

The Sky's the Limit

The heavens are officially open in the Nielsen Physics Building, the result of years of dreaming, months of construction, and support from the university's College of Arts and Sciences.

On May 2, the University of Tennessee Earth and Space Sciences Theater opened its doors to demonstrate the university's newest programs for astronomy outreach and teaching. With support from the college, as well as the physics and the earth and planetary sciences (EPS) departments, the 20-foot dome inside the physics building will give visitors a chance to see any part of the universe, at any point in history or even into the future.

Paul Lewis, who directs space science outreach for the physics department, walked 40 or so open house guests through some of theater's features, including a view of Jupiter much the way Galileo would have seen it in 1610. With clicks of a remote, he made stars appear and fade, then grabbed the belt stars of

Orion to use as pointers to introduce the star Aldebaran in Taurus. From there it was on to the seven sisters (also known as the Pleiades) and an open cluster of hot young stars, before reversing direction and racing back over the brightest star in the heavens, Sirius. Lewis then illuminated the lines of the asterisms to connect the dots, making recognizable patterns to help viewers find constellations dating from the ancients.

"This is a time machine that we're standing in," he said. "We can set the sky to any time of day or night, into the past or into the future to see how the heavens change over

time. We can have the sun rise or set or show it eclipsed by the moon to simulate real time sky situations.

"I have always thought of the telescope as the ultimate time machine," he continued. "Every time we look at a distant object we are looking at light that left the object and has traveled a long time to get to our eyepiece. With the planetarium we move forward in time as well to preview upcoming events. The planetarium is a powerful and very flexible teaching tool."

"Time travel" is just the tip of the iceberg.

"The theater gives us a way to teach planet, comet and asteroid hunters how to use coordinates as an easy way to find and track their targets," Lewis explained. "Our students can download and run on their own computers the same software that runs our planetarium in order to learn deep sky objects, star names and constellations. They can also learn to locate deep sky objects that they will have an opportunity to image with telescopes and CCD imaging equipment when on the roof for their telescope labs."



Visitors to the UT Earth and Space Sciences Theater got an up-close view of the heavens at the May 2 open house. The planetarium will become a major part of astronomy education and outreach programs. (Photo credit: James E. Parks)

Lewis next launched a video (one of the first in what will be an ever-expanding library) entitled "Two Small Pieces of Glass: the Amazing Telescope," walking viewers through history from the work of Copernicus to Hubble. He has already conducted extra credit astronomy sessions in the planetarium and starting this fall, all astronomy labs will be taught in the facility. The outreach capabilities will complement the telescopes, CCD cameras, and computers on the roof of the physics building, where the department spon-

[Continued on Page 3](#)

Message from the Department Head

by Hanno Weitering



Dr. Hanno Weitering
Professor and Head

The 2012-2013 academic year has come to a close and it has been a good one for the department. First and foremost, the graduation rate of physics bachelors increased again and this spring we have witnessed a record number of graduating seniors: 20 in all. In addition, The department won seven honors at the chancellor's honors banquet, while three

professors have been promoted and three new hires were made. Norman Mannella, assistant professor in experimental condensed matter physics, will be promoted to associate professor with tenure starting AY2014. Associate Professors Stefan Spanier (experimental high energy physics) and Thomas Papenbrock (Nuclear Theory) will be promoted to full professors. We are all very proud to have these outstanding scientists on the faculty.

The department successfully recruited two junior faculty in the spring. Dr. Nadia Fomin will join the department on August 1. She is an experimental nuclear physicist and will be heavily involved with the Spallation Neutron Source at Oak Ridge National Laboratory, and with Jefferson Lab. She will also build an on-campus lab in the nuclear physics wing of the Science and Engineering Research Facility. Nadia received her Ph.D. at the University of Virginia in 2007 and is currently a postdoc with Scott Wilburn at Los Alamos National Laboratory while stationed at the SNS. Dr. Steve Johnston will join the department on January 1, 2014. Steve is a theoretical condensed matter physicist. He graduated from the University of Waterloo in 2010 with Thomas Devereaux and is currently a postdoc with Mona Berciu and George Sawatzky at the University of British Columbia in Vancouver. Kudos to faculty members Elbio Dagotto and Kate Jones, who both ran highly professional searches. Our faculty is growing again. We are getting younger and more diverse, and hopefully this trend will continue in the years to come.

Late last fall, we also welcomed Dr. Tony Mezzacappa as a new professor in theoretical and computational astrophysics. Tony also serves as the new director of the UT-ORNL Joint Institute for Computational Sciences and took the lead in putting together the renewal proposal of the Kraken Supercomputer. This has been a heroic undertaking of immense significance to UT faculty and students. The proposal has been submitted to NSF, so let's keep our fingers crossed. Last but not least, we welcome Joshua Bell who is a new craft specialist in the machine shop. He replaces Frank Spencer, who retired this spring after 34 years of service. Many other good things have happened and you can find frequent updates on our departmental Web site at www.phys.utk.edu and elsewhere in this newsletter.

Last fall, I asked the graduate and undergraduate majors and non-majors curriculum committees to prepare for an extensive review of our course curriculum and to identify ways to improve the quality and attractiveness of the physics curriculum. Norman Mannella, Kate Jones, and Jon Levin enthusiastically agreed to chair the respective committees. Although the current curriculum is very solid, we cannot be complacent in the rapidly-changing world of higher education. In particular, the curriculum can be modernized and made more attractive, especially to students with physics interests who intend to move on to non-physics careers. We need to convince those students of the benefits of a physics degree and retain them for our program. There are of course limitations as to what can be done with our current instructional capacity and limited possibility of adding extra requirements or credit hours. Nonetheless, creative ideas are beginning to emerge and faculty and students are invited to engage in this process.

Incidentally, soon after the committee started brainstorming on the issue, the university instructed all departments to formulate learning objectives for each graduate and undergraduate degree program, develop assessment criteria and methods to determine if these objectives are met, and to evaluate and close the cycle by implementing informed curricular changes, if necessary.

Establishing such a culture of assessment is becoming increasingly important in higher education and is thoroughly evaluated by college accreditation boards. UTK will apply for reaccreditation with the Southern Association of Colleges and Schools in AY 2014-2015 and departments are asked to complete several assessment cycles before AY 2014. The significance of this culture change goes of course beyond reaccreditation. Any aspiring top university should continually improve its course offerings and teaching effectiveness and the best way to do this is to implement informed changes based on assessment outcomes.

The very first question to be asked in all of this is: “what do we want our physics students to know?” What knowledge and skills are necessary for them to succeed in the workplace? Even among the physics faculty, you will hear many different opinions and these could and probably should change over time. This process thus promises to be highly educational to the educators themselves. One aspect most of us seem to agree on right now is to include a research experience or internship in the core curriculum. Another is the need to offer more specialized courses, both at the graduate and undergraduate level. Hopefully as the faculty

continues to grow, we will be able to offer more of those. These courses could entail in-depth studies within one sub discipline of physics. Alternatively, they could be used to bring the latest scientific developments into the classroom. This academic year we will begin offering two interdisciplinary special topics courses: “An Introduction to Quantum Computation and Quantum Information,” a graduate level course taught by Professor George Siopsis this fall, and Nano-BioPhysics, taught by Assistant Professor Jaan Mannik next spring. The latter course will be accessible to both graduates and undergraduates. Only very few faculty have been exposed to these very modern topics. These courses will be listed under PHYS 642, Advanced Topics in Modern Physics. While it is too early to tell whether these novel topics will eventually make it into the physics curriculum, special topics courses do allow us to experiment with the curriculum and appeal to a broader range of students. With a good functioning assessment program in place, curriculum development becomes an “experimental science,” leading toward a continued improvement of the college experience.



The Sky's the Limit, Continued from Page 1

sors public viewing sessions on the first and third Fridays of each month. Interestingly, Lewis and the late Professor Emeritus Kermit Duckett* used to stand on the roof and look down to the second floor, thinking it would be a good spot for a planetarium.

“This has been a long time coming, and the reality is that the planetarium is not very far from where we envisioned it 25 years ago” Lewis said, explaining that Duckett began gathering materials for a planetarium in the 1970s. The 32-seat theater took years of planning, generous funding from the college, and months of construction to become a reality. In the time since, the digital world has opened an entirely new realm of possibilities the department can now make available.

Hanno Weitering, Professor and Head of the physics department, acknowledged the contributions of the college in funding the project, as well as the people involved in

making it a reality: Lewis, Dr. Larry Taylor of EPS, Dr. Jim Parks and Dr. Soren Sorensen of the physics department, as well as physics staff members Rick Huffstetler and Brad Gardner, who helped install the dome and the associated electronics.

“It’s really a great moment that we finally have a planetarium,” Weitering said.

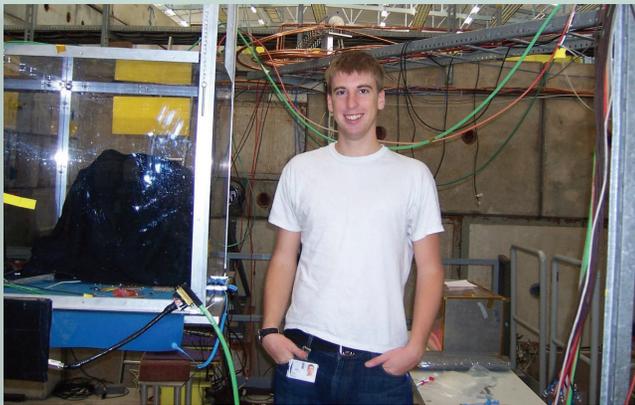
Lewis is currently developing a planetarium schedule for public and outreach opportunities. In the interim, those interested in learning more about UT’s astronomy outreach can get details via the Web at: www.phys.utk.edu/trdc/. 

**Dr. Duckett passed away on June 19. Read more about his life on page 13.*

It's a Higgs!

UT's Physicists Contribute to Key Particle Research

In July 2012, scientists working at the Large Hadron Collider (LHC) at CERN announced that at long last, they had coaxed what appeared to be the Higgs boson out of hiding. In March of this year, they revealed even more conclusive results about the particle's identity. UT's physicists have made valuable contributions to these efforts and continue to do so, as the hunt is actually far from over.



UT graduate student Grant Riley in a laboratory area at CERN in Geneva, where a prototype detector made of artificial diamonds is tested with beams of high energetic particles.

The Higgs has been viewed as the missing piece to complete the Standard Model of Physics, which incorporates all the subatomic particles and forces in the universe and the interactions between them. While the model assumes that all elementary particles start out massless, most particles observed in detectors clearly have mass (the photon is one exception). In 1964 physicist Peter Higgs and others proposed that all particles are subjected to some sort of omnipresent force that generates their mass and completes this theory. The particle associated with this force is the Higgs boson. Last summer, researchers with the ATLAS and Compact Muon Solenoid (CMS) experiments at the LHC (located in Geneva, Switzerland) announced the discovery of a new particle thought to be the Higgs. Since then, scientists have analyzed two and half times more data than was available last July. In mid-March, they announced the latest findings from protons collided at a somewhat higher energy, which now show an even more significant signal.

Determining whether this signal is the Higgs boson depends both on how it falls apart into other particles and its quantum properties. The main observation of the Higgs was in its decay into two photons and two Z particles, and the observed rates are close to Standard Model predictions. To work as predicted, the Higgs should show no preference in the direction it interacts with other particles. This can be measured from angular distributions of the decay into two Z particles. In February, the CMS experiment published a study in *Physical Review Letters* that showed the observed Higgs candidate particle is consistent with this requirement. Among the paper's authors were UT Physics Associate Professor Stefan Spanier, Postdoc Zongchang Yang, and physics graduate students Giordano Cerizza (now a postdoc), Matthew Hollingsworth, and Andrew York.

So is it THE Higgs particle? First of all, the detection of the boson is very rare; it takes around 1 trillion (10^{12}) proton-proton collisions for each observed event. Characterization of all the decay modes will require much more data from the LHC. The even more exciting perspective is that discrepancies with detailed predictions show up. After all, the Standard Model doesn't yet incorporate the physics of dark energy or the full theory of gravitation as described by general relativity. Even the mass of the Higgs particle, though well-constrained by the Standard Model, appears a bit like an accident unless there are other force particles involved that still need to be discovered. If present, they will at some level modify the appearance of the Higgs. This includes the possibility that there are other Higgs particles, which means the hunt is far from over.

In 2006, UT's High Energy Physics group became involved with the Higgs hunt as collaborators on the CMS detector. They've made substantial contributions to the particle tracking detectors needed to study the decay properties, particularly the angular distributions of the Higgs boson.

For future applications at much higher beam intensities, the group studies pixelated artificial diamond detectors in the laboratory and particle beams. The detectors will measure particle trajectories in the ongoing hunt for rare signals. Particle rate measurements in the CMS depend on knowing the overall production rate in proton-proton collisions. To this end, the UT group is working with Rutgers, Vanderbilt, CERN, and Princeton researchers to implement a new instrument based on diamond pixel detectors deep inside the CMS detector. Prototypes are tested in test beams and the installation is scheduled for next year. [CS](#)

Many thanks to Dr. Stefan Spanier for these insights.

Physics and bacteria may not seem the most likely match, but Assistant Professor Jaan Mannik uses one to study the other, and his efforts have resulted in **the department's second CAREER award from the National Science Foundation in two years.**

Mannik's research combines physics, biology, and nanotechnology to understand how bacteria (specifically *E. coli*) are organized at the cellular level and how robust this organization is relative to perturbations. What molecular mechanisms maintain cellular organization in bacteria against perturbations of bacterial shapes? To what extent can scientists perturb the cellular organization without affecting an organism's viability? To what degree do basic cellular processes, such as cell division and chromosome replication, depend on cell shape?

The NSF funded Mannik's proposal—"Understanding robustness of cellular organization in *Escherichia coli* through nanofabricated environments"—to answer fundamental questions such as these. The award comes through the prestigious Faculty Early Career Development (CAREER) Program, whose goal is to encourage junior

Mannik uses fluorescence microscopy to image the bacterial cells and what's going on inside them and then builds on this experimental work with quantitative analysis. These studies bring with them a number of possible applications. Locating vulnerabilities in cell organization, for example, could help define new targets for antibiotics. Other labs involved with live cell imaging of bacteria or yeast cells could benefit from the development of micro- and nano-engineered chips that will be carried out during this project.

"What I want to do is very physics-related," Mannik explained. "(It's) answering biological questions using physics methods and concepts. Indeed biological systems organize themselves according to the laws of physics but how this happens is yet poorly understood."

The CAREER Award will advance this work, primarily by supporting the addition of new graduate students. Mannik's research group includes physics graduate student Matthew Bailey, undergraduates Clayton Greer (mechanical engineering), Laura Mumley (chemical engineering), William Deadrick (microbiology), Iya Stoyer (premed) and Oak Ridge High School student Liam Schramm. He would like to add more graduate students from physics

The Physics of Living Systems

faculty who have demonstrated exceptional research, teaching, and the ability to integrate the two. Mannik's grant is renewable over five years and brings with it a total of \$635,000 in support.

To see just how robust a bacteria's cellular structure is, Mannik develops a kind of obstacle course for *E. coli*: nanoscale mazes that challenge these tiny organisms to show how they handle the unexpected. He starts with a silicon wafer. On top of that is a polymer layer that's sensitive to light or electron beams. Using computer-generated designs, he etches the silicon with channels for the bacteria to navigate—some more narrow than the organisms themselves and some much larger. The wafer is then separated into individual chips about the size of a penny, each one a sort of nano-laboratory where Mannik controls various physical and chemical stimuli to coax bacteria into revealing their properties. These micro- and nano-engineering methods create an environment where he and his students observe how bacteria assume different shapes as they negotiate the channels in which they're placed. Of keen interest is how those adaptations effect the way chromosomes are organized, as accurate chromosome positioning is critical in cell division if the daughter cells are to inherit the complete genetic code from the parent cell.



Jaan Mannik's research lies at the intersection of physics, biology, and nanotechnology. With a CAREER grant from the National Science Foundation, he'll study how bacteria are organized at the cellular level. Pictured with Mannik (center) are students (L-R) Laura Mumley, Will Deadrick, Matthew Bailey, and Clayton Greer.

to these interdisciplinary endeavors, which he pursues in his campus lab in the Science and Engineering Research Facility. Motivating students to go into science is a primary goal of the CAREER program, and Mannik's proposal includes integrating his research into the undergraduate curriculum and supervising VolsTeach students (undergraduates in science, math, and engineering majors who will also be certified teachers). He is also providing summer internships to minority students in the Tennessee Louis Stokes Alliance for Minority Participation program.

Mannik, who earned a Ph.D. in physics at SUNY Stony Brook, joined the UT Physics Department as an assistant professor in September 2011. His CAREER Award is the second for the department in two years: in 2012 Dr. Norman Mannella won a CAREER grant for his work in condensed matter physics. [CS](#)

Paying it Forward



Dr. Eric Black (B.S., 1991) teaches the senior physics lab at Caltech and works for the Laser Interferometer Gravitational-wave Observatory (LIGO). He's also part of the ALPHA Immersion program, which sponsors hands-on laboratory experiences for upper-level lab instructors.

When Eric Black was an undergraduate physics major at UT, he mused about how nice it would be if he could make a living out of senior lab. As it turns out, he did just that.

A 1991 bachelor's graduate, he now holds a dual appointment at the California Institute of Technology, where he not only teaches the senior physics lab but also works for LIGO (the Laser Interferometer Gravitational-wave Observatory).

Black is, as he describes it “kind of a fourth-generation Volunteer.” His father, grandfather, and aunt all attended UT, as did four of his high school classmates. There were other draws to the Hill for him as well.

“I grew up in Tennessee and Kentucky, and it was just common knowledge that UT was a good school, especially with the honors programs that were starting up at about that time,” he explained. “I toyed with the idea of going out of state, but balancing the quality of the education UT offers, the cost savings from in-state tuition, and a particular girl I didn't want to be too far away from made UT the obvious choice.”

Black recalls Professors Tom Callcott and Soren Sorensen as “really outstanding professors” who taught the honors freshmen and sophomore courses, respectively.

“They really opened my eyes to a new way of looking at the world,” he said. “Bob Deserio taught senior lab when I was there, and he just sort of turned us loose in the lab and let us build things. That was a great experience, and I remember thinking at the end of the term that it was a shame

you couldn't do senior lab for a living. It turns out you can, after all.”

Black still sees Deserio (now at the University of Florida) at advanced-lab conferences, where he also runs into current UT Undergraduate Physics Lab Director Jim Parks, whom he had a chance to visit on campus in March.

As an undergraduate physics major, he also worked with Drs. Al Sanders and Ed Deeds on a proposal for a micro-gravity experiment. That interest in gravitational physics has tugged at him throughout his career, underlying both his postdoctoral work as well as his current research. His years in Big Orange Country, however, were not purely confined to the classroom or the lab.

“I also remember the Vols beating Florida decisively in football at Neyland stadium,” he said. “I was a senior, and it was homecoming, if I remember correctly. It was pouring down rain all through the fourth quarter, and a bunch of us in the student section were ‘doing the gator,’ making fun of the Florida team that had been heavily favored to win. That was a good day.”

A Real Job

After finishing up his studies (and gatoring) at UT, Black headed off to graduate school, looking around a bit before deciding on the University of Colorado. He considered the standard big-name programs that carry with them lots of prestige and history, but ultimately chose to strike out into newer territory.

“I didn't want to go to a place where people had already done great things and were resting on their laurels,” he said. “I wanted to go to a place where people were doing great things or were about to do great things. And I got a strong sense that Colorado was that place, and it turns out I was right. There were four people who have won Nobel Prizes for work they did in the physics department while I was there.”

His doctoral work, however, proved to be a temporary detour from his earlier flirtation with gravity.

“I had wanted to go into gravity and kind of changed my mind,” he said. “I was originally planning on being a theorist, and after an undergraduate experience in theory I decided I didn't. So I decided, ‘Well, I'll go out and get a real job,’ so condensed matter seemed like the most practical way to get a real job. And it turns out that the guy that I worked for (John Price) had done the same thing. So he and I were getting a real, practical job together doing condensed matter.”

Both, however, abandoned that line of work a few years later and returned to gravity research. When Black finished

the Ph.D. in 1997, he went to Caltech as a postdoc, where he spent three years working with LIGO on gravitational-wave detection research. He continued this pursuit after he was appointed a lecturer and began teaching the undergraduate advanced lab course. This two-term senior lab typically comprises about 20 students and introduces them to the finer points of optics, spectroscopy, condensed matter, and atomic physics.

“The lab has always been a collection of various experiments, each contributed by someone with expertise in that area,” Black explained. “Ken Libbrecht is a professor here who has worked in cold atoms, and he contributed the optics labs. I did my dissertation in condensed matter and designed that track based on what I knew. Nuclear magnetic resonance, optical pumping, and the Hanle Effect were here when I took the job, but I updated the hardware and handouts. We teach what we know.”

In recent years the lab has emphasized a “design and build” approach, whereby students design, build and test a project. Black said planning is probably the biggest challenge for them, as most students come to lab without a background of tinkering or technical hobbies, so they tend to struggle somewhat with self-direction on a project.

“(Students have) been trained from an early age to take exams and do problem sets assigned to them,” he said. “They do those very well, but tests and problem sets just don’t teach independent, self-directed thinking. They teach facts and tools. Those facts and tools are essential. You can’t do independent, self-directed thinking without them, but they aren’t the whole story any more than a pile of bricks and loose mortar is a building.”

Students’ grades are dependent on a combination of pre-lab exercises and, most importantly, their lab notebooks.

“That is one essential skill we really focus on in this course,” Black explained. “Unlike a lot of schools, we don’t

“That was often a source of frustration for the old-guard professors who didn’t know where to start with us,” he said. “What they didn’t see, though, was that about the same time, there was a kind of a revolution in the way math was taught. In the last twenty years or so, students became much less technically proficient but much more able in mathematics. Today’s students tend to be more conversant in higher-level, abstract math than their predecessors, and I like to think that I am of the same ‘generation’ and can speak to them in their language.”

Science and Service

An underlying theme in both Black’s teaching and his research is the opportunity to expand his work to the broader physics community. In teaching the senior physics lab, for example, he defines three roles the lab plays in serving physics as a field.

The first is to educate undergraduates and prepare them for a career in physics research; the second is the education—in terms of both physics and leadership—of the graduate students who serve as teaching assistants; and the third is providing course materials and content that other schools can adopt to their own labs. In that vein, he’s involved with ALPhA (the Advanced Laboratory Physics Association), which, among other projects, sponsors laboratory immersions at different schools for upper-level lab instructors. Hosts provide a two-to-three day program of intensive hands-on work with a single experiment. The program began in 2010, with 10 programs slated for 2013 in locales spanning the country from California to Florida.

“When I first took the job of teaching here at Caltech, it had been a goal of mine to contribute to the broader advanced-lab community by developing and distributing new teaching materials,” Black said. “I had been informally distributing course material we developed here to

professors at other schools, when Gabe Spalding (Illinois Wesleyan University) and Lowell McCann (University of Wisconsin-River Falls) approached me about the ALPhA Immersion program they were starting. It seemed like a great opportunity to work with like-minded individuals: people with the same goals as mine but with a bit more experience; and

the collaboration have been both fun and productive.”

Black has four immersions scheduled for Caltech this August, covering vacuum techniques and thin-film deposition, the Hanle Effect, low-noise signal detection, and spectroscopy, with a structure similar to that of the senior physics labs. The difference is that these immersions are only three days long.

“Participants take on the role of students and actually do the experiments,” he explained. “I have two ‘teaching

“Bob Deserio taught senior lab when I was there, and he just sort of turned us loose in the lab and let us build things. That was a great experience, and I remember thinking at the end of the term that it was a shame you couldn’t do senior lab for a living. It turns out you can, after all.”

require a formal report or presentation at the end of an experiment. Keeping a lab notebook with enough detail to consistently reproduce their results is probably the essential skill we want to see them develop at this age.”

Part of Black’s success as an instructor is rooted in his ability to relate to students via a kind of generational kinship. When he was coming through the undergraduate ranks, for example, he and his contemporaries were among the first group of majors to study physics without a background tinkering with ham radios, model rockets, and old Chevrolets.

Continued on Page 9

Electron Stripping for the Next Generation



Undergraduate Physics Majors Frances Garcia (left) and Nickolas Luttrell (right) are working at the Spallation Neutron Source this summer with Sarah Cousineau (center), an accelerator physicist and joint faculty member with UT. They're working on a laser stripping project to develop next-generation tools for accelerators.

The Spallation Neutron Source produces the most intense pulsed neutron beams in the world, giving scientists a powerful tool to track down atoms and the way they move. But before all those neutrons can be used in studies, they must first be liberated from the liquid mercury where they reside. That process begins with ions speeding down a linear accelerator, and Sarah Cousineau helps ensure that journey is timely, efficient, and safe. She recently submitted her first grant proposal, winning \$825,000 to develop next-generation tools for accelerators that handle ever-increasing energy and intensity.

Cousineau is an accelerator physicist at Oak Ridge National Laboratory and holds a joint faculty appointment with the physics department. Her grant, which came from the U.S. Department of Energy and began May 1, is for "Laser Stripping for High Intensity Proton Beams."

At the SNS, located at the national laboratory, neutrons are shuttled down 18 different beamlines, where scientists put them to work in a number of different research strategies. They find their origin, however, in a rapid series of events that begins with ions, each comprising a proton and two electrons. The process begins when a negatively-charged ion beam of hydrogen is accelerated to 2.5 million electronvolts and then delivered to a linear accelerator, or linac. Once there, the beam is revved up to one a billion electronvolts (which translates to a beam velocity of 90 percent the speed of light) before it's injected into an accumulator ring. The ions are stripped of their electrons, leaving the remaining protons to spin around the ring before finally

being fired in short pulses at a liquid mercury target, freeing the neutrons inside. The result is 20 to 30 neutrons per proton for delivery down the beamlines.

"At the SNS, you do all the acceleration of the particles in the linear accelerator," Cousineau explained. "The ring is only there to accumulate pulses from the linear accelerator. We want a lot of protons and we can't get all of them at once from the linear accelerator, so we accelerate a bunch, put it in the accumulator ring, and then we accelerate another one and we stack that one on top. We do that 1,000 times. The whole process of acceleration and accumulation and then sending it to the target for spallation takes only one millisecond, so 0.001 seconds. And we repeat it 60 times per second."

More protons means more neutrons for study, and physicists like Cousineau work to make sure the beamline scientists have a deep well from which to draw.

"We are an accelerator that pushes particle intensity, not particle energies," she explained. "(It's) not how fast, but how many. And there are different challenges."

The accumulator ring, for example, is set up somewhat like a scientific racetrack, with four 90-degree arcs and four straight sections. Each supports a different function: injection or collimation of the ion beam, or proton bunching or extraction. Cousineau's proposal deals with the injection of the beam from the linac to the ring, where it passes through "stripper foils" that remove the electrons. Thin and delicate, these pieces of carbon can cause all kinds of headaches, especially as future accelerators become more powerful.

"This whole stripper foil technology is probably the main limiting problem for high intensity accelerators," Cousineau said. "We're already starting to see that they break, they tear; they lose quality. You're putting a tiny piece of material in front of a lot of high energy particles. Nobody knows if those foils are going to survive, and they already cause a lot of beam loss. If you increase the intensity, they're going to cause a lot more."

"That's what our proposal has to do with," she continued. "We're not so much geared toward the SNS as we are toward the whole high energy physics community. This system is actually more relevant to the next generation of accelerators than it is to us."

Cousineau explained that there's a two-pronged approach to resolve these issues: the first being an active branch of research and development geared toward making better, stronger foils; and the second (including her work)

being the development of new technology that doesn't use foils in the first place.

"We want to be material-less," she explained. "We don't want any material to intercept the beam because that's what causes problems."

Cousineau's work for next-generation accelerators includes contributions from next-generation scientists. This summer, UT undergraduate physics majors Nickolas Luttrell and Frances Garcia will be part of the laser stripping project. Garcia will work with a laser specialist to develop new diagnostic techniques for measuring very short laser pulses. Luttrell will work with Cousineau to set up an experiment to strip the H- particles in the linear accelerator. He'll work on calculations to dispose of protons that were successfully stripped of their electrons in the experiment.

Cousineau mentors interns from all the over country, and has made it a priority to recruit UT students into her research program, both undergraduate and graduate. UT Physics Graduate Student Robert Potts is part of her group and studies high intensity beam dynamics.

"We can put a low-intensity beam in the ring and we can predict how it's going to behave," she explained. "Once we get a lot of particles, things change. How does a beam of such a high intensity behave inside an accelerator environment? That turns out to be very complex and it's not that dissimilar from plasma physics. You have this extreme beam in this extreme environment. And at SNS, everything . . . comes down to beam loss. Every particle we lose causes radiation. And there's a certain level we can tolerate. You really have to understand the mechanics of the beam and what's going on and then subsequently how to control it."

Paying it Forward, Continued from Page 7

assistants,' and the three of us roam from group to group throughout the workshop, offering advice, suggestions, and corrections as needed, just like we do for the regular class. It has been my experience that the faculty immersion participants tend to be a little more independent and work faster than your typical undergraduate, so we can cover quite a bit of territory in three days."

The other half of Black's professional life is equally interwoven with carrying science beyond the lab where it's done. He is lead engineer on optical levers for advanced LIGO, a next-generation detector under construction to be installed at observatories in Washington and Louisiana.

"Optical levers' refers to a subsystem that monitors the alignment of the mirrors in the interferometer, which is kind of important when they are separated by four kilometers," he explained. "It's very much big science, and the organizational structure of a big engineering project like this turns out to be, in many cases, as interesting as the science. I have supervised two graduate students through their dissertations, and both now have thriving careers of their own."

Brandon Cathey previously worked with Cousineau after graduating from Middle Tennessee State University and is set to join UT's physics graduate program this fall. She is looking for additional graduate students for other projects, including a lab-based effort to recycle laser power. The emerging field of laser applications and accelerator physics has plenty to offer students, particularly undergraduates who may still be deciding what sort of work they want to pursue.

"What I hope they'll learn is just a little bit about accelerator physics; that they'll learn about a field that's different from perhaps what's presented to them in their coursework," Cousineau said. "For students who haven't done research, it gives them a glimpse of what it's like to do research on a daily basis. It's good to sample a couple of different research programs before going to graduate school to know what types of programs are out there: what you do on a day-to-day basis and what it's like to work in a scientific environment. That's what I want them to understand."

Cousineau has a first-hand appreciation of the student experience in a research environment. She met her husband, Earth and Planetary Sciences Associate Professor Jeffrey Moersch, while working as a summer intern where he was in graduate school. In 2001, while a graduate student herself at Indiana University, she came to the SNS to write her thesis and has worked there ever since. She still works closely with SNS Accelerator Physicist and UT Adjunct Professor Jeff Holmes, who was her on-site thesis advisor.

"It's a good place to work," she said. "It's exciting, and people are always ready to help students. We work as a team, and we treat our students like team members." CS

LIGO is a resource available to the world scientific community, which fits well into Black's philosophy about the connection of science and society.

"That's kind of the role of the scientist in society, isn't it?," he said. "Even the ones who go into industry and get rich do so by providing a valuable service or product to the community. That's the whole point."

When he's not teaching senior physics or building the next-generation of interferometric gravitational-wave detectors, Black's avocation is looking for a bit of downtime.

"I wound up marrying that girl I didn't want to be too far away from, and we have four kids and four dogs," he said. "My hobby is mostly trying to get some sleep!" CS

More Information on Eric Black's Work

- » ALPhA Immersion program:
www.advlab.org/immersions.html
- » Senior Physics Lab at Caltech:
www.pma.caltech.edu/~ph77/
- » LIGO: www.ligo.caltech.edu

The Physics Top 10 List

In the Fall Of 2010, CrossSections began highlighting the Top 10 Most-Cited Papers from our department, with insight from the authors, beginning with Number 10. These papers show the breadth and influence of the physics department's research program.

#5

Title: Observation of a Narrow Meson State Decaying to $D_s^+ \pi^0$ at a Mass of $2.32 \text{ GeV}/c^2$

Authors: B. Aubert *et al.* (BABAR Collaboration)

Journal: *Physical Review Letters* **90**, 242001 (2003)

Times Cited: 441 (as of 4/30/2013)

Summary

Courtesy of Dr. Stefan Spanier
Associate Professor, UT Physics
BaBar Collaboration

This publication vitalized the field of charm meson spectroscopy and was the first in a series of new particle discoveries. At the time several particles consisting of a charm and strange quark were predicted by theory, but only three of them were actually observed. It turned out that the BaBar experiment at the Stanford Linear Accelerator Center (SLAC) had access to possible new states via their decays into lighter particles.

At the time the focus of the BaBar collaboration and its competitor experiment Belle in Japan was on measurements of particle and their anti-particle properties. Differences in their decays to some extent are predicted by the Standard Model of Particle Physics, but not large enough to understand the matter anti-matter asymmetry in the universe. The effect is also called CP-violation. The BaBar detector was constructed to measure such differences in many different ways. Therefore, it could detect many different light particles that are the result of heavy particle disintegration to very high precision. The heavy particles that were expected to exhibit such differences are the so-called B-mesons, with the particle called B and its anti-particle called B-bar: this motivated the naming of the experiment Ba-Bar. These B-mesons were created when electrons and positrons annihilated each other in the PEP-II accelerator of SLAC at a location in the center of the BaBar detector. After creation the B-particles

decay into lighter particles in stages; in the first stage most likely into particles containing charm quarks. This publication took a close look at such secondary particles. They are also produced directly when an electron and positron annihilate each other. Indeed, in this way they presented a potential background to the primary studies of CP-violation. Hence, in 2003 this search was rather considered a sideshow. This analysis benefited from the unprecedented detection capabilities of the BaBar detector and the fact that the experiment was able to store and process an enormous amount of information in a short time so that there was no need to filter out certain event categories. The leading investigator was Dr. Antimo Palano, Professor at the University of Bari, Italy, a good colleague of mine whom I met first while I performed meson spectroscopy with antiprotons at CERN. Our group's involvement here at UT in this analysis was the identification of the particles, also called kaons, which carry away the strange quarks from the new states by using the novel Cherenkov detector, DIRC, of BaBar. This new detector was invented specifically for BaBar. Our postdoc at the time, Dr. Maha Krishnamurthy, was leading the operations of this detector at SLAC and we developed and tuned the software needed to identify kaons with very high efficiency ($\sim 97\%$) and with a very low rate of false identification ($< 2\%$). This software played a key role in this analysis as the secondary DS mesons disintegrate primarily into kaons.

The most exciting aspect of this analysis was that the newly discovered state did not fit into any of the theoretically predicted particle spectra because of its low mass, the way it disintegrated, and its long lifetime. This leaves the possibility that it is not an ordinary meson consisting of two quarks but rather an exotic object, for example consisting of four quarks. And it certainly motivated many theoreticians to revisit their calculations of charm meson spectra. Today those experimental and theoretical efforts are ongoing, and many other experiments joined those searches. The relative uncertainty of this particle's mass is better than $5 \cdot 10^{-4}$ and it has its place in the Review of Particle Properties (pdg.lbl.gov) with the official name D_{s0}^* (2317).



The close of the spring semester traditionally brings with it a long list of honors for physics faculty and students, and this year was no exception.

On April 22 the physics department honored a distinguished alumnus, exceptional students, and the year's outstanding teacher at the annual Honors Day celebration.

The ceremony opened with the presentation of the **2013 Distinguished Alumnus Award, which went to Professor Emeritus Bill Bugg**, who earned his Ph.D. with the department in 1959. His citation was "for his leadership in the creation of and research with the UT Particle Physics Group leading to participation in legendary experiments at BNL, Fermilab, SLAC, LEP and LHC at CERN, KamLAND, and others; and for his service as Physics Department Head for 27 years."

Dr. Bugg is a graduate of Oak Ridge High School and received his bachelor's degree in physics from Washington University in 1952. He spent two years in the Army before enrolling in UT's graduate program in 1954. He joined the physics faculty after

completing the Ph.D. and helped build the elementary particle physics research group, winning continued support over four decades from the U.S. Department of Energy, the National Science Foundation, and the university. He helped bring UT's particle physics efforts to a leadership role in detector development and construction for important high energy physics experiments. In 1969, he became head of the department, holding that post until 1996. He retired from UT in 2002, but maintained a funded research program for several years, and is still a fixture in the department.

Dr. Bugg gave the Honors Day talk, which covered the history of the university and was followed by the presentation of student awards and recognition of the Society of Physics Students Teacher of the Year (see below).



Department Head Hanno Weitering presents Professor Emeritus Bill Bugg with the 2013 Distinguished Alumnus Award (far left). Among the guests at the department's celebration were members of the Roseberry Family, for whom the Douglas V. Roseberry Award is named. Pictured are (left to right) Viki Smartt, Kay Roseberry McCarron, 2013 Roseberry Awardee Alex Perhac, and Steven Roseberry.

2013 Physics Honors Day Awardees

- » Outstanding First Year Student: **Jesse Buffaloe**
- » Robert Talley Award for Outstanding Undergraduate Research: **Emily Finan**
- » Robert Talley Award for Outstanding Undergraduate Leadership: **Richard Prince**
- » James W. McConnell Award for Academic Excellence: **Bart Weitering**
- » Douglas V. Roseberry Award: **Alex Perhac**
- » Robert W. Lide Citation for Physics Laboratory Service: **Richard Prince and Kristen Beard**
- » Outstanding GTA Award: **Joseph Tubergen and Santiago Munoz**
- » Outstanding Tutor Award: **Allison Sachs**
- » Colloquium Award: **Mark Foerster**
- » Stelson Fellowship for Beginning Research: **Nick Sirica**
- » Stelson Fellowship for Professional Promise: **James Austin Harris**
- » Fowler-Marion Award: **Miaoyin Wang**
- » Society of Physics Students Teacher of the Year Award: **Professor Soren Sorensen**
- » Students inducted into Sigma Pi Sigma, the national physics honor society: **Logan Hoskins, Nickolas Luttrell, Richard Prince, and Hanneke Weitering**

More 2013 Honors Day Information is online

- » View the **photo album**: www.phys.utk.edu/events/2013-honors-day/index.html
- » Learn more about **the names behind our awards**: www.phys.utk.edu/honors.html

Physics Wins Seven Chancellor's Honors

The physics department was well-represented April 8 at the annual Chancellor's Honors Banquet, taking home two faculty and five student awards.

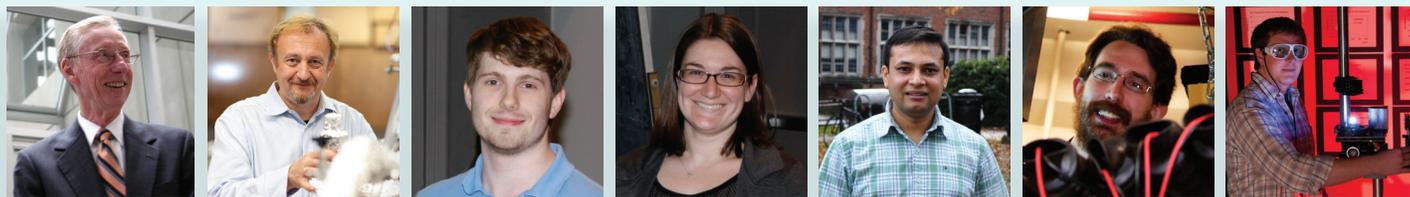
Professor Lee Riedinger was recognized with the L.R. Hesler Award, which is awarded to faculty members who demonstrate outstanding teaching ability and service to the university community. Riedinger is a former department head and is founding director of the Bredesen Center for Interdisciplinary Research and Graduate Education. This is one of many honors in Riedinger's distinguished career, including a 2008 Macebearer Award, UT's top faculty honor.

Assistant Professor Norman Mannella was honored for Professional Promise in Research and Creative Achievement. Mannella, a condensed matter experimentalist, won a National Science Foundation CAREER Award in 2012 for his research, in which he

studies complex electron systems as part of a broader effort to understand and develop novel materials.

Physics students were also acknowledged for their efforts. The College of Arts and Sciences had 19 students honored for either Extraordinary Academic Achievement or Extraordinary Professional Promise, and five of those honorees were from the physics department. **Alex Perhac** was recognized for Extraordinary Academic Achievement. Honored for Extraordinary Professional Promise were **Emily Finan, Nirmal Ghimire, Stanley Paulauskas, and Alex Woods**.

Every spring the university hosts the Chancellor's Honors Banquet to recognize students, faculty, staff, and friends of the university both for their achievements and their contributions to the UT community. More information about this year's honorees is available at the Chancellor's Web site: <http://chancellor.utk.edu/honorsbanquet/2013/>.



Physics Department Chancellor's Honors Awardees (left to right): Lee Riedinger, Norman Mannella, Alex Perhac, Emily Finan, Nirmal Ghimire, Stanley Paulauskas, and Alex Woods.

More News from the Physics Family



Graduate Student Stanley Paulauskas, who works with Dr. Robert Grzywacz, presents his work at the North American Workshop on Beta-Delayed Neutron Emission at the Joint Institute for Heavy Ion Research.

Faculty

It's been a busy spring for **Professor Robert Grzywacz**. Along with Krzysztof Rykaczewski of Oak Ridge National Laboratory, he co-organized the North American

Workshop on Beta-Delayed Neutron Emission at the Joint Institute for Heavy Ion Research in Oak Ridge. The workshop was held May 2-3, giving Grzywacz a three-day window before attending his duties as co-director of a workshop on Advances in Digital Spectroscopy organized by the International Centre for Theoretical Physics and the International Atomic Energy Agency. **Iain Darby**, a former postdoc in the nuclear physics group, was the director. Held in Trieste, Italy, May 6-10, the workshop included lectures and tutorials on digital pulse/signal processing and data acquisition and analysis, complemented by training and experiments including gamma-ray spectroscopy and imaging and analysis techniques with neutrons.

Students

Undergraduate physics major **Connor Gautam** was among the awardees at the 2013 Exhibition of Undergraduate Creative Research and Achievement (EURECA). His project was titled "Simulations of Mirror Neutron Oscillation/Regeneration," and his faculty mentor was **Dr. Yuri Kamyshev**.

The inaugural class of VolsTeach graduates in May 2013 includes physics major **Joel Smith**. VolsTeach allows students to pursue undergraduate degrees in math and science while simultaneously completing requirements for teacher certification. In 2012 Smith was one of four U.S. students selected for an international training program for future teachers.



David Surmick

aluminum sources for the purpose of accurate temperature determination.

David Surmick, a Ph.D. student working with **Dr. Chris Parigger** at the UT Space Institute in Tullahoma, has been selected for an internship at Sandia National Laboratory, where he will work in the research area of Fire and Aerosol Sciences for data reduction of aluminum combustion. Surmick's graduate research focuses on the reduction of spectral data taken from combusting

Graduate student **Kemper Talley** will spend this summer at the Computational Physics Student Summer Workshop at Los Alamos National Laboratory. Talley, who works with **Physics Professor Witek Nazarewicz** and Mark Williams of Oak Ridge National Laboratory, was one of 24 students accepted to the program via a competitive selection process. He is a member of the inaugural class of graduate students in UT's Bredesen Center for Interdisciplinary Research and Graduate Education. Talley's work with Nazarewicz and Williams involves nuclear theory and data as related to energy problems.

Alumni

The American Meteorological Society announced in January that **Wanda Ferrell** (Ph.D., 1985) was the 2013 winner of the prestigious Cleveland Abbe Award for Distinguished Service to Atmospheric Sciences. The award recognized Ferrell "for skillful, dedicated leadership in managing the Atmospheric Radiation Measurement (ARM) Climate Research Facility, which has improved knowledge about the interactions among clouds, radiation, and aerosols." By virtue of the award, Ferrell also joined the newly-elected class of American Meteorological Society Fellows. She is program manager of the ARM Climate Research Facility, which is managed and operated by nine Department of Energy national laboratories. She is also the program manager for the Climate Information & Data Management group within the Energy Department's Office of Biological & Environmental Research.

Olga Ovchinnikova (B.S., 2005; M.S., 2007; Ph.D., 2011) and fellow authors Vilmos Kertesz and Gary Van Berkel of Oak Ridge National Laboratory's Chemical Science Division received the Benyon Prize in June at the American Society for Mass Spectrometry conference. The award

recognized their paper "Combining transmission geometry laser ablation and a non-contact continuous flow surface sampling probe/electrospray emitter for mass spectrometry based chemical imaging," which appeared in *Rapid Communications in Mass Spectrometry*.

James Wicker (Ph.D., 2006) is co-author of the paper "Gravitational Conundrum? Dynamical Mass Segregation versus Disruption of Binary Stars in Dense Stellar Systems," which appeared in *The Astrophysical Journal* in March. The paper outlines findings from researchers at the Kavli Institute for Astronomy and Astrophysics at Peking University in Beijing. After analyzing images of a star cluster in the Large Magellanic Cloud, they found that, in contrast to expected results, more binary star systems were at the periphery of the cluster than in the center. Wicker wrote the statistical code the research team used to demonstrate that there is a statistical difference in binary stars at different radii in the cluster. He is an editor and researcher at the Chinese Academy of Sciences.

Staff

Congratulations to **Debra Johnson** of the physics business office for completing Leading at UT certification in November. This 70-hour program includes training in technical processes and compliance, employee and team development, organizational development, and personal and professional development.

In Memoriam

The department is saddened by the loss of **Dr. Kermit Duckett**, who passed away June 19. He was 77. He grew up in Canton, North Carolina. In 1958 he earned a bachelor's degree at Georgia Tech and then spent a year working for the American Enka Corporation in textile research and manufacturing. After finishing a master's degree in physics at the University of Colorado in 1961, he joined the UT Physics Department as a graduate student, accepting an assistantship in Dr. Ken Hertel's fiber research laboratory. When he completed the Ph.D. in 1964, he spent a year with the U.S. Department of Agriculture before returning to UT to take over the fiber research lab upon Hertel's retirement. As this program was supported by the University's Institute of Agriculture, Kermit was part of the agricultural engineering faculty as well as the physics faculty. Later his research became part of the College of Human Ecology program in textiles and nonwovens, but he maintained his physics faculty appointment until his retirement in 2001. He served as associate dean of the College of Human Ecology and was a visiting lecturer at China Textile University in Shanghai; he was also elected a fellow of the Textile Institute in the United Kingdom.

Continued on Page 14

Physics Family Photos: Spring Picnic



Candice Messick and Physics Graduate Student Max Heres were among the more than 100 physicists and friends who attended the April 26 Physics Department picnic.



Professor (and Bredesen Center Director) Lee Riedinger spent some time with daughters of fellow nuclear physics faculty members Kate Jones and Robert Grzywacz.



Graduate students Ao Teng and Weisong Tu availed themselves of the barbeque buffet, once again skillfully organized by the physics department's front office staff.

Undergraduate physics major Allison Sachs celebrates the end of the 2013 spring semester (photo courtesy of Richard Prince).



Aside from his research, Duckett was a highly-regarded teacher, particularly in Astronomy, winning the department's Teacher of the Year Award in 2005. In 1983 he published an astronomy lab manual still in publication. In 2002 he began working with the K-12 Teachers' Aerospace Education summer workshop, which includes support from the Civil Air Patrol, of which he was a member. He already had plans in place for the 2013 workshop, and this year's program will be held in his honor. He was also among the first people to tour the department's new planetarium, a project he had championed since the 1970s and was delighted to see come to fruition this spring.

The department lost another retired faculty member with the passing of **Dr. Norman Gailar** on February 23. Born in Alfred, New York, Gailar was one of three children, all of whom were physicists. He earned bachelor's and master's degrees in physics at Syracuse University before serving in the U.S. Air Force as a navigator during World War II. He then joined the U.S. Bureau of Standards before resuming his education, earning a Ph.D. in physics at the Ohio State

University. In 1960 he joined the physics faculty at UT, becoming an important part of Dr. Alvin Nielsen's research group in molecular spectroscopy. Gailar was instrumental in winning a multimillion dollar grant from NASA for the design and construction of a state-of-the-art high resolution vacuum spectrometer to study the molecular structure of fuels of interest to NASA. For many years the instrument was the foundation of a highly successful research program. The Gailar family also hosted several physics picnics and other departmental gatherings at their farm. Gailar retired as a professor emeritus after a three-decade career, leaving a vibrant legacy of research and teaching.

The department also lost a friend when **Barbara Trask Lide**, widow of Dr. Bob Lide, passed away on January 13. The Lide Citations presented at Honors Day each year are given in honor of Dr. Lide's contributions to the undergraduate physics labs, and he and Mrs. Lide were valued members of the physics family.

Thanks to our Donors

The department is pleased to acknowledge the generosity of our donors for their support:

Pauline Abbott
Jeffrey R. Badger
Elizabeth M. Bains
James A. Bains, Jr.
Boeing Company
Foundation
Kris Brummett
William M. Bugg
Margaret M. Compton
Robert N. Compton
Julian Crowell
Mary Ann C. Davidson
Dean A. Deeds
Tanner D. Devotie

Dennis J. Erickson
John T. Foust
Rebecca J. Foust
Michael W. Guidry
Leigh H. Harwood
Sandra J. Hinsdale
Samuel M. Hung
Albert C. Kahler, III
Sarah H. Kahler
Beverly C. Martin
Richard M. Martin
Kay R. McCarron
Witold Nazarewicz
Barbara C. Parks

James E. Parks
Thomas R. Robacker
George Siopsis
Maria Siopsis
Soren P. Sorensen
James Davis Trolinger
Shu-Chen Uang
Yea-Hwang Uang
Kenneth H. Wright, Jr.
Michael C. Wright
Elise I. Young
Glenn R. Young
Ming Zhang

(Gift records forwarded to the department dated December 1, 2012, through May 31, 2013.)

Giving Opportunities

The physics department has several award and scholarship funds to support our vision of excellence in science education at both the undergraduate and graduate levels:

Undergraduate Scholarships

The William Bugg General Scholarship Fund
The G. Samuel and Betty P. Hurst Scholarship Fund
The Dorothy and Rufus Ritchie Scholarship Fund
The Robert and Sue Talley Scholarship Fund

Undergraduate Awards

The Douglas V. Roseberry Memorial Fund
The Robert Talley Undergraduate Awards

Graduate Awards & Fellowships

Paul Stelson Fellowship Fund
Fowler-Marion Physics Fund

Other Departmental Funds

Physics Enrichment Fund
Physics Equipment Fund
Physics General Scholarship Fund
Robert W. Lide Citations
Wayne Kincaid Award

If you would like more information on how to make a gift or a pledge to any of these funds, please contact either the physics department or the College of Arts and Sciences Office of Development at (865) 974-4321. You can also donate online by going to: <http://artsci.utk.edu/> and clicking on "Give to the College of Arts and Sciences."

Address Changes

Please remove my name from the *CrossSections* mailing list.

Please update my information as marked below:

Name: _____

Address: _____

City: _____ State: _____

Zip or Postal Code: _____

E-mail Address: _____

Return by mail to:
401 Nielsen Physics Building
The University of Tennessee
Knoxville, TN 37996-1200
USA

or

Send an e-mail message to cal@utk.edu

CrossSections is published twice each year by the UT Department of Physics & Astronomy.

Department Head: Dr. Hanno Weitering

Associate Department Heads: Dr. Marianne Breinig and Dr. James E. Parks

Publications Coordinator: Catherine Longmire

Phone: (865) 974-3342 **Fax:** (865) 974-7843

E-mail: physics@utk.edu

Web: www.phys.utk.edu

Facebook: www.facebook.com/UTKPhysicsAndAstronomy



Original photo by Chad Middleton (Ph.D., 2005)

UT Department of
Physics & Astronomy
COLLEGE OF ARTS & SCIENCES

401 Nielsen Physics Building
The University of Tennessee
Knoxville, TN 37996-1200

Non-Profit Org.
U.S. Postage

PAID

Permit No. 481
The Univ. of Tenn.
Knoxville, TN

The University of Tennessee is an EEO/AA/ Title VI/Title IX/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services. All qualified applicants will receive equal consideration for employment without regard to race, color, national origin, religion, sex, pregnancy, marital status, sexual orientation, gender identity, age, physical or mental disability, or covered veteran status. PAN E01-1060-001-14. A project of the UT Department of Physics & Astronomy, (865) 974-3342, with assistance from the UT Office of Communications and Marketing. Rev: 6872