PHYSICS & ASTRONOMY
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NEWSLETTER
CrossSections

IT TAKES A VOLUNTEER | **CONDUCTING RESEARCH THAT MAKES LIFE & LIVES BETTER**

Focusing on Fundamentals

You may not realize that you're carrying around a little bit of neutron star inside. Or that this sentence won't take long to read, but the technology that made it possible took decades of scientific discovery and creative thinking. From astrophysics to quantum materials, massive stars to atoms, the physics department engages in fundamental research that helps explain the world we live in and improve how we live in it. With awards totaling more than $6 million, **Andrew Steiner** and **Steve Johnston** provide two examples.

Neutron Stars as Labs

Steiner, associate professor, is the principal investigator on a $3.25 million National Science Foundation grant to establish the Nuclear Physics from Multi-Messenger Mergers (NP3M) Focused Research Hub.

Andrew Steiner

Steve Johnston

When the core of a massive star collapses under the weight of its own gravity, the result may be a black hole, or a much denser neutron star. The 2015 detection of gravitational waves—"ripples" in space-time set off by black hole collisions—not only won a Nobel Prize but also gave astrophysicists an additional tool to observe objects in the universe. In 2017 scientists detected a gravitational wave signal from the collision of two neutron stars.

For millennia the best information neutron stars provided to curious astronomers came from photons—quanta of light. Having additional data from gravitational waves ushers in a new era of "multi-messenger" astronomy. Coupled with advanced computational power, this approach can help scientists create ever-more sophisticated simulations to link their neutron star observations to nuclear physics and help them answer fundamental questions about matter.

"One way I like to think of it is using neutron stars as a laboratory," Steiner said. "Everything is made out of atoms and nuclei, and nuclei are dictated by how neutrons and protons interact. One way of understanding how they work is by pushing them a little in one direction or the other. We make them a little hotter, a little denser; we put them in a different environment (or) give them a little bit of a magnetic field—all of these things are kind of knobs that we turn so that we can figure out more about what's going on. Neutron stars allow us to study matter in many different ways."

He explained that the detection of gravitational waves was a strong indicator that neutron star mergers play an important role in creating heavy nuclei, such as the iodine necessary for our thyroids to function.

"We all carry a little neutron star within us," Steiner said.

The NP3M collaboration includes another 13 senior investigators (including UT Physics Professor **Raph Hix**) representing universities and national laboratories across the United States, as well as collaborators from across the world. The program emphasizes training a diverse cadre of new doctoral graduates to ensure a next generation of scientists will broaden the field and carry the research forward.

Giant Strides from Small Systems

Like Steiner, Johnston uses modern computational tools to pursue fundamental research, though the systems he studies are much, much smaller. His interests lie in quantum materials.

Continued on page 3

FULFILLING UT'S STRATEGIC VISION | **IT TAKES A VOLUNTEER**

What's Inside

Change

Change is happening fast, and this year it has been dazzling.

At the institutional level, we have witnessed a significant overhaul of our general education curriculum with the introduction of the new Volunteer Core Curriculum in fall 2022. This was needed to better meet the needs of our changing student populations and to improve their readiness for the future workforce. Meanwhile, the university is transitioning from an incremental budgeting model to a new Budget Allocation Model that aims to better align resources with strategic priorities, create greater transparency and accountability, and give colleges and departments more control over their own revenue and expenditures. It is meant to incentivize academic entrepreneurship. Finally, with an eye towards 2050, the university is evaluating its academic organizational structure and is asking us to imagine new structures that would promote greater innovation, agility, and collaboration. Amidst these changes and uncertainties, all of us are still navigating the pandemic and its impact on the work experience and student learning. As a result of the pandemic, college enrollments are dropping nationwide. UT appears to be an exception, however, as our numbers keep increasing. Even in this changing economy, college remains your best chance for landing a rewarding job, and we seem to be getting that message across.

The physics department is undergoing its own transformational processes, trying to anticipate the future lay of the land in terms of increased student numbers, instructional needs for diverse student populations, curricular development, research, and innovation. On the research side, we have seen some major programs take off, including several multimillion-dollar initiatives. Associate Professor **Andrew Steiner** is leading a National Science Foundation-funded Focused Research Hub in Theoretical Physics to probe the properties of hot and dense nuclear matter with advanced computational modeling, simulations, and ‘multi-messenger’ astronomical observations of merging neutron stars. Associate Professor **Steven Johnston** is leading a multi-institutional collaboration on the design of “Quantum Materials for Transformational Technologies” via artificial intelligence and machine learning. The Department of Energy’s Office of Scientific Research is funding this effort. Meanwhile, the department is moving ahead with the formation of an interdisciplinary faculty cluster in quantum materials and recruited Assistant Professor **Ruixing Zhang** and Professor **Alan Tennant**. Both have split appointments with the Department of Materials Science and Engineering. Dr. Zhang was a postdoctoral fellow at the Joint Quantum Institute and member of the Condensed Matter Theory Center at the University of Maryland. His expertise centers on topology and quantum dynamics in condensed matter systems. Dr. Tennant is a widely acclaimed and prize-winning international leader in quantum matter research and directed major scientific user facilities and renowned research institutes. He will be joining us in January 2022. This spring we hope to hire three additional faculty for the quantum cluster. With these new initiatives, we are also building new interdisciplinary courses at both the graduate and undergraduate levels.

Our high-energy physics program also got a boost recently with the hiring of Assistant Professor **Lawrence Lee**. Larry came to us with a PhD from Yale and postdoctoral experience at the University of Adelaide and Harvard. He was involved with the ATLAS experiment at the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland, looking for ‘long-lived particles and “supersymmetry.” He recently joined Professor **Stefan Spanier** and Assistant Professor **Tova Holmes** with LHC’s sister experiment at the Compact Muon Solenoid detector. Last but not least, we are searching for a junior faculty member in theoretical multi-messenger astrophysics, who will complement our strengths in supernova science, neutron star theory, and nucleosynthesis. With the advent of gravitational wave astronomy, multi-messenger astronomy and astrophysics have become some of the most exciting and fastest growing fields in all of science, and we are excited that the department is venturing into this area.

Arguably the biggest or most notable change is the introduction of a BA program in Physics. It replaces the less flexible BS General Concentration and is part of a comprehensive curriculum overhaul that also strengthens the Academic and Astronomy Concentrations within the existing BS program. The modernized BS program provides a stronger physics and mathematical foundation for the upper-level courses and generates more options for students who wish to enrich their curriculum with elective courses in their field of interest. The BA program, on the other hand, will provide an attractive and less daunting access to the physics major. It will appeal to students who are interested in physics but may be less mathematically inclined, or to those wish to double major with a professional degree program such as a business, pre-health, or pre-law. The overarching objectives are to provide students with many more options, to increase the number of physics graduates, and to shorten their time towards graduation. All these changes will take effect in fall 2022, pending final approval of the new BA program by THEC and the UT Board of Trustees. This has been a major undertaking by the undergraduate curriculum committee, led by Professor **Tony Mezzacappa**. I would like to acknowledge Associate Head and Professor **Kate Jones** in particular as chief architect of the BA program and lead author of the proposal to THEC, and Undergraduate Program Director and Associate Professor **Christine Nattrass** for her always thoughtful advice and help with the practical and administrative implementation.

It is easy to forget that change can only take root in an environment that provides steady support with existing operations and new implementations. In our department, faculty and students enjoy rock-solid support from our support staff, be it the administrative staff, business office, IT and technical support, and others. Their workload increases each year and that is not always recognized. In short, they are amazing and that never seems to change!

I hope the year 2022 will bring welcome changes for you and your loved ones and I wish you a wonderful holiday season and a healthy and prosperous 2022.

> "The physics department is undergoing its own transformational processes, trying to anticipate the future lay of the land in terms of increased student numbers, instructional needs for diverse student populations, curricular development, research, and innovation."

Focusing on Fundamentals, Continued

From the first transistor to supercomputers that can perform 200,000 trillion calculations per second, science and engineering have made giant strides in developing tools that make our lives safer, healthier, and easier. Advances in materials enabled this progress. For example, modern computing would not be possible without semiconductors. Similarly, future revolutions in science, engineering, and technology will be driven by advances in quantum materials.

Johnston, an associate professor, sees the origins of such enormous gains at the microscopic level. Capitalizing on UT's multidisciplinary expertise, he won $3 million in support from the US Department of Energy Office of Science to use artificial intelligence in predicting how quantum materials behave.

Where quantum mechanics are in play, atoms and their smaller constituents can behave in ways that defy classical expectations. Electrons, for example, typically repel one another. Yet in correlated quantum materials they react so strongly with each other that their properties can become strongly coupled and entangled. Understanding the behavior of such strongly interacting systems is a grand challenge of modern science, but has merit well beyond scientific curiosity.

The surprising phenomena that emerge in quantum materials have the potential to transform billion-dollar industries ranging from consumer electronics, classical and quantum computing, medicine, and energy production, storage, and transmission. Johnston sees these novel properties as a path to revolutionize technology. Designing those materials, however, requires solving some complex problems.

"If you want to engineer quantum materials for specific purposes then you need to understand the microscopic origin of their behavior," he said.

"This is becoming particularly evident when you start coupling different materials together, and new unexpected functionality appears at the interfaces between them. As we develop new quantum materials and incorporate them into novel devices, we need to identify which factors control this functionality."

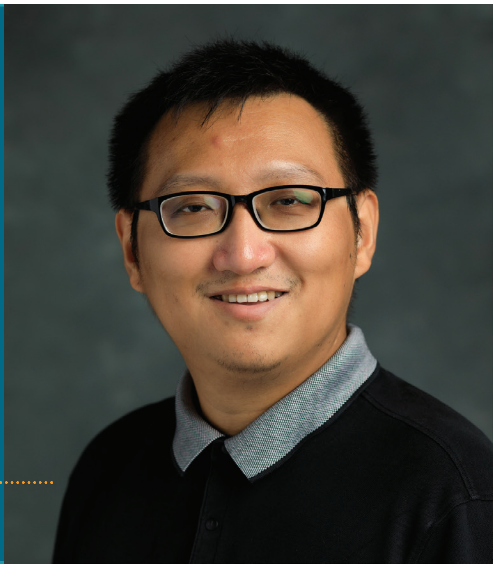
He and fellow researchers will use artificial intelligence and machine learning tools to develop computational frameworks for untangling the complexity of these systems.

"Creating these types of methods requires expertise at the interface between physics, electrical and computer engineering, computer science, and materials science," Johnston said. "UT's ability to lead projects like this is tightly linked to institutional support of interdisciplinary initiatives like the Quantum Materials for Future Technologies cluster."

Though their labs may be as large as stars or as small as atoms, UT's physicists build collaborations to pursue the fundamental research discoveries that drive innovation and make life, and lives, better.

A Quantum Universe

Ruixing Zhang is part of the Quantum Materials for Future Technologies Cluster, which combines expertise from multiple disciplines to build a dynamic research and development presence in quantum science, artificial intelligence, and their technical applications.



As a kid, **Ruixing Zhang** loved to look up at the night sky and stargaze, inspired by the vast wonders overhead and the beauty of nature. He followed that curiosity to become a physicist and now explores the smallest of physical systems, each a universe of its own.

Zhang, a condensed matter theorist, joined the faculty in August as an assistant professor. As an undergrad at the University of Science and Technology in China, the Dongying native was drawn to particle physics, but by the time he finished his bachelor's degree in 2012 his motivation to understand the universe took a different direction.

"That's when I started to appreciate the beauty of quantum materials," he said.

Each quantum material, he explained, can be thought of as a quantum universe with its own rules. (The electrons and quasiparticles inside it are more like stars and galaxies.)

While classical physics describes a system such as a ball falling from a balcony, that model doesn't work in a microscopic system. Quantum mechanics defies the predictable when electrons and particles interact or behave in unexpected ways. Though atomic scale materials may seem mysterious, they're actually part of our everyday experience.

"Quantum materials are basically everywhere," Zhang explained. "Without understanding them, we would not have our hard drives, our central processing units … they're all based on the state-of-the-art understanding of these quantum materials."

Dividing the Electron Highway

Zhang is particularly interested in topological systems, whose properties remain unaltered even if a material is moderately disordered or deformed.

"For me there are two major motivations for understanding topological quantum materials," he said. "We want to understand them and see how they can actually better serve us and also give a boost to modern technology."

He explained that energy dissipation in electronic devices is one important example. If you're watching a movie or working on your laptop, you'll notice the device gets hotter. That heat comes from energy dissipation. Topological quantum materials can curtail those losses by providing electrons with a more orderly traffic pattern.

"The reason an electric current can generate heat is because these moving electrons are bouncing back and forth, getting scattered because of impurities in the materials," he said. "In some sense it's like if you're driving on a very crowded street, you can't drive very fast."

He continued: "In some topological materials we can have one-dimensional electron channels where electrons can only move to the left, and in some part you can have some other channels where the electrons can only move to the right, like a divided highway. Everyone is moving in one direction. This is how you can promote energy efficiency if you're making electronic devices with these materials."

This is one motivation for Zhang's work with quantum materials. Another is their potential to help scientists realize anyons.

"We call them fractionalized quasi-particles," he explained. "An anyon can be made of a thousand electrons: it's like a composite object. But the surprising thing is, it can only behave like a fraction of one single electron."

Anyons are interesting to physicists like Zhang in part because they're exotic and also because they could be the foundation for topological qubits, which in turn can be used as building blocks for quantum computers.

"I think the most exciting aspect in quantum science is how we can make use of quantum materials to revolutionize our way of processing information," he said.

Combining Talent for a Quantum Future

Zhang earned a PhD in physics at the Pennsylvania State University in 2018 and then joined the University of Maryland Joint Quantum Institute as a postdoctoral fellow. Next he came to UT as part of the university's cluster hire program in Quantum Materials for Future Technologies and holds a joint appointment with the Department of Materials Science and Engineering.

"When I first saw the opening, I was super excited, because you were asking for exactly the person that I am," he said.

The cluster combines expertise from multiple disciplines to build a dynamic research and development presence in quantum science, artificial intelligence, and their technological applications. Faculty from physics, computer science, and materials science and engineering all play a role.

"We all have partial overlaps with each other's research interests, but we all have some different expertise and directions," Zhang said. "We're creating links."

He's already working with experimentalist **Joon Sue Lee**, assistant professor of physics, on higher-order topological materials and has been actively interacting with other faculty members in both departments to establish collaboration opportunities. He's also excited about collaborating with the new cluster hires who'll join the university in the coming months, including physicist **Alan Tennant**, who arrives in January. In the meantime, two students have joined his group and one postdoc is joining in mid-January 2022. Zhang enjoys mentoring young scientists, both in research and in the classroom.

A Physicist's Life

Though he had a teaching release for his first semester, Zhang chose to postpone it so he could get a jump on classroom experience. He'll teach Structure of Matter in the spring (a joint physics/engineering course) and started off last fall by teaching Electricity and Magnetism.

"I love teaching," he said. "You design the course and you see the students become excited about learning something new. (You) see that they make progress and improve their understanding—it's really rewarding for me."

For Zhang, the most important elements of teaching are communication and direction.

"I learned a lot about teaching this course from my students," he said, laughing.

Once the term started he surveyed the class and let them vote on whether they were happy with his approach or would like to see some changes. They indicated they'd like to see more examples worked out, so he updated his format to include more handwritten examples in the classroom.

"That helped me understand better what the students need," he said.

Zhang's, teaching, research, and even his hobbies have an underlying theme—appreciating the beauty of something and pursuing it joyfully. His outside-of-physics interests range from photography to badminton to singing. He's also an avid cook—a skill he started developing when he moved to the US and missed dishes from home.

"If you start appreciating the beauty of cooking, then you can start to enjoy it," he said. "I'm good at appreciating the beauty of something."

From the wonder of the stars he watched growing up to the right combination of ingredients in the kitchen or a syllabus, seeing that beauty is key.

"Enjoying the research subject that I'm working on, or enjoying the life of being a physicist, that's actually a very important thing," he said. "In research you will encounter a lot of difficulties (and) different problems. You need to have some motivation to keep you moving forward. For me, that motivation is to enjoy the beauty of the research subject I'm working on and also to enjoy the life of a physicist."

> "We all have partial overlaps with each other's research interests, but we all have some different expertise and directions … we're **creating links**."

Sharing a Collaborative Spark

Larry Lee can look out over his classroom of physics majors and empathize. As an undergrad he struggled with the very same course—down to the identical textbook. Yet classical mechanics became one of his favorite classes once he saw how it fit into everyday life. Helping his students make those connections for themselves is part of what he's excited about as a new assistant professor.

Falling in Love with Physics

When he joined the department in August, Lee hit the ground running both in teaching and research. He taught undergrads and a graduate seminar. He expanded UT's research involvement at the Large Hadron Collider (LHC) at CERN. This path would have surprised him as kid, back when he had no idea what a physicist was. But the makings were there, as he knew at a young age he wanted to understand the most fundamental ideas.

Lee hails from South New Jersey, in the suburbs of Philly, and explained that "everyone from South Jersey is contractually obligated to mention that South Jersey and North Jersey are entirely different places."

Having grown up on food stamps, scarce funds meant he had to turn down more expensive colleges in favor of his home state school, Rutgers University. Even so, he still had to work multiple jobs to finance his education. At first he was focused simply on getting a degree that would lead to a good job and financial stability. Halfway through his undergraduate studies, a specific route came into focus.

"I started to really fall in love with my physics classes, but I soon started to understand that research was a profession," he said.

What's our universe made of? This is the fundamental question that intrigued him, and physics helped point him in the right direction.

"In college I started to see that the technical skills I had—computing, electronics, etc.—could be put to use to try and answer this question," he said. "So I was really pulled in. It felt very human to fall down this particular hole."

The journey wasn't always glamorous. His introduction to research came in a loading bay, where he spent hours painting metal tubes (in Rutgers scarlet) for an experiment at Fermilab.

"It was initially hard to see the connection between this and research," he said, "especially when other students were doing coding, and other things less like painting."

Still, it paid enough to let him take fewer shifts at his other jobs and showed his advisers that he was competent and reliable. Soon, they trusted him with greater responsibilities.

"In the end, it worked out great," he said.

Larry Lee joined the department as an assistant professor in August 2021. His research speciality is elementary particle physics and he's part of the CMS experiment at the Large Hadron Collider.

More (Metaphoric) Orange

After graduating in 2009, Lee enrolled at Yale University, where he earned both a master's and a PhD in physics. From the beginning his research interest has been elementary particle physics, a field that suits his inquisitiveness about nature. He found a perfect fit when he joined the ATLAS Collaboration at the LHC.

The largest detector ever constructed for a particle collider, ATLAS records billions of collisions per second to answer questions like what are the building blocks of matter and what forces govern how subatomic particles interact. Not only is this fundamental physics, it also requires sophisticated computing and provides a large international community working together to move science forward—all elements important to Lee. Postdoctoral appointments took him to Australia (the University of Adelaide) and Harvard, but ATLAS was always a common denominator.

When he came to UT, he moved to the Compact Muon Solenoid (CMS) experiment, joining Professor **Stefan Spanier** and Assistant Professor **Tova Holmes**, who's his real-life partner as well as his colleague. (He pointed out that since the beginning of 2020, the CMS group has grown by more than 200 percent.)

Lee explained CMS and ATLAS have the same physics goals and fundamental design philosophies. They sit on the opposite ends of the LHC ring and are separated by a 20-minute drive. His move to CMS magnifies UT's presence there.

"If you look out onto the collaboration, you see a lot more orange, metaphorically," he said. "This growth really means that to the highly international community of CMS, UT will have a strong record and be a major player. I see this as a moment for UT to become a significant powerhouse of LHC physics in the southeast, in the US, and throughout the international particle physics community."

Saxophones Don't Sound Like Flutes

Over time Lee realized another benefit from working on these huge experiments.

"I learned that I really love mentoring," he said. "I love training people to become physicists (and) sending them out into the world to be successful. That's the *best*," he said with genuinely happy emphasis. "Nothing beats that."

As a faculty member he carries that optimism into the classroom. He taught classical mechanics in the fall, where the syllabus began with "Welcome to PHYS 311! This is one of my favorite classes and is a real foundational course in your undergraduate physics education. I have the privilege of introducing you to some of the most elegant techniques in the field."

His love for the subject took some time to evolve. Lee made it a point to tell students he did *terribly* when he first took the class at Rutgers.

"I literally have the same copy of the same book that I learned from," he said. "I hated it. I just felt so lost, because I was really unprepared when I took it."

By the second semester, however, he started to understand what the actual physics was.

"In a course like this, you can relate everything you learn to everyday experience. It was the eventual understanding that the system can describe everything: earthquakes; why a saxophone sounds different from a flute; all the way up to what the Higgs Boson is. It's all the same math. It's such a fundamental piece of physics. Once I understood how applicable it was to my everyday life, it was a game-changer."

That's the experience he wants his students to have. He's especially pleased to be teaching at a public university, where opportunities are available to a much larger community.

"I see in UT a community that is very similar to what I had in undergrad," he said. "The real beauty of state schools, of public education, is that if you can wade through the sea of people between classes, the departments are so large and so full of world-class work, that anyone can have access to a world-class education. I grew up on food stamps—I'm the first in my direct familial line to graduate college, let alone get a PhD and become a university professor."

Collective Creativity

From the classroom to enormous international collaborations, Lee attributes success to a few fundamental elements: communicating well, being open-minded, and sharing a creative spark.

"Collective creativity—that's how you create new knowledge," he said. "Someone comes up with something and others catch that spark. In physics the only way to effectively increase our understanding of the universe is in collaboration."

In the best collaborations, he explained, "just conversing with someone who has a different view or a different skillset, you can really produce something that is far greater than what you could have done individually. Open-mindedness is super important, which of course also means supporting DEI initiatives because the more perspectives, the better for the research."

Creativity underlies his hobbies as well. He's a mushroom hunter and passionate cook, as well as a scientific musician. Lee designed the ColliderScope project, combining oscilloscope music with sights and sounds from the LHC, and, in collaboration with Holmes, played European festivals before the pandemic hit.

"COVID really shut down my budding electronic music career," he said, though he hopes to revive it stateside when life gets back to normal.

Until then, teaching and research will help provide a creative outlet for sharing that collaborative spark.

"Being able to be here and provide opportunity to those that don't know they can have it—that's the thing I'm most excited about," he said.

"The real beauty of state schools, of public education, is that … the departments are so large and so full of world-class work that anyone can have access to a world-class education."

Learning World-Class Physics in Their Own Backyard

High School Physics Academy Brings UT Research to Local Schools

Nineteen students file in with backpacks and laptops, many bundled up in hoodies against the chill of a gray December afternoon. Among them it's easy to spot the iconic Chuck Taylors and phones and at least one notebook with colorful sketches, notes, and stickers. They take their seats and chat amiably as they pass around copies of a worksheet they need to complete.

Anthony Mezzacappa will be providing the answers.

This is **Brooke Carter**'s astronomy class at Knoxville's L&N STEM Academy, but today she's ceding the floor to Mezzacappa, professor of physics at UT. He'll walk students through the death of massive stars—a battle of forces in David and Goliath fashion—as part of a high school academy program where physics faculty bring their work to local schools. That includes topics like quantum physics in everyday life and the cosmic origin of the periodic table.

On this afternoon Mezzacappa is explaining *Research on the Origin of the Elements in Your Own Backyard*. He asks what comes to mind when students think of the universe.

"Space," one answers. "Finite," says another. "Expansive," says a third.

Mezzacappa nods, encouraging more input. He tells them people shouldn't feel disconnected from the universe because "we're made of the same stuff.

"We have 10,000 more atoms in our bodies than there are stars in the universe," he says. "We are 65 percent oxygen."

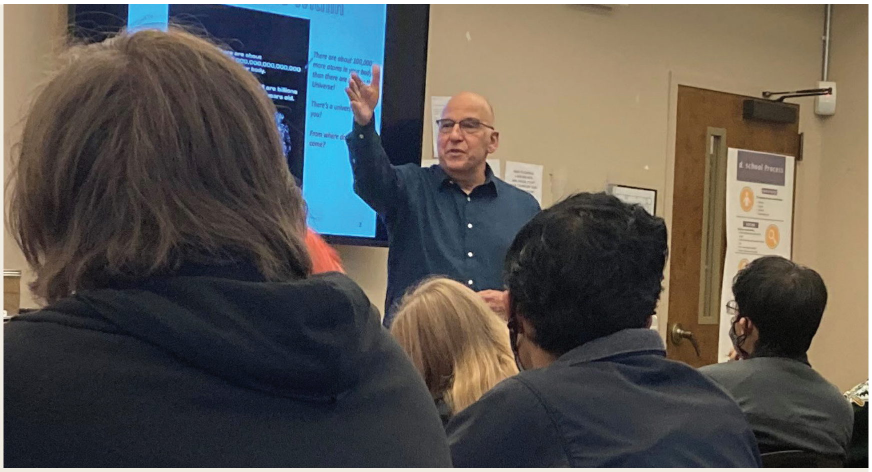
All of that oxygen comes from the death of massive stars. Over the next hour Mezzacappa leads the class through the cosmic soup, sharing colossal battles between electromagnetic and strong forces and tales of the neutrinos who re-launch shock waves through stars. He talks about how stars are born and die, and how one day Betelgeuse, currently situated comfortably in the constellation Orion, will "go supernova."

The reference to "your own backyard" in his title is literal, he tells them, because UT and Oak Ridge National Laboratory are truly in their backyard and if they have an interest, it's a great place to learn more about astrophysics.

"We've worked with high school students," he tells the class. "We've *published* with high school students. So if you're interested, reach out."

It's Personal

What led Mezzacappa to Carter's classroom actually began in another Knoxville school five years ago. His children attended West High School and he built on that connection (as well as the school's International



Left: Professor Anthony Mezzacappa with Brooke Carter ('17), now a teacher at the L&N STEM Academy in Knoxville, and speaking to her classroom. Through the high school physics academy program, students learn about world-class research right in their own backyard.

HAPPY BIRTHDAY SIGMA PI SIGMA!

A once-in-a-century party: Sigma Pi Sigma turned 100 on December 11 and our SPS chapter held an early celebration on December 3.

Baccalaureate program) to invite physicists from UT to speak to science classes. A pilot program launched in 2016 with two presentations.

Meanwhile, Carter was finishing her bachelor's degree in physics at UT ('17) and went on to become a science and math teacher at the L&N STEM Academy. As an undergrad she worked with Professor **Kate Jones**, who connected her to Mezzacappa, and in 2021 the high school physics academy became the West High School & L&N STEM Academy, with nine guest lectures between the two schools in the fall of 2021.

"The teachers who are willing to do this are the linchpins," Mezzacappa said, referring to Carter and Tommy Eggleston at West High.

He's working with Knox County Schools to find future candidates, eyeing a slow expansion that grows in the smartest, most sensible way and includes a broader reach of schools across the city. (The name will no doubt change.) The speaker list has expanded to 11 physics faculty and Mezzacappa said new professors are excited about signing on.

The academy has proven to be a hit with students. Carter said they survey classes after talks and the response is overwhelmingly positive.

"It's a good way to show research that's actually happening," she said. "What does research look like; what are the applications? The kids love it."

UT Physics faculty evidently love it too.

"The professors are reacting the same way as the kids," Mezzacappa said, and that enthusiasm can be contagious. He knows this from personal experience.

Growing up in New York, he was 16 when he was introduced to relativity and there was, in his words, "no looking back." Ultimately he earned a PhD at the University of Texas at Austin Center for Relativity and went on to become an astrophysicist. Now he helps lead international collaborations from his professorship at the University of Tennessee.

"These kids are just like I was," he said. "Some, I hope, will choose physics because of this program. Part of the motivation is to show them they don't have to go elsewhere to study physics. We have world-leading groups."

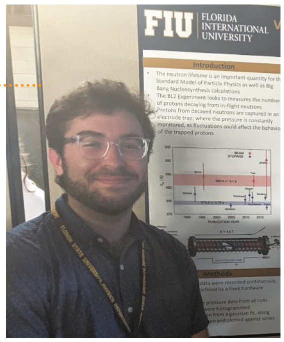
What began as a dad volunteering in the classroom has become a program where high school students hear about international research going on at their hometown university. Mezzacappa said the most important element isn't all that complicated: commitment from the educators involved.

"It just takes a group of people who really care and know that it's important to do this," he said.

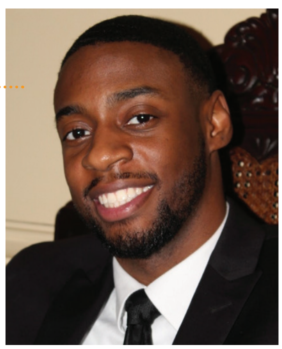
> "Part of the motivation is to show them they don't have to go elsewhere to study physics. We have world-leading groups."

To learn more about the program, visit ***www.phys.utk.edu/WHSPA.html***

Diversifying Nuclear Physics & Building New Relationships



Alejandro Cepero



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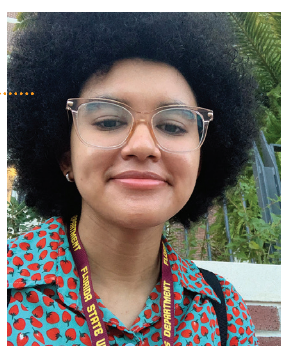


Gema Villegas

Nadia Fomin had a straightforward goal in mind: recruit students from underrepresented groups to go into nuclear physics, adding diversity and strength to the field. **Alejandro Cepero, Thaddeus Smith, and Gema Villegas** wanted to bolster their research experience and learn more about nuclear physics opportunities. With funding from the US Department of Energy for the Nuclear Physics in Eastern TN (NPET) fellowship program, those objectives aligned perfectly.

Recruiting Tomorrow's Physicists

An American Physical Society Study showed that only about 13 percent of physics undergraduates in 2018 identified as being from underrepresented racial and ethnic groups. Fomin, an associate professor, recognized the opportunity to strengthen nuclear physics as a whole by attracting students from a broad range of backgrounds and experience. Engaging them as undergraduates might well persuade them to pursue graduate degrees and become the professors and national laboratory scientists of the future. NPET is the result of that ambition.

Fomin recruited UT Physics faculty and scientists from Oak Ridge National Laboratory (ORNL) to serve as mentors, guiding students through projects in neutron beta decay, nuclear astrophysics, and the nuclear physics of neutron stars, among others. NPET launched in June 2021 with a cohort of 10 fellows from Minority Serving Institutions across the country. For now, the program is virtual because of the pandemic. Students worked full-time in the summer, transitioning to a 15-hour-per-week schedule in the fall and spring while they resumed their studies. Workshops on career development and practical skills round out the program.

Stars, Neutrons, and a GODDESS

Smith is a senior at Fisk University in Nashville and was excited to apply when he learned about the fellowship.

"I thought it was a really good opportunity to get some hands-on learning in the field," he said.

He's paired with ORNL's **Steven Pain** on the GODDESS detection system, which supports experiments that illuminate the structure of exotic nuclei.

"I'm working on (monitoring) the health of the GODDESS detector system at ORNL while experiments are taking place and also after (they've) taken place," he said. "What makes that kind of unique is that ideally, you should be able to monitor it from different places."

For Smith, having a mentor is a key element of the fellowship. He said he appreciates guidance on "learning how you show the work, organize the work, and all the soft skills in between."

Villegas is a physics major at Florida International University (FIU) in Miami and for her, applying to the program had a decidedly personal motivation after navigating a tough semester during COVID that left her feeling depleted.

"I wanted to answer the question, do I really want to keep taking classes?" she said. "I know I love physics. That's my passion. I know that's what I want to do. I just wanted to know if the sacrifice was worth pursuing my passion."

The NPET fellowship answered that question.

"I've loved it," she said. "My experience has been great. I basically found the answer that I was looking for."

She's working with Associate Professor **Andrew Steiner** and is trying to model what a neutron star looks like inside, with an eye toward applying that model to neutron star merger simulations.

"In those extreme events we can learn a lot about questions physics wants to answer," she said.

She presented her work at the November 2021 meeting of the Southeastern Section of American Physical Society (SESAPS), as did Cepero, a fellow FIU panther. He works with Fomin and her graduate student, **Jimmy Caylor**, on the measurement of the neutron lifetime.

"I've learned a lot working with Nadia and Jimmy," he said. "Even if I change directions, the experience will help me no matter what I do in the future."

A Great Experience

While this year's program was distance-based, all three students said that didn't lessen its value. While in-person contact would have been ideal in some cases, they were still able to do computational modeling or data analysis from home. The online approach reinforced other skills and actually made the program possible for some fellows.

"I would have loved to be at Oak Ridge and see everything," Smith explained, "but at the same time it also gave me a sense of freedom to be able to work separately."

Managing his assignments independently so he was ready for informal discussions taught him how to stay organized so he was always ready to contribute.

"Whenever I present research, or new progress points, or even just write in a data log—it really helped me build up some skills in that department," he said.

Villegas wouldn't have been able to participate if not for the remote model.

"I didn't have the option to move for the summer," she said.

Seeing the program was virtual encouraged her to apply.

Smith, Villegas, and Cepero are all seniors set to graduate in spring 2022, working with their mentors until then. All said their advisers have been flexible and helpful about balancing projects with their respective course loads. They also had praise for the workshops where they've worked on writing resumes and personal research statements: ideal exercises for graduate school applications or job searches.

"The workshops have been so helpful," Villegas said. "They put us on a deadline. This made me accelerate the process. Now my applications are mostly done; I just have to submit them."

Like Smith and Cepero, she plans to pursue a graduate degree in physics. She knows she'll stay with nuclear physics, while her counterparts are giving the field serious consideration as what Smith calls "a heavy favorite."

As part of the first NPET cohort, they've built a network of colleagues and helped each other out with projects and ideas.

"This program has been a great experience," Smith said.

Fomin will build on this success with the next group of fellows.

"We're going to switch it to start at beginning of school year, rather than beginning of summer," she said. "That way, students slowly ramp up and learn about the physics of the projects they'll be working on, so when they show up in person in the summer of 2023, they can hit the ground running."

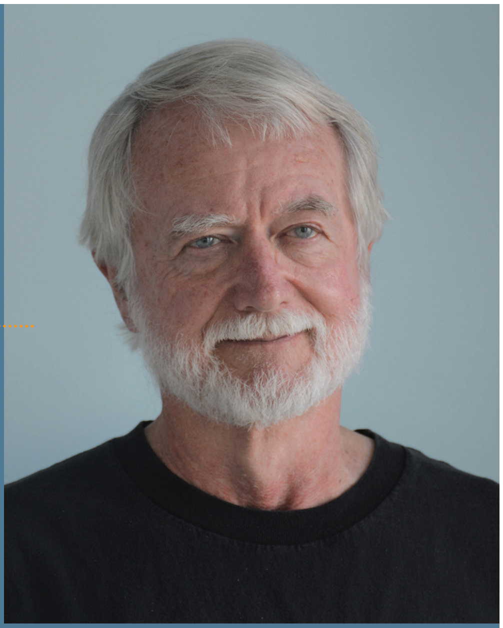
Nadia Fomin accepts the 2021 Francis G. Slack Award from SESAPS Chair Mohammad Waseem Ahmed

Nadia Fomin Honored with Francis G. Slack Award

Nadia Fomin concentrates on the fundamentals. In her research, that's the building blocks of matter: nucleons and their constituents, quarks. In her commitment to the nuclear physics community, that's encouraging scientific collaboration and creating student opportunities. For her dedication to physics in the South, the Southeastern Section of the American Physical Society (SESAPS) awarded her the Francis G. Slack at the 2021 meeting.

The Slack Award recognizes scientists who work unselfishly to raise the region's stature in physics through research, university service, outreach, and support for organizations and conferences. Fomin, an associate professor who joined the physics faculty in 2013, has thrown her energy into these endeavors from the outset with leadership roles in both SESAPS and the American Physical Society Division of Nuclear Physics. She has organized and hosted in-person and virtual meetings, organized the 2019 National Nuclear Physics Summer School, and won funding for NPET (featured on these pages). Two of her students won Department of Energy Graduate Student Research awards in 2020 for their work with her group.

Swimming in the Primordial Soup



Former Department Head Soren Sorensen retired in August after 37 years with the university. During his career with UT he was named Chancellor's Professor, Macebearer, and the SPS Teacher of the Year.

Soren Sorensen has earned some impressive (and interesting) titles between joining the faculty in 1984 and retiring in 2021. Chancellor's Professor and Head. Macebearer. Muffin Man. All have to do with his commitment to both science and the people he's encountered during his pursuit of it. The last speaks to his innate ability not to take himself too seriously, despite a laudable career in nuclear physics that began in a 1960s classroom in Denmark.

A Would-Be Astronomer

Sorensen grew up in the suburbs of Copenhagen, where he took his first physics class in sixth grade and was immediately intrigued by the idea that physics deals with the most fundamental aspects of nature.

"Initially I wanted to become an astronomer, but when I started in college and realized that I could be a student at the Niels Bohr Institute and learn from the world-class researchers there, I became hooked on studying physics," he said.

He went on to earn both master's (1977) and doctoral (1981) degrees at the institute, housed at the University of Copenhagen. During a postdoctoral appointment he spent a year at Oak Ridge National Laboratory, which brought him to East Tennessee. By 1984 he was an assistant professor on UT's physics faculty.

Sorensen studies nuclear matter—the stuff that makes up all atomic nuclei—and how it behaves under extreme conditions in terms of temperature and density. His interest in the fundamentals of nature goes all the way back to the Big Bang and the state of the universe immediately after, known as the Quark Gluon Plasma. His contributions to research on this "primordial soup," as he calls it, won him election as a Fellow of both the American Physical Society and the American Association for the Advancement of Science.

Sorensen's work also put him in the company of countless other scientists and students over the years, including the PHENIX collaboration at Brookhaven National Laboratory and ALICE at the Large Hadron Collider. Spending time with colleagues from all walks of life proved to be a bright thread in the tapestry of his research.

"An important lesson that my career taught me, that was not taught during my time in college, was the importance of positive personal interactions with my peers," he said. "Science is a wonderful combination of solitary contemplations and intense human interactions, and I have come to appreciate the importance of these human interactions more and more as my career progressed."

Leadership, Honors, and Pigskin Pick'Em

In 2000 Sorensen took on a new challenge as head of the physics department. For 12 years he handled committee assignments, tenure dossiers, development and all other tasks, large and small, required in the role. Sometimes that meant budget hearings with the dean. Sometimes it meant sharing birthday cake in his office with the physics staff. Reflecting on that period, he counts hiring "wonderful people" as his proudest achievement.

"In a maybe too simplistic way you can say that the only thing that really matters for a head is to hire, and to give tenure to, the right people," he said. "And I feel we did hire many great people."

Sorensen's commitment to the personal—to actively looking for every person's potential and nurturing their growth—fuels his dedication to diversity initiatives across all levels: from the whole of physics to individual research groups. His combined scholarship and leadership have not gone unnoticed. In 2016 UT named him Macebearer—the university's highest faculty honor. Alongside that accomplishment are two Teacher of the Year Awards, equally important to him, bestowed by the department's Society of Physics Students.

Sorensen has always loved being in the classroom, typically teaching the introductory honors course for undergraduates. His students not only learned about mechanics and thermodynamics but also earned T-shirts emblazoned with "I survived Soren's freshman honors physics class." He's been known to wear one himself, as he's quick to appreciate a good joke.

This was evident in 2003, when one of his hobbies—using computational tools to rank football teams—took on higher stakes. Sorensen was among the "Pigskin Pick'em" group across campus, ultimately ending up in a final showdown with the *Daily Beacon*'s sports editor, who extrapolated from Sorensen's Danish heritage a relationship with all pastry items and dubbed him the "muffin man." Sorensen wasn't bothered in the least. He enjoyed being part of the campus community beyond his role as a physicist and professor.

With his August 2021 retirement, he'll have more time for football fanship and other hobbies. (He plans to improve his sports team ranking system with modern tools like artificial intelligence.) He has a stack of books he wants to read, and is working on a biography of his father, who died when he was a young child. The top priority, in keeping with his way of doing things, is people, especially his wife Dianna and their kids and grandkids.

"The oldest of the grandchildren is 21 and studying art at UT and the youngest is eight months old and studying how to progress from crawling to walking," he said.

That doesn't mean Sorensen won't be around the department. He plans to mentor graduate students and will have a lifetime of experience to offer them. No doubt he'll teach them a storied career is built by engaging with, and supporting, other people.

> "Science is a wonderful combination of solitary contemplations and intense human interactions, and I have come to appreciate the importance of these human interactions more and more as my career progressed."

Soren in the classic "I survived Soren's freshman honors physics class" T-shirt.

An Ongoing Neutron Mystery

Geoff Greene may have officially retired from the university, but he's by no means going to abandon the neutrons he's been following closely for most of his career. Their relationship dates to when he was fresh out of graduate school, but his love for science began much earlier.

A Good Book Makes All the Difference

"I was always interested in mechanical things and in science," Greene said, "but a huge influence was a book I read in junior high school called *One Two Three … Infinity* by George Gamow.

"Gamow was a great physicist and gifted popularizer of science," he explained. "*One Two Three … Infinity* discussed transfinite numbers, relativity, cosmology, quantum mechanics and more in an amazing and accessible way. I was hooked."

Greene took that enthusiasm to Swarthmore College, where he earned a BA in physics and played on the baseball team. He went on to complete both master's (1974) and doctoral (1977) degrees at Harvard University, where he pulled for the Boston Red Sox, whose triumphs and heartbreaks he's shared ever since.

After graduate school he worked at the Rutherford Appleton Laboratory in Oxford, England, and the Institut Laue Langevin's high flux reactor in Grenoble, France. This scientific globetrotting set the path for his life's work.

"During that time I first learned about neutrons, which have been a passion ever since," he said.

Specifically, Greene's passion is pinning down how long a neutron lives. How a neutron decays is a window into how the sun produces energy and why the Big Bang left us with a balance of elements that supports life as opposed to a vast emptiness.

Greene has followed these questions for decades. After a stop on the Yale University faculty, he went to the National Bureau of Standards (now the National Institute of Standards and Technology) where he focused on the measurement of fundamental constants: descriptions of the particles and forces that make up our universe and how they interact. From there he went to Los Alamos National Laboratory to help set up a fundamental neutron physics program. He served as deputy director for research at the Los Alamos Neutron Science Center (LANSCE), home to one of the country's most powerful linear accelerators.

Geoff showing off some Volunteer pride (inset) on top in Nepal (Lhotse in the background) and spending some time in what he hopes will be his new office during retirement.

Cold Bottles of Neutrons

Always following—and developing—the best tools, Greene came to UT in 2002 with a joint appointment at Oak Ridge National Laboratory. The national lab is home to the Spallation Neutron Source (SNS), which was then under construction. Greene rolled up his sleeves to build the Fundamental Neutron Physics Beamline. Of all the SNS beamlines, it's the only one that studies the neutron itself, rather than using it to study other materials.

There are two approaches for measuring neutron decay: beams and bottles. The first, which Greene uses, looks at the rate at which neutrons in flight decay. He has colleagues elsewhere who use bottle-driven experiments, yet the two methods reach different conclusions, with a gap of about 10 seconds. The neutron lifetime is still an unsolved mystery, with plenty more ground to cover.

Greene has spent time at nearly every facility in the world that does this kind of neutron science. He drew on that experience to develop fundamental neutron programs in the US and build facilities that move this research forward. He also served on the Nuclear Science Advisory Committee, which helps federal agencies map out the country's nuclear physics agenda. In 2021 the American Physical Society awarded him the Tom W. Bonner Prize for Nuclear Physics in recognition of these contributions.

Making QM Popular

Since arriving at UT two decades ago, Greene has embraced the role of professor. He's mentored graduate students in nuclear physics, served on the department's planning committee, and managed to turn quantum mechanics into the most popular undergraduate physics course (the students showed their gratitude with the 2011 Teacher of the Year Award). He's also quick to give credit to physics faculty and staff who've supported his work, especially Associate Professor **Nadia Fomin** and the **entire staff of the department's machine shop**. In 2016 the university awarded him the Alexander Prize for his superior teaching and distinguished scholarship.

A dedicated mountaineer, Greene has carried UT's colors to summits across the Alps and the Himalaya and hopes to find more time for this and other hobbies in retirement. There will, once COVID recedes, be more skiing, hiking, and spending a good deal of time with his family, now as a new grandfather. He also plans to continue working on the neutron lifetime project with Fomin. The neutrons may be decaying … but they aren't going anywhere.

In Memoriam

The department's success has been shaped by the talent, dedication, and vision of gifted scientists over the decades—some with full-time university appointments and others with connections that strengthened our research profile and broadened opportunities for our faculty and students. We were saddened by the loss of so many of them in 2021.

John Cooke

John Cooke passed away on January 5, 2021. He was a theoretical condensed matter physicist and an expert in magnetism who was instrumental in promoting the joint faculty program between the physics department and Oak Ridge National Laboratory. After retiring from ORNL, Cooke maintained close ties with the physics department, taught graduate courses, and made it a point not to miss the weekly colloquium.

Tom Ferrell

Tom Ferrell passed away on October 18, 2021, after a brave battle with ALS. He was a research professor with UT Physics and a distinguished staff scientist at Oak Ridge National Laboratory. Ferrell worked with colleagues in UT's Department of Electrical Engineering and Computer Science as well as ORNL on instruments and devices for biomedical and condensed matter systems. He also worked closely with the late Rufus Ritchie, a distinguished physics alumnus whose research on surface plasmons opened an entire new vista in physics research.

Paul Huray

Paul Huray, a UT Physics Distinguished Alumnus, passed away January 28, 2021. A gifted researcher and teacher, he helped found the university's Science Alliance Program and served as its first director. The Science Alliance became the home of the Distinguished Scientist program, which has brought outstanding scientists to the university, especially in physics. He became a senior policy analyst for the White House and went on to an illustrious career at the University of South Carolina. In 2010 the department honored Huray with the Distinguished Alumni Award "for leadership in establishing and directing the Science Alliance and building the relationship with Oak Ridge National Laboratory, his excellence in teaching physics, and his research in solid-state physics."

Gerald Mahan

Gerald Mahan, one of the original UT-ORNL Distinguished Scientists, passed away November 22, 2021. He was the first UT faculty member to be elected to the National Academy of Sciences (1995) and leaves an impressive legacy as a scientist and a professor. Mahan was a theorist who described his research in solid state physics and materials as part pure research and part applied technology. In 1984 he was one of the first two professors to be appointed a Distinguished Scientist in a new Center of Excellence, the Science Alliance. The Distinguished Scientist program recruited internationally prominent scientists to jointly-appointed faculty positions at the university and research positions at Oak Ridge National Laboratory. Mahan's respective homes were UT Physics and Astronomy and the ORNL Solid State Division. He left the university in 2001 to become a Distinguished Professor at the Pennsylvania State University and was a Distinguished Emeritus Professor there when he died.

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After a two-year hiatus due to the COVID pandemic, the department's Women in Physics Lunch tradition restarted on December 2, 2021. Graduate and undergraduate students, as well as post-docs and faculty, participated. The next lunch is set for Wednesday, May 11, 2022.

CrossSections