Spring 2013
Vol. 1 No. 2

the Physics Illinois Bulletin

inside this issue:

Department of Physics
College of Engineering
University of Illinois at Urbana-Champaign

A Message from the Head: Looking Forward

Dear colleagues, alumni, and friends,

At the end of another academic year, it is an appropriate time to reflect on where we are as a department and where we want go. Certainly compared with where we were a few years ago, at the peak of the financial crunch and administrative turnover at the University of Illinois, we are in a much better place. At that time, the size of the Physics faculty had dropped precipitously and was approaching 50, well below our typical numbers in the mid-60s—the combined result of not hiring new faculty for several years and the unexpected departures of several key people. With student enrollments increasing and research productivity growing, the declining faculty size was putting enormous pressure on our ability to carry out our core missions in teaching, research, and service.

The last three years have been increasingly brighter. By the end of 2013, we expect to have hired a dozen faculty members over the last three years—half of those just this year—all excellent scientists in areas of strategic interest to the department. This year alone, we interviewed more than 20 faculty candidates from a combined pool in all areas of more than 250 candidates. That's a lot of applications and a lot of dinners, but it was worth the effort, because nothing energizes a program more than bringing in talented young people who take us in new and exciting directions. Even with these hires, we remain short of our target of 60 faculty members, so we expect to conduct even more searches next year.

There has been a corresponding increase in staff size in the department over the last few years, filling critical needs in introductory course administration, communications, advancement, and technical support for research. Our staff plays an essential role in enabling the department to do great physics and develop great physicists, and we are grateful for their extraordinary talents and commitment.

The growth in student enrollment and faculty size has triggered a need for more and better space for instruction and research, and we are making plans to address that. We are about to begin a major classroom renovation supported by University funds: this project will expand the classrooms in which we teach courses for our physics majors, upgrade discussion and lab rooms for our introductory courses, and create a new active-learning classroom in the space formerly occupied by scientific journals (which are now available online). It will also bring us brighter hallways, new restrooms, fire suppression sprinklers, and a faculty-staff lounge and kitchen from which to stage departmental events. The proposed project, like the recent construction of the Physics Interaction Room in the old Physics library space and the recent remodeling of the main department office, continues our investment in infrastructure to improve both the utility and attractiveness of our space.

We have even more ambitious plans. Two feasibility studies are underway for projects that will expand the size and capabilities of the Department of Physics. One is a design for an Advanced Experimental Research Building that would provide high-bay, low-vibration, electromagnetically shielded space for sensitive experiments in condensed matter physics—it would be located behind the Materials Research Laboratory on the site of the former nuclear reactor, which was decommissioned and razed. The other is an addition to the Loomis Laboratory of Physics on the west side, building over the lecture halls. This project would create new lecture halls, space for departmental and faculty offices, a complex for graduate students, an open atrium for events, and a new gateway for the Department of Physics that faces the core of campus. It is not clear when or if these projects will be realized—it will take a creative effort to identify the necessary resources and an equally creative plan for covering our course loads during the construction phase—but it certainly will never happen unless we make a plan and do our best to convince the University, the State, and our friends of the transformative impact that these projects would have on advancing physics research and teaching at Illinois.

With all the attention to the future of the department through hiring and infrastructure, one longstanding and distinguishing feature of our department remains constant: the commitment and excellence of our faculty, students, and alumni and their record of achievement and recognition. This newsletter highlights just a few of the many accomplishments of those who are or have been a part of Physics Illinois.

The road ahead will not be easy. The State of Illinois continues to have serious financial issues that have translated to decreasing support for higher education and imminent pension changes that could affect the career plans of our faculty and staff. Similar pressures nationwide are resulting in a squeeze on federal funding after many consecutive years of increases in research expenditures. Our faculty has responded by seeking new grant opportunities to support their research programs and by exploring innovative interdisciplinary collaborations to address complex scientific problems and to solve societal problems in health, energy, and the environment.

To our alumni, changes in the funding of public universities nationwide are also driving a targeted expansion of our advancement activities. We want to maintain contact with as many of you as possible and to keep you apprised of what is happening in Urbana—this newsletter is one way to do that. You are important to us: you are our legacy, you serve as role models for our students by demonstrating what you can do with a physics degree, and you are a steady and greatly appreciated source of support for the Department of Physics through your gifts and your role as ambassadors for our program. I encourage you to keep us informed of what is going on in your world and to visit us at any time.

the Physics Illinois
Bulletin

Dale Van Harlingen
Professor and Head

Celia Elliott
Director, External Affairs
and Special Projects

Erin Kirby
Assoc. Director of Advancement

Siv Schwink
Communications Coordinator

the Physics Illinois Bulletin
is a semiannual publication of the
Department of Physics
at the University of Illinois
at Urbana-Champaign.

Please send us your comments
or ideas for future stories:

the Physics Illinois Bulletin
Department of Physics
Loomis Laboratory
1110 West Green Street
Urbana, IL 61801-3080

or contact Siv Schwink at
sschwink@illinois.edu
or (217) 300-2201

Printed on recycled paper with soybean ink.

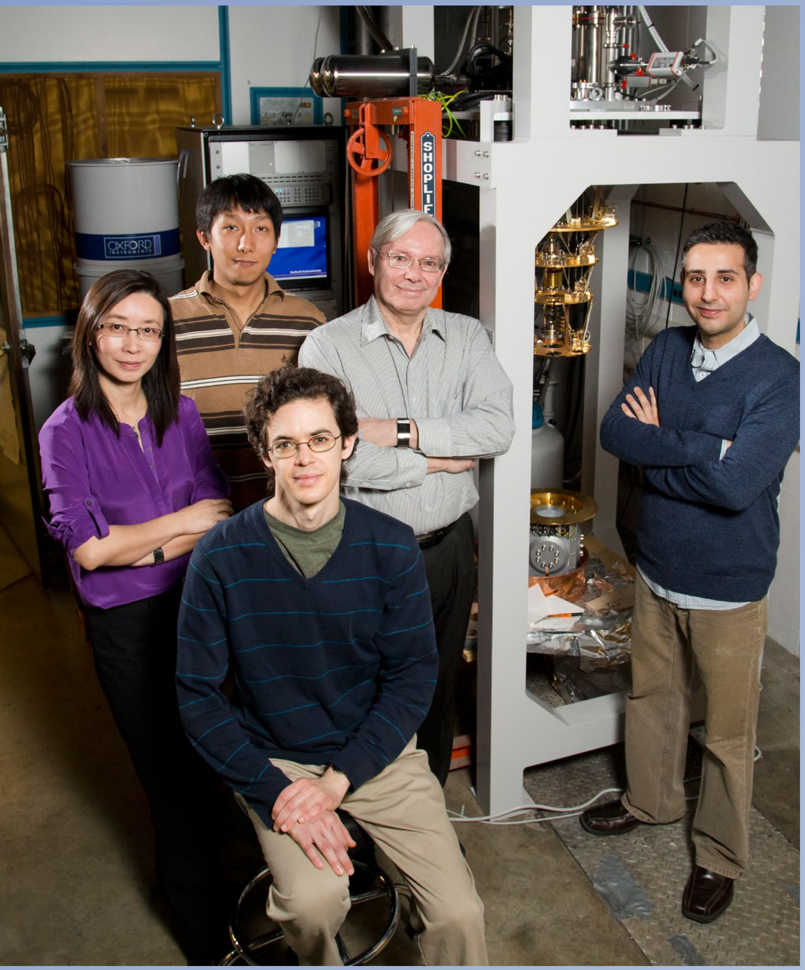
The tremendous accomplishments
and varied life paths of our
Physics Illinois alumni
never cease to amaze us.
Where did your path take you after
Physics Illinois?
Let us know where you are and what
you are doing—we would love to
hear from you!

Get our latest news. Update your contact information.

http://go.physics.illinois.edu/alumni

Follow us. Like us.

Cover image: Research team leader Dr. Aaron Finck (seated) poses with (L-R) ECE Professor Xiuling Li, ECE graduate student Kyooho Jung, Professor Dale Van Harlingen, and ECE researcher Dr. Parsian Mohseni, next to one of the closed-cycle ^{3}He dilution refrigerators in Van Harlingen's laboratory in the Frederick Seitz Materials Research Laboratory. The team detected Majorana-like signatures in a hybrid semiconductor/superconductor device. Photo by L. Brian Stauffer



Glimpses of interfering Majorana pairs at Illinois

Research team leader Dr. Aaron Finck (seated) poses with (L-R) Electrical and Computer Engineering (ECE) Professor Xiuling Li, ECE graduate student Kyooho Jung, Professor Dale Van Harlingen, and ECE researcher Dr. Parsian Mohseni, next to one of the closed-cycle ^{3}He dilution refrigerators in Van Harlingen's laboratory in the Frederick Seitz Materials Research Laboratory.

Since it was first theorized more than seven decades ago by Italian physicist Ettore Majorana (1906–1938), the Majorana fermion—believed to be the only particle that is its own antiparticle—has eluded the searches of experimental particle physicists. Unlike more familiar fermions such as electrons, protons and quarks, this hypothetical quasiparticle would have zero charge. While it is still an open question whether fundamental particles such as neutrinos might be Majorana fermions, recently there have been a number of theoretical proposals that certain condensed matter systems contain zero energy states that act like Majorana fermions. If discovered and ifcapable of being manipulated and exchanged, Majorana fermions hold promise for applications in quantum computing as qubits (quantum bits) that would be protected from dephasing.

The first glimmer of the elusive quasiparticle was seen last year, when a team of condensed matter physicists at the Delft University of Technology in the Netherlands, led by Leo Kouwenhoven, (and including Physics Illinois alumnus Sergey Frolov, now at the University of Pittsburgh) reported evidence of a Majorana-like state in a hybrid semiconductor-superconductor device. These researchers observed a peak in the electrical conductance at zero voltage in an indium-antimony nanowire, a single-crystal semiconductor having strong spin-orbit coupling, in contact with a superconducting lead at high magnetic field. This anomalous conductance peak is the predicted evidence of a pair of Majorana fermions, one positioned at each end of the wire. The peak is expected to be exactly at zero energy when the Majorana fermions are well separated from each other.

In March of this year, condensed matter experimentalists in the Department of Physics at Illinois announced they had detected further evidence of Majorana-like signatures using a device similar to that of the Dutch team but with some important differences. In particular, the superconducting leads were narrower, enabling any Majorana fermions produced in the nanowire to be closer together, possibly leading to distinctive interactions.

The team, led by postdoctoral researcher Aaron Finck in the laboratory of Professor Dale Van Harlingen at the Frederick Seitz Materials Research Laboratory, used a semiconducting indium-arsenide nanowire expertly grown by three members of the Department of Electrical and Computer Engineering at Illinois—postdoctoral researcher Parsian Mohseni, graduate student Kyooho Jung, and Professor Xiuling Li.

The nanowire was mounted on a substrate with an electrostatic gate beneath it to tune the electron density in the nanowire. The researchers measured the conductance across the wire between two superconducting niobium nitride leads as temperature, magnetic field, and gate voltage were varied and observed the characteristic Majorana fermion signature: a conductance peak in the wire at zero voltage.

However, when the experimentalists changed either the magnetic field or electron chemical potential, the conductance peak would broaden and sometimes split into two finite voltage peaks which were observed to oscillate—to open then reform as a single peak—with variations to the back gate voltage or magnetic field.

These double peaks and their oscillations had been predicted last December as "smoking-gun" evidence of Majorana states by condensed matter physicist Sankar Das Sarma and colleagues at the University of Maryland in College Park in a paper they published in *Physical Review B.* The phenomena arises from the quantum wave functions of each Majorana fermion on either end of the wire interfering with the other.

Finck said the findings, while not conclusive, are consistent with the predicted behavior of two Majorana quasiparticles communicating with one another through the nanowire, wherein the wave functions of the two fermions reach toward one another, overlap, and hybridize, effectively annihilating, or in other words, transforming into more commonplace collective electronic states.

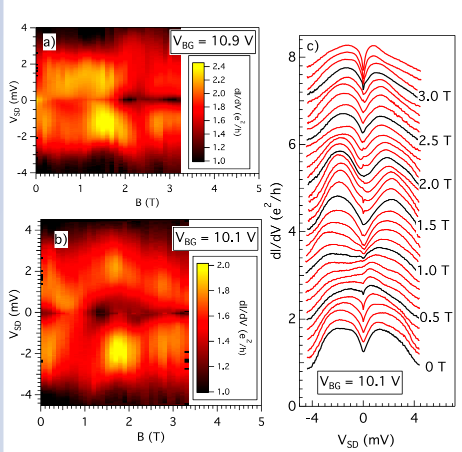
Van Harlingen added, "We are trying to understand—if in fact these are Majorana states—whether they are very robust or fragile. Over wide ranges of magnetic field, these states come in, lock onto zero voltage, and stay there so we think they are robust; others think they are fragile and difficult to stabilize. We're trying to get a picture of this."

Definitive proof of the existence of a fundamental Majorana particle has yet to be found, and some skepticism is sensible and justified, explained Van Harlingen. But this experiment does rule out certain possible explanations of the observed zero-energy state, including magnetic Kondo resonances and superconducting bound states that can also produce zero-energy peaks.

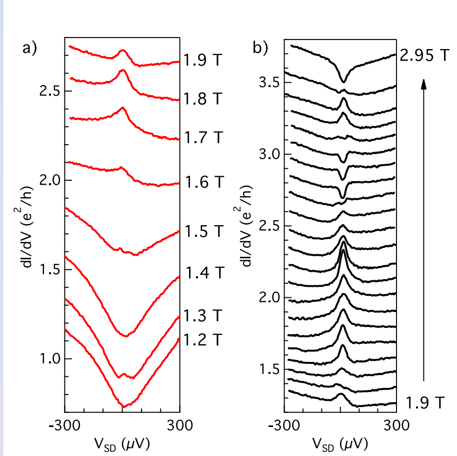
"Our second-generation experiment isn't conclusive evidence for the existence of the Majorana fermions, but it does provide further, stronger evidence for it. Other research groups are now seeing the same thing," said Van Harlingen.

The Van Harlingen group is continuing to search for this as-yet theoretical quasiparticle and has already submitted a second paper for publication based on a different approach. "The newly completed experiment provides additional evidence for Majorana fermions in a related system—topological insulators in proximity to superconductors. We see intriguing signatures of Majorana excitations in the Josephson effect," said Van Harlingen.

The search for Majorana fermions is one problem in the emerging field of topological quantum phenomena that is being explored worldwide, and researchers at Illinois will attack it with all the advantages that the Urbana style of physics affords: the interaction of theorists and



(a), (b) Conductance traces vs. the magnetic field for two different densities. (c) Individual traces for V_{BG}=10.1 V, each trace differing by 0.1 T. Adjacent curves are offset for clarity.



(a), (b) Conductance traces at V_{BG}=10.1 V for various *B* values. In (b), the traces differ by $\triangle B$=0.05 T. Adjacent curves are offset for clarity.

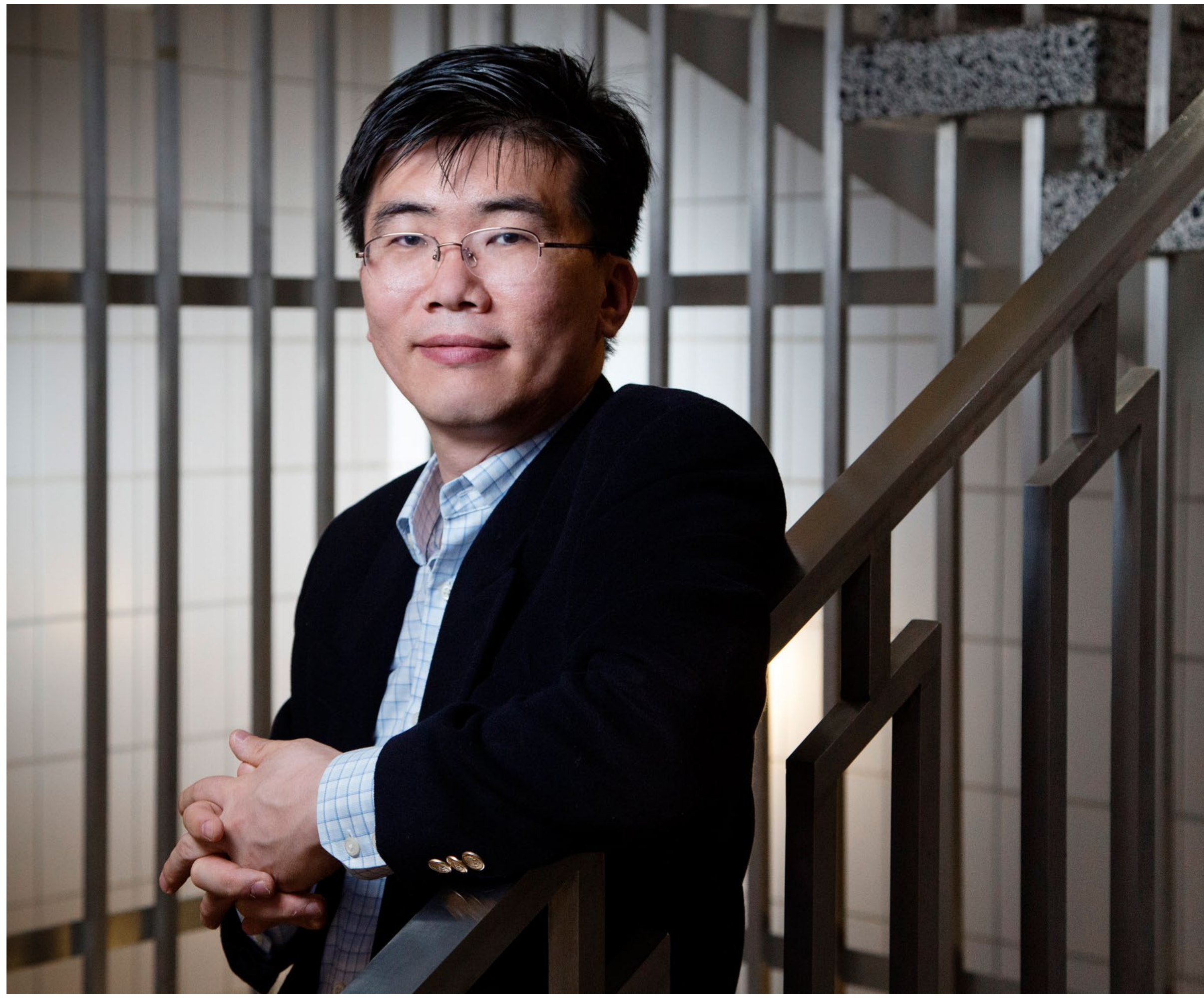
experimentalists working in tandem on big questions.

"We collectively think that the physics of topological materials and topological states is a very important and intriguing topic. Our theorists and our experimentalists are coming at it from many directions," said Van Harlingen. "Other experimentalists who are also working in this area include Raffi Budakian, Nadya Mason, and Jim Eckstein, and most of our condensed matter theorists are engaged in this effort, including Eduardo Fradkin, Mike Stone, Tony Leggett, Smitha Vishveshwara, Taylor Hughes, and Shinsei Ryu. We also have outstanding collaborators at ECE, including Xiuling Li and Matthew Gilbert. It should be an exciting time." ■

Finck and Van Harlingen gratefully acknowledge funding for this experiment through Microsoft's Station-Q. Mohseni, Jung, and Li gratefully acknowledge funding from NSF under award no. DMR-1006581. Device fabrication was carried out in the MRL Central Facilities, partially supported by the DOE under DE-FG02-07ER46453 and DE-FG02-07ER46471. The conclusions presented are those of the scientists and not necessarily those of the funding agencies.

Ha team solves mystery of DNA repair mechanism

By Diana Yates, Life Sciences Editor, Illinois News Bureau



Professor Taekjip Ha. Photo by L. Brian Stauffer

Every time a human or bacterial cell divides, it first must copy its DNA. Specialized proteins unzip the intertwined DNA strands while others follow and build new strands, using the originals as templates. Whenever these proteins encounter a break—and there are many—they stop and retreat, allowing a new cast of molecular players to enter the scene.

Scientists have long sought to understand how one of these players, a repair protein known as RecA in bacterial cells, helps broken DNA find a way to bridge the gap. They knew that RecA guided a broken DNA strand to a matching sequence on an adjoining bit of double-stranded DNA, but they didn't know how. In a new study, researchers report they have identified how the RecA protein does its job.

"The puzzle for scientists has been: How does the damaged DNA look for and find its partner, the matching DNA, so that it can repair itself?" said University of Illinois physics professor Taekjip Ha, who led the study. "Because the genomic DNA is millions of bases long, this task is much like finding a needle in a haystack. We found the answer to how the cell does this so quickly."

The research is described in a paper in eLife, a new open-access journal supported by the Howard Hughes Medical Institute (HHMI), the Max Planck Society and the Wellcome Trust. Ha is an HHMI investigator. The National Science Foundation provided primary funding for this work.

DNA repair is vital to health, vitality and longevity. Disruptions of the process can lead to the early onset of diseases associated with aging or cancer in animals. The breast cancer mutation known as BRCA2, for example, disrupts a gene involved in loading Rad51 (the human equivalent of RecA) onto a broken DNA strand to begin the process of repair.

Previous studies have shown that in bacteria, RecA forms a filament that winds itself around a broken, single strand of DNA. Like a matchmaker trying to find a partner for an unpaired dancer, it scours the corresponding DNA strands for a sequence that will pair up perfectly with the broken strand. Once it finds the sequence, the broken strand steps in and chemically bonds to its new partner, displacing one of the unbroken strands (which eventually pairs with the other broken strand). This elaborate molecular square dance allows the cell to go back to the work of duplicating its genome. Each broken strand now is paired with an unbroken one and uses the intact strand as a template for replication.

"If a break in DNA occurs, you have to repair it," Ha said. "We wanted to know how RecA helps the DNA find a sequence complementary to it in the sea of genomic DNA, and how it does it so quickly."

To answer this question, the researchers made use of fluorescence resonance energy transfer (FRET) to observe in real time the interaction of the RecA protein and the DNA. FRET uses fluorescent molecules whose signals vary in intensity depending on their proximity to one another. By labeling a single DNA strand bound by RecA and putting a different fluorescent label on a stretch of double-stranded DNA, the researchers could see how the molecules interacted with one another.

The team determined that RecA that is bound to a broken, single-stranded DNA molecule actually slides back and forth along the double-stranded DNA molecule, searching for a match.

"We discovered that this RecA filament can slide on double-stranded DNA for a span of sequences covering about 200 base pairs of DNA," Ha said. "This is how one strand of DNA can be exchanged with another from a different DNA duplex. That's the process called 'recombination.' "

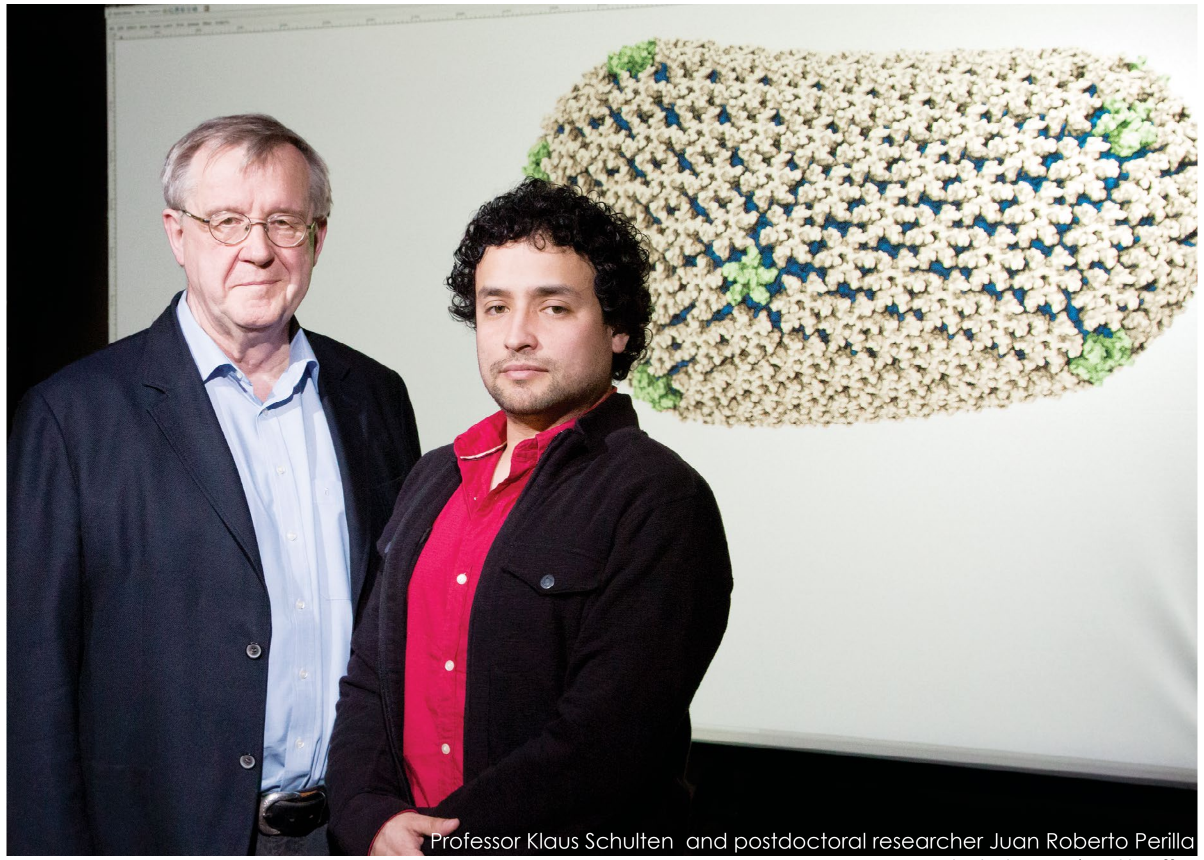
The discovery explains how DNA repair can occur so quickly.

"We did a calculation that found that without this kind of process that we discovered, then DNA repair would be 200 times slower," he said. "So your DNA would not be repaired quickly and damage would accumulate, possibly leading to serious diseases."

The research team included graduate students Kaushik Ragunathan and Cheng Liu. Ha is an affiliate of the Institute for Genomic Biology and a co-director of the NSF Center for the Physics of Living Cells at Illinois. ■

This research was funded by National Science Foundation grant nos. PHY-0646550 and PHY-0822613; by a National Institutes of Health grant no. GM065367; and by the Howard Hughes Medical Institute. The conclusions presented are those of the scientists and not necessarily those of the funding agencies.

Wit, grit, and a supercomputer yield chemical structure of HIV capsid



Professor Klaus Schulten and postdoctoral researcher Juan Roberto Perilla
Photo by L. Brian Stauffer

By Diana Yates,
Life Sciences Editor,
Illinois News Bureau

Illinois researchers report that they have determined the precise chemical structure of the HIV capsid, a protein shell that protects the virus's genetic material and is a key to its virulence. The capsid has become an attractive target for the development of new antiretroviral drugs.

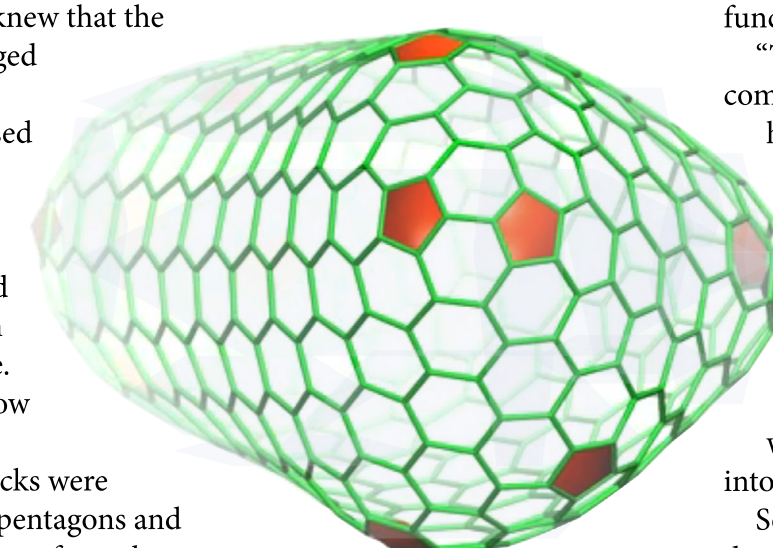
Scientists have long sought to understand how the HIV capsid is constructed, and many studies have chipped away at its mystery. Researchers have used a variety of laboratory techniques—cryo-electron microscopy, cryo-EM tomography, nuclear magnetic resonance spectroscopy and X-ray crystallography, to name a few—to peer at individual parts of the capsid in revealing detail, or to get a sense of the whole.

Until the arrival of petascale supercomputers, however, no one could piece together the entire HIV capsid—an assemblage of more than 1,300 identical proteins forming a cone-shaped structure—in atomic-level detail. The simulations that added the missing pieces to the puzzle were conducted during testing of Blue Waters, a new supercomputer at the National Center for Supercomputing Applications at the University of Illinois.

> *"The timing of the opening of the capsid is essential for the degree of virulence of the virus. This is where we could perhaps best interfere with HIV infection."*

"This is a big structure, one of the biggest structures ever solved," said Professor Klaus Schulten, who, with postdoctoral researcher Juan R. Perilla, conducted the molecular simulations that integrated data from laboratory experiments performed by colleagues at the University of Pittsburgh and Vanderbilt University. "It was very clear that it would require a huge amount of simulation—the largest simulation ever published—involving 64 million atoms."

Previous research had established that the HIV capsid contained a number of identical proteins. Scientists knew that the proteins were arranged into pentagons and hexagons, and guessed that the pentagons formed the most tightly rounded corners of the capsid shape seen under an electron microscope. But they did not know how many of these protein building blocks were needed, or how the pentagons and hexagons fit together to form the capsid.



Led by structural biology professor Peijun Zhang, the Pittsburgh team exposed the building blocks of the capsid to high salt conditions, leading the proteins to assemble into tubes made entirely of hexagons. Further experiments revealed interactions among specific regions of the proteins that were "critical for capsid assembly and stability, and for viral infectivity," the researchers report.

The team also conducted cryo-electron tomography of the complete capsid, slicing it into sections to get a rough idea of its overall shape.

Perilla and Schulten used the data from these experiments and from their own simulations of the interactions between the hexamers and pentamers to conduct a series of large-scale computer simulations that accounted for the structural properties of the capsid's building blocks.

"The work of matching the overall capsid, made of 64 million atoms, to the diverse experimental data can be done only through computer simulation using a methodology we have developed called molecular dynamic flexible fitting," Schulten said. "You basically simulate the physical characteristics and behavior of large biological molecules but you also incorporate the data into the simulation so that the model actually drives itself toward agreement with the data."

The simulations revealed that the HIV capsid contained 216 protein hexagons and 12 protein pentagons arranged just as the experimental data had indicated. The proteins that composed these pentagons and hexagons were all identical, and yet the angles of attachment between them varied from one region of the capsid to another.

"That is really the mystery of it," Schulten said. "How can a single type of protein form something as varied as this thing? The protein has to be inherently flexible."

The pentagons "induced acute surface curvature," the researchers reported, allowing the capsid to be a closed structure that would not have been possible if the capsid were composed only of hexagons.

Possessing a chemically detailed structure of the HIV capsid will allow researchers to further investigate how it functions, with implications for pharmacological interventions to disrupt that function, Schulten said.

"The HIV capsid has actually two completely opposite properties," he said. "It has to protect the genetic material but once it gets into the cell it has to release the genetic material. That has to happen with really good timing—too quick is not good, too slow is not good. And this is a moment when you can throw a wrench into the system."

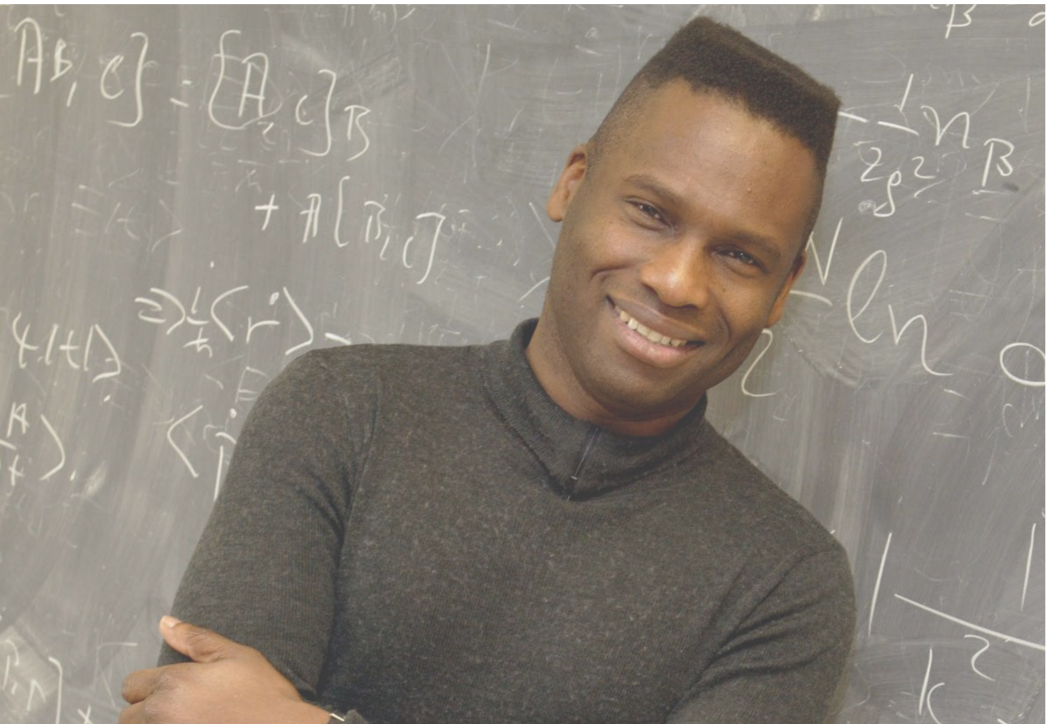
Some of the most potent antiviral drugs target the viral capsid, Schulten said.

"The timing of the opening of the capsid is essential for the degree of virulence of the virus," he said. "This is where we could perhaps best interfere with HIV infection."

Schulten and Perilla's research is reported in the paper, "Structure of the Mature HIV-1 Capsid by Cryo-EM and All-Atom Molecular Dynamics Simulation," in the May 28 issue of the journal *Nature*. ■

The computational research was carried out at the Beckman Institute at the University of Illinois. The National Institute of General Medical Sciences at the National Institutes of Health and the National Science Foundation supported this research. The Blue Waters supercomputer is funded by the National Science Foundation.
The conclusions presented are those of the scientists and not necessarily those of the funding agencies.

This page: HIV capsid image courtesy of Professor Klaus Schulten



Electrons are not enough: Cuprate superconductors defy convention

Photo by L. Brian Stauffer

by Liz Ahlberg, Physical Sciences Editor, Illinois News Bureau

To engineers, it's a tale as old as time: Electrical current is carried through materials by flowing electrons. But physicists at the University of Illinois and the University of Pennsylvania found that for copper-containing superconductors, known as cuprates, electrons are not enough to carry the current.

"The story of electrical conduction in metals is told entirely in terms of electrons. The cuprates show that there is something completely new to be understood beyond what electrons are doing," said Professor Philip Phillips.

In physics, Luttinger's theorem states that the number of electrons in a material is the same as the number of electrons in all of its atoms added together. Electrons are the subatomic particles that carry the current in a conductive material. Much-studied conducting materials, such as metals and semiconductors, hold true to the theorem.

Phillips's group works on the theory behind high-temperature superconductors. In superconductors, current flows freely without resistance. Cuprate superconductors have puzzled physicists with their superconducting ability since their discovery in 1987.

The researchers developed a model outlining the breakdown of Luttinger's theorem that is applicable to cuprate superconductors, since the hypotheses that the theorem is built on are violated at certain energies in these materials. The group tested it and indeed found discrepancies between the measured charge and the number of mobile electrons in cuprate superconductors, defying Luttinger.

"This result is telling us that the physics cannot be described by electrons alone," Phillips said. "This means that the cuprates are even weirder than previously thought: Something other than electrons carries the current."

"Theorists have suspected that something like this was true but no one has been able to prove it," Phillips said. "Electrons are charged. Therefore, if an electron does not contribute to the charge count, then there is a lot of explaining to do."

Now the researchers are exploring possible candidates for current carriers, particularly a novel kind of excitation called unparticles.

Phillips, U. of I. undergraduate student Kiaran Dave (now a graduate student at MIT) and University of Pennsylvania professor Charles Kane published their findings in the journal *Physical Review Letters*.■

This research was funded by the National Science Foundation under grant nos. DMR-1104909 and DMR-0906175, and by the Center for Emergent Superconductivity through a DOE Energy Frontiers Research Center grant no. E-AC0298CH1088. The conclusions presented are those of the scientists and not necessarily those of the funding agencies.

Mason's group uncovers superconducting qualities of topological insulators

Topological insulators (TIs) are an exciting new type of material that on their surface carry electric current, but within their bulk, act as insulators. Since the discovery of TIs about a decade ago, their unique characteristics (which point to potential applications in quantum computing) have been explored theoretically, and in the last five years, experimentally.

But where in theory, the bulk of TIs carry no current, in the laboratory, impurities and disorder in real materials mean the bulk is, in fact, conductive. This property has proven an obstacle to experimentation with TIs: findings from prior experiments designed to test surface conductivity of TIs unavoidably included contributions from the bulk's surplus electrons.

Now an interdisciplinary research team at the University of Illinois at Urbana-Champaign, in collaboration with researchers at Brookhaven National Laboratory's Condensed Matter Physics and Materials Science Department, has measured superconductive surface states in TIs where the bulk charge carriers were successfully depleted.

The experiments, conducted in the laboratory of Illinois condensed matter physicist Nadya Mason at the Frederick Seitz Materials Research Laboratory, were carried out by postdoctoral research associate Sungjae Cho using a TI material—specially developed by the Brookhaven team—coupled to superconducting leads.

To deplete the electrons in the bulk, the team used three strategies: the TI material was doped with antimony, then it was doped at the surface with a chemical having strong electron affinity, and finally an electrostatic gate was used to apply voltage that lowered the energy of the entire system.

"One of the main results we found," said Mason, "was in comparing the two experimental regimes, pure surface (bulk depleted of electrons) vs. bulk (excess electrons present in impurities in bulk material). We learned that even when you have the bulk, the superconductivity always goes through the surface of the material."

This finding was established by comparing experiments with theoretical modeling by research team members at Illinois's Department of Electrical and Computer Engineering. Asst. Professor Matthew Gilbert and graduate student Brian Dellabetta showed that superconductivity occurred only at the surface of topological insulators and that this is a unique characteristic of these new materials.

It's been predicted that TIs harbor the highly sought Majorana quasiparticle, a fermion which is theorized to be its own antiparticle and which, if discovered, could serve as a quantum bit in quantum computing.

"Since we now have a better understanding of how topological insulators behave with regard to superconductivity, this will assist our search for the Majorana quasiparticle," Mason explained.

The team also plans to investigate the same experimental configuration at lower energy to further explore its characteristics.

"The potential of this new material is very exciting. We are exploring possible uses for TIs in terms of conventional electronic devices and novel devices," said Mason. "And if we can find the new particle predicted to exist in the material's solid state and then learn to manipulate its position relative to a second particle, we could use it for quantum computation.

"The implications for quantum computing are truly profound," she explained. "With today's technology, computer components really can't get much smaller. If Majoranas behave as predicted and can be manipulated to serve as quantum bits, our future computers would be extraordinarily powerful; their components would be much smaller and would be able to store much more information." ■

This research was funded by the Office of Naval Research under grant N0014-11-1-0728. The conclusions presented are those of the scientists and not necessarily those of the funding agency.

The world-class undergraduate program in physics at Illinois attracts extraordinary individuals from near and far. Students come to us with interesting backgrounds, diverse interests, and deep passions for particular hobbies or areas of study. Some are swept into new interests after they are submersed in the rich Urbana-Champaign culture. Here are three stories that reflect today's Physics Illinois undergraduate experience.

Contributing to physics research as an undergrad:
Natasha Sachdeva at Physics Illinois

Natasha Sachdeva in Professor Douglas Beck's laboratory, next to an apparatus used to measure the rate of ^{3}He depolarization as it is exposed to various materials that will be used at Oak Ridge National Laboratory's upcoming neutron electric dipole moment experiment.

When Natasha Sachdeva entered the physics program at Illinois as a freshman in 2008, she couldn't wait to get into a lab to get started in research. She mentioned this to an adviser and learned that most undergraduate students don't start research until the summer after their sophomore year, after they've got a few courses under their belts.

She was undeterred. She asked around. It was Toni Pitts, the department's coordinator of recruiting and special programs, who steered her toward Professor Alfred Hubler's lab.

"I started at the very end of my first semester here. I worked on simulating a chaotic water wheel, to investigate the effects of static friction and noise in a chaotic system.

It was a good starting point, but as Sachdeva grew in her understanding of physics, her interests shifted.

"At the point where I finished that project, I realized this area of physics wasn't what I was most interested in. I had started to take subatomic physics and modern lab courses, and it really clicked for me that I wanted to go into nuclear and atomic physics."

Once she realized it, it was clear that this was the path she had been headed toward from the start.

"When I was a kid, I was very interested in patterns, numbers, and symmetries. You start to see these in physics, even at the undergraduate level. We see rules that the sub-universe and even the greater universe obey. The area of physics research that I'm interested in is fundamental symmetries, a subfield of nuclear and particle physics. This field probes symmetries and how they are violated and why they are violated."

About that time, Sachdeva learned about an opening for an undergraduate in Professor Douglas Beck's nuclear physics laboratory and she wasted no time in making inquiries. That was two years ago.

In Beck's lab, Sachdeva worked on small-scale materials testing for the upcoming neutron electric dipole moment (nEDM) experiment at Oak Ridge National Laboratory. This experiment will attempt to measure the neutron electric dipole moment.

"Several different experiments around the world are working on this question," explained Sachdeva. "In the early universe, why was there a preference for matter over antimatter in the creation of everything?

"The nEDM experiment could have major implications for the future of physics. In particular, it may help to solve the mystery of the matter-antimatter imbalance in the universe. Precision measurements of electric dipole moments help us to understand the processes that lead to asymmetry in the composition of universe."

In the lab, Sachdeva worked with principal research physicist Steve Williamson, under Beck's guidance.

"What I did specifically was to measure the rate of ^{3}He depolarizing off surfaces. I got to work independently in a very hands-on way. Research can be difficult sometimes, since you don't always have somebody telling you what to do and when. But the process is actually really rewarding because you have to figure things out for yourself. You don't always have a go-to solution."

"I think, especially, learning how to do stuff can be challenging. A year into it, I looked back and thought, wow, I'd be so much further if I knew then what I know now. But it's part of learning and part of the process of research."

Sachdeva has found the work related to fundamental symmetries in Beck's lab intriguing. It inspired her to research the topic more deeply, and she ended up writing her senior thesis on it.

"Electric dipole moments violate an important symmetry known as CP-symmetry, which may be partly responsible for matter-antimatter asymmetry. A precision measurement of the neutron electric dipole moment brings us a step closer to understanding what mechanisms cause CP-violation, because many theories predict different values for the neutron EDM.

"During my research experience, I used pulsed nuclear magnetic resonance to monitor ^{3}He as it depolarized. Since a large amount of ^{3}He is used in the nEDM experiment, it is critical that it does not depolarize too quickly, because unpolarized ^{3}He causes a background signal."

Sachdeva graduated this spring and has been accepted to a doctoral program at the University of Michigan in Ann Arbor, where she plans to do research in atomic, molecular, and optical physics.

Before leaving Beck's lab, Sachdeva trained a new undergraduate researcher to continue her work. She kept in mind that steep learning curve she herself had already climbed.

"I tried to write it out step by step. She'll understand why I wrote those things later. It really takes time to understand the context of everything, particularly in physics," Sachdeva noted.

"I've had a really great experience at the U. of I. and will be sort of sad to leave. At the same time, I'm pretty excited to move on to something new and like that I will be directly involved in the outcome of the experiment, instead of just a component.

Sachdeva said she is grateful to have had so much time in the lab while she was here.

"Undergraduate research opportunities are everywhere at the U. of I. I started research my first semester, and was able to switch to a different adviser and project when my interests changed, as I started to learn more about the various fields of physics. I've learned so much about what I enjoy and what I want to do with my future career through my undergraduate research experience. Once I started working in Professor Beck's lab, I realized that I wanted to continue on in experimental nuclear physics," she said. ■

In the ring with physics major Nathan Ridings

Photo by Brett Roseman for the Southtown Star, courtesy of Sun Times Media

Nathan Ridings is not a confrontational person. In fact, to meet the easy-going, gregarious rising sophomore, one would never guess he is highly trained in punching people's lights out. Growing up in Homer Glen, in the outskirts of Chicago, Ridings dedicated himself to the sport of boxing from a young age—starting when he was just 10 years old.

The following year, Ridings made it to the US nationals and placed second in his age bracket, weighing in at just 85 pounds. He was a natural.

"I was this skinny white kid from the suburbs who had never been in a fight," remembers Ridings. "I had never hit anyone, and here I was fighting these really tough guys who had been in prison, been in gangs, maybe killed someone or stabbed someone. And I beat them."

Winning felt good. It came at a sacrifice, but he came to love the sport.

"In the ring, you are really going against someone else's will. The human will can be stretched so far, to limits you don't even understand. When you get to the end and they raise your hand, it's just awesome."

In high school, Ridings spent most of his waking hours outside of school at the gym working to get into peak condition. He had little social life outside of church and the guys at the gym. There were no late nights on the town, and he kept to a strict diet.

He remembers, his father John Mark Ridings was always there by his side, watching him, coaching him, keeping him motivated—and of course, shuttling him on the daily 45-minute drive to and from his gym.

The training was at times brutal. Riding's coach would sometimes put him in the ring with bigger guys—180 to 200 pounds—and direct him not to punch back, to improve his defensive maneuvers and to get him used to taking hard shots. Sometimes, the coach would even have Ridings keep his hands behind his back.

"Those are the moments that define you as an individual. How far could you go? It took me beyond, just in terms of my mental ability to face down any challenge."

Ridings graduated from high school in 2011 at the age of 17. He was accepted to the University of Illinois, but, with the support of his parents, decided to defer entrance for a year in order to pursue his Olympic boxing dream.

A dual citizen of the US and El Salvador, Ridings opted to fight as an El Salvadoran, and he contacted the El Salvadoran Olympic Committee. He was invited to participate in some fights to attempt to qualify for the team.

His father at his side, Ridings travelled extensively, competing against the best boxers in El Salvador, Venezuela, Ecuador, Panama, and the Dominican Republic. He made it as far as the World Championships in Azerbaijan in September 2011.

He had fought hard for his place there, but when he arrived, he knew he wasn't in his best form. He had recently lost 10 pounds, and the intensive travel schedule had perhaps taken its toll.

"Looking back, I know I was a bit burned out. I was training 7 days a week, 3 times a day for 3 to 6 hours. That was my job. It was my life.

"I lost the first fight. I was drained and there was no stay in my punches—no power. I wasn't performing at my best. It's hard, it happens sometimes, and you have to move on."

Ridings finished one of five runners up. He hadn't made the cut for the Olympic team.

The next Olympic qualifier was in Rio de Janeiro. Ridings fought hard. He got a "bye" in his first fight. In the second match, he developed a persistent nosebleed so, in accordance with fight rules, the officials stopped the fight. With that, Riding's 2012 Olympic dream ended.

"I felt like a couple of those judges didn't give good calls. That was hard. I had worked so hard for it. But that's where the perseverance comes in. You have to let go and move on. Of course there was great disappointment when I lost, but there was also relief. The longest break I had taken from boxing was two weeks. Now I could take a real break."

Ridings admits, it was hard returning to the books this year, especially in math and physics. But the resilience and dedication required to fight at the highest levels of the sport does spill over into other areas of his life.

"I like studying physics because I love understanding how things work. But I wasn't a natural—it's really something I have to work for. In boxing, perseverance is key. Now with my classwork, I know there are no short cuts. And I think I try harder because I know the game is 80 percent mental. That perseverance I learned in boxing is applied to every aspect of my life."

Ridings took this academic year off from boxing—and he misses the sport. So much so, in fact, that he is giving serious thought to taking another year off from school to try out professional boxing. But nothing is set in stone. If not boxing, Ridings is considering pursuing a career in financial law or engineering.

"I love to talk to people and I don't want to just sit behind a computer. Physics opens a lot of doors—we'll see where it takes me," he said. ■

Nate Ridings battles Ed Brown in the title bout of the 141 open class at the Chicago Golden Gloves in April 2011. Photo by Brett Roseman for the Southtown Star, courtesy of Sun Times Media

Physics and opera: Richard Schonberg's two great passions

Rising junior Richard Schonberg, originally from Rolla, Missouri, admits that for him, it's challenging not to overthink the mechanics of things. And while that's never a bad trait for an aspiring physicist to have, it can get in the way of his operatic voice training.

"The way the classically trained voice produces tones is so complex—it's not just a simple A4 = 440 Hz mechanism. The pressure waves coming off the vocal cords resonate through the various resonating chambers. The sound is uniquely determined by the size, shape, and thickness, of the soft palate, how the throat is shaped, how your sinus cavities resonate. This all contributes to every person's unique timbre," he explained.

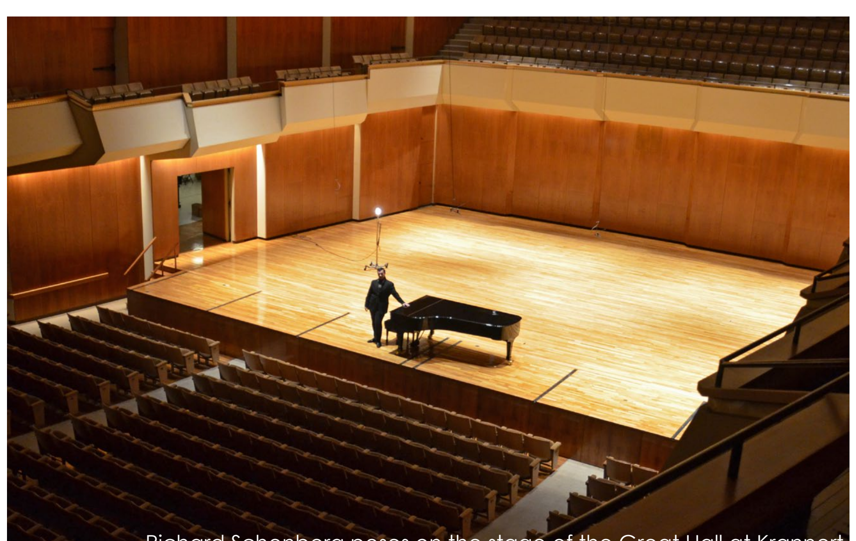
When Schonberg shares what he has learned about the physics of opera singing, his usually quiet, subdued demeanor immediately brightens, his profound interest in the subject evident in his swift flow of words and joyful tone.

Schonberg is working toward a bachelor's degree in physics with a minor in mathematics. In his time off from his studies, he has rehearsed and performed in the School of Music Opera Program's productions of *The Magic Flute, The Barber of Seville, Florencia en el Amazonas,* and *My Fair Lady,* as well as in Opera Venezuela's production of Giacomo Puccini's *Gianni Schicchi* last fall, and most recently, Bertholt Brecht's *Threepenny Opera*, composed by Kurt Weill.

Opera is a passion Schonberg discovered as a student here at Illinois. He started singing in his senior year of high school when he joined the school chorus. He enjoyed it. As a freshman at Illinois, he wanted to continue, so in the fall of 2011, he joined the Varsity Men's Glee Club under the direction of Barrington Coleman.

It was through that connection that Schonberg learned the School of Music was producing *The Magic Flute* and needed bass voices in the chorus. Schonberg joined the production and enjoyed it immensely. When he learned the School would be producing Rossini's *Barber of Seville* in the spring, he asked Maestro Diaz Muñoz if he could take part in it, as well.

"That production was even more fun than the first," said Schonberg. It was a big set that rotated. At one point, at the end of Act One, a bunch of student musicians who played the soldiers were searching the house. Everyone was keeping things from each other, the Count was pretending to be the Captain of the Guard, and then the Captain comes in, and the stage is rotating—it was so much fun!"



Richard Schonberg poses on the stage of the Great Hall at Krannert.

The lead tenor in that production was John Gomez, and Schonberg, now sure he wanted to continue to sing opera, arranged to get private voice lessons with him.

"The lessons really helped me to prepare for the 2012–13 year," said Schonberg. "I used to sing bass because I didn't have the top notes, so I had matched my range to bass. But with the correct process, John warmed me up to higher notes the first day, and he told me, 'You're actually a baritone.'"

Schonberg explained that voice training is a long, difficult process.

"The voice is an instrument that you can't see or tune. The training is based on sensation and feeling. John teaches by the old Italian method of the *bel canto* school, which puts the most power, flexibility and range into the voice," Schonberg commented.

"Sometimes, John will refrain from telling me certain things because I'm a physics major—I think a lot. The *bel canto* method is about conditioning the voice and not thinking about it, just letting it develop and take place. I'm still working on it—I'm only nine months into my training with him. But it's really rewarding to see the advancement you can make when

Richard Schonberg in last fall's production of Giacomo Puccini's *Gianni Schicchi,* presented by Opera Venezuela. Photo by Anna Longworth, courtesy of Opera Venezuela.

you put your mind to it," he added.

Schonberg aspires one day to sing the most challenging baritone parts, though he is patient in getting to that—it's not uncommon for baritones to be referred to as young while in their 40s, he explained.

"In *The Barber of Seville*, as a baritone, I could be Figaro, the barber. He's always having fun, pulling high jinks, and helping the Count to get the girl. It's a funny role. But I have to say, it's the darker roles that most appeal to me. As a baritone, I could be Iago in *Otello*—that's a role I would love to play. The voice is an extension of the self, and in that role, I could be dark and brooding."

But Schonberg's all-time favorite composer is Verdi, and that has much to do with being a baritone.

"Everyone always goes to opera to hear the tenor's high note—it's a thrilling thing if you can condition your voice for that," explained Schonberg. "But Verdi took the baritone *tessitura* and ratcheted it up higher, which makes it much more powerful and dramatic, but also much more difficult to sing. He wrote only two comedies; all the rest are tragedies. I would like to play Don Carlo in Verdi's *La forza de destino.* I hope when I'm 45 that I'll be able to sing that stuff—it's amazing!"

If you had asked him two years ago what he wants to do with his life, Schonberg would have answered, "Get a doctoral degree in physics and teach."

And while he still plans to finish his bachelor's degree and move on to a doctoral program in physics, it's clear, for him, physics will share the stage with opera.

"If I pursue my PhD in physics, by the time I'm done, my voice might be ready. That would give me a decade of classical voice training. At that point, I would have a choice to either go directly at that point into a career in physics, or—I would love to sing professionally."

"In opera I have found a passionate love, and I am happier here than I would have been anywhere else. Harvard, Stanford, or Princeton—they don't have the quality of music program that we do. Illinois is number two in undergraduate physics and also in the top ten in the nation for music. Sometimes I think about it—just how very lucky I am to be here."

"I want to take Professor Errede's lab for Physics 406. I'm very interested in the physics of acoustics and the way voice produces sound," Schonberg added. "He gets singers to sing, and the students do a harmonic analysis and split the sound waves into fundamental frequencies, to find out just how many simple sound waves there really are coming out of the human voice to make such a complex, beautiful sound." ■

Richard Schonberg in Giacomo Puccini's *Gianni Schicchi*, presented by Opera Venezuela last fall. Photo by Anna Longworth, courtesy of Opera Venezuela.

The changing face of undergraduate physics at Illinois

by Professor Kevin Pitts, Associate Head for Undergraduate Programs

Undergraduate physics ain't what it used to be.

In times past, the physics bachelor's degree curriculum at Illinois focused entirely on math and physics. The technical training our undergraduate program offered was extremely strong, but we didn't attempt to prepare students for anything other than graduate school and research careers.

Our program continues to be extremely strong—one of the best in the country—but times change, and we have changed with the times, sometimes as followers, often as leaders. Because we now offer greater flexibility in our degree programs, our students leave better equipped to succeed in the profession of their choosing. We offer new curriculum tailored toward academic, government, teaching, and private-sector careers, improved academic and career advising, and more opportunities for students to network through student-led organizations and community outreach events.

Our efforts to improve the program have paid off. Three years ago, we had just over 300 physics majors. Today, enrollment is at 450 physics majors and growing. In fact, we expect the incoming class of Fall 2013 will be our largest ever; meanwhile, our retention rates are better than ever.

Unlike decades ago, we don't expect all of these students to go on to graduate school and become physics professors or researchers. We celebrate our alumni's successes in an astonishingly wide array of fields.

Curriculum flexibility

In recent years, we modified our program requisites to allow students with diverse career interests to enroll as physics majors and take advantage of new elective options. At the same time, the new pedagogical approach in our introductory courses allows a broader range of students to succeed as physics majors, thanks to the collaborative efforts of the physics education research group and many faculty members. And to help students transition out of the introductory offerings, we have developed a bridge course that covers special relativity and math methods, to better prepare students for the rigors of our advanced courses.

The elective option curriculum allows for flexibility in an individual student's program of study based upon the student's own interests. Students still have a strong foundation in physics—courses we believe are absolutely necessary as part of a physics degree, such as classical mechanics, electricity and magnetism, quantum mechanics, and advanced laboratory. Additionally, students take a set of 4–5 courses in an area of specialization.

For students who want to go to graduate school in physics, the concentration will include more physics courses. But if a student plans instead on a career in information technology, the elective option would consist of computer science courses. If medical school, chemistry and biology courses, and so on. These elective option courses count toward the students' physics degrees and provide customization in line with individual goals.

Today, instead of 70 percent of our alumni going on to graduate school in physics, the numbers are somewhere in the 40–50 percent range (with about 50 percent growth in total enrollments). We still serve the constituency of students who want a research career in physics, but we have now expanded our program to better serve the students who don't—students who pursue graduate study in other fields (law, medicine, economics, nuclear engineering, computer science, materials science, architectural acoustics, biomedical engineering, neuroscience, or electrical engineering) and the many students who enter the workforce with a bachelor's degree (employers hiring our alumni include CISCO Systems, Intel, Simplex Investments, Accenture, Belvedere

Trading, IBM, Google, Department of Defense, private and public high schools, and the military).

With our successes come new challenges. We are continuing to work to make students aware of all of the possibilities that a physics degree allows and to make employers aware of the flexibility and strengths of a physics degree holder. And we continue to build ties with our alumni in the private sector. We've made tremendous progress in these areas but need to do more. For example, we need to work with our alumni to provide corporate internship opportunities for our students who aren't pursuing graduate studies.

Communication skills

To be competitive in today's job market, a degree holder needs more than science smarts and top-notch technical training. The ability to communicate, via the written and spoken word, is what sets people apart in today's world. Our curriculum provides ample opportunities for students to develop excellent communication skills.

Instituted more than a decade ago, our senior thesis sequence is aimed at helping students who plan to pursue graduate studies in physics learn how to write papers, document research, and make presentations. This sequence has helped our alumni get great jobs, secure excellent graduate opportunities, and win prestigious awards such as National Science Foundation fellowships.

The quality and depth of the senior-thesis sequence is something that sets us apart from virtually every other school in the country. We routinely have our alumni telling us how much these courses have helped them. It is clear that every student could benefit from the writing and presentation skills emphasized in these courses, and we are currently looking at ways to expand the course to make it available to all physics majors.

Undergraduate Research

We continue to be effective at including undergraduates in research activities, providing hands-on, practical experiences that supplement classroom learning. The Department has increased the number of undergraduate research experience opportunities we provide (between 90 and 100 students in each of the last two summers), but we aren't keeping pace with demand from our growing number of physics majors.

To that end, we have revamped our modern physics laboratory course to utilize modern equipment, data acquisition methods, and experiments. Students aren't trying to reproduce the century-old Millikan oil drop experiment; instead, they are performing experiments to measure the muon lifetime, second sound in liquid helium, bioluminescence, and quantum interference. Students leave this course with hands-on experimental experience. Along with the senior-thesis sequence, our new modern physics lab is ranked as a top course by graduating seniors.

Relevance

In recent years, students have expressed a greater desire to apply their physics education to issues of societal relevance: alternative energy, the environment and sustainability, climate change, and health and national security. To help students better understand the applications of physics as they enter the curriculum, we designed a course, The Relevance of Physics, aimed at freshman physics majors.

In this course, students learn how physics applies to energy, space travel, defense, medicine, and many other areas. The curriculum is also designed to develop students' competency in communication skills.

As the culmination of the course, students produce a short video in which they explain the physics of a chosen topic to non-experts. For this assignment, students must research the science and consider how to present it to the lay person. Videos produced last year focused on magnetic resonance imaging, superconductivity, wind energy, and optical fiber communications, among other topics.

Other new courses have also been developed that address physics applications. Most recently, we added a course in biophysics and a new laboratory course on the physics of musical instruments.

Challenges

With change comes new challenges, both for the faculty and for the students.

There is the challenge of increasing enrollments: classes that used to have 40 students now have 120. In addition to more physics majors, we have more non-majors taking advanced physics courses to earn a minor or simply to expand their knowledge. Higher enrollments also put added stress on our teaching assistants, as they have to handle more students in their already overcrowded sections.

There is also the challenge of providing more high-quality undergraduate research opportunities, without overburdening our faculty's schedules and resources. We could ease the demand somewhat by finding more corporate internship opportunities.

By far, the biggest challenge facing our students is financial. Alumni who attended in the 80s and 90s will remember an era of affordable tuition—those days are gone. Illinois has seen in-state tuition increase 47 percent since 2006, and significant tuition increases in the preceding years. In addition, federal and state financial aid has fallen far behind tuition costs, with the result that many students cannot afford college. Many of our extremely strong undergraduate candidates—with outstanding grades and high test scores—tell us they simply cannot afford to attend the University of Illinois; this at a time when our nation needs more young people trained in math, science and engineering.

The University is trying to generate scholarship and financial aid funds, but that takes time, and those efforts haven't caught up with explosive costs. Many competing institutions that charge a higher base tuition are able to provide needed financial support and so can outcompete us for the best students. In addition to developing more need-based financial support, we also must develop more merit-based awards to help further the tradition of excellence in our department; currently, we have many high-achieving students who are never acknowledged in a tangible way.

In Closing

The improvements in our program have resulted in an excellent education as well as a better overall experience for our students. This outcome has been achieved through a true team effort, with numerous faculty and staff making incredible contributions. I thank them for their continued hard work to provide our students with the best possible educational experience.

We are excited to watch our numbers increase, but we face a new set of challenges as we train more and more physicists. It's a great problem to have, and we look forward to finding new ways to improve the Physics Illinois student experience, while providing an outstanding education that best prepares our degree holders for the 21st century workforce. ■

Follow Professor Kevin Pitts's undergraduate blog at http://physics.illinois.edu/undergrad/posts.asp.

Physics theses and dissertations archive, alumni releases sought

by Mary Schlembach, Engineering, Physics, and Astronomy Librarian

Alumni who completed a master's thesis or doctoral dissertation may recall submitting copies to the department and wonder whatever became of them. Some were bound, cataloged, and added to the Physics and Astronomy Library collection. Other copies were left unbound and stored in a small room behind the library. After the Physics Library closed in 2009, there was some discussion about what should be done with the decades of unbound theses and dissertations.

This was a great opportunity to digitize the collection and make it available in electronic format. A copy of every thesis and dissertation from 1950 to 2009 was packed up and sent to the Grainger Library. Library-science graduate assistants scanned each one and deposited it into the Illinois Digital Environment for Access to Learning and Scholarship (IDEALS), the institutional repository for research by faculty, staff, and students at the University.

Since 2010, all University theses and dissertations are published in electronic format and deposited into IDEALS. Physics, however, was the first department on campus to digitize its entire thesis and dissertation archive, thanks to the availability of the unbound copies. There are 1,783 items in the Physics Electronic Theses and Dissertations (ETD) collection. The collection is searchable by title, author, faculty advisor, degree year, and department.

Graduates own the copyright to their own theses or dissertations. In order to protect the copyright, all theses and dissertations were added to IDEALS with limited access for University of Illinois users only. This means that only current students, staff, and faculty are able to access the full text of these theses and dissertations.

Alumni may authorize public release of their scanned thesis and/or dissertation by filling out an online form at http://hades.grainger.uiuc.edu/pawel/projects/ideals/IDEALS.asp. Updating access rights will likely take two to three weeks once permissions are submitted. ■

Please send inquiries to Mary Schlembach, at schlemba@illinois.edu.

"... the beginning of a beautiful friendship."

Greene blogs on outreach trip to Casablanca

These are excerpts from Professor Laura Greene's travel blog, posted during her trip to Casablanca in Morocco, where she participated in her first COACh International (iCOACh) workshop, "Building Partnerships Workshop on Water, Energy and the Environment for Women Scientists from Morocco, Algeria, and Tunisia," March 5–8, 2013.

Professor Laura Greene poses with fellow participant Nora Berrah outside a mosque.

Tuesday, March 5, 2012

This trip takes us to Casablanca where we meet with Moroccan, Algerian, and Tunisian women scientists.

It took me four airplanes in 19 hours, plus an hour taxi ride from the airport to the hotel, to get here—AOK because that is just what I do (... my name is Laura Greene and I'm a travelaholic...). The taxi ride from the airport to Casablanca was simple and easy, but entering the city all is changed. There appears to be no traffic signals and making turns is quite an ordeal in ruling the road. Brake screeches and horns' blaring fill the audible spectrum. It actually did not seem unfriendly—just that kind of driving was one of the local sports. It reminded me of the traffic in Naples; just more crowded and somewhat more aggressive…

Tonight, we all met and had a reception and dinner. We all went out of our way to interact with women not from our home countries. Here are three I had dinner with—two from Morocco and one from Algeria. I also had dinner with Sonia Haddad from Tunis who has been doing great work on graphene. With her recent IoP comment, I think we will grow more communication and collaborations. I met her first at the STRIPES conference last year.

Wed, March 6, 2012

After lunch there was a panel run by Nora Berrah (Algerian born and raised and now at Western Michigan—I know her well from BESAC) with two women each from Algeria, Tunisia, Morocco, and the US. Sue Clark, a chemist from Washington State, and I were the US panelists. We compared and contrasted funding, career paths, roadblocks to science in general, and roadblocks to women scientists. We all learned a great deal! Some bullet points:

- The percentage of women in the sciences in North Africa was much higher than the US!
- A North African scientist gets a guaranteed base, which is very small; dependent on ratings of that professor and institution and then can apply for more grants from their ministry and outside. They do not have to cover student tuition—that is covered. The funding they get as a base can maybe allow them to go to one conference a year, and sometimes one cannot accomplish her work with the available funds.
- This is quite different from US, where the grants are larger but are used mostly for salaries and tuition waivers.
- Tuition is free in North Africa—but the sources to pay the students are low. Many students live at home, and their entire subsidy goes to commuting and some food. The ones far from their university have to find families to live with—or some of the schools do have dorms—but those are harder to afford. Rural students were definitely more challenged in this.
- Career paths were not all that different between countries—in academia it is assistant to associate to full professor. However, the requirements for each level were quite disparate.
- Recruitment of good students seemed not to be such a big problem. I pointed out that in the US, the undergraduates declaring physics as their major basically doubled over the last few years—the problem was not recruitment but how to give these increased numbers the same quality of education as before.
- All agreed that barriers were infrastructure (like equipment), funding, and other demands on time—teaching loads, committee work, etc. This is for all scientists—men and women alike.
- Barriers for women were all over the map—some great stories and some not so great. This is clearly spotty and changing rapidly—transience rules. This is best not to blog!

Professor Laura Greene has a monkey on her back (and another on her arm) during a group excursion to Marakesh.

Thurs, March 7

After the panel on Wednesday afternoon, we got into breakout groups to see how we could establish collaborations. Most of this workshop was composed of chemists, so finding the right group for superconductors or strong electron correlations was a challenge. Mary Wirth suggested we determine a research goal and work to see how we cold collaborate on it, but in my case, it was more important to see what the capabilities of my group members were and then design the research around that. You see, it is true I have "holy grails" in my research, but I would be happy working on almost any problem—maybe that is one of my problems: that I can scatter shot so easily—but any unanswered question in science can be absolutely fascinating to me. I just wanted to work with some of the other women—particularly the North African ones.

My breakout group consisted of Janet Tate, an old friend who is at Oregon State but born and raised in South Africa, Leila Adane from Algeria, who was also an organizer of this workshop and a University Professor at USTHB, Nadia Saoula, who is in a National Laboratory in Algeria (DCTA), and Sonia Haddad, the theorist from Tunisia. We shared our ideas and found what could and could not be done—won't bore you here but between alloy growth (Algeria), a variety of thin film capabilities (Algeria, IL, and OR), computational materials modeling (Tunisia) and a whole lot of materials characterization (US), we had a plan to hammer out.

Friday, March 8

Thursday afternoon were more breakout sessions, and we better defined how we would self-assemble. The main areas were phosphites, water, and materials. My group was all about design, analysis, and computation of materials to understand their properties and design new functional materials—an old idea but maybe with some new twists. This will be exciting to work out—the diversity in laboratories, and even backgrounds, will give us new tacks for approaching these old problems. ■

COACh is a grass-roots organization that promotes the number and success of women in science. iCOACh workshops are designed to build scientific and engineering leadership abilitities among women scientists in developing nations and to catalyze and sustain scientific collaborations and networks among women across international and cultural boundaries.
Greene's next iCOACh meeting will be on June 23, in Bali, Indonesia, as part the Kavli Indonesia Frontiers in Science workshops. Read more: http://coach.uoregon.edu/coach/

Musings of an ESB Lounge Lizard

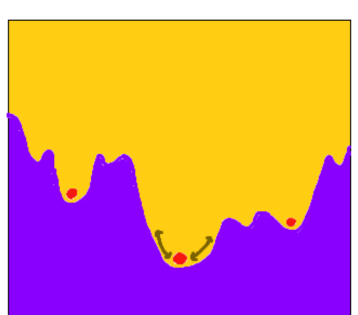
Professor Smitha Vishveshwara shares her inspiration and perspective—on life, physics, the universe—from her vantage point as a theoretical condensed matter physicist (housed in ESB, the Engineering Sciences Building).

Life OUt-of-Equilibrium

In the deep cosmos, galaxies collide, stars explode, gaseous nebulae swirl. On Earth, at high tide, white surf crashes against dark rocks. A rift in tectonic plates sets off a cascade of geological events. The stock market fluctuates. A prayer gong resounds. A lone anemone makes its way to shore. And so, a system tipped out of equilibrium dynamically evolves from one state to the next.

We all have an intuitive understanding of equilibrium, of balance. In the language of physics, a system in equilibrium exists in a steady state, devoid of any external forces acting on it. Generally, unlike a pencil precariously balancing on its tip, we think of stable equilibria, where the system is at a minimum point in some energy landscape, and a slight nudge results only in dynamically bringing it back to this point.

While understanding complex systems in equilibrium is an exciting and vast study in itself, in the past few years, I have begun to learn from my colleagues and marvel at the multitudes of ways in which the dynamics of systems taken far from their equilibrium point can play out. It could result from a violent jolt, as in an earthquake. It could just be that the system is so complex, as with glass, it becomes trapped in a series of states that are stable only locally (metastability) and never reaches true equilibrium. Or perhaps it is a change in environment that seeds the formation of exquisite patterns, as in the emergence of glistening six-fold symmetric snowflakes on a wintery eve.

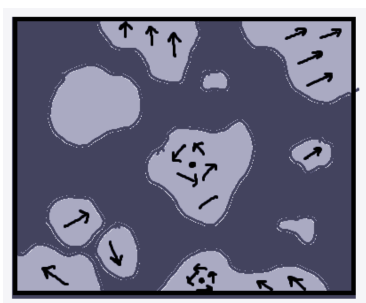


Metastability: being trapped in local energy minima.
Doodle by the Lounge Lizard

Even the universe, after the big bang exploded it into being, followed a fancy out-of-equilibrium trajectory as it cooled below a critical temperature, as per one description. The ensuing scenario, known as the Kibble–Zurek mechanism, concerns shifting between two different phases of matter by tuning some parameter across a critical point that separates these phases.

For instance, in iron, these two phases would be i) a ferromagnet at low temperatures, where each of the little magnetic moments in individual iron atoms order themselves to point in the same direction and create a giant magnet; and upon heating above a critical temperature, ii) a paramagnet, in which the moments are in a disordered state, pointing every which way, and the piece of iron shows no net magnetization.

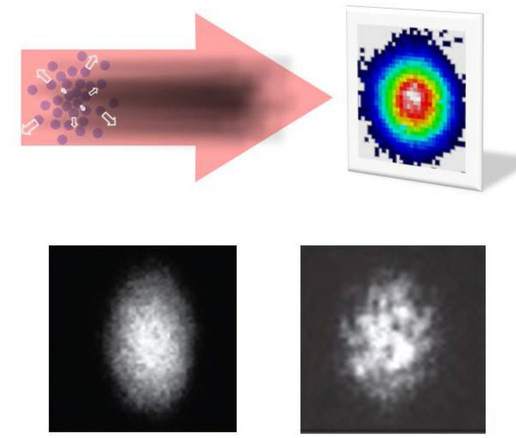
Now if one started in the disordered phase and dynamically changed this parameter beyond the critical point (cooling below the critical temperature in the case of the universe and with magnets), globules of order would emerge in different regions, grow, and create global order, save for places where these regions would meet to form fascinating structures known as defects.



Kibble–Zurek physics: Order (light) emerges from disorder (dark), creating defects (dot).
Doodle by the Lounge Lizard

Does this scenario account for features of our cosmos? Are we ourselves defects of some sort? We may not have a large enough Petri dish to contain the universe and to repeat the experiment. But the same scenario can be studied in solid state systems, for example, by cooling a material through a critical temperature at which it becomes a superconductor.

Several of us have been exploring this scenario in different guises, currently with renewed verve in the context of cold trapped atomic gases. As a fascinating manifestation, Brian DeMarco's group has pioneered observing Kibble–Zurek physics in a quantum system of trapped rubidium atoms. Here, the atoms inhabit an "optical lattice" created by interfering laser beams and either form a disordered insulator in which atoms are stuck at lattice sites, or an ordered superfluid where they cruise around the entire lattice. Hovering in near-vacuum and manipulated with tremendous control, these trapped gases occupy one of the coldest spots in our cosmos and form isolated, malleable mini-universes in themselves—right in DeMarco's lab on the third floor of Loomis.



Above: Shadow images are taken of ultra-cold gases. Below: Two images of nano-Kelvin gas; gas in left image is quenched but does not cross a quantum phase transition; gas in right image is quenched through a phase transition; the topological excitations are vortices produced as part of the quantum Kibble–Zurek mechanism.
Image courtesy of Professor Brian DeMarco

On our own planet, while the transformations drifting across its largely emerald-blue surface primarily follow the steady rhythm of its voyage around the Sun, they are also punctuated by cataclysmic events stemming from within. Among folks in the department who study these geological phenomena, Richard Weaver finds that rocks, because of their complex internal structure, show fascinating transient long-term behavior due to shock, or even to variations in the environment. Karin Dahmen has shown that "the Earth responds to the slow strains imposed by continental drift through a series of earthquakes." These avalanches traverse a slew of metastable states to cause earthquakes that span several magnitudes and produce "crackling noise," similar to that found in magnets or crunchy cereal (breakfast has become a different experience after Karin's demonstration of pouring milk into a bowl of Rice Crispies and then holding a microphone over it).

Over my travels of the past months between the Pacific shores by the San Andreas fault and those of the Indian Ocean, I encountered those who have personally experienced the disaster of meteorological phenomena thrown out of balance, from Hurricane Sandy on the east coast to Cyclone Neelam in Chennai, which also experienced remnants of the devastating Asian tsunami last year. It makes one wonder, forget drastic changing of ambient temperature, what havoc do we have in store as a result of the mere few-degree rise from global warming?

But for the most part, I have celebrated observing the rhapsody of splendid out-of-equilibrium events found in nature, especially while swimming content in the briny sea water, feeling gentle surges of waves, hearing cries of gulls and watching shifting clouds in the bright sky, the occasional surfer balancing and then pirouetting in the air, or the effusive spray created by playful harbor seals.

In all this, there is the biggest miracle on earth, life itself. In the film *Koyanisqaatsi* (meaning "Life Out of Balance," or "Equilibrium," in the Hopi language), one witnesses scenes of changing light over desertscapes, humanity, traffic racing at a frenzied pace, mushroom clouds, the thematic deep-throated chanting, the camera halting on the smile of a child.

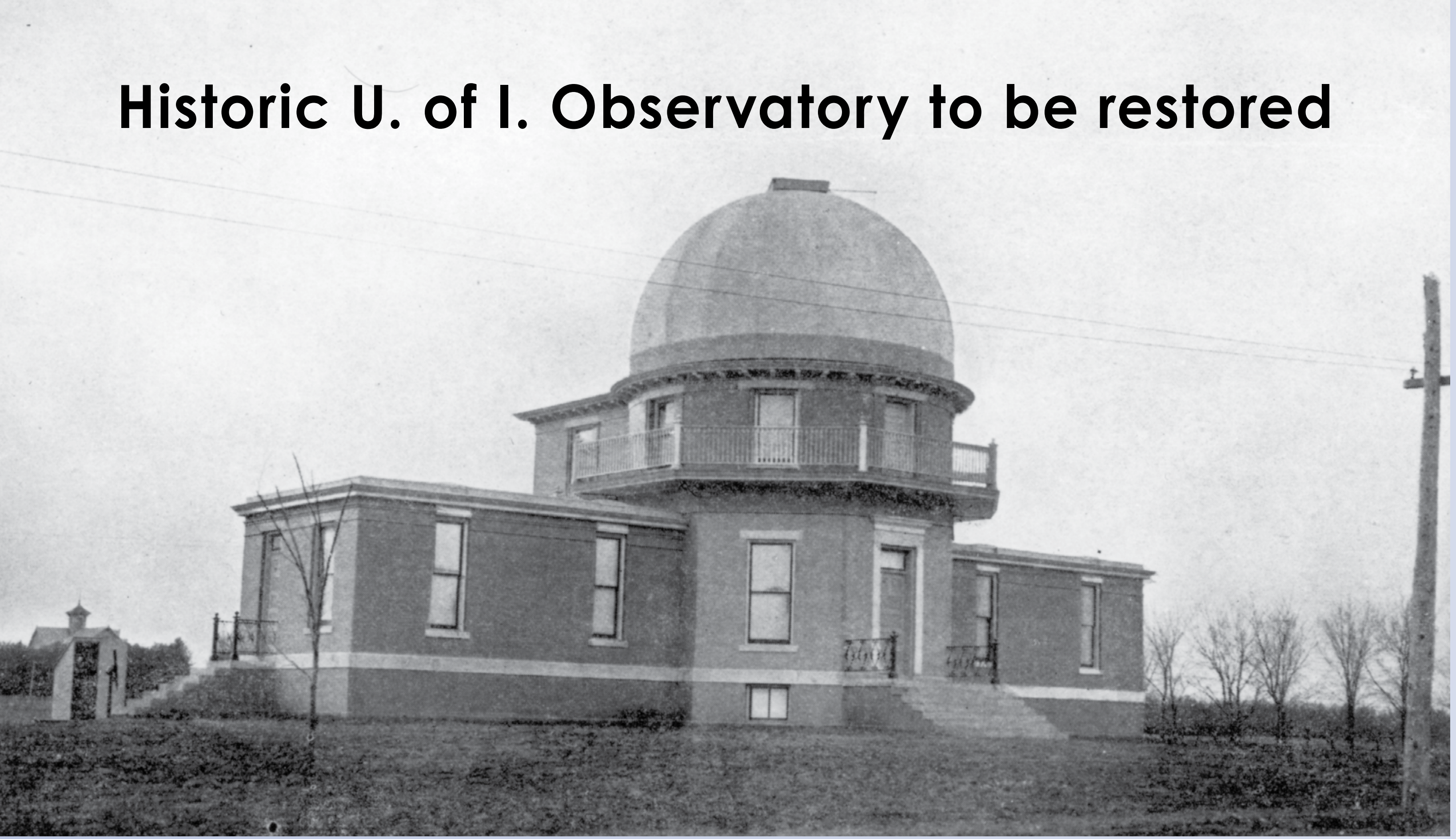
More fundamentally, Nigel Goldenfeld in our department and the revolutionary scientist, Carl Woese, who passed away last year, have envisioned evolution and the associated manner in which the genetic code morphs across generations as a collective far-from-equilibrium process. Adorned by the colorful, gigantic sculptures of *Darwin's Playground*, the Institute for Genomic Biology on Gregory Drive explores related questions on the emergence of life.

Finally, in one's individual life, as we know too well, from conception to death, each of us undergoes constant flux between creation, growth and demise, at best resting now and then in a temporary, shifting equilibrium.

For me, the past months of sabbatical travel from Illinois have gone through metastable states between several homes, allowing me in spurts to sit in my hometown in India at the desk where my grandfather once wrote plays and have the joy of drafting this first column for our beloved department. ■

An earthquake fissure caused by the sudden shifting of tectonic plates below.

Historic U. of I. Observatory to be restored



The University of Illinois Observatory circa 1897, before campus buildings (and their associated light interference) grew to surround it.
Photo courtesy of the University of Illinois Archives (image 2707.tif)

Erected in 1896 and home to the Department of Astronomy until 1979, the University of Illinois Observatory has not been used for research since the 1960s, but remains an important teaching facility. Since it first opened its eye 117 years ago, a great number of University of Illinois students have used the facility for observational work in their astronomy classes—currently more than 1,000 per year.

The facility, which houses a historic U. of I. instrument collection from the 1930s and 40s, is also frequently used for public outreach: The University of Illinois Astronomical Society (UIAS) hosts free monthly open houses. Trained members of the UIAS have keys to the facility and are allowed to use the facility when it is closed.

Now, thanks to fundraising efforts initiated by the Friends of the University of Illinois Observatory and supported by the U. of I. Chancellor's Fund for Excellence, the facility is getting a well-deserved and much-needed renovation, to preserve both the telescope and the building that houses it for future generations.

Professor Charles Gammie, head of the astronomy department, said maintaining the integrity and functionality of the facility is important, especially given the observatory's illustrious history.

In the early part of the 20th century, the field of astronomy was revolutionized by technological advancements developed at the U. of I. In the summer of 1907, for the first time in history, University of Illinois Observatory Director Joel Stebbins and Professor of Physics Fay C. Brown used electric current to measure astronomical brightness, taking a measurement of the moon's brightness during a lunar eclipse with a selenium cell photometer they had rigged to the observatory's 12-inch Brashear refractor telescope.

This pioneering work in photometry opened new possibilities for study, and Stebbins published numerous research articles on his applications of the new technology. In the following years, Stebbins worked with physics professors Jakob Kunz and W.F. Schulz, who had developed a photoelectric cell photometer to obtain even more accurate relative brightness measurements.

Today, these innovations continue to be recognized as significant and lasting contributions to the field of astronomy. In fact, they are what give the 117-year-old University of Illinois Observatory its status. The observatory was listed on the National Register of Historic Places on November 6, 1986, and on December 20, 1989, the U.S. Department of Interior designated the observatory a National Historic Landmark.

After ridding the building of mold and mildew in Fall 2012 and repointing the external wall masonry, the first priority in the renovation was to repair the primary telescope. The $54,000 restoration is being completed by Ray Museum Studios in Swarthmore, PA; the telescope was disassembled and removed mid-May, with all work due to be finished by August 2013 in time for start of the fall semester.

The company will make mechanical repairs to gears and motors to reduce wobble and will restore the steel telescope tube, the mount, and the brick pier on which it all sits (the pier is separate from the building's foundation, to reduce vibration).

Gammie said the restoration will not upgrade the telescope, though that could have been done at about the same cost: "We are sticking with a refractive lens: it's a beautiful old instrument that was used in the experiments that gave the building its status."

The original two-piece lens is being stored on campus, to avoid damage.

But the telescope will be fitted with a few modern improvements, including a new data port that will make it easier to transfer photos taken through the telescope to a computer, and a mount for solar telescopes or other accessories. Small cameras will also be installed to help position the telescope with more precision, and bulbs will be replaced with longer-lasting LED lights.

The company will also paint the telescope, to restore its original appearance.

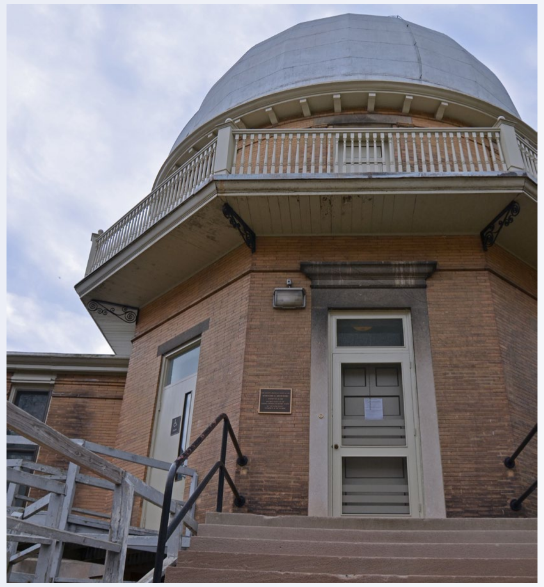
Gammie said this is the first of several phases required to complete the renovation of the University of Illinois Observatory, and future phases are still in the planning and fundraising stages.

"The building is decaying," he said. "There are leaks in the roof plus drainage problems in surrounding tiles. The viewing balcony collects water, because it slopes inward. There has been damage to storage closets and problems with mold and mildew. The poor condition the facility is in today is the result of deferred maintenance."

"We started with a survey through a U. of I. architecture class on historic preservation, taught by Paul Kapp. The students did a survey and drew up plans for the renovation. They had some really cool ideas, but of course, money was no constraint—one student even included an underground planetarium. But most of the plans included restoration and improvements to the room on the east side of the building, converting it to a classroom."

"At this point, we are about $60,000 into a $3- to $5-million campaign," said Gammie. "Our alumni are excited, the Friends are very supportive, and the UIAS is also very supportive." ■

Above: The observatory's original 12-inch Brashear refractor telescope prior to disassembly and removal
Below: The exterior of the 117-year-old observatory today looks much the same as when it was first erected, but for some telltale signs of age.



Learn more about the Friends of the University of Illinois Observatory and take a virtual tour at **http://www.astro.uiuc.edu/friends/fuio/**. Visit the University of Illinois Astronomical Society website at http://uias.astro.illinois.edu/.

Fradkin elected to National Academy of Sciences

The National Academy of Sciences has elected to membership Professor Eduardo H. Fradkin, director of the Institute for Condensed Matter Physics, for his seminal contributions to theoretical condensed matter physics. Joining Fradkin in the 2013 class is U. of I. Professor of Chemistry and of Physics Martin Gruebele and Professor of Chemistry Sharon Hammes-Schiffer.

Fradkin is internationally recognized for ground-breaking work at the interface between quantum field theory and condensed matter physics. He pioneered the use of concepts from condensed matter physics and statistical physics, such as order parameters and phase diagrams, to problems of quantum field theory and high energy physics.

Perhaps his most important contribution in this area was the proof that when matter fields carry the fundamental unit of charge, the Higgs and confinement phases of gauge theories are smoothly connected to each other and are as different as a liquid is from a gas. This result remains one of the cornerstones of our understanding of the phases of gauge theories and represents a lasting contribution to elementary particle physics.

Fradkin was one of the first theorists to use gauge theory concepts in the theory of spin glasses and to use concepts of chaos and non-linear systems in equilibrium statistical mechanics of frustrated systems. Fradkin also pioneered the use of Dirac fermions for condensed matter physics problems, particularly in two space dimensions. A prime example is his work on Dirac fermions on random fields, which is now regarded as the universality class of the transition between quantum Hall plateaus in the integer Hall effect. This work is important for the description of quasiparticles in disordered *d*-wave superconductors and in the recently discovered topological insulator materials.

A major achievement has been the development of the fermion Chern–Simons field theory of the fractional quantum Hall effect, which has played a central role in the current research effort in this exciting problem. Fradkin has also recently developed a theory of electronic liquid crystal phases in strongly correlated systems and formulated a mechanism of high-temperature superconductivity based on this new concept. He is also a leader in the theory of topological phases in condensed matter and on the role of quantum entanglement at quantum critical points.

Fradkin received his *Licenciado* (master's) degree in physics from Universidad de Buenos Aires (Argentina) and his doctoral degree in physics from Stanford University in 1979. He came to the University of Illinois in 1979 as a postdoctoral research associate and became an assistant professor of physics at Illinois in 1981. He was promoted to associate professor in 1984, and became a full professor in 1989.

Fradkin is a fellow of the American Academy of Arts and Sciences, a Simon Guggenheim Foundation fellow, and a fellow of the American Physical Society.

About the National Academy of Sciences

Established by President Lincoln in 1863, the National Academy of Sciences of the United States is charged with providing independent, objective advice to the nation on matters related to science and technology. Scientists are elected by their peers to membership in the NAS for outstanding contributions to research. The NAS is committed to furthering science in the United States, and its members are active contributors to the international scientific community.

Membership is a mark of excellence in science and is considered one of the highest honors that a scientist can receive. A total of 84 new members and 21 foreign associates from 14 countries were elected this year. ■

Ha selected for Gutgsell Professorship

Professor of Physics Taekjip Ha has been appointed an Edward William and Jane Marr Gutgsell Endowed Professor, one of the highest distinctions conferred by the University of Illinois on distinguished faculty members for achievements in research, teaching, and service that represent significant contributions within their respective fields.

Ha has established a large, successful research group at Illinois, with collaborations both within physics and across campus. In addition to physics, he holds appointments as professor in the Center for Biophysics and Computational Biology and as a theme leader at the Institute for Genomic Biology. He is an affiliate of the Beckman Institute, the Department of Medical Biochemistry, College of Medicine, and the Department of Chemistry. He is co-director of the Center for the Physics of Living Cells, a Physics Frontiers Center funded by the National Science Foundation.

Ha has achieved many firsts in experimental biological physics—the first detection of dipole-dipole interaction (single molecule fluorescence resonance energy transfer, or smFRET); the first observation of "quantum jumps" of single molecules at room temperature; the first detection of the rotation of single molecules; and the first detection of enzyme conformational changes via smFRET. His work using single-molecule measurements to understand protein-DNA interactions and helicase enzyme dynamics has led him to develop novel optical techniques, fluid-handling systems, and surface preparations that have advanced his field.

Head of Department and Professor Dale Van Harlingen said, "We are delighted to see Taekjip receive this significant recognition from the campus. Since he came here, he has been a pioneer in single-molecule imaging studies of DNA, RNA, and the helicase enzymes. His work has always been innovative, pushing the boundaries of biological physics and enabling new questions to be posed and answered. Many of the techniques he has developed are now in use in labs the world over, and his interdisciplinary research with HHMI and IGB is setting the agenda for campus initiatives to understand how life evolves from and is controlled by fundamental biological processes."

Ha received his doctoral degree in physics in 1996 from the University of California, Berkeley. Prior to joining the Department of Physics at the University of Illinois in August 2000, he was a postdoctoral fellow at Lawrence Berkeley National Laboratory (1997) and a postdoctoral research associate in Steven Chu's laboratory in the Department of Physics at Stanford University (1998–2000).

Ha is a Fellow of the American Physical Society and the recipient of many honors. Among these, he was named Searle Scholar in 2001, was named an investigator of the Howard Hughes Medical Institute in 2005, was selected for the Michael and Kate Bárány Award of the Biophysical Society in 2007, and was named a University Scholar at the University of Illinois in 2009. In 2011, Ha was awarded the Ho-Am Prize in Science by the Ho-Am Foundation of Korea.

The Edward William and Jane Marr Gutgsell Endowed Professorships were established in 1998 and are funded through a gift to the University by the late Edward William Gutgsell and Jane Marr Gutgsell. The professorships are five-year renewable-term appointments. ■

Nadya Mason and Mark Neubauer win Dean's Award for Excellence in Research

Associate Professor Nadya Mason and Assistant Professor Mark Neubauer have received the College of Engineering's prestigious 2013 Dean's Award for Excellence in Research, in recognition of the outstanding research contributions each has made.

Department Head and Professor Dale Van Harlingen said both recipients are more than deserving of the recognition: "Nadya has greatly distinguished herself as a leading-edge experimentalist in complex materials, superconductivity, and nanotechnology. In true Urbana style, she maintains a close rapport with theorists to make swift headway on some of the most persistent unsolved problems in transport in low-dimensional systems at the quantum limit.

"Mark equally exemplifies our highest standards of scholarship, creativity, and leadership. He is a talented high-energy experimentalist who has made singular contributions to the ATLAS collaboration at the Large Hadron Collider (LHC) at CERN, participating last July in the big announcement of compelling evidence for the discovery of a Higgs boson. With his extraordinary experimental skills and vision and his remarkable productivity, Mark is making trailblazing contributions to experimental high-energy physics and to petascale distributed computing here at Illinois and internationally."

Professor Nadya Mason

Mason is a principal investigator in the Frederick Seitz Materials Research Laboratory. Mason's list of publications in peer-reviewed journals attests to her seminal research contributions to experimental condensed matter physics and has established her as an international leader in the physics and electronic properties of carbon nanotubes, graphene, and topological insulators. Because of the low dimensionality of these systems, they often display novel electronic properties and hold promise for applications in superconductivity and quantum computing. Mason's work has direct bearing on our understanding of electronic transport in these materials, which is essential for the design of nanoscale circuit elements, an emerging area of study.

Mason has received numerous awards for her work, including the Maria Goeppert Mayer Award of the American Physical Society (2012), the Denice Denton Emerging Leader Award of the Anita Borg Institute (2009), a Woodrow Wilson Career Enhancement Fellowship (2008/09), a National Science Foundation CAREER Award (2007), and her appointment as a Center for Advanced Study Fellow (2011/12) at the University of Illinois. She was one of 122 young scientists selected to take part in the National Academy of Sciences' US and Chinese-American Kavli Frontiers of Science symposium (2011).

Mason received her bachelor's degree in physics from Harvard University in 1995 and her PhD in physics from Stanford University in 2001. She then returned to Harvard for a postdoctoral fellowship and was in short order elected a Junior Fellow in the Harvard Society of Fellows. She joined the Physics Illinois faculty in 2005. She is currently serving as the Chair of the Facilities Committee for MRL and as as one of the theme leaders for the DOE Basic Energy Sciences cluster on quantum materials and nanoarchitectures.

Mason said she is very honored by this recognition: "I feel lucky to be working on topics that are interesting and fun to think about. And most importantly, I'm grateful to my students for their hard work, and also to my great collaborators in the college and the department."

Neubauer is an experimental physicist whose research spans diverse topics in the study of elementary particles and their interactions, with his primary focus centered on the search for the Higgs boson first at Fermilab's now retired Tevatron collider and more recently at CERN's LHC.

Professor Mark Neubauer

As a member of the ATLAS collaboration at LHC, Neubauer played a leadership role in the design and implementation of a fast track-finder upgrade of the ATLAS trigger, the instrument that detects and records events of physics interest within the project's multi-petabyte data stream. Through his collaboration with colleagues at the National Center for Supercomputing Applications (NCSA), Neubauer was also instrumental in establishing data acquisition systems within the project's distributed computing environment and was a major player in the University of Illinois' becoming the first US University to become a Tier-3 data analysis center.

Recently, Neubauer built the first prototype of a fully grid-capable computing cluster, a powerful tool for big-data high-energy physics nationally and internationally.

Last year, in collaboration with colleagues at the University of Chicago and Indiana University, Neubauer helped to create a Tier-2 Midwest Center for ATLAS.

Neubauer is the recipient of several honors, including a National Science Foundation CAREER Award (2011), an appointment as a Center for Advanced Study Fellow (2012/13) and as an NCSA Faculty Fellow (2008/09), and an Arnold O. Beckman Research Award (2007).

Neubauer received his bachelor's degree in physics from Kutztown University in 1994 and his PhD in physics from the University of Pennsylvania in 2001. He went on to work as a postdoctoral research associate at the Massachusetts Institute of Technology in 2001 and then at the University of California, San Diego in 2004. Neubauer joined the Illinois faculty in 2007.

"This past year has been the most exciting time that I have encountered in particle physics research," commented Neubauer. "The discovery of a Higgs boson and measurement of its properties is one of the great achievements of human scientific inquiry. To play a role in this achievement and receive the Dean's Research Award from the College for my research in this area are great honors for me. As is often the case with important scientific discoveries, this one answers some long-standing questions but also raises many new ones. It will be an exciting time over the next decade to study the properties of this newly discovered particle in detail and search for other new phenomena." ■

DeMarco named Willett Scholar

Professor Brian DeMarco was one of eight College of Engineering faculty members to be named a Donald Biggar Willett Scholar for 2013.

DeMarco's research focuses on solving outstanding problems in condensed matter physics using ultra-cold atoms trapped in an optical lattice.

Current research problems being tackled by his team include the properties of the disordered Bose–Hubbard model, thermometry in strongly correlated lattice systems, and thermopower in the Hubbard model.

DeMarco's group was the first to identify the cross-over between quantum tunneling and thermal activation of phase slips in an optical lattice (published in *Nature*) and the first to realize 3D Anderson localization of matter (published in *Science*). DeMarco's group was also the first to trap atoms in a disordered optical lattice in a regime described by the disordered Bose–Hubbard model.

DeMarco is the recipient of an NSF CAREER award, an ONR Young Investigator award, a Sloan Foundation Fellowship, and a College of Engineering Dean's Award for Excellence in Research. ■

Philip Phillips elected Fellow of AAAS

Professor Philip Phillips was elected a Fellow of the American Association for the Advancement of Science (AAAS) for "distinguished contributions to theoretical condensed matter physics, including the developments of the random dimer model and the concept of 'Mottness.'"

Phillips is a theoretical condensed matter physicist whose leading-edge research on high-temperature cuprate superconductors focuses on explaining current experimental observations that challenge the standard paradigms of electron transport and magnetism. Phillips applies geometry and quantum field theory to disordered and strongly correlated low-dimensional systems to understand the properties of these materials.

Phillips's work has earned him an international reputation. He is the inventor of various models for Bose metals, of the term "Mottness," and of the random dimer model, which exhibits extended states in one dimension, thereby representing an exception to Anderson's localization theorem. He is the author of the comprehensive textbook Advanced Solid State Physics, published by the Cambridge University Press.

Head of Department and Professor Dale Van Harlingen said, "This is a well-deserved honor for Philip and significant recognition for our condensed matter physics group. Philip has distinguished himself as one of the most creative theorists in the area of strongly correlated electronic materials, especially via his pioneering work elucidating the concept of Mottness in these systems. He is leading our ambitious efforts to understand the mechanism of the high-temperature superconductors and to design new superconductors with even higher transition temperatures. He has been particularly effective at bringing concepts to bear on this problem from high-energy physics and string theory, moving the field into previously unexplored territory."

Phillips earned his bachelor's degree in math and chemistry from Walla Walla College in 1979, and his doctoral degree in theoretical chemistry from the University of Washington in 1982. After a Miller Postdoctoral Fellowship at Berkeley, he joined the faculty of the Department of Chemistry at Massachusetts Institute of Technology (1984–1993). Phillips's research interests led him to the Department of Physics at the University of Illinois in 1993.

Phillips is a Fellow of the American Physical Society and served the society as general councilor during the 1999/2000 academic year. He is the recipient of many honors; among these, he received the Senior Xerox Faculty Award of the College of Engineering in 1998, was named a Beckman Associate at the Center for Advanced Study for the 1998–1999 academic year, was the Edward A. Bouchet Lecturer of the American Physical Society in 2000, was selected as a University Scholar at the University of Illinois in 2004, and was named Bliss Faculty Scholar by the College of Engineering in 2005.

Founded in 1848, AAAS is the world's largest general scientific society. Election as a Fellow is an honor bestowed upon members by their peers in recognition of meritorious efforts to advance science or technology. This year's fellows were recognized during the AAAS annual meeting in Boston in February. ■

Faculty highlights

Klaus Schulten awarded Biophysical Society's Distinguished Service Award

Swanlund Professor of Physics Klaus Schulten was awarded the Biophysical Society's 2013 Distinguished Service Award for "laying the groundwork for the realistic molecular dynamic simulations of biological macromolecules on time scales that match the physiological realm, and for making the methods and software openly available."

Schulten heads the Theoretical and Computational Biophysics Group (TCBG) at the Beckman Institute for Advanced Science and Technology. Under Schulten's direction, TCBG has been an innovator for more than two decades in developing software for molecular scale, dynamic simulations that give unprecedented insight into biological structures and processes.

Two programs developed by Schulten and his group, VMD and NAMD, have more than 200,000 registered users worldwide. Schulten has used the software for scientific discoveries as well as for groundbreaking simulations, such as visualizing the gating mechanism involved in generating and controlling nerve cell signals and the first-ever simulation of an entire life form, the satellite tobacco mosaic virus.

The Biophysical Society is a professional, scientific society established to encourage development and dissemination of knowledge in biophysics with more than 9,000 members worldwide in colleges, universities, laboratories, government agencies, and industry.

The Distinguished Service Award is given to those who have "made an exceptional contribution to the field of biophysics and in its advancement outside of research." ■

Beck, JSA's Outstanding Nuclear Physicist

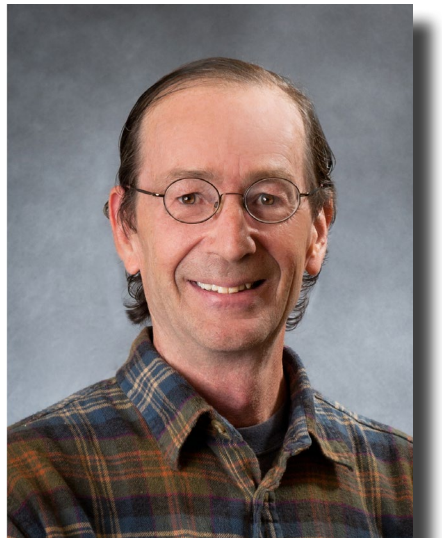
Jefferson Science Associates, LLC, selected Professor Douglas Beck for the 2013 Outstanding Nuclear Physicist Award; he shares the award with Paul Souder of Syracuse University. The recipients were selected for leadership in the development of parity-violating electron scattering as a tool for the study of nucleon and nuclear structure, and precision studies of the standard model.

"This award to Doug Beck and Paul Souder recognizes two outstanding nuclear physicists for leading distinctive and incisive physics programs at Jefferson Lab," said JSA President and Jefferson Lab Director, Hugh Montgomery. "Both Doug and Paul have also been enormously supportive of the entire Jefferson Lab enterprise."

Beck was the spokesperson for a collaboration of more than 100 researchers for the Jefferson Lab's G0 electron scattering parity-violation experiment. Beck led the team that developed the toroidal spectrometer for G0, overseeing its design, testing, installation, and commissioning at Jefferson Lab.

Beck is the recipient of many honors: he was named a Sloan Foundation Research Fellow in 1991, was an NSF Young Investigator from 1992–97, was elected Fellow of the American Physical Society in 2002, was named a University Scholar from 2001–03, and received the Arnold T. Nordsieck Award for Excellence in Teaching in 2007. He is the Chair of the Brookhaven National Lab Nuclear and Particle Physics Advisory Committee and a current member of the APS Division of Nuclear Physics Executive Committee.

Jefferson Lab is a world-leading nuclear physics research laboratory managed and operated by Jefferson Science Associates for the US Department of Energy. ■



Errede selected for 2013 Nordsieck Physics Award for Teaching Excellence

Professor Steven Errede has been selected to receive the Arnold T. Nordsiek Physics Award for Teaching Excellence for the 2012/13 academic year, for "creating innovative, engaging instructional laboratories in acoustics and the physics of musical instruments for beginning and advanced undergraduate students."

Errede has developed undergraduate courses, undergraduate research opportunities, and pubic outreach programs that allow music lovers to explore the acoustical physics of music (POM).

In addition to teaching a freshman discovery course, Physics 193, and an upper-level undergraduate course, Physics 406, on the acoustical physics of musical instruments, Errede has provided a significant number of students with independent-study opportunities in the physics of music. The seeds for these offerings were planted in the summer of 1996, when Errede got back in to playing music after a hiatus of about 25 years:

"I spent much time during my childhood and teenage years playing classical violin and piano, then playing in various rock 'n roll and blues bands. That summer, I rediscovered the joy of playing music again, but I also laughed at myself when I realized that about half the time, I was instead trying to measure things to figure out why or how the musical instruments I was playing made the sounds that they did. It was impossible to shut off the physicist. I was having so much fun myself doing this, that I thought that this might be a fun class to teach. After a decade of teaching these two POM courses—incorporating into them all of what we have learned along the way—they are a total joy for me to teach."

Errede admits, "I shamelessly use the fact that all humans love music as a 'hook' to get students excited about the science underlying music and musical instruments. All of the course material in the more technical upper-level POM course is eminently applicable—with appropriate modifications—to other physics courses."

Errede said it was his own "immensely beneficial" research experience as an undergraduate that sealed his enduring personal commitment to providing high-quality undergraduate research experiences for Physics Illinois students.

Department Head and Professor Dale Van Harlingen said Errede's initiative, creativity, and hard work have turned his passion for music into unique learning opportunities for students:

"Errede is using music to introduce students to rigorous experimental physics. I speak for every member of the faculty when I say that we are immensely proud of his work and deeply grateful to have him as a colleague."

The Nordsiek Award is made possible by a memorial endowment from the family of distinguished Professor Arnold T. Nordsiek (1911–1971), a theorist in the mathematics of computation at Illinois from 1947 to 1961.

Among his many contributions, Nordsieck built the first computer to be used at Lawrence Livermore National Laboratory, the differential analyzer. This innovative analog computer was assembled in Urbana in 1950 from $700 worth of surplus World War II supplies and is today on display at the Computer History Museum in Mountain View, California.

Errede dedicates the award to his parents and all of the exceptional teachers (K–grad) who had a hand in his own education. ■

Ryu wins Condensed Matter Science Prize

Assistant Professor Shinsei Ryu was selected for Japan's 7th Condensed Matter Science Prize for his development of a "periodic table" for the classification of topological phases of matter in three spatial dimensions. Ryu made use of Anderson localization theory of disordered electron systems and the methods of quantum field theory to categorize known and theoretical topological materials for a given set of symmetry properties (such as time-reversal, particle-hole, and chiral symmetries). His schematic has proven invaluable in systematizing the search for new

electronic states and topological superconductors.

Ryu received his bachelor's degree (2000) in physics and his master's (2002) and doctoral (2005) degrees in applied physics from the University of Tokyo. In 2001, he received the Tanaka Shoji Prize (master's thesis prize) from the Department of Applied Physics at the University of Tokyo. He was awarded a research fellowship by the Japan Society for the Promotionof Science (2002/03).

The Condensed Matter Science Prize, established in 2006, is aimed at encouraging young researchers in condensed matter physics. It was privately endowed by Professors Jun Akimitsu of the Aoyama Gakuin University and Hidetoshi Fukuyama of the Tokyo University of Science. ■

Elliott selected for Excellence in Teaching Award

Director of External Affairs and Special Projects and teacher of several courses at Physics Illinois, Celia Elliott has been selected as the second recipient of the Doug and Judy Davis Award for Excellence in Teaching Undergraduate Physics.

Department Head and Professor Dale Van Harlingen said Elliott has been an asset to teaching faculty and students alike.

"No one in our department is more deserving of this award than Celia for her many years of commitment to our educational mission, helping faculty, staff, and students at all levels," said Van Harlingen. "We particularly want to recognize the extraordinary contributions she has made and continues to make to develop our senior-thesis course sequence into one of the most popular and effective programs in our curriculum."

Known also among her colleagues for her exacting standards in everything to do with the written word, Elliott has exceptional skills in grant writing, on which subject she has authored two books in Russian and is a sought-after speaker and consultant.

Elliott is recipient of the U. of I. Office of Public Affairs's ACME "Team Player" Award, 2010, the Civilian Research and Development Foundation Recognition Medal, 2005, the Physics Haiku Grand Champion, American Physical Society, 2004, and the Chancellor's Academic

Professional Award, 2002.

The Davis Award was created and funded by Doug and Judy Davis to recognize faculty or staff members who truly enhance undergraduate education at Physics Illinois. ■

Photo courtesy of the White House

Physics Illinois alumnus Sidney Drell receives National Medal of Science

Arms control expert Sidney Drell, a theoretical high-energy particle physicist and Physics Illinois alumnus, was awarded the nation's highest scientific prize in a ceremony at the White House on February 1, 2013. President Barack Obama presented Drell and 11 other eminent researchers with the National Medal of Science; at the same ceremony, 11 inventors received the National Medal of Technology and Innovation.

Drell's citation reads: "for contributions to quantum field theory and quantum chromodynamics, application of science to inform national policies and security and intelligence, and distinguished contributions as an advisor to the United States Government."

"I am proud to honor these inspiring American innovators," said President Obama. "They represent the ingenuity and imagination that has long made this nation great—and they remind us of the enormous impact a few good ideas can have when these creative qualities are unleashed in an entrepreneurial environment."

Drell is a longstanding and still active member of JASON, an elite group of scientists that advises the government on technical and highly classified national security matters. Since the 1960s, Drell has served on numerous advisory panels to Congress, the Department of Defense, the Department of Energy, and the Central Intelligence Agency. He is currently a professor emeritus of physics at the Stanford Linear Accelerator Center, having retired as its deputy director in 1998, and is a senior fellow at Stanford's Hoover Institution.

Longtime friend and colleague Illinois physicist Charles Slichter said, "Sid is a magnificent human being, a great scientist, and a great patriot, who has made enormous contributions to nuclear arms control. He deserves the National Medal of Science for any one of his many accomplishments."

Drell said it is a responsibility of the scientific and technical community to participate in the political dialogue with respect to applications of new technologies for national defense or military intelligence.

"Many scientists have felt this responsibility, and it's been a great asset to our nation," said Drell. "The scientific and technical community is creating innovations that affect the conditions of life. There are great advances, as with medical technologies, but there are also dangers that come with it. How do we best apply this for peace and for the good of people?"

Drell said as a young professor, he had imagined his career would center on academics, but colleagues encouraged him also to contribute more broadly to issues of national security. He in turn has encouraged his own students to be mindful of how new technologies will be applied in the best interests of the nation.

Since the 1960s, Drell has been a key voice against nuclear arms proliferation, and he helped to develop the verification methods for the world's first nuclear arms control treaty, among many other important contributions.

"I thought this would be the total focus of my life, the realization of a dream to be a high-energy particle physicist: to understand what energy is made of, what are the building blocks of matter, and what are the forces that bind them," said Drell. "But I also had to realize how to deal with the potential nightmare of a nuclear holocaust. In the 1960s, the world situation was one of great turmoil."

"Once I realized the importance, I felt that it was an important call to try to help in the areas of arms control and technologies related to national defense. So that is how my life bifurcated into two parts, basic research—the subject I loved best—and the opportunity to work on national technical issues to help us decide, based on what we were learning was the threat and what was the good science that we could do, how to prevent a second holocaust."

> *"Sid is a magnificent human being, a great scientist, and a great patriot, who has made enormous contributions to nuclear arms control."*

Drell at Illinois

Drell earned his master's degree and doctorate in physics from the University of Illinois at Urbana-Champaign in 1947 and 1949, respectively.

After earning his bachelor's degree from Princeton in 1946, Drell set his sights on the Department of Physics in Urbana for his graduate studies. He very nearly took the long way to campus. Drell, who had never traveled west of the Delaware River, had inadvertently booked a train ticket to Urbana, Ohio. A couple of weeks later—before boarding the train—he noticed and corrected the error.

When he arrived at campus in 1946, it was teeming with new students, many of whom were veterans who had taken advantage of the educational benefits offered under the 1944 G.I. Bill.

"It was exciting—the G.I. Bill was a great piece of legislation that brought millions to a college education. The campuses in the country were buzzing like they'd never buzzed before. They were marvelous times," said Drell.

Since there was not enough housing to accommodate the great throngs of young scholars, Drell and his 299 roommates made the most of makeshift arrangements for well over a year.

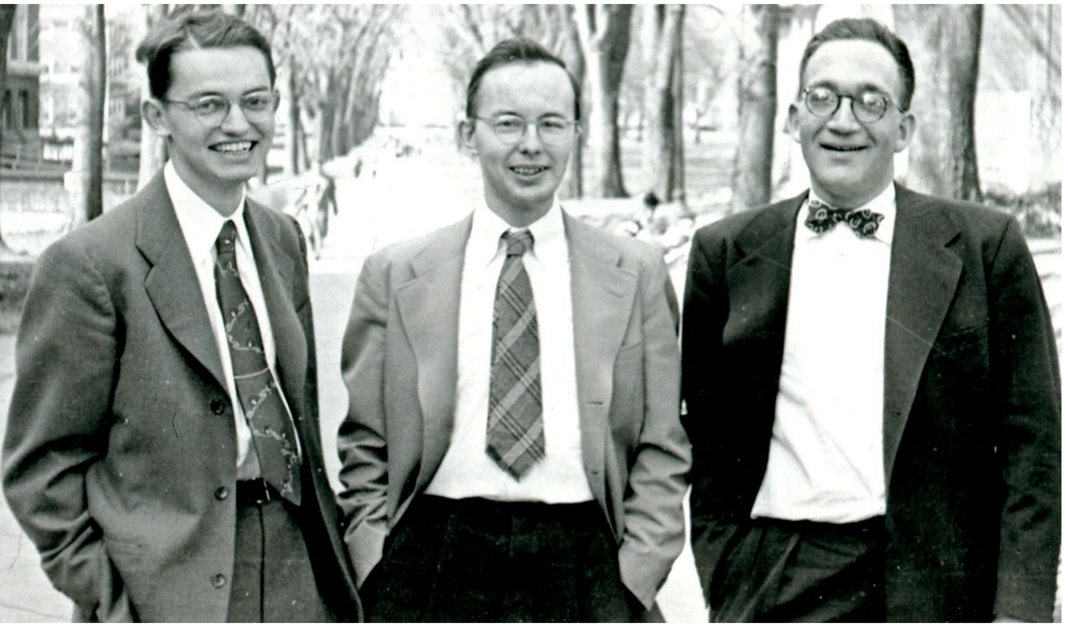
"I have very fond memories of the University of Illinois. Getting a bed to sleep in was the hardest part," Drell remembers. "The first 15 months of my life there were spent in half of a double-decker bunk in a basketball court in the Men's Old Gym. To get a bed wasn't easy, and I felt quite fortunate that I got a bed. Of course, when you're young, these things don't matter."

The rough accommodations notwithstanding, Drell describes his time at Illinois as four of the greatest years of his life. Drell said he enjoyed the rich culture that had grown up around the university.

Drell said he felt privileged to play in the university orchestra under guest conductors Igor Stravinsky and Aaron Copland. And it was during his time at the U. of I. that he met his wife, Harriet Drell, who earned her master's degree in German languages and literature from the U. of I. in 1950.

"Urbana was an exciting town. The university created a fantastic culture," he said.

Drell grew to be fast friends with two other young physicsts who would become lifelong colleagues, Charles Slichter and John Blair. Slichter remembers: "We were three bachelors, though Sid and John had girlfriends at the time whom they eventually married. The three of us were very good friends and we did everything together. We went to all the football games, and at that time, you couldn't have alcoholic



Brand new faculty member Charlie Slichter, graduate student John Blair, and Sid Drell on the Quad on their way back from a U. of I. football game in 1951

beverages at the stadium, so we had to smuggle in liquid refreshments.

"After the game, we would go to one of the pubs on Wright Street, and we would check to see which Ivy League team had won that day. Since Sid had attended Princeton as an undergraduate, John had attended Yale, and I had been a Harvard man, whichever team lost, that person would pick up the tab that night. I remember Harvard lost quite frequently in those days.

"The three of us had a great time together. Sid is a wonderful, warm human being and he has a great sense of humor. He's a sunbeam wherever he is, warm, with a magnetic smile. And he's a brilliant theoretical physicist."

Drell said he found a great mentor in Sidney Dancoff, an Illinois physicist whose career was cut short by lymphoma.

"I had an excellent education," said Drell. "My thesis adviser, Sidney Dancoff, was a brilliant young theorist—a student of Robert Oppenheimer. I was his only student because he died of cancer the next year. He was a wonderful person and a brilliant, brilliant scientist. Everyone loved him. I give him enormous credit for my achievements."

Drell has received numerous awards, including the Enrico Fermi Award, a fellowship from the MacArthur Foundation, the Heinz Award, the Rumford Medal from the American Academy of Arts and Sciences, the National Intelligence Distinguished Service Medal, and the National Nuclear Security Administration Administrator's Gold Medal of Excellence for Distinguished Service. He was honored by the US National Reconnaissance Office as one of the "founders of national reconnaissance as a space discipline." Drell was elected to the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society and was president of the American Physical Society in 1986.

Drell has served on the President's Foreign Intelligence Advisory Board, the President's Science Advisory Committee, the Panel on Nuclear Weapons Safety of the House Armed Services Committee, the Technology Review Panel of the Senate Select Committee on Intelligence, and the Senior Review Board of the Intelligence Community's Technology Innovation Center. He is a retired member of the Board of Governors for both Lawrence Livermore National Security LLC (LLNS) and Los Alamos National Security LLC (LANS), the managing contractors for the Lawrence Livermore and Los Alamos national laboratories. And he served as the founding co-director of Stanford's Center for International Security and Arms Control. ■

The National Medal of Science was created by statute in 1959 and is administered for the White House by the National Science Foundation. Awarded annually, the medal recognizes individuals who have made outstanding contributions to science and engineering. A committee of Presidential appointees selects nominees on the basis of their extraordinary knowledge in and contributions to chemistry, engineering, computing, mathematics, or the biological, behavioral/social and physical sciences.

Physics Illinois alumnus Sergey Frolov shares Newcomb Cleveland Prize

Physics Illinois alumnus Sergey Frolov, now an assistant professor of physics at the University of Pittsburgh, was selected for the prestigious 2012 Newcomb Cleveland Prize of the American Association for the Advancement of Science (AAAS). He shares the award with his colleagues at Delft University of Technology Vincent Mourik, Kun Zuo, Sébastien R. Plissard, Erik P. A. M. Bakkers, and Leo P. Kouwenhoven.

The Newcomb Cleveland Prize is awarded annually to the author or authors of an outstanding research article or report published in the journal *Science*. Frolov and his colleagues won for their report "Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nanowire Devices," in the May 25, 2012, issue.

In the article, the team presents their observation of evidence of Majorana-like states. The long-sought Majorana fermion, a quasiparticle theorized to be its own antiparticle, had only been predicted mathematically. The Delft group is the first research team to have found experimental evidence in support of its existence.

The team engineered a nanostructure of a superconductor in contact with a semiconductor wire that, when placed in a strong magnetic field, showed several features consistent with those predicted for the elusive Majorana state.

The hybrid superconductor-semiconductor device could allow for the manipulation of Majorana states, which, if verified, could lead to new types of quantum computing and other applications.

The team's results and approach have generated numerous follow-on experiments and work (including one at Physics Illinois; see page 6).

"We are humbled by the honor of this prize," said Frolov. "We will continue exploring the field that we started with this paper, and, in my new laboratory at Pitt, we'll use Majorana particles to assemble the building blocks of a quantum computer."

The AAAS's oldest award, the Newcomb Cleveland Prize, supported by The Fodor Family Trust, was established in 1923 with funds donated by Newcomb Cleveland of New York City and was originally called the AAAS Thousand Dollar Prize. It is now known as the AAAS Newcomb Cleveland Prize, and its value has been raised to $25,000. ■

Physics Illinois alumnus William Edelstein receives Alumni Achievement Award for lifetime of pioneering contributions to MRI

Eminent Physics Illinois alumnus William Edelstein (BS *summa cum laude*, 1965) revolutionized health care with his numerous pioneering contributions to the technology behind the life-saving medical diagnostic tool, high-resolution MRI. The holder of 49 patents, Edelstein is extensively published on the subject; he laid the groundwork for the design of current and future medical MRI apparatuses.

In recognition of his prodigious contributions to the field of MRI, Edelstein was presented with the University of Illinois 2013 Alumni Achievement Award during commencement ceremonies in May.

Professor Charlie Slichter, long-time friend and colleague, said, "Bill Edelstein has contributed brilliant ideas to the design of the modern medical MRI machine, starting when MRI technology was first being developed and continuing through the period of its widespread application as a diagnostic tool. Today he is still working to refine and improve this important, sometimes lifesaving piece of equipment. Bill is part of a great legacy in MRI out of Physics Illinois: Paul Lauterbur and Sir Peter Mansfield, who shared the Nobel Prize for inventing MRI, worked here as professor and postdoc respectively. And Walter Robb, who received this alumni achievement award in 2001, headed the team at GE that developed their commercial product."

After completing his bachelor's degree in physics here at Illinois, Edelstein earned his master's and doctoral degrees in physics at Harvard University (1967, 1974). At Harvard, he completed his thesis under Professor Robert V. Pound, co-discoverer of nuclear magnetic resonance, for which the Nobel Prize was awarded in 1952.

Edelstein then travelled to Scotland, where he completed two three-year postdoctoral research fellowships, the first at Glasgow University, the second at Aberdeen University. At Aberdeen, he was part of the team that invented the first MRI machine to make good whole-body images. It was there he invented the "spin warp" imaging technique, still in use in all commercial MRI systems today.

From 1980 to 2001, Edelstein worked at the General Electric Corporate Research and Development Center near Schenectady, NY, as part of a team that developed and commercialized MRI for GE Medical Systems. His contributions there allowed GE to dominate the commercial MRI industry for many years. In 1991, he was named Coolidge Fellow, the highest corporate scientific honor bestowed by GE.

Edelstein's pioneering contributions to MRI technology are numerous, from pulse sequence optimization, to rf-coil and gradient-coil design, to circuitry improvements, high field imaging, acoustic noise reduction, and the NMR phased array. He was part of the team that produced the first high-field head image, and of the team that developed the famous "birdcage" coil, a mainstay of MRI technology for decades now, which made it possible to operate a stable, predictable high-frequency rf transmit/receive antenna large enough to enclose the human head and torso. And he contributed to the small-imaging-coil technology that made it possible to take detailed pictures of small body parts, such as the eyeball.

After retiring from GE, Edelstein founded MRScience LLC, through which he continued to work on MRI as an independent scientist and consultant. He also served as a visiting scientist at Rensselaer Polytechnic Institute in New York and a senior research associate at Case Western Reserve University in Cleveland.

Since 2007, Edelstein has held an appointment as visiting distinguished professor of radiology at The Johns Hopkins University School of Medicine, where he is exploring methods for dramatically shortening the duration of MRI scans and reducing high-level acoustic noise.

"The noise is brutally loud—often well over 100 decibels," explained Edelstein. "Right now, people have to wear ear defenders, which is a problem. It puts people off and in some cases could possibly pose a danger to their hearing. It's also a problem for functional MRI, where the scan is used to try to find activity in the brain, but the hearing part of the brain is already active. It's also a problem for functional MRI where a medical procedure is performed while imaging. And of course, the doctors have to wear ear protection too—it's really not good."

"Our goal is to bring the noise down to 70 decibels or less, to a conversational level.

"To apply this in a clinical setting, we would have to change various structural parts of the scanner, which would have to be done at an engineering company. Funding from a commercial source is an issue in moving forward, and I believe whichever company does this first will have a big marketing advantage."

The second problem Edelstein is working to solve is the duration of exams.

"We should limit ourselves to a 10-minute scan, with 5 minutes to get the person in and out of scanner. The reason the scans are so long is really a bit surprising. If a doctor orders a CT scan, the whole scan can be completed in a few minutes—that's counting everything, including injection of contrasts. But with MRI, there are so many different things we can do, so many different kinds of pulse sequences and image sequencing. Doctors will generally ask for several 4- to 5-minute scans that, with adjustments in between, may add up to 45 to 60 minutes. My thinking is that there is a lot of overlap in what's going on."

Edelstein said the answer to this problem isn't straightforward, but with advances in technology and clinical practices over the last decades, he believes a solution is on the horizon.

Edelstein has no immediate plans to retire and plans to continue his work on MRI as long as he is able to do it.

Edelstein has received numerous honors for his work in MRI, including the Gold Medal Prize from the International Society of Magnetic Resonance in Medicine (ISMRM) in 1990, Prize for Industrial Applications of Physics from the American Institute of Physics in 2005, and the University of Illinois College of Liberal Arts and Science's Alumni Achievement Award in 2008.

He is a Fellow of the American Physical Society, where he served on the executive board for the New York State Section from 1990 to 1998, and is a Fellow of the Institute of Physics (UK). He is also a Fellow of the ISMRM, where he is a charter member and served on the board of trustees from 1989 to 1992. He currently serves on the editorial board of *Magnetic Resonance Imaging* (since 1991), and *Magnetic Resonance Engineering* (since 2001).

The Alumni Achievement Award was established in 1957 to recognize alumni of the University of Illinois who have attained outstanding success and national or international distinction in their chosen business, profession, or life's work, and whose accomplishments reflect admirably on or bring honor to the institution. It is the highest honor conferred on Illinois alumni, awarded by the Illinois Alumni Association on behalf of the University.

Edelstein's portrait will be mounted in the Illini Union among those of other highly accomplished Illinois degree holders who have received this honor. ■

Physics Illinois alumna Shahzeen Attari on global climate change and human behavior

Most of us are aware that a smaller carbon footprint per US household would mean a healthier future for our planet. But where does that priority rank and what would motivate positive change?

Conserving energy use in our homes, recycling, selecting modes of transportation that generate lower emissions—the best practices we could (and should) set into place—it all takes time and effort to plan out, implement, and maintain.

Meanwhile, residential energy consumption accounts for more than 20 percent of total US carbon dioxide emissions, and the US is responsible for 21 percent of global carbon dioxide emissions.

Physics Illinois alumna Shahzeen Attari (BS 2004) examines how our shared perceptions about our consumption of energy relate to our behaviors. Her research seeks to to define why, with today's technology and understanding of the factors that lead to global climate change, we aren't collectively doing more to abate carbon dioxide emissions.

Attari is an assistant professor at Indiana University's School of Public and Environmental Affairs, in Bloomington. As a behavioral scientist, she asks what people think it's important to do and how hard they think it is to do it. Through surveys of residents across the US, Attari and her colleagues have researched how Americans would rank energy-conservation behaviors along those two lines.

"The list of behaviors came from Gardner and Stearns's short list of best changes homes can make for the greatest impact," Attari said.

Attari and her colleagues have discovered that most people slightly overestimate the amount of energy needed for low-energy uses and dramatically underestimate the amount of energy consumed in higher-energy uses.

"If you ask people how important it is to turn off the light when they leave the room, people would rank that behavior as very significant. Yet, turning out the lights is not considered an effective energy-saving behavior," Attari shared. "We should do it of course, because every bit counts, but if we are going to get people to do just one thing, we should go after one that's really effective.

"At the same time, people severely underestimate by orders of magnitude how much power large appliances use: dishwashers by factor of 800 times," she said.

What's more, their research reveals that many consumers erroneously believe the most effective changes they could make to reduce energy consumption would be the more expensive, time-consuming, or inconvenient alternatives—like replacing windows in homes, trading in older appliances for more energy-efficient models, hanging the clothes to dry on a line, or carpooling to work. But in fact, lowering the thermostat by a few degrees in the winter months is as effective as swapping out the windows, washing our clothes at a lower temperature is as effective as replacing our washer with a high-efficiency model or hanging out the clothes for several months, and having two tune-ups annually is as effective as carpooling.

Why do these misperceptions persist? Attari says too much information is a problem.

"Attention is our most scarce resource individually," she stated. "To model how people address problems like climate change, we apply the concept of bounded rationality: individuals are limited in the choices they make, not only by knowledge, but also by the amount of attention and time we have to focus. We keep searching for solutions that immediately satisfy, but don't optimize."

Changing people's biases about best energy-conservation and -efficiency practices will be challenging. Attari asserts that, given how busy American families generally are, an effective campaign for residential energy conservation would give due consideration to people's perceptions and misperceptions regarding their energy consumption.

So how does a physics major end up an environmental behaviorist? Attari said her physics background is actually a great advantage in the work she is doing now.

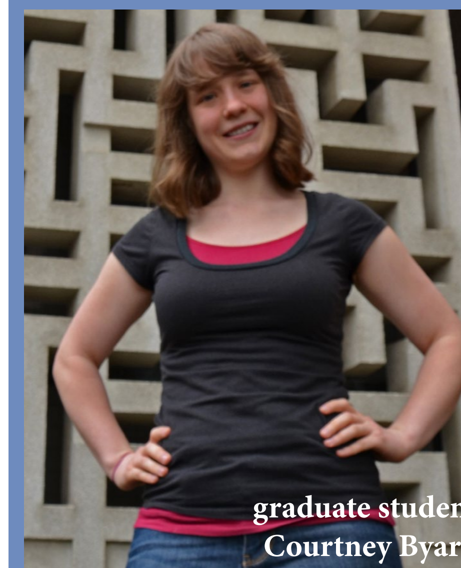
"A lot of behavioral scientists have a physics background," noted Attari. "Physics gives an understanding of risk and uncertainty. It teaches discipline and perseverance on a problem. And interdisciplinary training develops skills that allow you to see problems in a unique way."

Born in India, Attari grew up in Dubai in the United Arab Emirates—a city, she points out, which has the largest ecological footprint per capita in the world. She came to Illinois to study physics and discovered a great passion for studying the environment. The seeds for her eventual career were planted while a student at Illinois, when Attari spent one of her spring breaks in Florida volunteering for the Nature Conservancy, working on issues related to forest fires.

Attari said she remembers many formative experiences from her time at Physics Illinois, working with Professor Steven Errede on solar-cell efficiency at different temperatures, with Mike Weissman on statistics, uncertainty, and noise, and with the late Professor Bob Clegg on biological physics for her senior thesis.

After completing her undergraduate studies at Illinois, Attari went on to earn a doctoral degree in civil and environmental engineering and engineering public policy from Carnegie Mellon University in 2009. She then worked as a postdoctoral fellow at Columbia University's Earth Institute & Center for Research on Environmental Decisions before her current appointment at IU. ■

Physics Illinois students Byard and Brandt win NSF Graduate Research Fellowships



graduate student Courtney Byard

alumna Stephanie Brandt

Recent Physics Illinois graduate Stephanie Brandt (BS 2012) and graduate student Courtney Byard were each selected for a three-year National Science Foundation (NSF) Graduate Research Fellowship.

Byard is working in Professor Paul Kwiat's research group to improve the precision of weak-value measurements.

"Courtney Byard is bright young physicist, working to extend previous quantum-enhanced measurement schemes to achieve an unprecedented improvement in measurement sensitivity," commented Kwiat. "At the moment her system rivals the best in the world—she can detect the tilt angle of a beam of light to the level of a hair's width on the other side of the country! And there's still another potential factor of 10–20 to be gained. If the techniques can be generalized to other types of measurements, which we believe they can, then this may have benefit in a wide class of applications."

Byard is grateful for the freedom the research grant will afford her, both in her work and in community outreach efforts.

"Receiving the NSF fellowship will allow me to be fully involved in my research while having the chance to reach out to non-scientists without having to worry about funding," she said

"I'm excited to be able to work on my PhD here at Illinois," added Byard. "The mix of excellent science and warm community that I've found here makes it the perfect place to think, work, and live. And I'm grateful to all the teachers I've had the opportunity to work with who've helped me reach my goals."

Brandt will begin graduate studies in particle physics at the Massachusetts Institute of Technology (MIT) in Cambridge starting in the fall. Ultimately, she plans to pursue a career in physics at a university or national laboratory.

Brandt said she values the skills she learned through her research experiences at Illinois.

"Working in a lab group provides a different learning experience from regular schoolwork, where somebody has already figured out the answer and is giving it to you. I picked up some valuable computing skills through my lab work. I also really liked how the senior thesis class works here. In addition to research, you write about and present your work—these are important capabilities to have going forward."

Brandt worked in Professor Kevin Pitts's research group during her undergraduate tenure, starting her freshman year. Her work involved searching for a currently unobserved decay mode of the heaviest meson, the B_c particle.

"Stephanie spent much of her time analyzing data from the CDF experiment at Fermilab," commented Pitts. "She performed a search for a very unique signature of an extremely rare configuration of quarks. Although we didn't see a signal, the tools Stephanie developed are continuing to aid in our research."

Brandt has made arrangements to work at MIT with active members of the CMS experiment at the Large Hadron Collider at CERN. And she is looking forward to her first experience living outside central Illinois.

"Stephanie is great to work with and has been an important member of our team," added Pitts. "She will do extremely well in graduate school at MIT, and I am quite sure that we'll be hearing more from Stephanie in the future."

For several years, Brandt was also a regular Physics Van performer, travelling to elementary schools and special events to introduce children to the study of physics through exciting, visually compelling demonstrations.

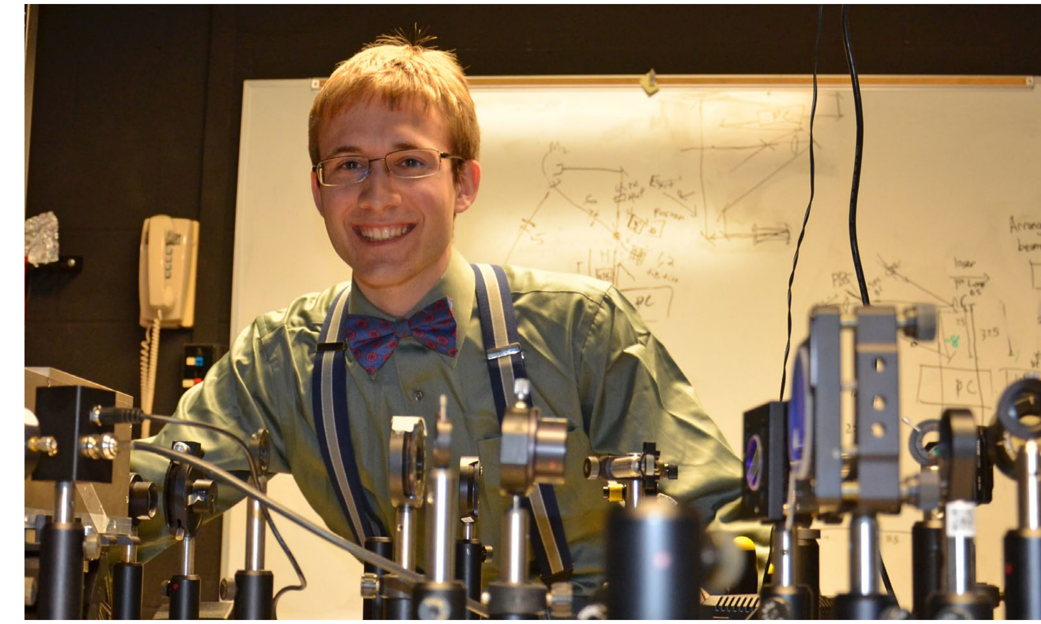
Brandt said she is honored to be selected for the NSF fellowship and she plans to take full advantage of the additional freedom the funding will allow her to continue her educational outreach efforts while a graduate student.

Three Physics Illinois alumni who are now pursuing graduate studies at other institutions also received NSF fellowships: Callie Demay (BS 2009) studies mechanical engineering at the University of Colorado at Boulder; Nikhita Mansukhani, (BS 2011) is a graduate student at Northwestern University in the materials research—biomaterials program; Vernie Redmon (BS 2011) is studying condensed matter physics at Stanford University.

Three from Physics Illinois received honorable mentions: alumnus Matthew Feickert (BS 2012) is a graduate student at the University of Virginia; Kevin Sebesta graduated in May 2013 in engineering physics with plans to continue his physics studies in the doctoral program at the University of Minnesota, specializing in astrophysics; John Henry Hinnefeld is a graduate student working in condensed matter physics as part of Professor Nadya Mason's group.

The National Science Foundation's Graduate Research Fellowship Program helps ensure the vitality of the human resource base of science and engineering in the United States and reinforces its diversity. The program recognizes and supports outstanding graduate students in NSF-supported science, technology, engineering, and mathematics disciplines who are pursuing research-based master's and doctoral degrees at accredited US institutions. ■

Stephanie Brandt performs with fellow Physics Van players during Engineering Open House 2013



David Schmid receives Goldwater scholarship

Physics Illinois junior David Schmid has been awarded a prestigious Barry M. Goldwater Scholarship for the 2013/14 academic year for demonstrating leadership and academic promise in science or engineering. Schmid has been working in the laboratory of Professor Paul Kwiat since Summer 2010, before his freshman year. There he has studied optical simulation, polarization-dependent focusing, and spectral filtering.

In his research, Schmid uses computer modeling and simulations to design optical setups that address current problems in quantum information, cryptography, and computation. Schmid's research has helped to expand various optical techniques used in research. His work shows promise in practical applications as well, including in the use of dual-focus beams for imaging or controlling tiny objects and spectral filtering for optical fiber communication networks.

Schmid has been recognized many times for academic achievement. At Illinois, he participates in the Campus Honors Program and is a National Merit and Illinois State Scholar, is on the Dean's List, and is a winner of a Provost Scholarship for academic achievement. He is also the recipient of the Vincent O'Brien Iroquois County Scholarship. Schmid has presented his research at the national Conference on Lasers and Electro-Optics. He is the primary author of a paper submitted to a peer-reviewed journal in optical physics.

Schmid hopes to earn a doctorate in physics and then pursue an academic career: "Ultimately, I hope to do research on the boundaries between quantum and classical physics," said Schmid, "and I am looking forward to teaching university students. I value great teachers immensely, and I hope eventually I will be the one inspiring others."

Schmid's passion for the study of physics is intrinsic to who he is.

"I love physics because I think that the universe is far more grand than any human could imagine," explained Schmid. "Only through physics can we begin to see its beauty. Despite the complexity we see all around us, physics gives universal laws that govern everything that can possibly exist.

"The best thing about physics is that in all this complexity, there are never paradoxes. There are no mistakes, no inconsistencies, in nature—only in our attempts to understand it. And we're working on that."

Schmid said he is very thankful for the opportunities this scholarship will afford him and thankful to everyone who makes such scholarships possible. And he recognizes that many have had a hand in his achievements as a physics major at Illinois.

"I owe a great deal to many of my friends and colleagues. My sister Mara has given me courage, support, and a broader perspective on life, for which I am ever grateful. A special thanks to Professor Paul Kwiat for giving me a chance to do research even before I knew anything useful! His support and wisdom have been invaluable, and I've loved researching and learning with his group."

The Barry M. Goldwater Excellence in Education Program was established by Congress in 1986 to honor Barry M. Goldwater, who served 30 years in the US Senate. The program provides a continuing source of highly qualified scientists, mathematicians, and engineers by awarding scholarships to sophomores and juniors from the United States who intend to pursue doctorates in these fields. ■

Physics Illinois commends its exceptional undergraduates


James Antonaglia


Isaac Carrasquillo


Matthew Coon


Anna Czerepak


Rebecca Glaudell

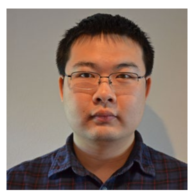

Shannon Glavin

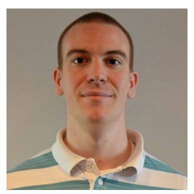

Donald Hane


Jeliazko Jeliazkov

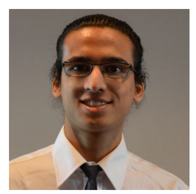

Novarah Kazmi


Michelle Kelley


Guannan Liu


Scott Luedtke


Sean McLaughlin

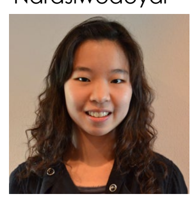

Sanjay Narasiwodeyar


Natasha Sachdeva


David Schmid


Meredith Staub


Ryan Swindeman


Mae Hwee Teo


Brian Trundy

Not pictured: Cory Alford, Ran Bi, Stephanie Brandt, George Jabbour, Daniel Kumor, Xin Liu, Stephanie Lona, Jack Meister, Anna Miller, Kevin Sebesta, and Matthew Wraith

University Honors Bronze Tablet: The names of the top performing students from each graduating class (highest 3 percent from each college) are inscribed on this tablet mounted in the Main Library. From the class of 2013, ***James Antonaglia, Ran Bi,*** and ***Mae Hwee Teo***.

Phi Beta Kappa, Gamma of Illinois Chapter 2012/2013 inductees were ***James Antonaglia*** and ***Guannan Liu***.

James Scholar Honors went to ***Ran Bi, John Hoffman, Guannan Liu,*** and ***Mae Hwee Teo.***

Engineering Excellence Scholarship went to ***Jack Meister.***

Illinois Engineering Enhanced Scholarship went to ***Isaac Carrasquillo.***

Vincent E. O'Brien Iroquois County Scholarship went to ***David Schmid.***

Bauer Michelson Pizzo Russell Scholarship went to ***George Jabbour.***

American Physical Society Minority Scholarship went to ***Stephanie Lona.***

The 2013 **Yee Seung Ng Award**, established by family and friends of alumnus Yee Ng (BS 1974) to recognize an outstanding junior or senior international engineering physics student, went to ***Guannan Liu***.

The **People's Choice Undergraduate Research Symposium Award** is given in recognition of original research presented at the Physics Undergraduate Research Symposium. The 2013 recipients were (bronze) ***Anna Czerepak,*** (silver) ***James Antonaglia***, and (gold) ***Ryan Swindeman.***

The 2013 **Robert E. Hetrick Senior Thesis Award**, presented in recognition of an outstanding senior thesis written by an undergraduate physics major, went to ***Cory Michael Alford*** and ***Natasha Sachdeva***.

The **Robert A. Stein Scholarship** was endowed by the family and friends of alumnus Robert A. Stein (BS 1955) after his death in 1998. Stein greatly valued the education he received at Illinois, and his family thought the best tribute to his memory would be to provide that opportunity to other youths. The 2013 recipients were ***Matthew Coon, Daniel Kumor,*** and ***Sanjay Narasiwodeyar.***

The **Excellence in Physics Scholarship** is awarded to support outstanding incoming freshman physics majors. If students remain in good standing, the awards are renewed each semester. The 2013 recipients were ***Isaac Carrasquillo*** and ***Novarah Kazmi.***

The **Undergraduate Outreach Achievement Award** recognizes the work of an outstanding undergraduate student involved in the Physics Society and/or with the Physics Van. The 2013 recipient was ***Scott Luedtke***.

The **Commonwealth Edison Scholarship/Beryl Bristow Endowed Scholarship** is presented in recognition of an outstanding woman physics major (freshman or sophomore). This award is named for Beryl Love Bristow, the first woman to receive both a bachelor's degree (1918) and a master's degree (1919) in physics from Illinois. At that time, Illinois had only 5,000 students and 12 buildings, and tuition cost $11 per semester. Beryl was inspired by her own mother, who graduated in 1883 from Illinois with a major in mathematics, the first woman ever allowed to take a math course at Urbana. After graduation, Beryl was employed by the Commonwealth Edison Company in Chicago as a mathematician in the science department. To honor her pioneering spirit, Commonwealth Edison created this award to recognize women in physics. The 2013 recipients were ***Anna Miller, Meredith Staub,*** and ***Xin Liu.***

The **Lewis C. Hack Scholar** award is made possible by a bequest to the University of Illinois to honor Lewis C. Hack, by his wife, Lois E. Hack. Both the Hacks devoted their lives to teaching in the public schools. The 2013 recipients were ***David Schmid, Matthew Wraith*** and ***Jeliazko Jeliazkov.***

The **Richard Cook Scholarship** is presented in recognition of an outstanding undergraduate engineering physics student at the end of his or her sophomore year. This award is named for alumnus Richard Cook (PhD 1935), who spent his entire carreer at the National Bureau of Standards (now the National Instititute of Standards and Technology). Cook specialized in ultrasonics and acoustics. The 2013 recipients were ***Donald Hane, Sean McLaughlin,*** and ***Brian Trundy.***

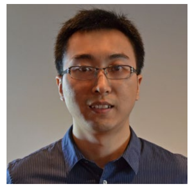
The **Laura Eisenstein Award** is presented in recognition of an outstanding woman undergraduate student in physics. This award was established by the department in cooperation with the American Physical Society and the Committee on the Status of Women in Physics to recognize exceptional woman physics students. It honors the late Laura B. Eisenstein (1942–1985), a distinguished biological physicist who made important discoveries of the mechanism of light energy transduction by biomolecules, using a variety of techniques including time-resolved resonance Raman and x-ray absorption spectroscopies. Eisenstein served the department and the biological physics community with distinction. The 2013 recipients were ***Shannon Glavin, Mae Hwee Teo,*** and ***Michelle Kelley.***

The **Ernest Lyman Prize** is presented in recognition of the year's outstanding senior in physics. This award is named after Professor Ernest M. Lyman, a distinguished researcher and teacher who served on the department's faculty for 36 years. In addition to making seminal contributions to experimental nulear physics, he was a world expert on electron scattering. Lyman maintained great interest in teaching undergraduate physics and was one of the early proponents of computer-assisted physics education. The 2013 recipients were ***James Antonaglia, Ryan Swindeman,*** and ***Rebecca Glaudell.***

And applauds our extraordinary grad students, too


John Damasco


Sylvester Joosten


Zuanyi Li

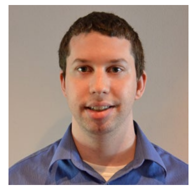

Yulia Maximenko


John Nichol


Seongjin Park


Onkar Parrikar


Garrett Vanacore


Scott Wolin

Not pictured: Courtney Byard, Xiaoqian Chen, John Henry Hinnefeld, Martin Leitgab, Ki Lie, and Philip Powell

Recipients of the 2013 **National Science Foundation Graduate Research Fellowship** were ***Stephanie Brandt*** and ***Courtney Byard.*** The 2013 Honorable Mention went to ***Kevin Sebesta,*** and ***John Henry Hinnefeld.***

The **Yee Memorial Fellowship**, named for Illinois alumnus Warren Yee, (PhD, Civil Engineering, 1943), is presented annually to recognize outstanding research achievements by a Chinese graduate student in the College of Engineering. The 2013 recipient was ***Zuanyi Li.***

The **Renato Bobone Award** is presented to an outstanding European graduate student in physics. This award is named for Dr. Renato Bobone, a PhD alumnus of Physics Illinois, who spent his entire career (1960–1987) at General Electric in Schenectady, NY, at the Knolls Atomic Power Laboratory, working on several aspects of naval reactor design. In 1985, when he endowed the award, Dr. Bobone wrote: "Interest in physics and the education I have been privileged to receive in Italy first, then in this country, have carried me over many obstacles and will be with me forever. Having thoroughly abosorbed both the Italian and the American cultures, and feeling I belong to both, I look on the award as another bridge between countries already joined by many ties of people, culture, and friendship." The 2013 recipient was ***Sylvester Joosten.***

The **Felix T. Adler Fellowship** is presented in recognition of outstanding work by a graduate student in nuclear physics. This award is named for Professor Felix T. Adler, a theoretical nuclear physicist who served the department from 1958 to 1979. His work spanned the development of nuclear energy—reactor control theory, reactor kinetics and stability, neutron transport theory, chemical physics, operational calculus in electrodynamics, accelerator physics, and theoretical plasma physics. He was an exceptional teacher, noted for his infectious enthusiasm for physics and his painstaking patience with students. The 2013 recipient was ***Scott Wolin.***

The **Giulio Ascoli Award** is presented in recognition of an outstanding physics graduate student in high energy physics. This award is named for Professor Giulio Ascoli, who served the department with distinction from 1950 until his retirement in 1986. During his career in high energy physics, Ascoli participated in experiments at CERN, Argonne National Laboratory, and Fermi National Accelerator Laboratory. He was versatile and painstaking, both in the design and fabrication of hardware and in the development of algorithms for data analysis. His peers described his contributions as "innovative, elegant, and thorough." The 2013 recipient was ***Ki Lie***.

The **John Bardeen Award** is presented in recognition of an outstanding physics graduate student in condensed matter physics or electronic devices. This award is named for Professor John Bardeen, the two-time Nobel laureate who was a professor of physics and of electrical engineering from 1951 to 1991. During his 60-year scientific career, he made significant contributions to almost every aspect of condensed matter physics, from his early work on the electronic behavior of metals, the surface properties of semiconductors, and the theory of diffusion of atoms in crystals to his later work on quasi-one-dimensional metals. He won his first Nobel Prize in 1956 for his work leading to the invention of the transistor. He won his second Nobel Prize in 1972 for the theory of superconductivity. He was named by Life Magazine as one of the 100 most influential people of the 20th century. The 2013 recipient was ***John Nichol.***

The **Scott Anderson Award for Outstanding Teaching Assistants** is presented in recognition of the year's outstanding graduate assistants. The award is named for alumnus Scott Anderson (MS 1937, PhD 1940) who founded Anderson Physics Laboratories (APL) in Urbana in 1944. Dr. Anderson, a creative and prolific entrepreneur, developed metal halide lighting systems. Until his death in 2006, Anderson remained an active consultant to APL and was a tireless supporter of Physics Illinois. It was through his initiative as president of our Physics Alumni Association and his general philanthropy that the Anderson Award was endowed. The 2013 recipients were ***John Jeff Damasco, Onkar Parrikar, Yulia Maximenko,*** and ***Garrett Vanacore.***

The **Drickamer Research Award** is presented in recognition of outstanding research by a physics graduate student. This award is named for Professor Harry G. Drickamer, a distinguished member of the University who contributed extensively to the understanding of the physics and chemistry of matter at high pressure. Drickamer's work led to advances in the understanding of the molecular, atomic, and electronic properties of matter and provided the tools to study these properties with greater detail and precision. He was the first to use infrared and uv-vis spectroscopy to study matter at high pressure, thereby discovering that high pressure perturbs different types of electronic orbitals to different degrees. He discovered a wide variety of electronic transitions in solids and molecules and the optical, electrical, chemical, and magnetic consequences thereof. A prolific and influential scientist, he published more than 450 original contributions to the scientific literature. The 2013 recipient was ***Xiaoqian Chen***.

The **L.S. Edelheit Biological Physics Fellowship** is made possible by the generous gift of alumnus Lewis S. "Lonnie" Edleheit (BS 1964, MS 1966, PhD 1970) and his wife, Susan (BFA 1966, MA Art Education 1968). In a professional career that spanned 33 years—all but 6 in various capacities with the General Electric Company—Edelheit championed the field of medical imaging. He served as the first project manager for a computed tomography (CT) scanner and went on to oversee GE's emergence in the medical electronics enterprises. Edelheit credits his three Illinois degrees with providing him important knowledge in the broad nature of physics and the ability to think about complex systems—electrical, mechanical, computer, and mathematics. The 2013 recipient was ***Seongjin Park***.

The **Vijay Pandharipande Prize** in Nuclear Physics is presented in recognition of the year's outstanding nuclear physics graduate student. The award is named for Vijay Pandharipande (1940–2006), an internationally recognized nuclear theorist who played a leading role in the development of the nuclear many-body problem. Professor Pandharipande served with great distinction on the department's faculty for 34 years. The 2013 recipient was ***Phillip Powell***.

Department of Physics
University of Illinois at Urbana-Champaign
Loomis Laboratory of Physics
1110 W. Green Street
Urbana, IL 61801-3080

NON-PROFIT ORG
U.S. POSTAGE
PAID
PERMIT NO. 453
CHAMPAIGN, IL

Physics Illinois
not a place, a habit of mind . . .