

Good Vibrations

Finding Superconductivity in Iron Selenides

Assistant Professor Steven Johnston and his colleagues have found that given the right environment, an underdog superconductor can set records. The results of those efforts were published November 13 in a *Nature* Letter entitled “Interfacial mode coupling as the origin of the enhancement of T_c in FeSe films on SrTiO_3 .”

A superconducting material exhibits no electrical resistance. The efficiency of uninterrupted current results in seemingly boundless applications: superconducting magnets for “floating” trains, compact power cables, and biomagnetic technologies are only a handful of examples. How superconductivity originates, however, isn’t entirely simple, and it has to do with how electrons behave.

Typically, electrons repel one another. Yet there are circumstances that induce them to pair off, clearing all resistance and ushering along current unimpeded. This phenomenon comes in variations: there are low-energy (conventional) superconductors, where resistivity vanishes at transition temperatures around 39 Kelvin or lower. Here, electron pairing is caused by phonons: vibrations in a material’s lattice-like structure (often described as a jungle gym). In the mid-1980s, high-temperature (or high- T_c) superconductors arrived, and they’ve shown an ever-increasing rise in transition temperatures. Yet how they become superconducting in the first place has been something of a mystery, as some schools of thought had ruled out phonons as candidates. That’s part of what makes this *Nature* letter all the more interesting.

Johnston and colleagues (including UT Physics alumnus Robert Moore, now with the Stanford Institute for Materials and Energy Sciences) investigated iron selenide (FeSe) films and found that phonons have a role to play in high- T_c superconductors after all. They grew the films (all of one unit cell thick) on a base layer, or substrate, of strontium titanate (SrTiO_3). Using photoemission spectroscopy, they found duplicate energy bands in the resulting spectra—called “shake-off” or “mirage” bands. These are the result of the iron selenide electrons’ interaction with phonons in the SrTiO_3 substrate.

“The fact that they’re there is important,” Johnston explained of these duplicate bands, but “what’s more important is that they’re actually complete carbon copies of the bands above them,” which explains how the lattice coupling occurs and that it’s beneficial to pairing. He and colleagues at Stanford have long embraced the idea that high-temperature superconductors, like their low-energy cousins, could trace their superconducting origins to phonons. This research, he said, “is the most conclusive demonstration of that.”

Interestingly, an iron selenide is actually a somewhat unlikely actor for such a starring role, but phonon interac-



Steve Johnston and colleagues (including alumnus Rob Moore) have recently published a *Nature* letter on high-temperature superconductivity in iron-based materials.

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Dr. Hanno Weitering
Professor and Head

Graduate Studies in Physics: Metrics and Perks

Graduate students are the heart of our research enterprise. This time of the year, the physics department usually receives well over 150 applications for our graduate degree

program. Many students apply from abroad; for instance from countries like China, India, and Nepal, and also from countries in the Middle East. On average, we admit about 40 graduate students each year with varying offers for financial aid. The latter usually comes in the form of a graduate teaching assistantship and a tuition waiver. Roughly half of them ultimately join the program, 70 percent of whom come from the U.S.

Faculty and their research portfolios are one of the most important considerations for prospective graduate students in their deliberations whether or not to join UT. Surely enough, faculty who actively recruit tend to get the very best students. Financial incentives also play a role, though not nearly as much as one might have expected. In fact, the road toward a Ph.D. in physics is a financial bargain to begin with, certainly compared to many other disciplines. (This became even more apparent to me now that I have two children in graduate school, neither of them in physics). Nearly all of our graduate students are financially supported. Nearly all of the incoming students, or about 30 percent of all graduate students, are supported on a full-time teaching assistantship, which comes with a tuition waiver. Their obligations, besides taking classes, include teaching the undergraduate laboratories for our general education and service courses, and/or grading homework papers for the professors.

Approximately half of the students enjoy full-time support from a research grant or contract, thus allowing them to work full-time on their dissertation research and to earn a graduate degree. The remaining 20 percent are supported by a combination of a half-time teaching assistantship and half-time support from grants, contracts or endowments. In essence, a graduate education in physics is almost free, for the student that is, and it is a very worthwhile investment in their future career. Indeed, Ph.D.-level physicists are especially well paid while unemployment among physicists is among the lowest.

UT's Top 25 initiative puts a heavy emphasis on increasing Ph.D. production. Can we do it? To graduate more students, we obviously need to increase our graduate enrollment. To accept more incoming graduate students, the physics department would also need more teaching assistantships, which is also essential to meet the increased demand for our undergraduate laboratories. However, after two years, the

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students need to be accommodated by research grants as they begin working on their dissertation research. This, in fact, requires that we also need to increase our research funding, which in turn requires hiring more faculty who aggressively pursue external funding.

This fall, we started off with 25 new graduate students. During the preceding academic year, 19 students graduated with a Ph.D. and seven graduated with a terminal master's degree. The numbers fluctuate of course, but they do indicate a steady state of about 20-25 students entering or graduating each year, which is a reflection of the faculty size and economic realities. The good news is that the average time to a physics Ph.D. at UT for the last 10 years is 5.75 years and it is getting shorter, as we are closely mentoring students who are falling behind schedule, taking corrective action where necessary. The average time to a degree is a very important consideration for prospective graduate students, and is also a big concern to funding agencies.

Given these realities, can we improve further? Endowed scholarships and Chancellor top-off funds are an attractive way to increase our stipends and thus we may become more competitive for students with multiple offers. These, however, are usually the top recruits of any major research university to whom the financial picture is often a secondary consideration. This year, we began offering a limited number of endowed part-time assistantships for incoming students, so that they can get involved with research from day one. This, we hope, will be another attractive proposition for students that are about to apply to our program.

In particular, women and minorities are among the top recruits as many universities, including UT, are beginning to realize that promoting gender and racial diversity among faculty and students is an excellent business proposition, as those departments tend to thrive. It's a tough proposition for the science departments, chemistry and physics in particular, because the pipeline needs fixing, much of which is beyond the control of academic departments. Those minorities that are on the market usually have many options to choose from. In the end, recruiting the best and the brightest again boils down to personal faculty contacts and making sure that the department is a welcoming place for all. And yes, a little money does help. [CS](#)

tions with strontium titanate elevate its status.

"Compared to other unconventional superconductors, it's pretty unimpressive on its own," Johnston said of the FeSe film, but "that layer seems to interact with its environment in a way that's very interesting."

In fact, "the interaction seems to prove an ideal way of boosting the superconductivity of the films," wrote Jan Zaanen of Leiden University in a News & Views article that appears in the same issue of *Nature*.

Yet another impressive result of the research is that the superconducting energy gaps appear at a temperature close to the boiling point of liquid nitrogen (77 Kelvin): a record for iron-based superconductors. Given the abundance of nitrogen in the air, finding materials that superconduct in liquid nitrogen could open the door to more applications.

For Johnston, however, the beauty of the work lies in finding out more about how strongly-correlated electron systems work. He performed theory calculations, building models to investigate how the electronic states in FeSe coupled to the substrate. The research also ties in with some of his earlier work on copper-based superconductors (cuprates). A condensed matter theorist, he joined the faculty on January 1, 2014, and works with other CMP theorists and experimentalists both on campus and abroad.

The co-authors on the *Nature* Letter include Robert Moore (as mentioned earlier) and other colleagues representing the Stanford Institute for Materials and Energy Sciences, the Stanford Synchrotron Radiation Lightsource, the Departments of Physics and Applied Physics at Stanford University, the University of California at Berkeley, and Lawrence Berkeley National Laboratory. [CS](#)

Ryan Holloman: From Lasers to Pipelines

Ryan Holloman is the kind of person who can accept seeing his art destroyed for the greater good. Since earning a master's degree from UT Physics in 2005, his career has taken him to the Department of Defense, a blasting range in South Carolina, and the ExxonMobil Pipeline Company. Yet he's never lost sight of the physics fundamentals that inspired him in high school where he learned first and foremost to solve problems.

It's 8:00 a.m. in Houston, Texas, and Ryan Holloman's voice over the phone is cheerful, with a laugh always just beneath the surface. He's at work at ExxonMobil, where he specializes in fracture mechanics: essentially identifying how much stress a material can take before it fails. This is critical information for a company with miles and miles of fuel-carrying pipeline traversing the planet.

"A lot of the pipe around the country was put in right around World War II, and we're still using a lot of it," he said. "And of course during that time, because of the war effort, it was a mad rush, (so) there are a lot of issues with that pipe."

His concern with this 1940s handiwork is that so many of the pipes were seam welded and are now beginning to have problems, so Holloman develops models to try to predict when they will fail. It's a tricky situation because it's impractical to bring the industry to a standstill; a challenge he shares, for example, with colleagues from the U.S. Department of Transportation.

"They have similar types of problems with railroad tracks; you have these systems that you can't actually stop but you have to inspect them and somehow try to replace them," he said.

Fixing a pipeline without disrupting oil flow may seem like a daunting problem, but it's the sort of work Holloman welcomes and for which his education prepared him well.

A Ph.D., After All

During his graduate studies at UT, Holloman decided to go the master's route rather than pursuing a doctorate.

"I couldn't imagine being in school until I was 28," he said laughing.

Instead he drew on his interest in optics and lasers and ended up basing his thesis on a CO₂ laser project, working with Don Hutchinson at Oak Ridge National Laboratory.

After finishing the degree, he took a job as a physicist with the U.S. Department of Defense.

"I ended up working there because of a career fair at UT," he said. "I remember handing a resume to many people and months and months later I got a call from (DOD). It was good timing because I was getting ready to graduate."

He worked as an analyst, dealing with laser technologies. But about six months in, he started thinking maybe he'd like to get a Ph.D. after all. He took advantage of a scholarship program for DOD employees for two years of graduate education, which covered his first two years in the doctoral program at the University of Virginia. That's when he made the move to materials science.

"I really enjoyed physics," he said. "I enjoyed learning all the intricacies of how things work, but I think I saw myself as being more applied, and working with real-world problems, so I just wanted to get more into engineering."

His advisor, Haydn Wadley, was involved in defense-oriented research, and Holloman began working on a project that stemmed from the bombing of the USS Cole.

"The Navy was really interested in finding ways to create lighter-weight structures that could mitigate impulsive loads caused by underwater blasts," he said. Over time the Army got interested in the work as soldiers began dealing with buried explosive devices. "The whole point of my project was to develop a lighter-weight structure that could absorb the impact of an explosive blast; and understand the fluid-structure interaction between highly impulsive sand and the structure."

This is what he found attractive, Holloman said: multi-mission projects that could solve problems—much like the pipeline work he's doing now. Sadly, he also had to watch some of his efforts destroyed in the name of research.

"I did a lot of lab work and a tremendous amount of finite element modeling," he said. "We actually worked with

a blast range down in South Carolina . . . to blow up our structures. It was a little sad sometimes. I did a lot of the fabricating for them: they became little pieces of artwork.”

The sacrifice was not without benefits, however: Holloman got experience working with lab personnel as well as people in the field; a talent he uses in his current position. He said he understands difficulties the operations crew faces: “actually going out in the field and replacing these pipes, (while) at the same time I get to work with the guys in the lab who do all the testing. That’s kind of what’s interesting about my role. I’m almost a liaison between an operations company and some of Exxon’s research lab groups.”

Another element of graduate work that had important implications for his future was meeting a master’s candidate named Katie, who is now his wife. They’ll be all set when their 10th anniversary rolls around, as the traditional gift is aluminum.

“I was working more on the mechanical aspect of our project . . . and she was working on the corrosion aspect, so her advisor sent her down to my office to ask for some aluminum structures that I was working on, and I guess we hit it off right away,” he said.

Katie had taken a leave of absence from ExxonMobil to earn her master’s and then was transferred to Houston. Holloman, still working for the DOD full-time in addition to his Ph.D. work, stayed in Virginia for two more years, leaving his job in May 2013 and taking an ExxonMobil internship that July. In October he went back to Charlottesville, defended his Ph.D. in April 2014, and then joined the company full-time. And while his graduate studies played a key role in preparing him for industry, the inspiration for his career path came much earlier.

Falling into Place

Holloman grew up in the Denver area, where an influential teacher guided him toward physics.

“I had a really good high school physics teacher. I’ve always been curious about learning how things work, and wanted to learn the details of those types of things, (but) it really goes back to having that good high school physics teacher.”

When he headed to the University of Northern Colorado, he knew from the start he wanted to major in physics.

“My parents thought it was a little crazy at the time,” he said, “but they didn’t question it and provided the best support they could.”

He earned a bachelor’s degree in 2002 and then began looking for graduate programs, focusing on universities affiliated with a national laboratory. That’s how Tennessee—which operates Oak Ridge National Laboratory with Battelle—appeared on his radar.

“At the time there were a lot of really great opportunities—the Spallation Neutron Source was being built—so a lot of it had to do with opportunities at the national lab and everything nearby,” he said of his decision to come to Knoxville. As someone who enjoys cycling and other outdoor activities, the natural surroundings were also a bonus, as was the company.

“I made a lot of really good friends; people in Tennessee are extremely friendly,” he said.



Ryan Holloman’s physics journey has taken him from his native Colorado to UT to the University of Virginia, (where he met and married a fellow graduate student and finished a Ph.D.), to Houston, where he studies fracture mechanics of pipelines for ExxonMobil.

While a career in energy wasn’t something he planned, Holloman finds it’s been a good fit for his inquisitive nature and education.

“I always viewed physics as being a problem-solving type of degree,” he said. “People think of oil and gas and may not think there’s a lot of Ph.D.s and those types of folks around, but in a company like Exxon we have pretty tremendous research groups that are looking at long-term things, (who) develop peer-reviewed journals and white papers. There are definitely a lot of opportunities for (physics) grads.”

He also built on the collaborative nature of scientific and engineering work to make the connections that led him to his present post.

“I never had any intention of going to the various places I’ve been,” he said. “Things have just fallen into place for me.” [CS](#)

New Faculty

UT physics professors might not have noticed the German exchange student sitting in their lectures some 15 years ago, but they've had the pleasure of getting to know him this fall as the newest member of the faculty.

Lucas Platter joined the university as an assistant professor of physics in August. Back in 1999 he was spending a year abroad from his native Germany and took undergraduate classes at UT, but these days he's focused on the nucleus and its properties and interactions.

"I want to understand and be able to describe observables using the simplest set of assumptions in a way that constitutes understanding," he said.

Platter's scientific interests and tools lie at the microscopic level. Density functional theory, for example, gives physicists like him a means to describe complex, "many-body" systems, such as heavy nuclei. The interactions between ultracold atoms can lead to novel phenomena. And effective field theory describes systems with separation of scales, which has to do with short-, mid-, and long-range correlations of nucleon interactions.

"There's a lot of discussion in physics about what is a model and what is an effective field theory," Platter explained. "If you want to describe some physical process you can construct an infinite amount of models," but it may be unclear if they "hold any physical truth" or can be extrapolated outside a particular system.

"An effective field theory," he said, "gives you a framework that clarifies the domain of validity that you're working with and also tells you the errors."

As an undergraduate at Bonn University in Germany, getting into such details of nuclei wasn't his original plan.

"I was looking for a major and I actually wanted to study astrophysics," he said. "In Germany you start out with physics and astronomy together, and I ended up doing physics."

He also spent a year in Knoxville taking courses at UT.

"I took a bunch of physics and math classes. I had a lot of fun here," he said.

When he returned to Germany he needed to look for a thesis advisor, and that's what led him to his current research.

"The German university system at that time was such that you started undergraduate work and you did not do a bachelor's in that sense, but you earned it with something like a master's, which already included a thesis."

His advisor's research was in phenomenology but somewhat related to particle physics and what Platter's working on now. After finishing his undergraduate work, he completed the Ph.D. at Bonn in 2005 and then held postdoctoral positions at Ohio University and Ohio State University. He has also held positions at the University of Washington Institute for Nuclear Theory, Chalmers University of Technology in Sweden, and Argonne National Laboratory, where he is still in touch with colleagues.

While Platter's studies can be somewhat independent, they overlap with Dr. Thomas Papenbrock's research and also work at Oak Ridge National Laboratory, so there is plenty of collaborative opportunity. He is also part of the NUCLEI project—the Nuclear Computational Low-Energy Initiative—funded through the



Lucas Platter joined the physics faculty in August 2014 as an assistant professor. His research interests are in low-energy nuclear theory and ultracold atomic gases.

Department of Energy's program for Scientific Discovery through Advanced Computing.

He will also enjoy interactions with students, not only as a research advisor but also through teaching, as he's slated to teach graduate-level nuclear physics in the spring.

Outside of physics, Platter enjoys reading when he gets the time, and also spending time with his family. He and his wife, Noelia, are parents of four-year-old Hannah and one-year-old Leo (Hannah's artwork adorns the bulletin board in his office). They have just bought a house, and so there's the requisite getting things organized and furnishing a new home as they settle into Knoxville.

"I'm happy here," he said smiling, with the goal to "just try my best." [CS](#)

Sleeping Late is Now an Option

It was unseasonably cold for a November afternoon in Knoxville, proving a bit much even for a South Dakota native like Joe Macek.

“You know, we always wore plenty of clothes so we didn’t freeze to death,” he said chuckling.

Macek, an atomic physicist who sports a Teddy Roosevelt moustache, joined the faculty in 1988 as a Distinguished Professor and retired at the beginning of the fall semester. He has an open, generous nature that’s evident as he recounted how he got into physics in the first place.

“I was interested in science so I went to South Dakota State, which at that time was relatively small, and just for lack of anything to do I majored in chemistry,” he said. “When I took the first real physics course in college, I really enjoyed it. So I decided, ‘Why don’t I switch my major to physics?’ And I’ve been associated with physics ever since.”

After graduation he set out for graduate school at the same time the country was formulating a response to the launch of Sputnik, the Russian satellite.

“One of the things Congress did was create a whole bunch of fellowships, but these were at specific schools,” he said. “And one they picked out was Rensselaer, which was an engineering school. But they also had the idea that they would support very specific subjects, and one of the subjects they supported at Rensselaer was physics, so that was what prompted me to apply.”

In the beginning, Macek said his interest in physics was quite general and so he covered some wide territory.

“I eventually did my research work in nuclear physics, but it wasn’t really nuclear physics; it got into sort of what was then elementary particles. But it was done in such a terrible way that I said, ‘I’ll never do physics this way again,’” he said laughing.

He finished the Ph.D. at Rensselaer in 1964 and vowed to streamline his work a bit.

“When I got my degree, I said, ‘I’m going to do a postdoc where I work with real things, like atoms and nuclei and so on,’ and fortunately I went to what was called the National Bureau of Standards (now known as NIST),” he said.

“In those days it was much more fundamental research,” he said of the bureau. “It wasn’t quite so broad. It was kind of homey.”

While there Macek was doing some research related to work at the Carnegie Institute, so his boss suggested he go for a visit.

“It was like stepping back into the 1930,” he said. “But they were doing really good stuff. Artificial satellites had just started going up so we were learning a lot about the earth. So they were talking about that. That was a lot of fun.”

Next came a two-year Oxford-Harwell Fellowship at the Atomic Energy Research Establishment in Harwell, England, before Macek joined the physics faculty at the University of Nebraska in 1966. While there he honed his interest in theoretical atomic physics, becoming the George Homes Professor of Physics in 1986.

Macek’s work on atomic collisions became quite well-known in the field. He is a fellow of the American Physical Society and a member of the Scientific Council of the Ioffe-Physical-Technical Institute in St. Petersburg, Russia. In 1971, he and fellow Nebraska physicist Don Jaecks wrote a paper outlining the theory for a new type of atomic collisions experiment: the atomic-photon-particle coincidence measurement. The paper was included in a 2000 journal called the *Physical Review—The First Hundred Years*, which covered 200 seminal research



Joe Macek retired this fall after 26 years on the faculty. He joined UT in 1988 as a Distinguished Professor with a joint appointment as a Distinguished Scientist at Oak Ridge National Laboratory.

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papers and an additional 1,000 articles in digital format chronicling the growth of modern physics.

In 1973, he and Professor Ugo Fano of the University of Chicago wrote “Impact Excitation and Polarization of the Emitted Light,” which was published in *Reviews of Modern Physics* and has been cited more than 800 times. The paper presented a new way of thinking about the angular distribution and polarization of light excited by atomic and electronic collisions.

“That’s an interesting story,” Macek said. “I wrote a paper earlier where I had explained, or thought I had explained, some experimental observations, and then I wrote a follow-up paper on some of the more general theory of that. I was talking to Professor Fano at the time, who had been working on the same thing, and apparently he had some different ideas. But then when he read the one paper I wrote, he said, ‘That may be the right explanation . . . but I don’t like the way you did it.’ I didn’t do it in a very elegant way. (Fano) said ‘Let me show you how to do it better.’”

“In the process of doing that I went from one step to another using just one line of words without having to do a lot of algebra, and this was something that Professor Fano had wanted to do earlier but never saw the right way to do it,” he continued. “And he said, let’s write a paper on it. So we did. And that became very topical; that’s why it’s quoted so frequently. Partly because Fano was a very *good* writer. He knew how to reach just the right audience, and he knew how to write it for the right audience. That’s what made it popular.”

By 1988 Macek’s scientific reputation prompted UT to ask if he’d like to be a candidate for a Distinguished Professor position, with a 50 percent appointment at Oak Ridge National Laboratory as a Distinguished

Scientist, and he said he would.

“I of course knew a lot of people here,” he said. “I knew people both at the university and at the lab. They were all sort of good friends of mine and professional colleagues.”

During his long tenure at the university, he said he’s enjoyed not only working with fellow scientists, but also teaching future scientists.

“When I first came here (then Department Head) Bill Bugg gave me the job of teaching a particular course, which had a lot of graduate students, and it was a course I like to teach, so I got off to a good start,” he said. “It was electromagnetic theory, one of the fundamental courses. I enjoyed the rapport you would get with the students. It’s a difficult course, but you can make it seem not so difficult. I taught it three years in a row and there was always a good turnout.”

With retirement, however, his obligations will slow down considerably.

“I don’t have *any* plans,” he said laughing. “I will quote (Physics Professor and Former Chancellor) John Quinn on this. Someone asked him just the other day what he was going to do. He says, ‘Well, I’m going to read a lot, I’m going to spend time thinking, and I might do a little bit of writing.’ And that sounds like a good way to frame what I’d do. Although I probably will do a bit of traveling.”

He and his wife Ellen will also be visiting with their children and grandchildren in different parts of the country, but he won’t necessarily be a retiree who gets an early-morning start on his days.

“This means if I want to sleep late, I can,” he said. [CS](#)

Joe Macek (left) presents Nobel Laureate Bill Phillips with a UT sweatshirt during the APS Division of Atomic, Molecular and Optical Physics (DAMOP) meeting, held in Knoxville in 2006. Macek was a co-chair of the meeting, which broke all previous records with 953 attendees.





The Physics Top 10 List

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

#2

Title: Magnetic Order Close to Superconductivity in the Iron-Based Layered $\text{LaO}_{1-x}\text{F}_x\text{FeAs}$ Systems

Authors: C. de la Cruz et al.

Journal: *Nature* **453**, 899 (2008)

Times Cited: 1,156 (as of 11/20/2014)

Summary

Courtesy of Clarina R. dela Cruz, Ph.D.
Oak Ridge National Laboratory

A great example of constructive synergy in nature is the strongly correlated electron systems. Not only do they open the door for physics to push its boundaries, but they often-times exhibit exciting new physical phenomena with associated properties that have viable technological applications. Advancement of this field necessitates a way to probe and tune various microscopic states to reveal the mechanisms behind the phenomena, and, based on this understanding, possibly fabricate materials by design in the future.

An important field of experimental condensed matter physics focuses on studying correlated electron systems including unconventional superconductors, iron-based superconductors, and multifunctional systems such as multiferroic compounds. The use of various bulk measurement techniques to characterize the physical properties in these systems is an essential first step in revealing the novel electronic and magnetic ground states. Further studies using powerful microscopic probes such as neutron scattering methods are crucial to advancing the central theme in understanding correlated electron systems, which is to make the correlation between structure, magnetism, and physical properties. One such system that has turned the world of condensed matter physics on its toes is the iron-based unconventional superconductors. Discovered by Japanese scientists in early 2008, the superconductivity found in a fluorine-doped LaFeAsO parent compound astounded the scientific community as the first non-cuprate superconductor with a relatively high critical temperature of 28K. By March that number had leaped to 43 and prompted Professor Pengcheng Dai's group to study the structure and

magnetic order of $\text{La}(\text{O}_{1-x}\text{F}_x)\text{FeAs}$. The findings were that the parent compound was antiferromagnetic but with the addition of fluorine, static magnetism vanished and superconductivity appeared.

Studies have shown the superconductivity in such compounds remains robust upon alteration of the crystal structure and substitution of various rare earth elements for the lanthanum. As a result, a wide variety of related iron-based compounds has been discovered to be superconducting. What remains common amongst all of them is the close proximity of the superconductivity to a magnetic state. This is where neutron scattering plays a unique and crucial role.

Neutron diffraction measurements have identified unambiguously the nature of the antiferromagnetic ground state in the parent compounds of unconventional superconductors as well as its direct competition with the superconducting state as the parent compounds are tuned by electronic doping, chemical, or applied pressure. These kinds of pioneering measurements led the way to identifying the important role of magnetic excitations in understanding the pairing mechanism in unconventional superconductivity. With the discovery of high temperature superconductivity in iron-based systems, the condensed matter community was stimulated further with the initial exciting discovery of the simple collinear antiferromagnetic order in the parent compounds revealed by neutron diffraction and the confirmation of similar magnetic structures exhibited by other sub-groups in the family of Fe-based superconductors. The subsequent systematic doping evolution studies clearly showed the competitive nature between static magnetic order and superconductivity.

In a similar fashion, the typically complex nature of the magnetic structures in single-phase multiferroic compounds, characterized by neutron diffraction, provides the microscopic details and symmetry-breaking property needed to understand the associated ferroelectricity in these materials. Such magnetic structures lay the groundwork to shed light on the physical correlations in these systems and give insights into the peculiarities in the resulting crystallographic structures. As is common across correlated electron systems such as unconventional superconductors and multiferroic compounds, highly degenerate ground states abound, which are readily disturbed by perturbing fields such as an applied magnetic field or pressure. Thus, studying these systems in extreme conditions reveals new emergent ground states with tunable magnetic, electronic or ferroelectric order parameters. [CS](#)

Gifts in Action: McConnell Scholarship



Amos Manneschmidt had a choice of colleges, but the James W. McConnell Scholarship was what brought him to UT.

When Amos Manneschmidt graduated from Farragut High School in Knoxville, he was pretty set on studying physics. Where he would do that, however, wasn't certain. When the physics department offered him a James W. McConnell Scholarship, the scales tipped in UT's favor.

"I really appreciate the McConnell Scholarship," he said. "It's been very helpful. I probably would have stayed in physics regardless (but) it helped me decide to come to UT. I had a full ride at Tennessee Tech, and so with the (McConnell) and a few other things, that made it so that I could more or less break even at UT. If everything continues as it has, then I'll be able to graduate without any debt, which is certainly a plus."

Now a junior, Manneschmidt said part of what he finds attractive about physics is that it's challenging. He also

has a level-headed assessment on how to navigate those challenges and keep things in their proper perspective.

"In high school maybe your lowest grade is a 70 on a test. And then you come to college and you make below a 50 on a test. Your first thought is 'Well, I guess that's the end of that class,' but then you find out that everybody else did too, and it doesn't really mean anything."

Manneschmidt said he's interested in making the best grades he can to get into graduate school, but he's more focused on the big picture: sometimes jumping ahead in course material when something interests him and reading others' perspectives to form a deeper understanding. As a veteran of the undergraduate program, he shares his experiences with newcomers, especially through the Society of Physics Students.

"It's fun when new people come in to SPS and they've just made their first under-50 test and you can go up to them and put a hand on their shoulder and say, 'Don't worry, it gets worse,'" he said laughing.

This fall he's taking Electricity and Magnetism, along with Mechanics, and he approaches his studies—especially homework—with the same even temperament and sense of humor.

"Sometimes you'll see a problem and see the solution and set it up real quickly; other times it will take a good four or five hours of solid work on it. There's not any other way to learn the material. There's that, or there's the alternative where you don't have homework, and that's worse."

Manneschmidt explained how he unintentionally signed up for a graduate course in Partial Differential Equations and couldn't switch because of a scheduling conflict. So he decided he'd give it a try and drop the class if it didn't work out. No homework was assigned until mid-term: then came 20 graduate-level problems, with no examples worked out in the textbook. He closed the story describing how he

and a fellow undergrad in the course walked away in the rain.

There have, however, been brighter moments in his time at UT, many stemming from Manneschmidt's involvement with SPS.

"SPS has been a lot of fun," he said. "A lot of the good moments where you say, 'That's really cool,' are when you're showing demos to people, and it might be the first time they've ever seen a little Van de Graaff machine."

He'd like to develop more demos for the department, and he's also interested in creating phone apps, an idea that was further encouraged by an SPS Zone meeting trip.

"There was an SPS trip to the University of Louisville last year and one of the breakout groups was talking about using smartphones in physics. And what I thought was it would be really cool if somebody would make a motion-tracker. You could set your phone down and take video of objects, and then it would automatically track the object so you wouldn't have to step through frame-by-frame; then it would generate the equations of motion for that object."

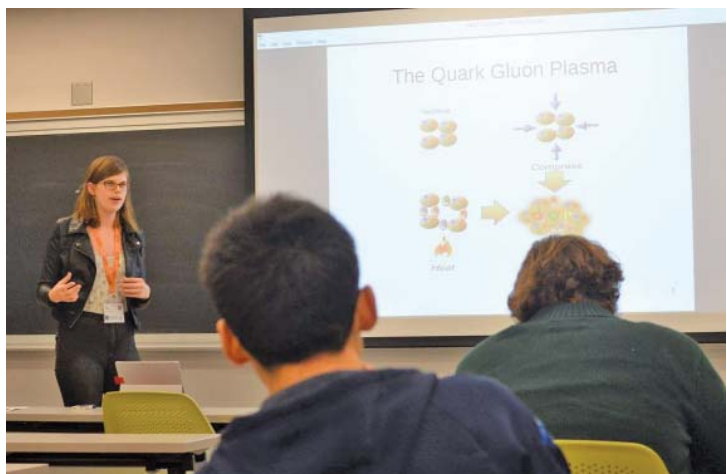
Manneschmidt's interests are not strictly technical, however. He's on the ballroom dance team, a member of the philosophy club, and just finished a scuba diving class.

"Also, I'm working on starting a metal-working club," he said. "At home I have a forge, but not very many people have access to that," so he's working on finding studio space and hopes the club will be official for the Spring 2015 semester.

After finishing his bachelor's degree in physics, Manneschmidt plans to go to graduate school and pursue a career in research. Yet he also works in the Physics Tutorial Center and likes helping people, and said that if in the long term he gets a position where he'd also teach, that would be fine.

"We'll see what happens. That's kind of loosely in the gray area known as the future," he said with a smile. CS

Gifts in Action: Physics Enrichment Fund



The Society of Physics Students (SPS) had a busy fall semester. They got in on the whole multidisciplinary nature of science, hosting a departmental picnic with guests from Georgia Tech as well as students from math and other science departments at UT. They gave physics demonstrations during the pre-game festivities for UT's homecoming, and sponsored workshops on getting involved in undergraduate research and applying to graduate school. With help from the Physics Enrichment Fund, they spent the last weekend of October at the University of Illinois at Urbana-Champaign for the fall Zone 8 meeting. Meg Stuart (above left) and Blake Erickson (above right) were among the UT students who gave presentations at the meeting.



News from the Physics Family

Faculty

Each year, the College of Arts and Sciences recognizes faculty excellence in research, advising, leadership, service, and teaching with the **Winter Convocation awards**. At this year's ceremony on December 3, **Professor Thomas Papenbrock** was recognized with a senior-level Excellence in Research and Creative Achievement Award. His citation reads in part, "his scientific discoveries, high number of invited talks, large role in organizing international workshops, and service to the national and international community are compelling indicators of his excellent professional reputation as a top scholar." **Professor Soren Sorensen** was recognized with the Diversity Leadership Award for "steadfast commitment to diversity and the transformation of UT into an institution that actively seeks, welcomes and fosters diversity."

Associate Professor Kate Jones was featured on the WUOT-2 radio program "Changing Course" where she explained the world of nuclear physics for listeners. You can hear the broadcast via iTunes by visiting <http://wuot.org/programs/changing-course-wuot-2>.

Students

Congratulations to **Richard Prince**, a senior physics major who won a Society of Physics Students Leadership Scholarship this summer, recognizing his outstanding academic performance and high level of SPS activity.

Graduate Student **Yuen Yiu** wrote a nice feature for *The Daily Beacon* on the 2014 Nobel Prize in Physics on light-emitting diodes. It's available online at: <http://utdailybeacon.com/opinion/columns/guest/2014/oct/20/let-there-be-light-emitting-diodes/>.

Machined by UT Physics: Ready for the World

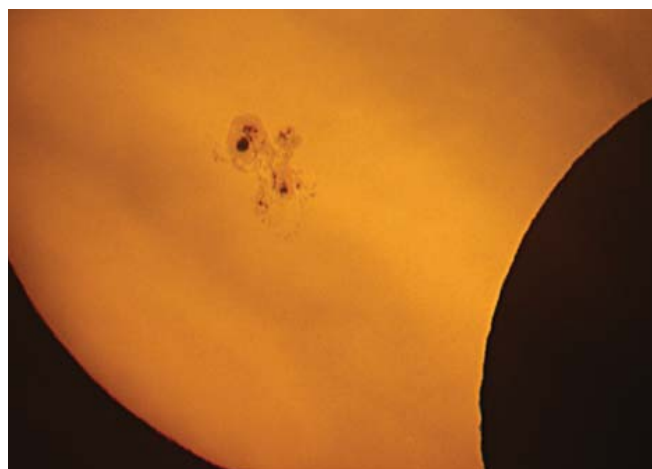
UT Physics Instrument Maker Josh Bell (right) with a piece he machined for an experiment at the Advanced Science Research Center (ASRC), a Japanese Atomic Energy Agency laboratory in Tokai, some couple of hundred miles north from Tokyo. The tandem accelerator facility is where the nuclear physics group continues their program on alpha decays following the HRIBF shutdown in Oak Ridge. They will have an experiment there in December to search for the alpha decay of ^{113}Ba . The main goal for the program is to identify the heaviest nucleus with amount of protons equal to amount of neutrons ($N=Z$), which will be ^{112}Ba . UT's nuclear group will provide the digital electronics for this experiment and also build a new vacuum chamber. This will host a set of particle detectors and be surrounded by a very large gamma ray system. (Courtesy of Professor Robert Grzywacz.)





Astronomy Outreach

The Nielsen Physics Building Roof was the place to be on October 23 for a partial solar eclipse viewing. The sun photo below shows not only the "cookie bite" eclipse, but also a sunspot as big as Jupiter (and Jupiter is 10 times bigger than Earth). Channel 10 Meteorologist Todd Howell (left, with Paul Lewis) stopped by to see, as did students wearing special (and stylish) eclipse-viewing eyewear.



Physics Family Photos

(L-R) Professors Lee Riedinger and Jon Levin, along with Associate Department Head Jim Parks, enjoy the weather at the fall picnic sponsored by the Society of Physics Students.



Physics front office staffers (L-R Chrisanne Romeo, Candice Kinsler, and Showni Medlin-Crump) were working an impressive Alice in Wonderland theme for Halloween.

News from the Physics Family

Alumni

Physics alum **Trent Nichols** (B.S., Engineering Physics, 1976; M.S., 1978; Ph.D., 2008; and an M.D. from UT Center for Health Sciences, 1986) is the director of a pilot program called STEM Scouts, which encourages kids from third grade through high school to learn more about science, technology, engineering and mathematics (STEM) through weekly meetings using fun, hands-on activities.

Nichols brought the STEM Scouts mobile lab (the Vortex) to campus for a visit on November 10. For more information about the program and volunteering opportunities, visit <http://stemscouts.org/>.

Dowman Varn (Ph.D., 2001) is now a programmer at the University of California, Davis, Complexity Sciences Center. He is co-author of the paper "Chaotic Crystallography: How the physics of information reveals structural order in materials," which was highlighted in a November "Material Witness" feature for *Nature Materials*. Varn noted that while the article was written in Davis, it stems from his Ph.D. work at UT with Geoff Canright and at the Santa Fe Institute with Jim Crutchfield.



Alumni: Don't forget to connect with UT Physics and Astronomy on Facebook at: www.facebook.com/UTKPhysicsAndAstronomy

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Big ORANGE GIVE

Thanks to all our donors who supported the Big Orange Give this year! The university set a goal to raise \$250,000 and ended up raising **\$766,330** during the five-day, online fundraising campaign in October. The total number of gifts was 1,185, with 75 percent being gifts of \$100 or less.

More information on the Big Orange Give is available online at <http://bigorangegive.utk.edu/>.

Thanks to our Donors

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

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(Gift records forwarded to the department dated July 1, 2014 to October 31, 2014.)

Giving Opportunities

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

Undergraduate Scholarships

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

Undergraduate Awards

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

Graduate Awards & Fellowships

- Paul Stelson Fellowship Fund
- Fowler-Marion Physics Fund

Other Departmental Funds

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

If you would like more information on how to make a gift or a pledge to any of these funds, please contact either the physics department or **Mr. Don Eisenberg** in the College of Arts and Sciences Office of Development at (865) 974-2504 or don@utfi.org. You can also donate online by going to: <http://artsci.utk.edu/> and clicking on "Give to the College of Arts and Sciences."

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

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