

Shih-Ying Hsu, PhD'96 a former student of Professor Jim Valles and **Chung-Hou Chung**, PhD'02 who received his PhD working with Profesor Brad Marston, are both faculty members at National Chiao-Tong University. **Heh-Nan Lin**, PhD'93 Professor Humphrey Maris's student, is a professor in the Department of Materials Science and Engineering at National Tsing Hua University. Another alumnus, **Hing-Tong Cho**, former student of Professor **Herb Fried**, came to a seminar presented by Professor Tan at National Chiao-Tong University.

L to R: Heh-Nan Lin, Chung-Hou Chung, Shih-Ying Hsu and Chung-I Tan

Outreach Activities

Mike Morse with students

Supported by Brown's NSF GK-12 education grant, graduate student **Michael Morse** taught weekly science lessons to fifth graders at Vartan Gregorian Elementary School during the winter, spring and fall of 2012. The GK-12 program also supported tours of the physics labs in October, for third, fourth and fifth graders from the school.

Professor **Jim Valles** provided two local high school students with the opportunity to work in his lab last summer. One of the students spent his time investigating how paramecium, a micro-organism, adjusts its swimming patterns in a current. The second student focused on superconductors and the creation of an apparatus for observing their supercondeucting transition.

Professor **Ulrich Heintz** is running a QuarkNet center with colleagues from Northeastern University. QuarkNet is a long-term, research-based teacher professional development program in the United States jointly funded by the National Science Foundation and the US Department of Energy. About a dozen high-school physics teachers from Providence and the Boston area have participated. There are several half-day meetings over the course of the academic year to share classroom activities and news from particle physics research, and a one-week summer workshop.

Professor **Humphrey Maris** arranged for a group of 8th graders from the Gordon School to visit Brown and see a presentation by **Jerry Zani**. Although the students didn't have any background on the science of soundwaves, the experiments and demonstrations were aimed at their level and held their interest. Jerry did a great job of involving the students and listening to their thoughts and questions. Professor Maris is currently planning a visit from the Met School with the help of alumnus **Lyle Fain** '67, ScM '73.

Ian Dell'Antonio

Professor **Ian Dell'Antonio** engaged in a wide range of outreach activities throughout 2012. He organized the astronomy event at the Rhode Island Science Olympiad last March, and he ran a teacher workshop for 20 high school teachers on spectroscopy and the properties of stars. He ran multiple "Stargazers" events at the Providence Children's Museum Ladd Observatory curator **Mike Umbricht** and graduate student **Ryan Michney**. Professor Dell'Antonio also worked with the Americorps volunteers at the Museum to deploy solar telescopes in Providence Boys and Girls' clubs to map out sunspots. Last but not least, he is organizing an exhibit for the Roger Williams Park Natural History Museum on galaxies and the expansion of the Universe. The exhibit is scheduled to open in February 2013.

Leon Cooper with students at Wheeler School

Two of our faculty made visits to the Wheeler School in Providence. Professor **Gerry Guralnik** gave a talk about the Higgs Boson and Professor **Leon Cooper** met with members of the BioMed Club to discuss string theory, memory, radiation, and Cooper Pairs.

Ladd Observatory

Ladd Observatory's 121st year of operation was the most active in recent history.

On the afternoon of the June 5th transit of Venus, Physics Department staff and faculty were deployed at the Ladd Observatory and both auditoriums of Barus and Holley, where the public anxiously awaited a view of this "last in a lifetime" historic event. It was mostly cloudy at the time of the transit but members of the public were able to watch live broadcasts from other observatories with commentary by our faculty. Curator **Mike Umbricht** was able to obtain images of the transit as seen through the clouds, using a CCD camera attached to the back of Ladd's 12" Brashear refractor.

For those interested in history, 2012 was a banner year for Ladd Observatory. Funding from NASA's RI Space Grant enabled Ladd to exhibit one of Brown's first scientific instruments, a telescope made in England and purchased by the Brown family. Benjamin West, professor of mathematics and natural history, used it to observe the 1769 transit of Venus from a location later named Transit Street. These observations were part of an international coordinated effort to measure the scale of the solar system, a kind of early version of "big science" which included Captain Cook's observations from Venus Hill in Tahiti. Faculty and staff joined forces with the History Department and the Providence Athenaeum to host a series of history of astronomy talks about both the world-wide effort and Brown's observations in particular.

Ladd also teamed up with the "Year of China" program and the Science Center to host a series of talks, including a talk on campus by the world's leading historian of ancient Chinese science and astronomy, Nathan Sivin, of the University of Pennsylvania.

The Smithsonian Institution recently approached Ladd with a request to assist with the creation of an exhibit on the history of timekeeping and navigation. Ladd has honored the request with the loan of a very significant 18th century sextant, which will be a centerpiece of the upcoming Smithsonian exhibit at the National Air and Space Museum.

Other historical ventures included Mike's work with the National Association of Watch and Clock Collectors, (including a Symposium at Ladd in September on Astronomical Clocks and Timekeeping) and work with members of the Photographic Historical Society of New England to restore Ladd's historic camera and spectrograph.

Ladd's first director was a dedicated meteorologist who set up Ladd as both a meteorological and an astronomical observatory. Over the past year, an effort was made to assemble detailed meteorological records in the archives including records that may ultimately provide data for climate scientists. Later historic records show the dramatic dip in barometric pressure during the Hurricane of '38. Some of these historic weather instruments are currently on display at Ladd.

In addition to the regular series of observing sessions held on Tuesday evenings, we have increased the number of public lectures, as well as demonstrations of astronomical concepts using historic instruments.

Benjamin West Telescope

Our collaboration with the Providence Children's Museum continues. In addition to our programs at the museum, **Ian Dell'Antonio** and Mike Umbricht trained Americorps interns to safely use solar telescopes for teaching children how to track sunspots. Our collaboration with the Roger Williams Museum of Natural History is ongoing and includes a loan of historic instruments as part of an exhibit supported by Rhode Island's NASA Space Grant. For more advanced amateur astronomers, **Bob Horton**, **Dave Huestis**, and Ian Dell'Antonio gave hands-on workshops in spectroscopy and H-alpha solar observation at the Seagrave Observatory in Scituate.

Over the summer, our staff was busy working with clockmaker David Gow of Shrewsbury, Mass, on the first complete restoration, since Ladd opened in 1891, of the main telescope's precision mechanical clock drive. Since there are few remaining experts in 19th century clock drives available, we expect the repair will last for another century. This work was made possible in part by donations to Ladd by John and Louise MacMillan, P '09, of Boston.

Francine Jackson's weekly column, distributed on a listserv of more than 1200 subscribers, includes the latest information about open nights and what people can expect to observe or hear about when hey arrive at the Observatory. She also includes enticing information about what to look for in the sky- whether they be appearances of the Space Station, meteor showers, or configurations of the planets, as well as fascinating information about the human side of astronomy and space exploration.

In addition to the weekly column, Ladd has a Facebook presence and a Twitter feed maintained by Mike Umbricht. It was a pleasant surprise to learn that of all of Brown's Facebook pages, Ladd's following is second only to the University's main page, with nearly 6,000 "likes."

Do you want to receive engaging weekly news stories about events in the night sky over Providence? More than 1250 people have signed up for Ladd's Listvserv, which provides information on events at Ladd and celestial happenings. Sign up at: www.physics.brown.edu/physics/commonpages/ladd/

Physics Demonstrator Extraordinaire

If Hollywood were to produce a movie based on Brown's physics department, Stanley Tucci would play manager of demonstrations **Gerald Zani**. Costume designers would gather a thin pair of round-wired frames, loose green pants, silver and blue Zig Tech athletic shoes and a gray T-shirt reading "I Heart PHZICS." The finishing touch to the Zani ensemble would be a black cellphone belt clip.

Zani aims to present demonstrations in a creative way, bridging academic fields. "My goal is to try to impact students with experiences beyond the equations in the classroom," he said. Inspired by a conference, he has also "learned about using the elements of theater-like music and drama" to show the "beauty of the phenomena." He seeks the help of one of his student assistants, Stephen Albright '13, who studies both physics and music. As a result, Zani synced Camille Saint-Saens' "Danse Bacchanle" with his demonstration on magnetism. Placing a light beneath a hollow copper tube, Zani asks students to look through it, like a magician convincing the audience "there are no tricks." As he drops miniature hockey puck-shaped magnet into the tube, Zani makes the magnet slowly float down the tube without touching the edges. "I time the music so that when you release the magnet, the music is playing," Zani said. "You hear this beautiful music and then it stops, and you hear the clunk as the magnet stops."

Over the course of his 19-year career at Brown, Zani has made lasting impressions on students and faculty. Students always know who "Jerry" is and feel his work should not go unnoticed. "He is definitely one of the most underappreciated people at Brown," said Abishek Kulshreshtha '15. Sarah Schade '15, who worked with Zani for nine weeks in the summer, was immersed in Zani's world as she helped digitize his videos and create new demos for the upcoming semester. "He will do anything to make sure that those demonstrations go well," Schade said. "Also, he tries to teach. He would always ask me if I knew what the demos really meant and would go up to the chalkboard and go into very minute detail."

On a hectic Wednesday morning before a lecture, Professor Savvas Koushiappas came into the office to pick up the demonstration about electron beams and magnetism for his class PHYS 0470: "Electricity and Magnetism." Zani had already prepared the table with the various pieces of equipment in advance, but Koushiappas realized he needed a larger piece for the class to be able to see. "Jerry is the best and very impressive," Koushiappas said as Zani set up the new electron beam demonstration. "I'll call him ten minutes before class and say, 'Hey, Jerry. Do you have anything to demonstrate this concept?' and he'll get it."

Zani says he feels fortunate to collaborate with the physics professors and enjoys coming in to work each day to learn something new and share a bit of science with students. "I have to be a salesman and encourage professors to do risky things," Zani said.

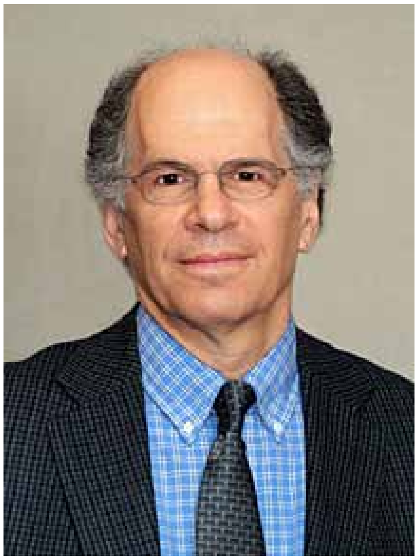
From article in Brown Daily Herald
by senior staff writer Mark Valdez'15

got energy?

Professor **Derek Stein** launched the Energy Science and Technology Seminars in 2009 with the intention of bringing together members of the Brown community who share an interest in energy. This effort was part of a larger initiative to stimulate and organize research in that area. The first seminar series featured Brown researchers exclusively, which allowed faculty to introduce themselves and describe their specific interests.

Subsequent seminars over the past two years have highlighted speakers from a range of professions, including scientists, technologists, entrepreneurs, and policy experts. The seminars attract a diverse audience of faculty, postdocs, grad students, and undergrads from Physics, Chemistry, Engineering, Applied Math, Computer Science, and Geology. Despite the breadth of the participants and attendees, the talks are typically not highly technical so they can remain accessible to a wide audience. The talks occur every other Friday at noon and are relatively short (usually about 40 minutes) so there is plenty of time for discussion, which is often lively and lots of fun. As Professor Stein says, "Bring your lunch, your friends and your energy!"

Arthur O. Williams Lecture



Stewart Prager, director of the Princeton Plasma Physics Laboratory, and professor of astrophysical sciences at Princeton University, presented the annual A. O. Williams Lecture on February 6, 2012. His talk, "The Path to Magnetic Fusion Energy," traced the development of fusion as an energy source by summarizing the physics progress in fusion research to date. He discussed the International Thermonuclear Experimental Reactor (ITER), which is designed to produce 500 megawatts of output power for 50 megawatts of input power, or ten times the amount of energy put in. Dr. Prager then outlined the remaining steps to successful production of fusion power.

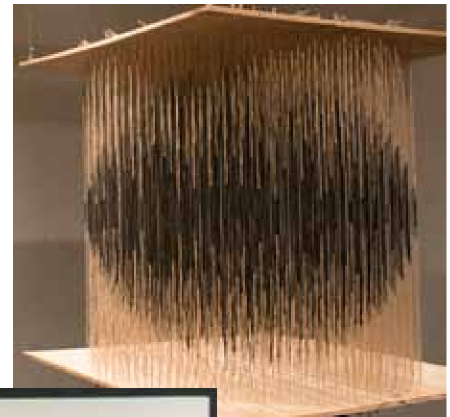
Prior to his current position at Princeton, Dr. Prager was director of the University of Wisconsin-Madison Symmetric Torus (MST) experimental facility supported by DOE. He also served as director of the Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, established through the National Science Foundation program of "physics frontier centers." Dr. Prager has participated in numerous scientific planning and advisory processes, including service as the chair of the DOE's Fusion Energy Sciences Advisory Committee, chair of the Division of Plasma Physics of the American Physical Society (APS), and President of the University Fusion Association. He is also a co-recipient of the APS Dawson Prize for Excellence in Plasma Physics, a fellow of the APS, and a recipient of the Leadership Award of Fusion Power Associates.

2012 Poster Session

The annual poster session was held on November 7 in the lobby of Barus & Holley. Thirty-eight boards and various multimedia displays represented 19 research groups led by Physics faculty as well as adjunct faculty from Chemistry, Engineering, and the MBL. Ladd Observatory also participated this year, presenting a poster on the work that **Michael Umbricht** and Professor **Ian Dell'Antonio** are doing with "Outreach and Citizen Science at Ladd Observatory" to recruit a graduate student to assist with programs in the local schools. About 100 faculty, postdocs, graduate and undergraduate students participated in the session.

People and Events

Physics Art Show



Roy Lichtenstein, the pop artist of the 1960s, said, "Organized perception is what art is all about." One could argue that the same statement applies to physics. The two disciplines share a creative process and certain fundamental compositional demands. In fact, one of our alumni, **Jack Leibowitz** PhD'62, has written a book, *Hidden Harmony: The Connected Worlds of Physics and Art*, that explores what art and physics have in common. Our annual show is a celebration of the creativity that comes with research and learning in physics.

Students, faculty and staff were encouraged to submit items to the third annual Physics art show, and the result was a gloriously diverse display of various media. Attendees browsed among more than 25 entries, including photography, ceramics, door stops, t-shirts and a video, just to name a few. One of the most stunning entries was senior Fahmina Ahmed's sculpture based on the equation of a sphere. Physics concentrator **Nathan Weinberger** '13, and other members of two Brown dance troupes performed several well-received pieces.

Todd French

Todd French, who has served as a custodian for Barus & Holley for many years, contributed an array of brightly colored doorstops. The whimsical pieces are a fixture in many offices throughout the Physics Department where they perch on desks. As one staff member said, "They are too nice to use as doorstops." No two are exactly alike, and a couple of Todd's finest creations were raffled off at the conclusion of the show. Inspired by these small works of art, Professor **Jim Valles** used them in his speech at Brown's Midyear Ceremony as a metaphor for inclined planes that promote access to challenging ideas.

Making ice cream at the Physics Picnic

Brown Degree Day

L to R: Graduate student Michael Jokubaitis, Lyle Fain '67, ScM '73, Professor George Seidel and Professor Rick Gaitskell

The fourth annual Brown Degree program, held on April 28, 2012, featured a keynote speaker, **Carmen Huber**, PhD'83, and five alumni panelists. Dr Huber, the NSF Europe Office Head, was introduced by Professor **Robert Pelcovits** and talked about the challenges and rewards of scientific program administration. Her presentation was followed by a panel discussion moderated by **Richard Cook**, PhD'12. The panel, which represented a wide range of career choices, included a patent attorney (**Michael Attisha**, PhD'06), geoscientist (**Amandine Cagnioncle**, ScB '03, PhD'08), medical physicist (**David North**, ScM'73), optical systems engineer (**Matt Truch**, PhD'07), and a retired business analyst and technology manager (**T. Frank Wong**, PhD'70). There was a Q&A session after the panel, and students had the opportunity to mingle with panelists over refreshments in the lobby. One undergraduate later commented that the program was "very instrumental in persuading me to choose Physics as a freshman." Professor **Savvas Koushiappas** gave a talk entitled "The Search for the Dark Matter Particle" before faculty and alumni set off for dinner at the Faculty Club.

Tony and Pat Houghton Memorial Lecture Series

Tony Houghton

On October 8, 2012, the Physics Department hosted the first of the **Tony** and **Pat Houghton** Memorial Lecture Series. This event, endowed by a very generous bequest from Tony and Pat, honored Tony's achievements as a condensed matter theorist and his lifetime devotion to the Physics Department. Tony joined the Brown faculty in 1963 and retired in July 2002. Sadly, he passed away a year later after a valiant struggle against cancer.

Tony served as department chair from 1992 to 1998. His wife Pat passed away in 2009 and was a constant source of support to Tony and his love for physics.

Tony was a great mentor to his PhD students, his postdocs and junior faculty. The speakers at the event included three of Tony's students, **Asle Sudbo,** PhD'90 **Oriol Valls,** PhD'76 and **Ilya Vekhter,** PhD'98; one of Tony's postdocs, Nick Read; and two of Tony's collaborators, Franz Wegner and Peter Young. The speakers presented talks on a wide range of topics in condensed matter physics and paid tribute to Tony's lasting influence on them as physicists as well as the deep friendship they had with both Tony and Pat. The Department was very gratified and pleased to have members of Tony's family in attendance. The event was a great success and a fitting tribute to a beloved member of the faculty and his wife.

Wonho Rhee, Class of 2016, Jim Valles, and Wonho's grandfather Chunghi Rhee PhD '70

Higgs

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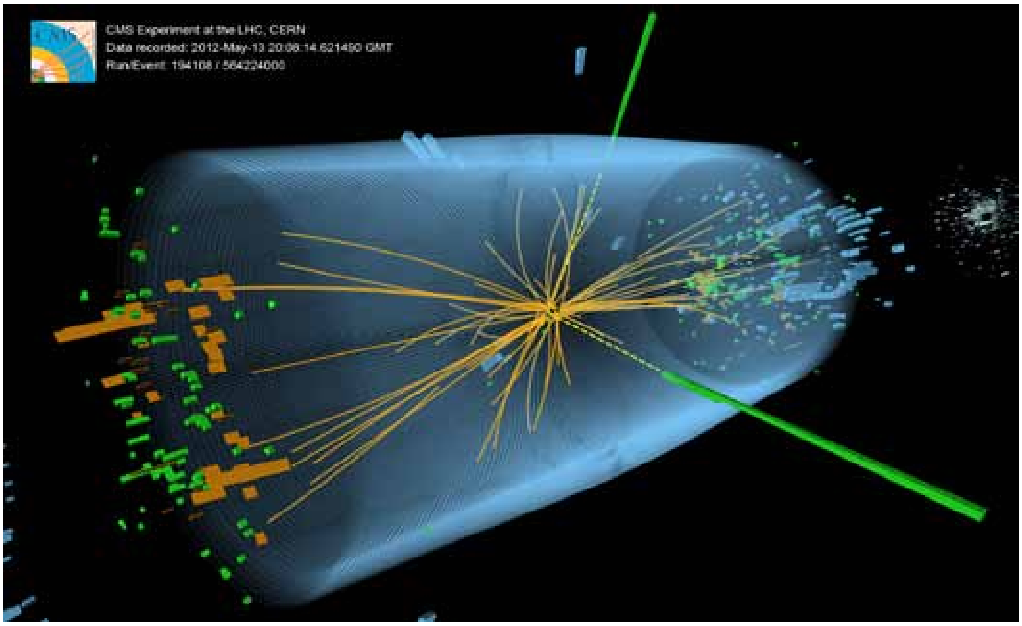

Figure 2: Event recorded with the CMS detector in 2012. The event shows the characteristics expected from the decay of the SM Higgs boson to a pair of photons which are shown as dashed yellow lines and green towers.

decays to pairs of Z bosons. At the time of the discovery Landsberg was Physics Coordinator and oversaw all physics analyses carried out by CMS Collaboration. Professor Ulrich Heintz led one of the review committees that were set up by the collaboration to make sure the analyses were carried out correctly and the conclusions would hold up to scrutiny. Professor David Cutts is one of the chairs of the Publications Committee which reviews all publications before they are submitted to journals. Members of the group conveyed the excitement of the discovery to the Brown Community in a public event on October 9, 2012 (see link under "News" at www.physics.brown.edu).

This discovery refocuses the program of particle physics at the energy frontier. We now have to measure the properties of this new particle to make sure it is the Higgs boson. Any discrepancies from theory predictions could give us information about physics at higher energies. The discovery of the Higgs boson has also given us reason to believe that there have to be new particles or interactions at higher energies. With the Higgs boson the standard model can describe massive particles. But the interactions that the Higgs boson has with these particles would themselves make the Higgs boson very massive, much more massive than the observed 125 GeV. There has to be a mechanism that keeps the mass of the Higgs boson small. This implies that there must be new particles and interactions that we have not yet observed – presumably because they only appear at higher energies.

The research that the Brown group carriers out spans much of this scope. The group is working on identifying additional decays of the Higgs boson such as Z boson plus photon and bottom quark pairs. We are searching for new particles at higher energy that could explain the small mass of the Higgs boson such as supersymmetric particles or new types of quarks. In order to achieve these goals, data from many more collisions will have to be analyzed. In order to deliver these data the energy and intensity of the proton beams that the LHC delivers will increase over the coming decade. The Brown group is carrying out R&D to develop the detector technologies needed to collect these data.

The Brown CMS group is looking forward to a fruitful decade of studying physics at the highest energies.

Physics at Brown

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