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Department of
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COLLEGE OF ARTS & SCIENCES

CrossSections
The Newsletter for UT Physics Alumni & Friends

Embracing the Inescapable

As powerful computation becomes a requirement rather than a luxury for scientific research, the physics department is equipping students with the needed skills to thrive in the future—using advanced computational techniques on platforms ranging from laptops to Titan.

Disruptive and messy. That's the landscape that next-generation scientists are facing, as described by Physics Professor Ken Read. He's one of many physicists using powerful computers to decode nature's mysteries and draws on that experience to teach Computational Physics (Physics 573/643), part of the departmental curriculum designed to make sure students are ready to conquer this new frontier.

A Team Sport

While change is inevitable in any field, the evolution of ideas and tools is often gradual. This has not been the case, however, in computing, especially over the past decade. Read explained that inexorably escalating computational demands relied for over three decades on the continued development of microprocessors with ever-increasing CPU clock speeds and ever-increasing transistor density. Over the past decade, however, this traditional scaling broke down as the industry confronted a "power wall" (an exponential increase in power for a factorial increase in clock speed).

"It became essential to increase performance with constrained power per processor core," he said, "and the solution was the transition to many-core computing."

Bill Dally spoke about this very topic at the 2013 International Supercomputing Conference in June. More importantly—for students at least—he talked about how, in this parallel computing environment, programming should be seen as a team sport, with everyone playing their respective positions.

Dally happens to be chief scientist at NVIDIA, the company that manufactured the graphics processing units (GPUs) for the Titan supercomputer at Oak Ridge National Laboratory, and as such, Read said, he has some "serious street credit."

"The programmers need to change in order to best utilize what's available and becoming available in this power-efficient world," he added. "It's time to start training a new generation of scientists and programmers who understand what's afoot here, because it's not going away. This disruptive change is here to stay."

Far Beyond the Abacus

The physics department has long understood the role computing plays in science and as such offers Computational Physics every spring semester. When Read inherited the

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Titan: the #1 open science supercomputer in the world and the first major supercomputer to use a hybrid architecture with CPUs and hardware accelerators (GPUs). Students in Physics 573/643 have access to this powerful tool for their course projects. *(Image courtesy of the Oak Ridge Leadership Computing Facility.)*

Message from the Department Head

by Hanno Weitering

Master Plans & Modest Dreams

Dr. Hanno Weitering
Professor and Head

Not many people in our department can remember the day in 1962 when Physics moved into a brand new building next door (named after Alvin Nielsen in 1980) from the old "Physics and Geology building." The old building is now home to the Department of Earth and Planetary Sciences (EPS). It is likely that physics will retake part of the EPS building (1928) in the not too distant future, but not before renovation or a complete makeover, of course. Our EPS colleagues next door are scheduled to move into the fully renovated and expanded Strong Hall building in 2016, and then, according to the 2011 campus master plan, the EPS building will be completely renovated utilizing the existing building façade, while the Nielsen Physics Building would be totally replaced by a new building. Ideally, these two buildings would be merged into one big 200,000 square-foot, seven-story complex, but details remain to be worked out and the renovation has yet to be included in capital outlay proposals to the State. Nonetheless, this renovation is part of the grand master plan for building renovations and new building construction that is happening all across campus. So it will happen on the Hill.

Our condensed matter physics colleagues won't have to wait very long. In summer 2015, most of them will move into the brand new UT/ORNL Joint Institute for Advanced Materials (JIAM), which will be housed in a new $47 million, 144,000 square-foot facility that is currently under construction on the new Cherokee Farm Innovation Campus, located west of Alcoa Highway on the banks of the Tennessee River near UT Hospital. The JIAM building is the first building on the 188-acre campus with 16 building sites.

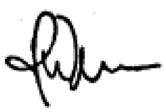
JIAM is a multidisciplinary research organization that formally began operation under the inspirational leadership of former UT Physics Professor and Distinguished Scientist Ward Plummer in 2006, and is now headed by George Pharr, Chancellor's Professor in the Materials Science and Engineering department. JIAM faculty—which comprises physicists, chemists, computer scientists, microscopists, and engineers, among others—provide a broad multidisciplinary platform to address an extensive range of challenges confronting today's materials scientists. For instance, JIAM scientists are exploring electronic, magnetic, and optical materials and devices that are smaller, more robust, and more energy efficient. These devices, often crafted from new materials, will advance fields as wide ranging as superconductivity, information storage and processing, sensors, and solar energy harvesting. Others explore specialty steels for use in nuclear reactors, or composite materials for use in air and spacecraft or sports equipment, or special polymers for flexible electronics, to name a few examples. Another very important mission of JIAM is to build state-of-the-art instrumentation and develop shared user facilities or "core facilities" that are accessible to other researchers from UT, ORNL, or elsewhere. Early this year, JIAM officially opened a new electron microscopy center, still in SERF, whereas several other facilities have become—or will soon become—open for outside usage.

A few weeks ago, Dr. Jim Parks, George Pharr and I toured the JIAM building site. It took a very long time before construction started but once underway, the building is now coming up rapidly and it is difficult not to get very excited by walking through it. The view across the river is magnificent, something the theorists on the top floor would certainly appreciate, while the basement is prime real estate for the experimental physicist. Note: physicists like dark basements. With plenty of open spaces, coffee corners, and even an outdoor terrace

The UT/ORNL Joint Institute for Advanced Materials (JIAM) will be housed in a new $47 million, 144,000 square-foot facility currently under construction on the new Cherokee Farm Innovation Campus, located west of Alcoa Highway on the banks of the Tennessee River near UT Hospital. UT's condensed matter physicists will move in to the new facility in summer 2015.
(Photo credit: Dr. James E. Parks.)

overlooking the river, the building will be a wonderful setting for informal meetings and the spontaneous exchange of ideas, and as such the building will be very conducive for interdisciplinary collaborations. The building itself is expected to qualify for LEED gold certification for environmental sustainability by the U.S. Green Building Council.

As usual, progress also takes its toll. Our physics faculty will be split across two campuses that are about two miles apart. This would certainly challenge departmental cohesion, but on the other hand it is really not that unusual for us physicists to be spread around. Through their teaching and advising obligations, our condensed matter friends will still be here regularly. It would certainly be nice and environmentally responsible if both campuses were connected with a rapid transit system, or at the very least with greenways and bicycle lanes. It is not clear if and when this idea will materialize but for now, let's keep this rather modest dream alive.



JIAM scientists are exploring electronic, magnetic, and optical materials and devices that are smaller, more robust, and more energy efficient. These devices, often crafted from new materials, will advance fields as wide ranging as superconductivity, information storage and processing, sensors, and solar energy harvesting.

Embracing the Inescapable, from Page 1

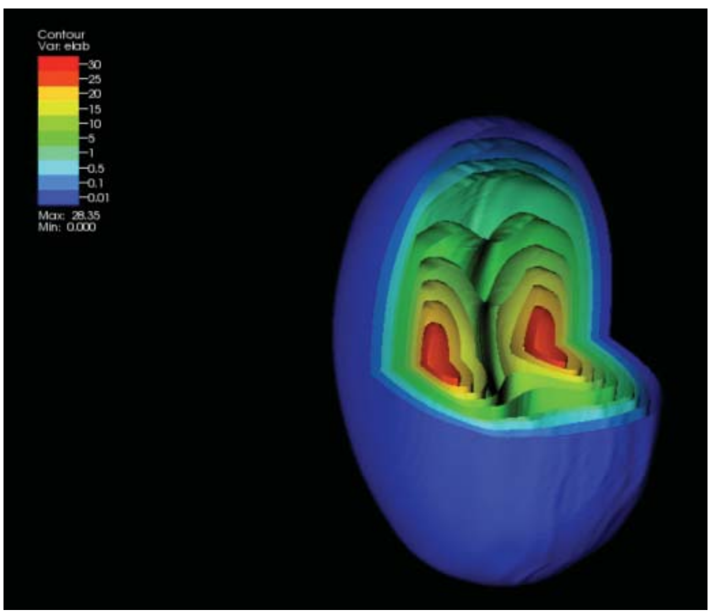
course in 2011, he built on the work of instructors Christian Cardall, David Dean, and Thomas Papenbrock, weaving in new topics to keep up with the current scientific environment.

"This is a particularly evolving field," he said. "We don't want to teach (students) to be adept at working on some Wang calculator or an abacus. It's very important that they can use not even necessarily today's machines, but *tomorrow's* machines, because these are tomorrow's researchers."

Given that there's no prerequisite that students have a programming background when they register for the course, teaching Computational Physics presents an interesting challenge in ensuring that students with varying levels of expertise are neither overwhelmed nor bored.

"There isn't some uniform entry point or some uniform exit point," Read explained. "The goal is that even a very capable student who walks through the door leaves having benefited by doing something incredible on Titan, and someone else, who was afraid of a computer, leaves very proud of what they accomplished having strengthened their physics and their computations."

These differing skill sets actually help underscore Dally's philosophy that programming is a team sport. In Physics 573/643, there are lectures and books, but there are also laptops and a lot of looking over shoulders. The first half of every Thursday class has students presenting their homework, which comprises what Read calls "mini-exercises in computational physics."



This image from the UT Relativistic Heavy Ion Physics Group demonstrates the power of high-performance computing in physics research. It shows a high resolution visualization of the relativistic hydrodynamical evolution by the CL-SHASTA code on a Titan GPU.

The homework requires use of UT's Newton High Performance Computing Cluster, which is, incidentally, shepherded by physics alumnus Gerald Ragghianti, who is part of the planning team for the course. All students get personal Newton accounts, providing a common platform for their work and thus building on the "software team" philosophy.

Students also have the opportunity to work on ORNL's Titan, the top open science supercomputer in the world and the second fastest overall. Computer scientists and outreach specialists from the Oak Ridge Leadership Computing Facility (including Suzanne Parete-Koon, another UT physics alumnus) co-teach two weeks of lectures, and prepare a sample project so students can get acclimated to the supercomputing environment. The OLCF also awards the class 100,000 hours on Titan each year, along with an e-mail helpline.

While most strong physics departments offer a computational physics class, Read said he's not aware of any leading supercomputing center making their resources available to a class of 15 students.

"They usually don't award hundreds of thousands of hours for those projects and contribute multiple staff to help co-teach and design the class," he said.

Still, he emphasized that the Computational Physics class is not about using Newton or Titan or any other specific tool. It's about teaching students to marshal their creativity and use the best available resources to solve current physics problems. Nowhere is that goal more apparent than in the final project requirement.

Getting Messy

Each student in the course is required to complete a semester-long final project and present it to the class. While this is hardly a new concept, the caveat is that the project topic must relate to current physics research appearing in a recently published physics journal article AND must include a computer program using *multiple* numerical methods related to the course.

In other words, Read said, "It isn't okay to solve some problem that was completely solved in 1900. Otherwise, we risk delivering people to our research groups or to the real world who can't quite make that step between what they got in their curricula and what they actually need, which is to use computation for current research in a way that isn't so canned and already cleanly solved, but is messy."

One of the most rewarding elements for Read is seeing students rise to the challenge. For some, just using Newton has been intimidating at first.

"That seemed daunting," he said. "But remember, last year's daunting is this year's baseline."

One student who came to the class lacking a strong computing background wasn't sure she'd be able to pull off a successful project. Yet she chose a topic from current literature, contacted the authors, and ended up presenting the problem to her classmates, along with a solution using her original code.

"Her job became to teach the class something: to connect in some unspecified way with a modern research project of interest and weave in solutions that she herself had utilized," Read said. "That stands today as one of the most successful projects."

Another student used Titan for his project and presented his work, in real time, in a Nielsen Physics classroom.

"This student had an assembly of molecules in a computational chemistry problem where the molecules were all wiggling around," Read explained. "This was done in a highly parallel calculation with GPUs, and that calculation was performed and streamed in real time to the screen in the classroom. It wasn't just a movie. It was live ... with an overwhelming, monumental amount of scientific computations unfolding before your eyes."

The course homework and projects, however, have implications that go beyond whatever grade appears on a student's transcript. All course alumni get to keep their Newton accounts, which they can use for Ph.D. research. Many use the class project as a springboard to contribute something new to the efforts of their research groups.

"I've seen that happen: a student has taken a project or application from our class and woven it in and continued it in a research project that their advisor welcomed," Read said. "I've been pleased by the collegial support of my colleagues."

The Inescapable Conclusion

It's not surprising that the physics faculty is open to having students embrace supercomputing, given the many ways they use powerful computation for their research: the hunt for the Higgs Boson, the expansion of the chart of nuclides, and the calculation of electron properties in superconductors, just to name a few.

Read explained that for UT Physics, putting "supercomputing in the classroom was just a recognition that *this* is the decade where such things are becoming commonplace and should be integrated better into the curriculum."

With strong encouragement from Department Head Hanno Weitering and a faculty committed to using the best available tools, Read sees himself as part of wider of initiative to advance computational physics education and position the department to lead the way in such research.

"I'm a cog in the wheel," he said. "I'm part of a mechanism for increasingly integrating supercomputing into the department."

That initiative gives the department an advantage over those who hesitate to incorporate high-performance computing into their physics programs.

"These are teams of hundreds, if not thousands, of physicists who are arriving at the inescapable conclusion that this is not a luxury that can be put off nor made completely invisible to the physicist, but that it's mandatory," Read said. "The world has changed. The longer you wait, the harder it's going to be on you." CS

Nazarewicz Named UT-Battelle Corporate Fellow

Witek Nazarewicz, James McConnell Distinguished Professor in Physics, was named a UT-Battelle Corporate Fellow in July, earning one of the highest honors bestowed by Oak Ridge National Laboratory and his second major ORNL honor in less than a year. While Nazarewicz is Distinguished R&D Staff in the ORNL Physics Division, his primary appointment is with the UT Physics Department. Last October Nazarewicz was named the national laboratory's Distinguished Scientist for 2012; the corporate fellowship distinction is yet another indicator of how highly-regarded his efforts are well beyond the university campus.

Witek Nazarewicz
(Photo Credit: ORNL)

Corporate fellow status is reserved for individuals who have made significant and sustained contributions to their respective fields over the years, and Nazarewicz is certainly a fitting candidate. He is a world-recognized authority on nuclear structure, with his work referenced more than 16,000 times, ranking him among the most highly-cited physicists as listed by ISI. He has published more than 350 papers in refereed journals, and served as scientific director of the ORNL Holifield Radioactive Ion Beam Facility from 1999 to 2012. He has helped organize dozens of workshops and conferences and has given nearly 250 invited talks and more than 250 more invited seminars and colloquia.

Nazarewicz is the physics co-director of NUCLEI, the NUclear Computational Low-Energy Initiative, a Department of Energy initiative that takes advantage of high-performance computing to advance research in nuclear physics, computer science, and applied mathematics. The program is the direct descendant of UNEDF (the Universal Nuclear Energy Density Functional), a highly-successful collaboration he directed with the goal of building a comprehensive framework of atomic nuclei.

The corporate fellowship is the latest in a long list of Nazarewicz's honors. In 2012 the American Physical Society awarded him the Tom W. Bonner Prize, which recognizes and encourages outstanding experimental research in nuclear physics. In 2008, he was named a Carnegie Centenary Professor by the Carnegie Trust in Scotland, and received an honorary doctorate from the University of the West of Scotland in 2009. He is a fellow of the American Physical Society, the UK Institute of Physics, and the American Association for the Advancement of Science.

Supercomputing & Supernovae

Tony Mezzacappa brings his expertise to JICS—and the classroom

For Dr. Tony Mezzacappa, navigating a day's work is a matter of both scale and balance.

There are fireflies and massive stars; a small class to teach and partnerships with world-recognized industries. Just one year after assuming the directorship of the UT-Oak Ridge National Laboratory Joint Institute for Computational Sciences (JICS), this highly-regarded astrophysicist is settling nicely into this multi-dimensional job involving equal parts leadership, discovery, and teaching.

Orchestrating Moving Parts

JICS puts powerful computing to work in the exploration of science and engineering, particularly in the development of sophisticated models and simulations. The institute encourages discovery in applied mathematics, biology and bioinformatics, chemistry, engineering, materials science, and physics. As director, Mezzacappa said his top priorities are not only the healthy maintenance of the program, but also overseeing its continued evolution as a vibrant scientific center. Like the conductor of a symphony, he makes sure that several different elements are working together.

"JICS is complicated," he explained. "JICS has a lot of moving parts."

For example, within the institute there's a National Science Foundation supercomputing center called the National Institute for Computational Sciences, or NICS.

"One of the jobs of the JICS director is to ensure the continuity of NICS, which is one of five major NSF supercomputing centers at the moment," he said.

A key component of NICS is Kraken, an academic supercomputing system with 1.17 petaflops of power (mind that a petaflop is one quadrillion calculations per second). In early 2014 JICS will submit a proposal to house Kraken 2, the successor to this powerful machine. If they win, the system will have a fitting name honoring the tiny, glowing celebrities of the Great Smoky Mountains.

"It'll be called 'Firefly,'" Mezzacappa explained. "That was a name that a young staff member within NICS came up with, and I think it's absolutely brilliant. In parallel computing, you fire up many processors simultaneously to compute and to advance science. So we invoke the firefly concept of synchrony. Our fireflies (processors) light up in synchrony to illuminate the world of science."

Having powerful tools like Kraken (and possibly Firefly) is one thing, but they're only as good as the people who use them.

"One of my jobs—and this is a job that is very important to me because I'm a scientist—is to grow the number of UT faculty and ORNL staff associated with JICS, and to grow it in a smart way," Mezzacappa explained. "I want to have a good solid core of people in physics, chemistry, biology, engineering, applied math, (and) computer science. Since taking the helm in December, I've been able to grow that number one good person at a time."

One way he's expanding the JICS roster is by reaching out to the private sector. Mezzacappa is working with university administrators to bring high-performance computing to industry and in the process, bring industry connections to UT. This is not new territory for the institute, which has for years enjoyed a strong relationship with the Intel Corporation. Just this fall JICS won funding for an Intel Parallel Computing Center.

The first two projects involve codes to study the interactions of biochemical molecules and the sequence of genes. Intel has invited JICS to submit additional projects for funding in early 2014, and Mezzacappa plans to target both astrophysics and statistics (data analytics) as candidates for new funding. This arrangement not only strengthens ties between the university and a corporate partner, but also brings the associated faculty under the JICS umbrella. With the biochemical molecules research, for example, Jeremy Smith, the UT-ORNL Governor's Chair in Biophysics, is now involved with the institute.

"Each time we land a project as part of this Intel activity, we get funding that allows me to fold that faculty member into JICS," Mezzacappa said.

Familiar Territory

It wasn't accidental that Mezzacappa was tabbed to lead JICS. He has been with Oak Ridge National Laboratory since 1996, where he was a group leader for theoretical physics and a corporate fellow. Among his honors are a Department of Energy Young Scientist Award and the Presidential Early Career Award in Science and Engineering. He is, however, perhaps best known for his studies on the lives and spectacular deaths of massive stars.

"A lot of years' worth of work is coming to fruition now," he said of his current research. "We're running state-of-the-art simulations of core collapse supernovae in three spatial dimensions with all of the requisite physics. These are realistic three-dimensional simulations, one of which we estimate will take 65 million processor hours on (ORNL supercomputer) Titan and will run over the course of eight months. We're running on tens of thousands of processors simultaneously.

"Our models are making predictions thus far that agree with observations, which is a very big deal," he continued. "At the end of the day, if you've got these sophisticated models and they agree with observations, then you're well on your way to solving one of the most important problems in astrophysics."

It was his astrophysics research that ultimately drew him in to high-performance computing, working with scores of people to come up with tools that would benefit not only supernova science, but the wider scientific community.

"This job as JICS director came very naturally," Mezzacappa said. "It's certainly a different kind of job than I've had in the past, but in many respects it's familiar."

Happy Days

It's not all fireflies and Intel and supernovae, however. When Mezzacappa became JICS director in December 2012, he also became the physics department's Newton W. and Wilma C. Thomas Endowed Chair in Theoretical and Computational Astrophysics. This fall he's teaching Physics 411: Introduction to Quantum Mechanics.

"I love to teach," he said with a huge smile. "My happy days are Tuesday and Thursday."

His class comprises 18 students, largely physics majors,—about the same size as the soccer teams he's coached in recent years—and Mezzacappa relishes the ratio.

"It allows you to really interact with each and every student," he explained. "I write on the board, but I'm constantly turning around and asking them to fill in the next step, so they're engaged, and it's just great. I absolutely love it."

He also appreciates that his influence as a teacher is just as important as his administrative or research accomplishments.

"Many people would look at my three hats—researcher, professor, and JICS director—and would probably say that the JICS director role obviously has the most impact," he said. "I'm not sure about that. When you teach, and you take it seriously and try to do it well, you are impacting 18 lives. That's immense. The opportunity to teach like that is a gift."

He is also working with Jack Dongarra (UT's Distinguished Professor of Computer Science) and Lee Riedinger (Physics Professor and Director of the Bredesen Center for Interdisciplinary Research and Graduate Education) to create an interdisciplinary Ph.D. program in computation.

"That's another aspect of the professor role and the JICS director role. (It) brings those together," Mezzacappa said.

Astrophysicist Tony Mezzacappa became the Newton W. and Wilma C. Thomas Endowed Chair in Theoretical and Computational Astrophysics *and* Director of the Joint Institute for Computational Sciences in December 2012. As such he balances responsibilities as an administrator, researcher, and classroom teacher.

He knows that supercomputing-based research requires an army of people, and he encourages students to find good mentors to not only walk them through the science, but show them the value of building networks.

"If you're talking about developing a code that's going to run on Titan, you're going to work with a lot of people," he said. "You're going to need the help of a lot of people with different kinds of expertise. So that's why, especially in computational science, it's important for a student to connect with a person, and a team."

A successful scientist, he said, also has to set a high standard and be uncompromising in holding to it. Above that, he said, "passion is the fuel of it all."

His own scientific passion is clearly a great fit for the physics department, and for JICS.

"Between the research and the teaching and the directorship, the variety of work is wonderful," he said. "I'm loving my new job." CS

Learn more about the research at the Joint Institute for Computational Sciences at: www.jics.utk.edu/

New Faculty: Nadia Fomin

UT's Physics Department owes its latest faculty addition to a stray letter, a phone call, and, ironically, a fair amount of persistence by the University of Virginia.

It was 2001, just shy of a year after Nadia Fomin had finished her bachelor's degree in physics and computer science at Georgetown University. She was working as a software engineer, a job that proved at times to be less than inspiring, especially after the camaraderie she had enjoyed as a student.

"It was a very 8-to-5 sort of job," she said. "It was a hard adjustment to make from school. When you're a science major, for us at least, (Georgetown) was very much a liberal arts college. We had a small but very close-knit group of physics majors. I was president of the Society of Physics Students. We had a very active group of people, and you just completely lose that."

As an undergraduate, Fomin had considered graduate work and applied to various programs. She visited the University of Virginia, where she told the physics department she was interested in joining the program but would like to defer admission for a year.

"But when I got home," she explained, "I just didn't think I was going to do it. So on the letter, I sent back: 'I decline admission.' A year later, when I was working at Lockheed Martin, I got a phone call from UVA."

The physics department was confirming her fall 2001 enrollment in the graduate program, though Fomin insisted that she had declined admission.

"They said, 'We never got the letter so we just assumed you were coming since you told everybody that you were deferring for a year.' And finally I said, 'Okay.'"

She went on to earn both her master's and doctoral degrees in physics at Virginia, and in 2007 she took a postdoc position with UT Physics Professor Geoff Greene, working at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory. Most beamlines at the SNS put neutrons to work: probing materials to extract their properties, for example. The research Fomin took on with Greene assigns them a somewhat higher status than that as a mere tool. In this approach neutrons are valuable physical systems worth studying in their own right, and nowhere is that more apparent than in the NPDGamma experiment.

Rules Violation

In the natural order of things, a mirror image of a system is typically a perfect, albeit "flipped" picture of the original: a concept known as parity. Within the Standard Model of Physics, however, there is one violator of this rule: the weak interaction, which is responsible for the weak force, one of the four fundamental forces in nature. The NPDGamma experiment uses neutrons as simple systems to measure the weak interaction between neutrons, which is not well-known. Subsequent experiments will test the Standard Model of Physics and perhaps reveal clues about larger scientific questions, such as the skewed balance between matter and anti-matter in the universe.

Bringing the NPDGamma experiment online ran beyond the timeframe of Fomin's postdoc assignment, so she took another position that allowed her to continue the work.

"I didn't want to leave the experiment just as we were getting started, so I did my second postdoc with another collaborator on NPDGamma," she said.

Nadia Fomin joined the physics faculty in August. Her research involves neutron studies and electron scattering efforts, and she will work both at the Spallation Neutron Source at ORNL and on the UT campus.

In 2011, she began working with Scott Wilburn of Los Alamos National Laboratory, keeping her station at the SNS. On August 1 of this year, she joined the UT physics faculty as an assistant professor. She'll continue her involvement with Oak Ridge, but also return to some of her earlier physics interests.

"The beamline will have different experiments that come and go, so the equipment will change; the actual experiments will change," Fomin explained. "Right now, I'm continuing my involvement there, but I'm free to work on other things as well."

Among those are electron scattering studies, which served as the basis of her thesis in graduate school. She is also building an on-campus research presence, where students are welcome to contribute.

"The idea is that we're going to try to build a lab to develop the next generation of proton detectors for an experiment that will run at the National Institute of Standards and Technology," she said. "This is pretty straightforward, to measure the lifetime of a neutron. I'm always looking for students, for both the neutron efforts and my continuing electron scattering efforts."

Social Networking

Fomin's faculty assignments, of course, extend beyond the lab and into the classroom. This fall she's teaching sophomores and juniors in Physics 250 (Modern Physics).

"A good number of them are extremely motivated and really into the subject," she said. "My students in that class have formed a Facebook group. They have study groups that they've set up. They're very entrepreneurial."

Fomin said organizing a schedule of faculty duties, research, and teaching has been an adjustment ("It's as overwhelming as everybody said"), but she's certainly successfully navigated big changes before. She was born in the Soviet Union, moving with her family to Canada when she was 12, and then to Erie, Pennsylvania, where she attended high school. It was there that physics revealed its charm.

"I took physics back in the Soviet Union. They introduced it in the 7th and 8th grade. That was not very fun. But by the time I took it again in high school, it appeared more interesting," she said, laughing. "It was the hardest class, so it was rewarding to actually do it."

She has also developed a network of new faculty members to make the transition to full-time academic life a bit easier.

"I have formed a social group of myself and other incoming assistant professors," she explained. "We get together and share our experiences."

When she's not pursuing physics, Fomin turns her attention to working on a "new" old house that she bought with her husband, Josh Pierce, in the historic Fourth and Gill Neighborhood. For the past four years, he's been a staff scientist at the Thomas Jefferson National Accelerator Facility in Virginia, but with her permanent position at the university, he's hoping to move his career to East Tennessee. Fomin also throws costume parties and isn't shy about encouraging her students to enjoy the lighter side of life.

"The second exam was on Halloween," she said with a smile. "They were encouraged to dress up." CS

The Wizard of Banner

Linda Painter Retires after 45 Years with the University

Linda Painter

Dr. Linda Painter's four and half decades at UT have included teaching the physics of music, studying the electronic properties of liquids, and more institutional service than seems humanly possible. Still, it's easy to review her impressive vitae and spot the central theme: much of her work has been all about the students, even when they didn't know it.

Painter officially retired on June 30, 2013. She came to UT in 1962 on a Woodrow Wilson Fellowship after earning a bachelor's in physics at the University of Louisville, in her hometown. In 1964 she was awarded a fellowship from the Atomic Energy Commission, and went on to finish her master's and doctoral degrees in physics, the latter in 1968, before joining the physics faculty as an assistant professor.

For years she did what all professors do: taught courses (including introductory courses in astronomy and physics, the nature of the physical world, the afore-mentioned physics of music, and health physics) and pursued her research. A health physicist by training, she studied the optical and dielectric properties of liquids in the vacuum ultra-violet and thin films including polyethylene in this spectral region. She also worked at the Oak Ridge National Laboratory Health and Safety Research Division as a consultant and R&D participant for more than 25 years. Her efforts garnered both accolades and financial support. In 1974, while working full-time and raising two pre-schoolers, she was named Tennessee's Outstanding Young Woman of the Year. Over a 20-year span, her research won consistent funding totaling more than $600,000. And then she got *really* busy.

"From 1985 to 1997, I was half-time in physics and half-time in administration," Painter said. "The challenge was to maintain teaching, research and administrative responsibilities. It was a very busy time for me."

In 1985 she took a post as Assistant Dean of UT's Graduate School. It was the first of many administrative positions she would hold until retirement, including Interim Associate Vice Chancellor and Dean of Continuing Studies and Distance Education. From 2002 until 2005, she directed the upgrade of the student information system. From 2005 until 2006, she served as director of the Textiles and Nonwoven Development Center; in 2006 she was Interim Dean of the Graduate School. From 2008 until retiring, she directed the UT Banner student implementation.

Where once all university records appeared on paper and required visits or phone calls to the Bursar, the Registrar, etc., Banner was designed to be an online collection of links and data for grades, registration, financial aid, and anything having to do with student information. The tricky part was to launch those systems so that students (and faculty and staff) could find what they needed with no obvious hiccups. Making that happen took a bit of magic, and a lot of magicians, with Painter at the helm. Continued on Page 11

Fast and Sleek, with No Moving Parts

Physics Grad John Hunt is at the Forefront of Metamaterial Technology

Physics Alumnus John Hunt (2008) works with metamaterials: composites that have novel optical properties. The research has been featured in *The New York Times* and *Wired*, among other publications.

John Hunt didn't suspect that his graduate work would keep him on the phone with the media for a week.

Yet for the past year, his research with the Duke Center for Metamaterials and Integrated Plasmonics has garnered plenty of attention, and there are no signs of slowing down.

Hunt's group studies metamaterials: composites made from components like metal and plastic that, when combined, take on intriguing optical properties. Before he became a media source, he was developing an interest in this kind of applied science as an undergraduate at UT.

The "Why" of Things

Hunt grew up in Knoxville and graduated from West High School in 2004. He came to UT planning to study engineering before migrating to engineering physics.

"I spent a lot of time trying to figure out what I wanted to study," he said. "I started out in the engineering program, but after the first year I felt that I wanted to understand more of the 'why' of things and so considered switching to physics. At the same time, I really liked the applied aspects of engineering. The engineering physics program met all these desires and afforded me the freedom to fill part of my course load with whatever subtopic I wanted."

Hunt credits Physics Professors Jim Thompson and Marianne Breinig with inspiring his understanding of electromagnetics and optics. Dr. Jim Parks and Dr. Stuart Elston helped develop his experimental skills. And the university's ties with Oak Ridge National Laboratory proved to be another advantage: one that led him toward his current research.

Hunt interned with the ORNL Center for Nanophase Materials Sciences, where he researched using carbon nanotubes to make flexible transparent electrodes for flexible displays.

"The idea was that if you could make very thin mats of carbon nanotubes, like a woven rug, they could be transparent and flexible, while being conductive," he explained. "This research made me start to think about how structured composite materials can achieve more than just novel *mechanical* performance (like plywood or fiberglass). Composite materials can provide all kinds of novel properties. This is what metamaterials are: composite materials that exhibit novel *optical* properties."

Seeing Through the Fog

The lure of metamaterials drew Hunt to Duke University when he graduated from UT in 2008. His graduate advisor, Dr. David R. Smith, is among the inventors of metamaterials and his group has led much of the field's innovation. That was evident in January 2013, when they published a paper in *Science* describing a compressive imaging system that created a flurry of interest.

In "Metamaterial Apertures for Computational Imaging," Smith's group (with Hunt as first author) explains how they developed an imaging system with a one-dimensional aperture made from a copper-based metamaterial. It captures microwaves in roughly 50 milliseconds and then reconstructs the image on a computer screen 50 milliseconds later. The system has several advantages: it's small, fast, and efficient; with no moving parts and no expensive components. Microwave detection also equips it for some interesting applications. Nestled in the electromagnetic spectrum between radio and infrared waves, microwaves can see through all sorts of obstacles: smoke, fog, wood, or clothing, for example. This makes the metamaterial-based imager an ideal candidate for security purposes: replacing scanners at airports, or scanning an area overhead from a plane.

The research was written up in *The New York Times* and *Wired*, among other news outlets. Hunt explained the work many times over, even doing a podcast for *Science*. At the beginning, his group attributed the calls to a slow news cycle, but, as Hunt said, "the requests kept coming, and I was basically on the phone for a whole week."

The imaging system is just one application for metamaterials. Nathan Kundtz, an alumnus of Hunt's group at Duke, came up with the idea of using the technology for antennas. He joined a company called Intellectual Ventures to pursue this research, and in 2011 Hunt spent some time working there.

"These antennas have very small size and are low cost, opening up entirely new applications," he said. "While I was at IV's lab, we focused on developing these antennas for satellite communications. When my internship ended, I started thinking about other ways that this type of antenna could be used, and imaging came up as an interesting possible application. When I returned to Duke I started working on this, and over the course of a couple (of) years we got a working system. The approach we came up with combines new concepts in two burgeoning fields: metamaterials and compressed sensing."

Kundtz and Intellectual Ventures created a spin-off company called Kymeta to commercialize the satellite communication technology by making what Hunt described as a "very thin, kind of like a laptop-sized" antenna; adaptable to the fuselage of a plane, a car, or other equipment.

"It can be incorporated into all kinds of different structures and vehicles," he said. "And then it can point a beam in any direction. That's the magic of it: it can be so thin, have no moving parts, and yet it can point a beam in different directions to talk to different satellites."

Puzzles are Part of the Fun

With his Ph.D. conferred in December, Hunt will have the opportunity to see how the work progresses when he joins IV full-time in January. It's a great playground for someone who clearly enjoys drawing on his "why" background in physics to create these materials. Designing metamaterials requires researchers to know what circuits they need and how to arrange them to build a composite with the desired behavior (e.g., for the imaging application, they wanted low absorption of light). Then they have to consider how they will be fabricated.

"It's no use if you think of a great design and have no way to make it," Hunt said. "You have to know about a lot of different things and know how they interact, and then it's kind of a puzzle to come up with exactly the right design. It's part of the fun."

The fun will continue for Hunt, as his group has now advanced to true three-dimensional images with their metamaterial imager design. The technology has grown into a large program at Duke, funded by the Department of Homeland Security. He will stay involved in that research, even after moving to Seattle for his new job with IV. When he leaves North Carolina, Hunt will continue on a path that makes him something of a pioneer, considering his research field is only about a decade old.

"It's really exciting to have so much open space to explore," he said, to ask "what if we tried to use metamaterials to do this; what would happen? And often that's a question that hasn't yet been asked. That's pretty exciting."

This next chapter of his career builds on the foundation he started laying at UT almost 10 years ago, when metamaterials was a new idea.

"I've found that growth and innovation happen at the boundaries of disciplines," he said. "Not just the outer boundaries—the frontiers—but also the interdisciplinary boundaries. The engineering physics program started to lead me down an interdisciplinary path."

It won't be all work, however. Hunt is a man of many interests, especially skiing, snowboarding, and rock climbing, and the Northwest has plenty of opportunities to do some exploring that doesn't involve composite materials.

"I plan to spend every minute that I'm not in the lab somewhere outside," he said laughing. CS

To learn more about John Hunt's work, read the *Science* paper "Metamaterial Apertures for Computational Imaging" at: www.sciencemag.org/content/339/6117/310, or visit his Website: people.duke.edu/~jdh51/.

The Wizard of Banner, from Page 9

"The teams for these projects included many from the Office of Information Technology and the student services areas," she explained. "Meeting go-live deadlines for new systems without interruption of student services was always a major challenge. The university is fortunate to have so many capable staff to support the mission of this large, comprehensive institution. I was grateful for the opportunity to work with them."

Whether working in the Graduate School, directing Banner, or teaching freshmen, she made students a top priority. Always a professor, she stayed in the classroom through 1998, and thoroughly enjoyed learning from her colleagues as well.

"I loved interacting with students, and I greatly value the many opportunities I had to meet and collaborate with health and radiation physicists from the U.S. and abroad," she said.

Only a few months into retirement, Painter hasn't made any hard and fast plans. There have been some trips and some long-delayed projects at home, but the call of the university is still there, and she plans to keep in touch.

"Hopefully, after the holidays, I'll take time to think about what I want to do in retirement," she said. "I welcome suggestions!" CS

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.

#4

Title: Suppression of hadrons with large transverse momentum in central Au+Au collisions at root s(NN)=130 GeV

Authors: PHENIX Collaboration

Journal: *Physical Review Letters* **88**, 22301 (2002)

Times Cited: 611 (as of 11/22/2013)

Summary

Courtesy of Dr. Soren Sorensen
Professor, UT Physics
PHENIX Collaboration

Since the inception of the program of relativistic heavy ion collisions in the 1980s at Brookhaven and CERN, the central issue was: how to find unique experimental signatures that indicate whether the hot nuclear matter created in the collision between two incident heavy nuclei moving at ultra-relativistic speeds is actually the predicted Quark Gluon Plasma (QGP). In the QGP, quarks are deconfined and not bound together in clusters of 2 or 3 quarks. Until the advent of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National laboratory in 2000, only very ambiguous signals had been observed and even these observations were disputed.

All this changed dramatically with RHIC, which could produce collisions with center of mass energies 10 times higher than previous experiments at CERN. Theorists had predicted that when very energetic quarks or gluons (a jet) are created during the initial phase of these high energy collisions, this jet will experience a loss of energy when it traverses the nuclear matter around it. Furthermore, this energy loss will be dramatically larger if the jet moves through a quark gluon plasma than in "normal" nuclear matter.

Ken Read and Soren Sorensen were very involved in the construction of the PHENIX detector at RHIC. Ken was responsible for the mechanical structure of the huge muon identifier detector and Soren was responsible for the design and implementation of the offline computing system. After 10 years of design and construction, we were of course very excited when RHIC and PHENIX finally started to operate, and were not disappointed as the third paper from PHENIX became a classic.

In this paper PHENIX describes the measurement of charged particles and neutral pions with large transverse momenta, assumed to be fragments of a jet, in Au-Au collisions and compares the results to those measured for proton – protons collisions, numerically scaled to take in to account the larger number of incident nucleons in the Au ions. Assuming no QGP could be created in proton – proton collisions, a deviation from unity in the ratio (known as the nuclear modification factor RAA) between the Au-Au results and the scaled p-p results would indicate novel behavior in the Au-Au system.

Indeed we discovered a ratio far below unity consistent with expectations based on the significant energy loss predicted for hadronic jets moving through a nearly opaque quark gluon plasma. Eureka! PHENIX had found a clear signature of the QGP.

This paper started the field of "jet suppression" studies. Increasingly refined tomographic studies of nuclear matter continue to be the most important tool for studying the properties of hot and dense nuclear matter.

Enriching the Student Experience

Josh Braverman

Josh Braverman began working at Oak Ridge National Laboratory in August 2011, but it was a year later, at a conference in California, when he got a vivid picture of just how influential his colleagues are.

Braverman is a Ph.D. student working with Adjunct Physics Professor Klaus Ziock in ORNL's Nuclear Security and Isotope Technology Division. Among their group's projects is development of a prototype nuclear material detector. This sort of sophisticated imaging device, which can "see through" varying levels of natural background radiation, is important for arms control, but also potentially valuable for nuclear medicine or even astrophysics. The work is funded by the National Nuclear Security Administration.

Braverman had an opportunity, via the Physics Enrichment Fund, to present a poster on this research at the 2012 IEEE Nuclear Science Symposium and Medical Imaging Conference, held last fall in Los Angeles. This was his first conference, and it proved to be a positive professional experience. He saw people he works with day-to-day in a different context: moderating panel discussions and presenting their work in a much wider arena.

"I got to see how much of an impact that people at Oak Ridge have," he said.

For Braverman, who's on track to graduate next fall, the networking aspect made attending the conference especially valuable.

"I met people from everywhere," he said, including "the British equivalent of the nuclear security administration."

There were also representatives from companies like SAIC and Raytheon, which was a bonus for Braverman, who plans to go into industry after graduation. The meeting was a trip home for the Los Angeles native, who hopes to return to the City of Angels after finishing his doctorate. His applied physics work with Ziock—and some networking—can help open lot of doors for him.

"Coincidentally, (Los Angeles) is a huge center for defense technology," he said.

It was the prospect of working at ORNL that brought Braverman to UT in 2010 after he finished a bachelor's degree in physics and English literature at the University of Colorado. Two years later he earned a master's in physics and immediately went to work on the Ph.D. When he first joined Ziock's research team they were in the planning stages of the detector project, but now, he said, "we've actually built a prototype version." Ziock will present a paper on that progress at a conference next spring, and Braverman is a co-author.

This is just one example of how UT's physics students are making important contributions to current scientific research with implications beyond the laboratory. Having the chance to travel to meetings and exchange ideas with like-minded professionals from all over the world, as Braverman said, "absolutely" enhances that experience.

The Physics Enrichment Fund sent members from UT's Society of Physics Students to the October 2013 SPS Zone 8 meeting at the University of Louisville. Some presented talks and posters, and they all had the opportunity to be part of small group discussions and meet informally with speakers. Our own SPS will be hosting the next Zone meeting in April 2014. *(Photo Copyright Austin Lassell; Courtesy of U of L SPS.)*

News from the Physics Family

Staff

The department is happy to welcome Crafts Specialist III **Josh Bell**, whose official first day was May 20. As a member of the instrument shop, he's part of the team that takes materials from aluminum to polyethylene and machines pieces for experiments both on campus and in research centers all over the world. He's worked on numerous projects for the teaching labs, including a recent project to make sound tubes. Considering the department's introductory labs serve about 800 students every semester, his work plays a big role in undergraduate education at UT.

Josh Bell

Interestingly, Bell didn't consider a career in machining at first. He was more interested in auto-body work. But when he was a senior in high school, his shop teacher told him machining was the direction he should take. He followed that advice, and graduated from the Tennessee Technology Center in 2007. He spent seven years as a machinist with Valley Mine Service before joining the staff in physics. Bell and his wife Jami live in New Tazewell, Tennessee, which means he has an hour-long commute to work, but he said he doesn't mind it. He hit the ground running in the spring, immediately getting an out-of-commission CNC (computer numerical control) lathe working, and has become a great addition to the physics department staff.

Faculty

The department suffered a great loss with the departure of **Professor Pengcheng Dai.** He joined the faculty in 2001 and was named a Joint Institute of Advanced Materials Chair of Excellence in 2008. He is also a Fellow of the APS and AAAS. Dr. Dai built a very prolific research program at UT in experimental condensed matter physics, focusing on studies of high-temperature superconductors with inelastic neutron scattering. He moved to Rice University last summer. We all wish him the very best with his future endeavors. The department hopes to replace Dr. Dai in the very near future.

In Memoriam

The department is sad to announce the passing of **Glen H. Cunningham** on June 24th at the age of 84. Alvin Nielsen hired Glen in 1966 as the first director and at the time the only employee of the newly-created electronics shop. Glen was a Navy veteran of WWII, serving as an electronics technician on a heavy cruiser during the war. Though he retired in 1987, his work left a lasting and positive effect on the department. Under his guidance the shop grew to a highly competent organization and remains so to this day.

The department lost another great friend and colleague with the death of **Professor John Oliver "Ollie" Thomson**, who passed away October 28. He was 83. Ollie joined the department in the 1960s and also maintained a long affiliation with Oak Ridge National Laboratory, first in the Physics Division and later in the Condensed Matter Sciences Division. His interests were broad, ranging from nuclear-solid state physics and superconductive phenomena, to an experimental test of Weyl's theory, to a search for fractionally charged macroscopic particles. With great enthusiasm, he vigorously pursued his interests, whether physics, music, skiing, or antiques. His congeniality and joie de vie will be sorely missed.

The Society of Physics Students co-hosted noted theoretical physicist Michio Kaku for a public lecture at UT on November 14. Kaku (center, red tie), poses with physics students, who had the chance to meet with him for a Q&A session after the talk. UT's SPS was also recently named an Outstanding Chapter for the 2012-2013 academic year by the national SPS organization.

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(Gift records forwarded to the department dated June 1, 2013 through October 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
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Undergraduate Awards

- The Douglas V. Roseberry Memorial Fund
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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."

Big ORANGE GIVE

When UT launched a 125-hour online giving campaign during Homecoming Week (November 4-9), the goal was to raise $125,000. When all was said and done, friends and alumni more than doubled that number, donating a total of $250,105. Learn more about the program at bigorangegive.utk.edu.

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