PHYSICS & ASTRONOMY
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SPRING 2023

CrossSections

Where Instability is a Good Thing

In November FRIB published the first paper from its first experiment. UT's physicists built the tools that made it possible.

What's Inside

Message from the Departing Head

HANNO WEITERING

On August 1, **Professor Adrian Del Maestro** became the new Head of the Department of Physics and Astronomy. Adrian joined the faculty just two years ago as the first senior hire for the faculty cluster in Quantum Materials for Future Technologies. He came to UT with impeccable credentials: an MS from Yale and PhD from Harvard, postdoctoral positions at the University of British Columbia and Johns Hopkins, and a distinguished faculty career at the University of Vermont.

Since his arrival in 2020, Adrian continued his highly successful line of research, working at the interface of quantum many-body physics and information theory, and played a key role in expanding the quantum materials cluster. He also developed new courses such as an interdisciplinary machine learning course that appears to be in great demand. Now, he has taken it upon him the lead the department through these tumultuous times.

Departmental leadership changes every so often. Since our beginning in 1908, we have only had seven department heads: **James Porter** (1908- 31), **Kenneth Hertel** (1935-56), **Alvin Nielsen** (1956-69), **Bill Bugg** (1969-1995), **Lee Riedinger** (1996-2000), **Soren Sorensen** (2000-2012), and yours truly (2012-2022).

As with all administrative jobs, the pressure and workload increased steadily over the years. Ever stricter emphasis on regulatory compliance and the non-stop rollout of new initiatives from higher up constantly demand the Head's attention. Fortunately, in many ways the university is changing for the better and this offers the Head opportunities to strategize, try new things, and hopefully reach for the stars. This has been the fun part of my job.

The physics department is doing very well and this truly has been a collective achievement. My predecessor, **Professor Soren Sorensen**, already left the department in an excellent shape, but the age distribution of the faculty was quite worrisome. Anticipating many upcoming retirements, we needed to recruit aggressively, but the country was hit with a recession that was impacting UT's budget. Faculty replacement is very costly, and I was convinced that at best we could hope for was a leaner and meaner physics department. Meanwhile we were confronted with departures of some of the department's top faculty (Nazarewicz, Dai). What I couldn't imagine at the time was the incredible support we would get from the College that helped us thrive this past decade. Importantly, the economy also turned around. Since 2012 we hired 20 tenure-line faculty (some with shared appointments), one centrally funded Joint Faculty, three full-time lecturers, and five new staff members. Fourteen faculty members either retired or left for other reasons. We have grown from 26.1 to 33.6 tenure-line FTEs with a total faculty count of 41. The average faculty age dropped from about 55 to 50.5.

I am still not quite sure how this all happened. However, we can all be thrilled with the caliber of the people we hired. We should credit the respective search committees and especially the search committee chairs for all the hard work they did in recruiting so many excellent candidates. We can all marvel at their wisdom in selecting our finalists. Meanwhile, our young faculty are very successful with teaching, research and funding. They are rising through the ranks and are making their mark on the department. They also bring a lot of enthusiasm and passion for shared governance and improving the departmental climate and educational experiences of our students.

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"I AM PROUD OF THIS DEPARTMENT AND THE THINGS WE COLLECTIVELY ACHIEVED. BUT NOW IT IS TIME FOR A NEW FACE AND A FRESH PERSPECTIVE, SOMEONE WITH LOTS OF ENERGY AND DRIVE. I FEEL VERY CONFIDENT LEAVING THE DEPARTMENT'S MANAGEMENT IN ADRIAN'S CAPABLE HANDS."

—PROFESSOR HANNO WEITERING

ADRIAN DEL MAESTRO

Excited to be Along for the Ride

I took over the reins as Department Head of Physics & Astronomy from **Professor Hanno Weitering** this past August, who served us selflessly and tirelessly for 10 years, and to whom I am personally thankful for his mentorship and friendship. Hanno has successfully placed our department on a trajectory with a large positive slope, and solidified Physics & Astronomy as one of the largest and most productive on campus. This was possible through our hard work, and shared sense of purpose to elevate physics research and education in Tennessee.

The past nine months have been a whirlwind of exciting and complex challenges where I have leveraged my passion for teaching and research to serve the department through advocacy and collaboration. We are facing major changes at the University level and a reorganization of our college into divisions, including one focused on Natural Sciences and Mathematics. This offers the department novel and improved opportunities to align our strategic vision with that of the College of Arts & Sciences. We continue to focus on growing our undergraduate programs through the launch of a new BA program, allowing us to attract and retain a new cohort of diverse physics undergraduates with interests that span and cross disciplines. This is being implemented alongside a refresh of our core and advanced curricula with new exciting classes on modern, mathematical, and computational physics, as well as new experiments in our advanced labs. The feedback from students has been outstanding, letting us know that they feel both prepared and engaged to tackle not only deep fundamental physics problems but also applications in addressing climate change, clean energy, and transportation.

Continued on Page 5

Message from the Departing Head, From Page 2

Physics is also doing well by other metrics. The undergraduate cohort has grown from about 80 to 140 students, and for the first time we graduated over 35 undergraduates in one year (2021) though numbers fluctuate a bit. Our graduate cohort is more diverse than ever. Physics continues to be UT's top department in terms of research funding, with annual research expenditures fluctuating between $10 and $15M. We are now ranked 36 among public universities in the latest *U.S. News & World Report,* a jump of 15 places compared to 2018.

Last year was the icing on the cake. Under the inspirational leadership of **Professors Kate Jones and Tony Mezzacappa**, we realized a major undergraduate curriculum reform, which included the creation of a new BA program in Physics. We hired four assistant professors, which also concluded the cluster hire in quantum materials, and we received the largest estate gift ever that promises to be a game changer in the way the department can promote and reward excellence.

Surely, the department faces many challenges. Achieving gender diversity remains a nagging issue. With eight women on the faculty, we are close to national average. However, recent trends showed a significant increase in the number of women faculty nationally while our recent searches fell short of this goal. With a shifting emphasis on cluster hiring and other special initiatives, it will become increasingly difficult to diversify our applicant pools. On the education front, innovation will remain key. Our graduation rates are still disappointing. Meanwhile, students are expecting more direct economic benefits from their education. They want flexible course offerings, online courses, certificate programs, and online degree programs. While the department has made great strides by offering more course online, much work remains to be done to develop these courses while faculty are already overcommitted. Excessive workload, pressure and anxiety is affecting faculty, students and staff alike and remains a concern.

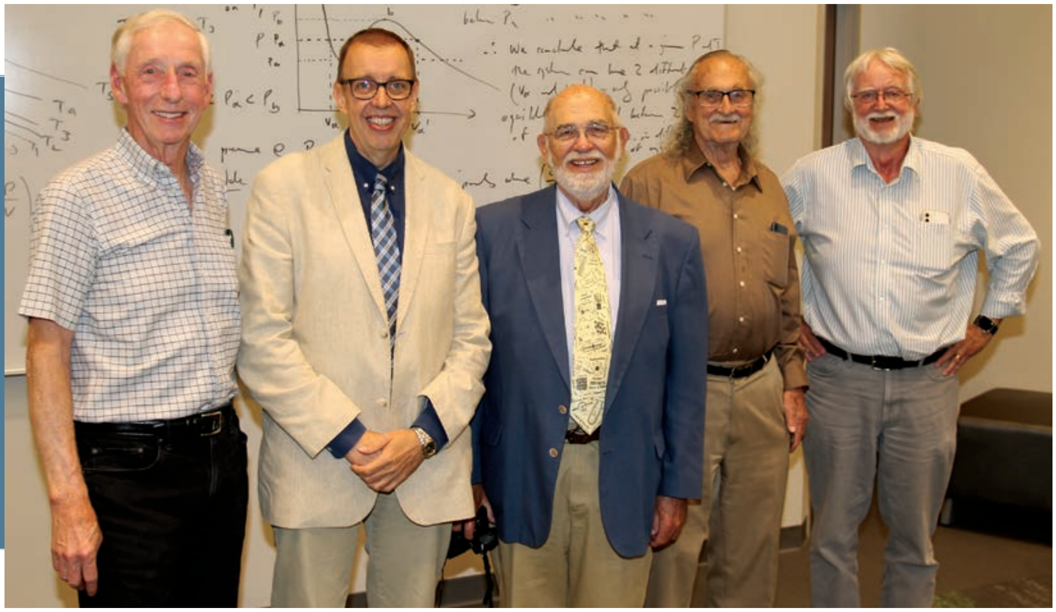
Departments are facing uncertainty in light of the university's implementation of a new budget model, also known as the RCM model. While these changes are not supposed to impact departments directly, at least for now, it is not clear how the College will be able to support competitive faculty startups. This, of course, directly impacts our ability to hire new faculty. This is only one of many concerns though we are told not to worry.

Stepping down brings mixed emotions. I am eager to get back into research. Condensed matter physics is evolving rapidly and it just seemed impossible for me to keep up. The Institute for Advanced Materials and Manufacturing (IAMM) is an exciting place to work and I greatly enjoy working with the quantum materials group. Hopefully we can land a big center grant together as it would be a major boost for our reputation and our ability to attract the best and brightest. But I will miss the daily interactions with my colleagues in Nielsen. My management team, with **Associate Heads Kate Jones and Marianne Breinig and Undergraduate Laboratory Director Dr. Christine Cheney**, was absolutely fantastic. Together we made many tough decisions, but those were made in good spirit and always leaving room for humor. Without the incredible effort of the departmental staff, the department would not function at all. I always felt very confident delegating some of the most important matters to the staff because I knew I can always trust and rely on them. This trust is absolutely critical.

I am proud of this department and the things we collectively achieved. But now it is time for a new face and a fresh perspective, someone with lots of energy and drive. I feel very confident leaving the department's management in Adrian's capable hands. He will provide inspirational leadership for years to come, and it won't be boring. Godspeed Adrian!

HW, August 2022

A LEADERSHIP REUNION (2022): LEE RIEDINGER, HANNO WEITERING, JAMES PARKS (RETIRED ASSOCIATE HEAD), BILL BUGG, AND SOREN SORENSEN.



Excited to be Along for the Ride, From Page 3

I have been incredibly lucky to have the confidence, support, and efficiency of an amazing team who have helped get me up to speed allowing me to focus on a number of initiatives. These include better communicating our shared successes through a new "This Week in Physics" update at the colloquium, new partnerships with Jefferson Laboratory via a Bridge Faculty position (stay tuned), streamlining our digital collaboration mechanisms, and investing in our large cohort of junior faculty members. This newsletter includes features on two of these amazing young professors (**Yishu Wang and Wonhee Ko**) who are members of our Quantum Materials for Future Technologies Cluster, which has made Tennessee a major destination for cutting edge research in this area. (**Professor Alan Tennant,** also featured in this issue, is part of the quantum cluster as well, bringing to our faculty the expertise of his distinguished scientific career.)

We celebrated one retirement this winter, with **Joint Faculty Professor Mike Fitzsimmons** leaving the department in January. Mike joined us in 2016, holding a joint appointment with Oak Ridge National Laboratory, and demonstrated profound intellectual curiosity in all things he did. His service to the department will be sorely missed. We wish him all the best as he takes on new national challenges at the U.S. Department of Energy.

The University of Tennessee is one of the great land grant universities in the country, and our mission is clear: to serve all Tennesseans and beyond through education, discovery, and outreach that enables strong economic, social, and environmental well-being. The Department of Physics & Astronomy is committed to this mission, and I'm excited to be along for the ride.

ADM, April 2023

A CENTURY OF LEADERSHIP

PHYSICS DEPARTMENT HEADS (1908-2022)

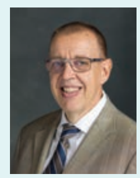
JAMES T. PORTER
1908-1931

LEE RIEDINGER
1996-2000

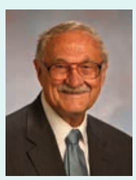
KENNETH HERTEL
~1931-1956

SOREN SORENSEN
2000-2012

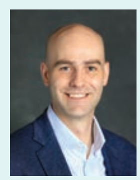
ALVIN NIELSEN
1956-1969



HANNO WEITERING
2012-2022



BILL BUGG
1969-1996



ADRIAN DEL MAESTRO
2022-

"THE UNIVERSITY OF TENNESSEE IS ONE OF THE GREAT LAND GRANT UNIVERSITIES IN THE COUNTRY, AND OUR MISSION IS CLEAR: TO SERVE ALL TENNESSEANS AND BEYOND THROUGH EDUCATION, DISCOVERY, AND OUTREACH THAT ENABLES STRONG ECONOMIC, SOCIAL, AND ENVIRONMENTAL WELL-BEING."

—PROFESSOR ADRIAN DEL MAESTRO

Where Instability is a Good Thing

The email came with a simple subject line: "Now with ribbon."

Professor Robert Grzywacz was at Michigan State University sending photos as dignitaries cut a giant green ribbon to open the Facility for Rare Isotope Beams (FRIB). For him and his colleagues it was more than christening a powerful research facility. It was a new chapter in a story of scientific creativity, and community, and turning drawbacks into opportunities.

Things Fall Apart

Grzywacz, like **Professor Kate Jones** and **Assistant Professor Miguel Madurga**, dwells in the land of low-energy nuclear physics. They're interested in how a nucleus is structured, how stable it is, and the way its components interact. Rare isotopes are an ideal vehicle to find out.

FRIB creates these exotic nuclei by stripping electrons from stable atoms and guiding the resulting ions into a linear accelerator where they travel faster than half the speed of light. When the beam hits a target, nuclei lose protons or neutrons, creating unstable, short-lived rare isotopes. FRIB can stop and re-accelerate the beam, filtering out isotopes so that researchers get the ones they want.

Studying isotopes as they fall apart gives scientists a window into a nucleus's innermost mysteries, knowledge that moves science forward and also meets practical needs.

"There are applications from medical imaging and therapy to energy," Jones explained.

In June FRIB completed its first experiment. Scientists slammed a stable beam of calcium-48 into a beryllium target. The fragments from that collision gave them a bunch of exotic isotopes to study. Observing their decay, which takes less than a second, led to the first reported measurements of half-lives for five exotic isotopes of phosphorous, silicon, aluminum, and magnesium. The findings were published in *Physical Review Letters* as the first paper from FRIB's first experiment.

"This result builds on a lot of our past work," Grzywacz said.

Making those measurements required sophisticated instrumentation called the FRIB Decay Station initiator (FDSi), a system he knows well.

Finding a Silver Lining

The FDSi didn't come out of nowhere. It's descended from generations of detectors designed before FRIB was born. Grzywacz has been part of this effort since 1998, when he started proposing experiments at FRIB's predecessor, the National Semiconductor Cyclotron Laboratory (NSCL).

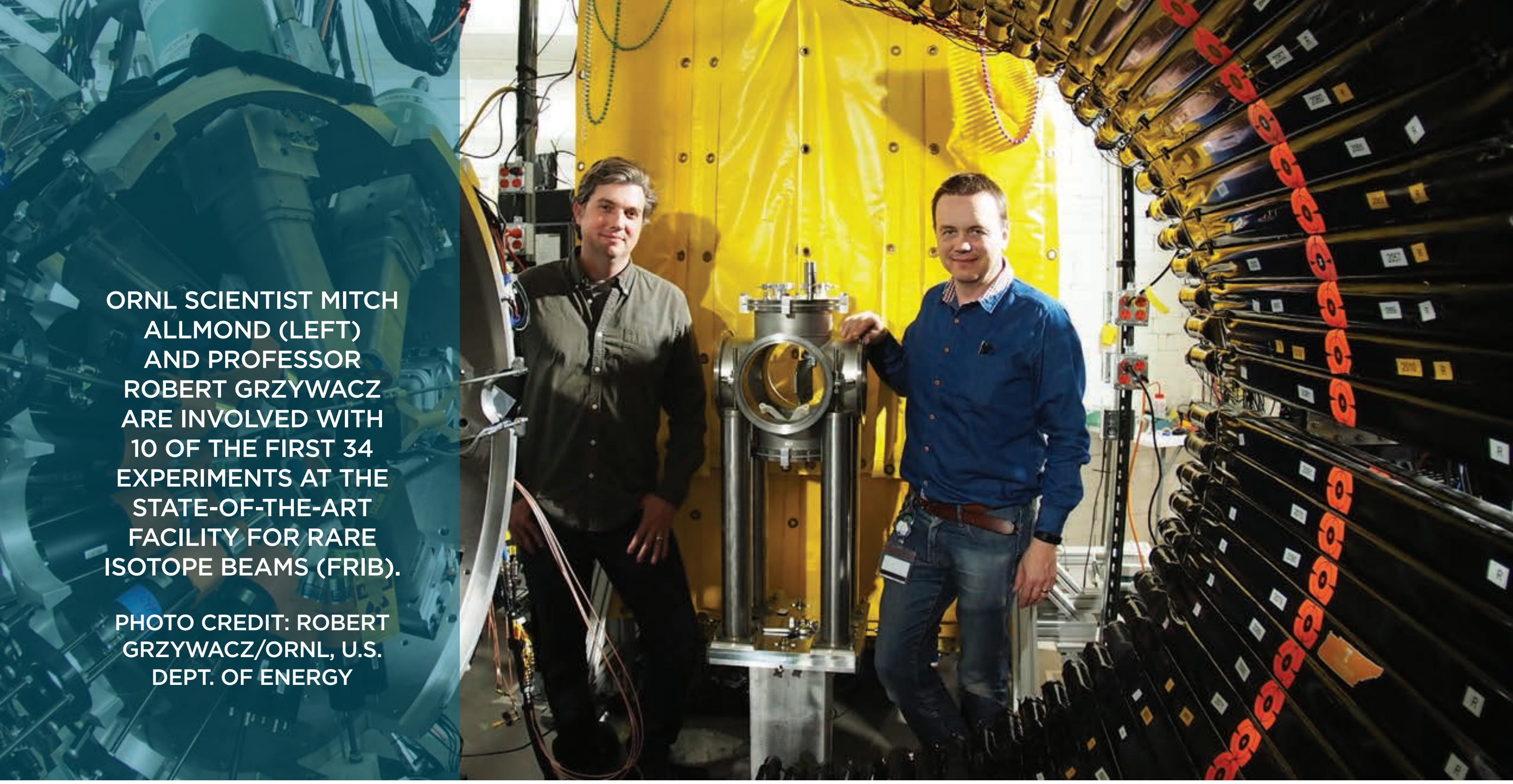
The facility was nearly 20 years old and "the nuclear physics community was in the process of discussing what and where the new generation facility (would) be," he said.

At the time, he and Jones were deeply integrated at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL). Grzywacz's group built and contributed to new instruments to study radioactive, neutron-rich isotopes. They were the first to use digital signal processing broadly for nuclear spectroscopy experiments for low-energy nuclear physics. They partnered with industry to develop a digital data acquisition system (which eventually made its way to FRIB).

Among their key accomplishments was building a suite of instruments to detect and measure decay patterns. **Krzysztof Rykaczewski** led an ORNL-centered program with buy-in from other universities (Georgia

"THE FUTURE OF LOW-ENERGY NUCLEAR PHYSICS IN THE U.S. DEPENDS TO A LARGE EXTENT ON THE SUCCESS OF FRIB. WITHOUT BUILDING NEW FACILITIES IT WOULD BE DIFFICULT FOR THE U.S. TO STAY AHEAD IN OUR FIELD."

—PROFESSOR KATE JONES



ORNL SCIENTIST MITCH ALLMOND (LEFT) AND PROFESSOR ROBERT GRZYWACZ ARE INVOLVED WITH 10 OF THE FIRST 34 EXPERIMENTS AT THE STATE-OF-THE-ART FACILITY FOR RARE ISOTOPE BEAMS (FRIB).

PHOTO CREDIT: ROBERT GRZYWACZ/ORNL, U.S. DEPT. OF ENERGY

Tech, Louisiana State, Mississippi State, and Vanderbilt) through the University Radioactive Ion Beam Consortium (UNIRIB) and the Joint Institute of Nuclear Physics and Applications (JINPA).

"The decay program at HRIBF was strong and unique," Grzywacz said.

In 2008, the U.S. Department of Energy decided the future was with FRIB and in 2011 HRIBF was closed. Despite their disappointment, Grzywacz and his colleagues found a silver lining.

"The scientific strength of the research program at HRIBF and available instrumentation encouraged us to engage in the construction of one of the key FRIB projects: the FRIB Decay Station," he said.

Use What You Have

The FRIB Decay Station (FDS) focuses on four strategic areas: nuclear structure, nuclear astrophysics, tests of fundamental symmetries, and applications of isotopes for society.

In 2016 some 60 scientists gathered at JINPA and established the FDS collaboration, with Grzywacz as spokesperson. The FDS would be a new instrument: an efficient, modular system of multiple detectors under one infrastructure that would provide parallel and simultaneous measurements. It came with a hefty price tag, so in the interim researchers formed the FDS Initiator (FDSi) group.

"This project aimed to realize the FDS vision but using existing instrumentation," Grzywacz said. "The FDSi was to provide a unified framework for the variety of instrumentation provided by the community. The essential elements of the FDS were to be realized by existing detectors."

In August 2021 FDSi went into production with a talented, collaborative cast.

ORNL staff led by **James Allmond** designed the elements and led construction. Machinists from UT Physics made precision parts for the frame. UT's low-energy nuclear physics group built new detectors, making sure they could be integrated in FRIB's digital data acquisition framework. Grzywacz came up with the idea of using two focal planes for easy switching between two sets of apparatus, as well as the designs for the implantation detectors. These are necessary to stop the nuclei and measure the charged particle decays.

While this was happening the FRIB Program Advisory Committee announced the first approved experiments. Of 34 accepted proposals, eight included the FDSi.

By February 2022 FDSi installation began at Michigan State. In June the system was ready for the calcium fragments that came its way, as were Grzywacz and Madurga; **graduate students Ian Cox and James Christie; and postdocs Noritaka Kitamura, Kevin Siegl, and Zhengyu Xu**, all of whom worked on FRIB's inaugural experiment.

Twelve Neutrons from Stability

After years of work to get FRIB up and running, scientists can now reap the benefits. The FDSi is one of multiple instruments along the beam, giving them lots of options to explore nuclei.

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In December Jones used a high-resolution spectrograph and gamma-ray energy tracking array in an experiment on the structure of light tin isotopes.

"Tin is magic," she explained. "It has 50 protons, which forms a closed nuclear shell."

The isotopes Tin-100 (50 neutrons) and Tin-132 (82 neutrons) are "doubly-magic."

"Doubly-magic nuclei are cornerstones of the nuclear shell model," Jones said. "Knowing the single-particle states outside of these nuclei allows theorists to calculate the properties of more complex nuclei."

Tin-112 is the element's last stable isotope. This makes Tin-100, at 12 neutrons from stability, particularly difficult to reach.

"The further from stability, the harder isotopes are to produce," Jones said. "Hence, FRIB."

By knocking out a neutron from Tin-104, her group will get a look at the states in Tin-103. They expect the ground and first excited states to have the same nature as Tin-105 and Tin-107. Ultimately, as they get closer to Tin-101 (which can be reached when FRIB reaches full power) they anticipate those states will be flipped.

This kind of research—learning about the structure of key exotic nuclei—is in line with FRIB's aspiration to be the world's leading laboratory in rare isotope science.

The Nuclear Family

A premier research facility needs a community with a shared purpose. Grzywacz and Jones's nuclear connections span decades and continents. Grzywacz still works with colleagues from his alma mater, the University of Warsaw. Jones can trace her nuclear family's roots to her undergraduate days at the University of Surrey and follow them through postdoc appointments across Germany and France, where she and Grzywacz met. FRIB is home to scientists they've met along the way as well as former students and postdocs they've mentored. And, of course, there's **Witek Nazarewicz**, a longtime professor of physics at UT before he signed on as FRIB's chief scientist.

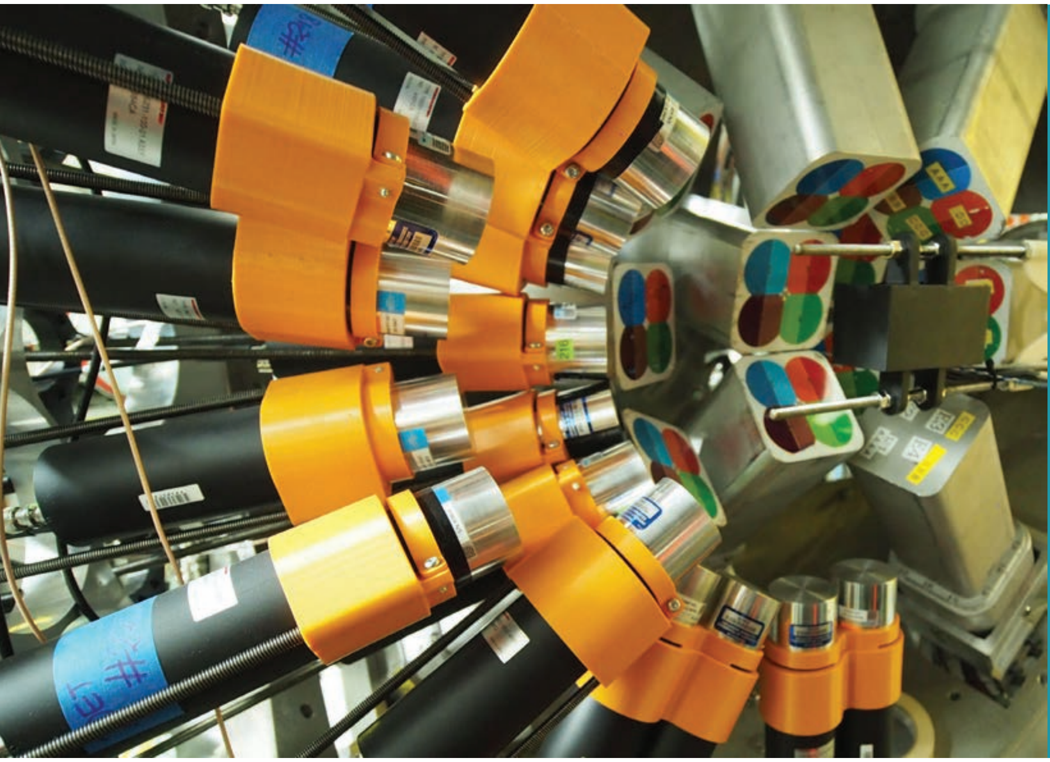
"There is a scientific community around FRIB that we are integrated in," Jones said. "There are people who are critical links in making FRIB happen, such as those who develop the rare ion beams, who we met back in Europe or here in East Tennessee."

This community is essential for FRIB, and nuclear science, to thrive.

"The future of low-energy nuclear physics in the U.S. depends to a large extent on the success of FRIB," Jones said. "Without building new facilities it would be difficult for the U.S. to stay ahead in our field."

She and Grzywacz met some of their colleagues long before they celebrated the ribbon-cutting at FRIB's opening. The importance of those early (and continuing) ties can't be overstated.

"There are decades of knowledge that are passed between researchers, not only in papers, but working together in labs, at workshops and conferences, and teaching in classrooms and professors' offices," Jones said. "If you break the chain, it's hard to rebuild."



ON THE COVER:

This is a part of the FRIB Decay Station Initiator, a detection system designed for the complete spectroscopy of decays of exotic nuclei. It consists of two detector arrays, one for high-resolution gamma and neutron spectroscopy and one for total absorption spectroscopy arranged in a tandem configuration installed at the end of the FRIB electromagnetic fragment separator the Advanced Rare Isotope Separator (ARIS). It enables studies of the same isotopes in one setting. The LaBr3 detectors in orange mounts belong to UT.

WHAT IF WE THREW A PARTY AND EVERYBODY CAME? THEN IT'S AN SPS PARTY.

Another Top Chapter Honor for SPS

They painted pumpkins and hiked in the mountains; celebrated a national birthday and threw a bash for the entire department. For the ninth time in 10 years, UT's Society of Physics Students (SPS) earned Outstanding Chapter honors for their hard work and contagious enthusiasm. They learned in December they were among only 86 of 844 chapters nationwide who won this distinction for the 2021-22 academic year.

A Home in the Department

William Greene served as secretary on last year's executive board and is the current chapter president. He credits SPS with giving him a sense of place at UT and volunteers his time to help the organization thrive. "SPS at the University of Tennessee has really helped me feel at home as a physics major in our department," he said. "I am very thankful that I had the opportunity to help our chapter get the national recognition it deserves."

That acknowledgment came after a busy year for these enterprising undergraduates. They hosted a Halloween party where they showcased their pumpkin decorating skills, threw a party to celebrate the national SPS centennial, hiked to Grotto Falls in the Smokies, and attended the annual SPS zone meeting in Kentucky.

The group is eager to keep that momentum going.

"SPS is my favorite thing about going to UT," said **Luke Carpenter**, a senior physics major. "I think it really strengthens our physics community and provides a wealth of opportunities for research and engagement. I know we do great work, and I'm excited to continue that in the future!"

Assistant Professor Maxim Lavrentovich is the group's faculty sponsor. In December he got word from the national organization that UT's SPS chapter was again selected as among the best in the country. This was no surprise, as he's seen firsthand how the students support not only one another, but the department (and the field) as a whole.

"I would say that the most important function of the SPS has been connecting undergraduates to the broader physics community, both within UT and externally, including representing our department at PhysCon and SESAPS (Southeastern Section of the American Physical Society) meetings," he said.

Among his favorite events was an inaugural end-of-year celebration.

End-of-Year Magic

UT's SPS won funding for, organized, and hosted a soiree for the entire physics department in the spring of 2022.

"It was a wonderful dinner with many speakers and surprises, including a magic show," Lavrentovich explained. "They made everyone feel welcome, including the graduate students and professors. I especially liked the 'awards' that all attendees received, highlighting some aspect of their personality. I thought this event made everyone feel seen and appreciated."

Gage Erwin was chapter treasurer last year and is now UT's SPS vice president. He has an eye on recreating that camaraderie.

"I am glad I was a part of our chapter last year and helped with us getting recognized," he said. "The banquet was definitely big in itself; surely that deserves the most praise. We managed to bring a big portion of the physics community together and we certainly plan to do it again!"

The Right Place at the Right Time

Alan Tennant, in his telling, "kind of fell into neutrons." Even so, it takes more than serendipity to see your name consistently pop up in breakthroughs related to these seemingly mild-mannered but powerful particles.

Neutrons are the centerpiece of Tennant's work to find out what's going on in materials that drive technological progress but keep a lot of secrets. He brought this expertise to UT when he joined the Quantum Materials for Future Technologies research cluster in early 2022. With a faculty position split 50-50 between the Department of Physics and Astronomy and the Department of Materials Science and Engineering, his appointment capitalizes on his deep experience in leading through innovation.

Falling into a Neutron Revolution

Tennant grew up in Galashiels, an industrial town of roughly 12,000 near Edinburgh, Scotland. Weekly trips to the library fed an insatiable curiosity that began early. As a kid he liked to build things all the time (a trait his two kids have inherited).

"I was interested in science and physics early on," he said. "I started getting interested in lasers and things like that when I was about five years old."

After earning a bachelor's degree in physics at Edinburgh University, Tennant headed to Oxford University. He planned to go into semiconductor research and technology until Professor Roger Cowley offered him a spot in his lab. Cowley had an illustrious reputation as a solid-state physicist and neutrons played a key role in his work. And so, Tennant said, "I kind of fell into neutrons."

ALAN TENNANT

That move sparked his interest in combining computational physics with neutron technologies, especially spallation sources. Tennant saw the potential for uncovering mysteries in quantum science—systems so small that classical physics can't describe them.

"From day one I've worked in quantum," he said. "I did some calculations on what would be feasible with neutrons and quantum systems. They convinced me there was a possibility for a revolution in that experimental field, which has been happening over the past three decades. I realized neutrons were able to do something potentially significant."

Kind Particles; Killer Technique

The revolution Tennant joined is big but its components are small. Much of modern life relies on knowing what electrons do; which materials conduct electronic current and which ones keep it from moving. Semiconductors like silicon claim the middle ground and made smartphones, LED lights, and laptops part of our everyday environment. This is well-understood territory for physicists and engineers. It's also the basis of a billion-dollar industry. As devices get smaller, however, materials like silicon reach their limits. To make ever-shrinking dimensions workable, scientists need to find, or design, new materials.

At scales this small quantum mechanics runs the show. Atoms and their constituents follow different rules. You may know how electrons interact in larger systems, but here all bets are off. If researchers can define subatomic behavior in quantum materials, they can impose some sense of control over their properties and build the foundation for stronger, lighter, faster systems in fields like energy, data science, and computing. In this quest scientists like Tennant have an unassuming but mighty tool: neutrons.

These neutral particles have a lot to offer. A beam of neutrons aimed at a sample becomes a non-destructive probe. Some pass right through, but others bounce off the material's nucleus. By mapping where they scatter, scientists learn about the atoms in a sample: where they are and how they move. Neutrons can also "see" atomic spins: a hint to the magnetism they foster. A bonus is that they cause no harm, making them an ideal package for quantum science.

"Neutrons are a big part of quantum," Tennant explained. "(They're) very kind, and come in as a quantum particle. It's like a quantum probe of a quantum system."

Neutrons are especially helpful when you're looking at complex quantum materials with lots of interacting particles. Calculating their dynamics can seem overwhelming, so any help in finding patterns and clues is welcome.

"Neutrons are a killer technique for that," Tennant said.

Polar Explorer

Tennant has a history of putting the neutron's killer technique to work in groundbreaking research. While ice and fractals make for catchy lyrics in Disney's *Frozen*, he has a more scientific take. A decade ago he was part of a team that used neutron scattering to find magnetic monopoles. Magnets have a north and a south pole, but magnetic monopoles have only one. They'd been predicted by theory but never seen until Tennant and his colleagues found them in spin ices, so named because their spin interactions mimic those of hydrogen bonds in ice. The work made *Science* magazine's list of 2009 breakthroughs.

Last December Tennant and collaborators found more surprises in spin ice when they uncovered a new type of fractal (also published in *Science*). In simple terms, fractals are patterns that repeat at ever smaller sizes. They appear in nature in phenomena as varied as snowflakes and the tributaries of rivers. In this work, researchers found a fractal introduced by the interplay of magnetic monopoles and the spin ice's crystal structure. Using neutrons to reveal patterns and magnetic properties in these materials could be as important to quantum science as the understanding of electrons has been to modern electronics.

Such accomplishments have brought Tennant a raft of honors, including the EPS Europhysics Prize in condensed matter and election as a Fellow of the Neutron Scattering Society of America. While he appreciates the accolades, he doesn't see them as the ultimate mark of a successful scientist.

"Real leadership is innovating," he said. "And innovation is ultimately an intellectual and creative pursuit."

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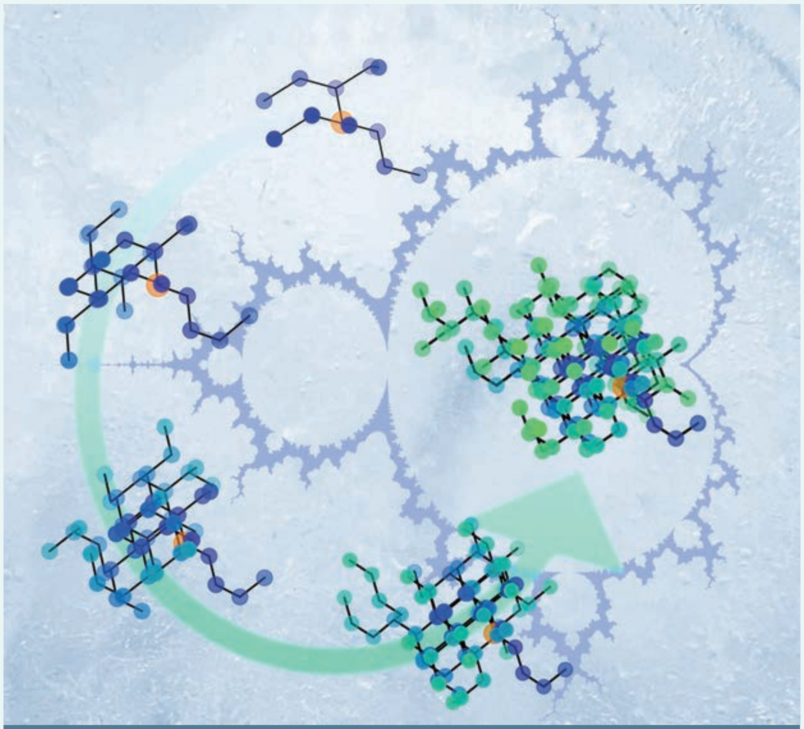


EXAMPLE OF THE FRACTAL STRUCTURES IN SPIN ICE TOGETHER WITH A FAMOUS EXAMPLE OF A FRACTAL (THE MANDELBROT SET), ON TOP OF A PHOTOGRAPH OF WATER ICE.

IMAGE CREDIT: JONATHAN NILSSON HALLÉN, CAVENDISH LABORATORY, UNIVERSITY OF CAMBRIDGE

In work published in *Science*, Tennant and colleagues found a fractal introduced by the interplay of magnetic monopoles and spin ice's crystal structure. Using neutrons to reveal patterns and magnetic properties in these materials could be as important to quantum science as the understanding of electrons has been to modern electronics.

The Right Place at the Right Time, From Page 11

Head of the Pack

Tennant has a long list of such pursuits, including teaching, research, and leadership positions in the U.S., the United Kingdom, Germany, and Denmark. He has led the Oak Ridge National Laboratory Labwide Quantum Materials Initiative, served as chief scientist of the ORNL Neutron Sciences Directorate, and been head of the Institute of Complex Magnetic Materials at the Helmholtz Center Berlin, Germany. He is currently director of the Shull Wollan Center, the successor to the UT-ORNL Joint Institute of Neutron Sciences. He's also part of the Quantum Science Center at ORNL.

Tennant said he's glad now to be firmly planted in East Tennessee with his roles at UT and the national lab. His two sons and his wife ("she's the social one, but I tag along," he joked) like living here, and they have plenty of opportunities for tennis, gardening, and other family activities. That is, when he's not doing science. His broad experience bodes well for UT's quantum cluster, which pools faculty talent across materials science, electrical engineering, computer science, and physics to position the university as a leader in quantum science.

"It's completely a team effort," Tennant said. "I think this really works, bringing people together to work on challenging problems. You want to have strength and depth where different people can take over roles."

With solid leadership in theory, experiment, and computation, he sees the university as a research powerhouse.

"That's positioning us in a very interesting realm in contemporary science," he said. "UT's becoming head of the pack in all of this. We've become nationally significant. It's the right place at the right time."

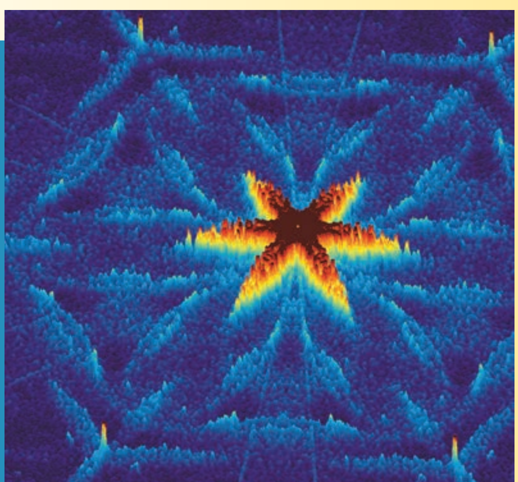
For Tennant, the cluster opportunity was a welcome return to university life after years of leading large-scale research facilities. He said teaching requires faculty to continually refresh their understanding of the basics while helping guide the field's future. Professors train students, who then train students of their own.

"In a way that's more impactful than management," he said. "You can see that reflected in why so many innovations and great ideas come from universities; because you're continuously recreating your subject." In 2023 he's teaching courses on neutron science and quantum materials open to students across departments.

"That's also part of the cluster vision," he said, "to deliver courses that can be accessed across the university and start forming a curriculum so that UT students are offered something which isn't available everywhere."

That, he said, is a unique benefit for graduate students interested in quantum science. By choosing UT, he would tell them, you'll have access to "the right people; the right research; the right courses. You're going to be prepared for the future."

Alan Tennant Photo Credit: Genevieve Martin, Oak Ridge National Laboratory



A quasi-particle interference spectrum of a monatomic superconducting tin layer on a silicon substrate. Professors Steve Johnston and Hanno Weitering; research published in *Nature Physics* and featured on the April 2023 cover.

IN CASE YOU MISSED IT

Our faculty found evidence for a chiral superconductor, reported on symmetry breaking in quantum systems, timed the checkpoints for cell division in bacteria, and calculated lead's neutron skin. Our students solved puzzles to win commemorative YETI figurines and covered UT's iconic Rock with physics. UT's physicists won prestigious university and national awards and even weighed in on the physics of taking down goalposts after beating Bama. All this and much more on our website and social channels.

Visit physics.utk.edu for news and highlights.

Cool Girls and Quantum Science

Yishu Wang didn't set out to be a scientist. She just wanted to be a "cool kind of girl" like the figures she grew up admiring (Marie Curie, Rosalind Franklin, and Chien-Shiung Wu, to name a few). It wasn't discovery or invention that first drew her to science and engineering. It was the women who'd done it before.

"Very luckily, I found out only later that the topics related to natural sciences, engineering, and technology are indeed attractive to me," she said.

A native of Zhengzhou, the capital city of China's Henan Province, Wang discovered her current research passion—quantum materials—in a classroom at Tsinghua University in Beijing.

"I first got interested in this area when I sat in an undergraduate class talking about superconductivity," she explained.

For Wang this phenomenon perfectly encapsulated theory, experiment, and technological advances. That's part of what she finds intriguing about quantum materials. She explained that under most circumstances, quantum mechanics shows up only at atomic and subatomic scales, but quantum materials embody quantum mechanics at macroscopic scales. If quantum phenomena could be realized in solid-based devices, scientists see potential gains for both fundamental and practical purposes.

"For the former, we would like to expand our knowledge of quantum mechanics," she explained. "For the latter, we hope to design functional devices with these materials which offer functions that the silicon-based devices could not achieve."

Quantum Bonds

After completing a bachelor's degree in engineering physics, Wang went on to earn a master's degree (University of Chicago) and a PhD (California Institute of Technology), both in physics. Over time she developed an expertise in quantum magnetism, which brought her to UT with a joint appointment in Materials Science and Engineering (MSE) and Physics and Astronomy. With MSE as her home department, she's also part of the interdisciplinary Quantum Materials for Future Technologies research cluster.

Wang is particularly interested in introducing device-based measurements to quantum materials and in turn applying the discovery of quantum materials to designing devices. With a foot in both MSE and physics, she's already got a strong group of colleagues who synthesize materials, develop theoretical models, and conduct experimental measurements. She sees the benefits of this collaboration for her own work as well as the broader research community.

"The complexity level of research in quantum science and technology has grown rapidly and is almost beyond (what) a single research group can comfortably handle," she explained. "To have a group of colleagues who share common interests but have different expertise is the best way to tackle challenges and make major contributions in this field. The quantum cluster is playing such a role and helps form a strong bond within our community. The access to collaboration and the quality of local discussion is going to be the valuable advantage."

Wang is already building a research group and taking her knowledge to the classroom, where she's taught an intro class on materials science and a cross-listed MSE/Physics course on the structure of matter. When she's not unravelling quantum mysteries, she said she loves to hike ("for which East Tennessee is a great place to live"), watch movies, and especially read. In fact, it was reading that introduced her to the scientific heroes that inspired her career.

"I was so charmed by their personalities and inspired by their dedication to exploring nature," she said. "I thought that was the cool kind of girl that I hoped to grow into."

The Middleman

Wonhee Ko is comfortable in the middle—somewhere between theory and experiment; industry and academia. His experience brings a distinctive perspective to his role as an assistant professor, where he's both a quantum science researcher and a mentor to young scientists.

WONHEE KO

Yes, Physics is Cool

Ko discovered an affinity for physics early on.

"I just had a general interest when I was a kid," he said. "Then around middle school I started to learn physics as a separate class and it sounded really cool to me."

A native of South Korea, Ko said science competitions were common in his early education and that's where he started to gain confidence.

"We had this physics competition and I had a good score," he said. "My teacher tried to make me take this specialized class. Learning physics theories (was) very interesting and I was good at it, so I tried to do more and more."

Ko went on to earn a bachelor's degree in physics and math from Seoul National University. Next came a PhD in applied physics from Stanford University. His dissertation was based on quantum imaging of materials, an expertise he continues to develop and brought with him to UT.

Change One Thing: Get New Physics

"Quantum is what happens when you look at the very small things; as small as individual atoms," Ko explained. "At the small scale, things behave differently from our intuition."

Researchers see this shift as the threshold for a new, post-silicon world.

"This is very useful to make new devices and new electronics," Ko said. "You can do a lot of very useful things. Now people are trying to make quantum computers out of it. That part I'm really interested in."

Ko's tool of choice is the scanning tunneling microscope, or STM. This instrument images a material's surface all the way down to the individual atoms. An STM works by running a sharp metal wire tip over a surface with an electrical voltage applied to either the tip or the material. Ko is interested in taking this a step farther by coming up with novel capabilities to find, and control, new quantum phenomena.

"(The) STM is a well-established tool," he said. "It's been there for 30 years. People know how to use it for conventional things. I'm very interested in quantum information science and for that you need to control individual quantum states. A normal metallic tip cannot do that, so to reach that goal you have to be creative and put new functionality into this machine. That's what motivates me."

Ko sees possibilities in changing the probe material—like using a superconducting tip—which he said "can give you a lot of new physics. Changing one material gives you many more capabilities."

New Science from the Middle

Ko has firsthand knowledge of how science like this plays out in the private sector. After finishing his doctorate, he spent four years on the research staff at the Samsung Advanced Institute of Technology.

"I kind of understand why it's important for industry people," he explained. "Making something (that) works right now is very important. They don't care how much it costs if it works. It's a very different mindset."

What's missing in industry, he explained, is the chance to do basic, fundamental research, which is where his interests lie.

"This experience made me want to come back to academia," he said.

He came to UT first as a postdoctoral research associate and worked in Oak Ridge National Laboratory's Scanning Tunneling Microscopy Group. He officially joined the university's physics faculty in August 2022 as part of the Quantum Materials for Future Technologies research cluster.

"UT has a very strong materials science background and also a very strong condensed matter theory background," he said. "I think I can really go in between that: get the materials, get help from the theory people, and then get new science out of this collaboration."

ALL THINGS QUANTUM

Advances in materials help drive technology and by extension the economy. With new hires and expertise already in place, the department is helping lead the university's Quantum Materials for Future Technologies cluster. Working across disciplines in theory, modeling, synthesis, and experiment, our researchers are untangling the mysteries of quantum systems to help lead the post-silicon age.


CRISTIAN BATISTA


ADRIAN DEL MAESTRO


ELBIO DAGOTTO


STEVE JOHNSTON


WONHEE KO


JOON SUE LEE


JIAN LIU


NORMAN MANNELLA


ADRIANA MOREO


GEORGE SIOPSIS


ALAN TENNANT


YISHU WANG


HANNO WEITERING


RUIXING ZHANG


YANG ZHANG


HAIDONG ZHOU

Helping Students Find the Right Path

Ko is always on the lookout for students as he builds his research program. Part of academia's appeal is the opportunity to work with young scientists. His first semester he co-taught the modern physics laboratory course and coordinated the department's condensed matter physics seminars. The spring 2023 term had him teaching a Careers in Physics seminar. This is natural fit for Ko, who also volunteers his time as a career mentoring fellow for the American Physical Society.

"I want the students to find the right career for them," he said. "If they find research is their career, I really want to help them become independent researchers. That's my educational goal."

Ko's avocations make him a relatable figure for the next generation. In addition to time with family, he likes to pursue hobbies like cooking with a little help from one of students' favorite resources.

"I watch all kinds of YouTube," he said laughing.

A Transformative Gift

It was 1964 when **Elizabeth (Liz) Miller** became the second woman to graduate from Lebanon Valley College (LVC) with a physics degree. She thought about going to graduate school but postponed her application for a year, working for the US Navy to help cover the cost before coming to Knoxville to start her studies.

Now, with a generous bequest to the UT Physics Department, she and her husband, **Jim Bains**, have ensured not only financial support for graduate students, but also more diverse representation in the graduate program.

Starting fall 2022, the Dr. Elizabeth M. Bains and Dr. James A. Bains, Jr. Graduate Fellowship provides a stipend for excellent graduate students who also contribute in meaningful ways to the department's diversity of gender, nationality, economic status, race or ethnicity. Incoming graduate students are invited to apply.

Getting Serious in Ultrasonics

Liz was drawn to UT because of the physics department's connection to Oak Ridge National Laboratory. Initially she planned to pursue either atomic or nuclear physics, but changed her mind soon after arriving, deciding on ultrastonics instead. That proved to be a pivotal decision in more ways than one. It's where fellow student Jim Bains came into the picture.

"We met in the ultrasonics lab," she told fellow LVC alumnus Art Ford as part of an oral history project. "Well, got serious in the ultrasonics lab."

Liz finished a master's degree in 1968 and a PhD in 1972. She and Jim married, and he graduated with a doctoral degree in 1974. She joked with Ford that she "was better at working with the machine shop than (Jim) was, so I helped him build his equipment."

John Cantrell (BS, 1965; PhD, 1976) and **Laszlo Adler** (PhD, 1969) were part of the ultrasonics program as well, and both remember Liz (or Betsy, as she was also known) and Jim.

Cantrell recalls Liz as "very intelligent, kind, generous, and always willing to lend a hand. She was a gifted teacher, highly regarded by her students."

She also had a myriad of interests, including the outdoors. Once during a camping trip in the Smokies, Cantrell, his wife Davie, and Liz encountered a mama bear and her curious cub, who decided to get a closer look at the humans. The mother charged, and the group made loud clanging noises with their dining utensils and backed away.

"Admittedly, the slow backing gave way to an acceleration as we approached the shelter and scampered into the upper bunks, but the tactic worked," Cantrell explained. "The cub scampered off and mama bear gave up the harassment. So, as the song goes, it pays to know when to hold them and when to fold them."

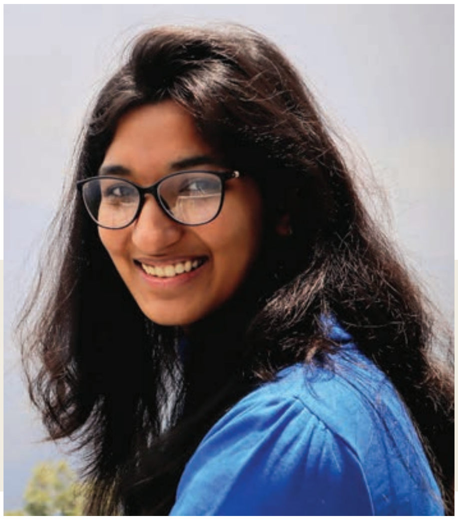
Adler also has fond memories of both Liz and Jim.

"I felt a connection with (Liz) not only as a competent researcher but also as a reliable, responsible and caring friend," he said.

His family shared dinners with her and Jim, and Liz even babysat for the Adlers' small children on occasion. He also recognized the couple's physics acumen.

"Her scientific work on measurements of ultrasonic parameters in the critical regions of mixtures gained international recognition," he

LASZLO ADLER (WITH LAB NOTEBOOK) WITH (FROM LEFT): JOHN CANTRELL, MACK BREAZEALE, KEN BOLLAND, JIM BAINS, MIKE TORBETT, AND ELIZABETH MILLER BAINS.



ELIZABETH BAINS (LEFT) AND SHRUTI AGARWAL

"THE BAINS FELLOWSHIP OFFERED ME THE OPPORTUNITY TO START EARLY ON MY GRADUATE RESEARCH ALONG WITH MY STUDIES, MAKING THE OFFER FROM UT STAND OUT."

—SHRUTI AGARWAL, INAUGURAL BAINS FELLOW

said of Liz. "Jim … was probably the best expert in electronics whom I've known at that time. Not only his knowledge was instrumental developing new research methods in the field of ultrasonics, but he developed some timing instruments for local lawyers in Knoxville."

Witnessing History & Securing the Future

With degrees in hand, the couple spent a few years in Mississippi and ultimately settled in Texas, with Liz taking a job at NASA in 1988 and Jim working in the oil industry designing equipment. Liz saw every launch of the space shuttle and described the program as her "personal history." She helped create software for the computer simulators used to train astronauts and was in charge of analyzing the assembly of the International Space Station. She retired from NASA in 2013 after earning numerous honors. In 2015 LVC presented Liz with the Distinguished Alumnus Award. Sadly, she passed away the following year, and Jim died in 2020. Yet that was hardly the end of their contributions to physics.

Five decades after they "got serious," their hard work and generosity supports outstanding young scientists who'll draw on their diverse backgrounds and experience to strengthen physics research and scholarship. The Bains' bequest, the largest gift ever made to the department, has already made a meaningful difference in the place their story began.

Shruti Agarwal is the first Bains Fellow, joining the graduate program in fall 2022 and working with Professor Cristian Batista in theoretical condensed matter physics. She earned her integrated BS-MS degree from the Indian Institute of Science Education and Research (IISER) in Mohali, India.

"The Bains Fellowship offered me the opportunity to start early on my graduate research along with my studies, making the offer from UT stand out," she said. "It has given me greater freedom to choose the research I want to pursue without worrying about the financial aspects of it. I am grateful and happy to be at the receiving end of this fellowship."

With gratitude to the Voices of Lebanon Valley College Oral History Project and The Valley Magazine.

Photo of Elizabeth Bains, Credit: Nick Gould, Lebanon Valley College.

Honors & Awards


ANTHONY MEZZACAPPA (LEFT)


ELBIO DAGOTTO


ANDREW STEINER


HANNO WEITERING

AAAS FELLOWS

3

APS FELLOWS

10


TOVA HOLMES


LARRY LEE

PROFESSOR ANTHONY MEZZACAPPA, Newton W. and Wilma C. Thomas Chair of Theoretical and Computational Astrophysics, was honored with the university's 2022 **Alexander Prize**. Named for former UT president and U.S. Senator Lamar Alexander and his late wife, Honey, the award recognizes superior teaching and distinguished scholarship. Professor Mezzacappa (pictured with **Provost John Zomchick**) has also been named a **College of Arts and Sciences Excellence Professor**.

For his "pioneering work on the theoretical framework of correlated electron systems and describing their importance through elegant written and oral communications," the American Physical Society awarded **DISTINGUISHED UT PROFESSOR/DISTINGUISHED OAK RIDGE NATIONAL LABORATORY SCIENTIST ELBIO DAGOTTO** the 2023 **David Adler Lectureship Award in the Field of Materials Physics**. The honor is awarded annually to a scientist making outstanding contributions to materials physics and who is notable for high quality research, review articles, and lecturing.

ASSOCIATE PROFESSOR ANDREW W. STEINER, who holds a joint appointment at Oak Ridge National Laboratory was elected a **Fellow of the American Physical Society** "for pioneering a data-driven approach to constraining neutron star properties and the dense matter equation of state that combines advanced statistical methods, state-of-the-art nuclear theory, experimental constraints on bulk nuclear properties, and astrophysical data." **He becomes the 10th APS Fellow on the current physics faculty**.

PROFESSOR HANNO WEITERING won a trifecta of 2022 honors. He was elected a **Fellow of the American Association for the Advancement of Science** "for outstanding contributions to the fundamental understanding of correlated phenomena at interfaces and in thin films and for distinguished academic leadership," **bringing the UT Physics AAAS Fellow count to three active faculty members**. He was selected as a **UT Chancellor's Professor**, a designation honoring extraordinary scholarly attainment in an individual discipline or field and a record of excellence in teaching and service to the university. Last but not least, in March he was honored with the **College of Arts and Sciences Distinguished Research Career Award**.

ASSISTANT PROFESSOR TOVA HOLMES has a challenging but welcome task: looking for hidden physics with particles no human can see. She'll pursue this aim with an **Early Career Research award from the US Department of Energy Office of Science**. The grant began last summer and includes $750,000 of support over the next five years. Holmes is part of the research group using the Compact Muon Solenoid detector to study high-energy particle collisions in the search for new particles, and new physics, at the Large Hadron Collider in Geneva.

ASSISTANT PROFESSOR LARRY LEE gives vintage tech equipment a second life, as he engineers audio waveforms to show images from experimental particle physics—painting musical pictures through his ColliderScope project. For this innovative means of bringing science to the general public, he was awarded the **College of Arts and Sciences Outreach Teaching Award. The Department of Physics and Astronomy has won 11 College Honors since 2016 for outstanding research, teaching, advising, and outreach.**

Feature articles on these awards, as well as news and highlights, are always available at: physics.utk.edu.

PHYSICS & ASTRONOMY STAFF NEWS

PAULA KEATON

TAMRIA CAMERON

AMANDA BLAIR

MIKE ROACH

BRAD GARDNER

We've got new team members! **Paula Keaton** is our Travel Administrator. She worked with Clayton Homes for several years and also has experience working for the Microbiology Department. **Tamria Cameron** is our Graduate Program Assistant. She joined the department after 23 years with Knox County Schools. **Amanda Blair** is our Grants and Payroll Manager. She joined the department from Student Health Services.

Physics was well-represented at the College of Arts and Sciences staff awards, where Business Manager **Mike Roach** received one of two financial support awards and Senior IT Technologist II **Brad Gardner** won the technical support award.

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PAN E01-1060-002-23

HE KNOWS EXACTLY WHAT HE'S TALKING ABOUT

Graduate Student **Jesse Harris** won Best Oral Presentation in the field of Nuclear and Particle Physics at the National Society of Black Physicists (NSBP) conference in November. Pictured: **Hakeem Oluseyi** (NSBP President), **Bryan Kent Wallace** (NSBP Treasurer), Awardee **Jesse Harris**, and **Elaine Lalanne** (NSBP Past-Treasurer). Harris works with **Professor Stefan Spanier** in the Compact Muon Solenoid group. UT Physics is proud to co-host the 2023 NSBP Conference this fall. (Photo credit: NSBP)