Quantum Leap
University of South Carolina
Department of Physics and Astronomy
2021

SmartState Center for Experimental Nanoscale Physics Charts New Course with Arrival of Quantum Materials Expert Dr. Rongying Jin

The First SmartState Center

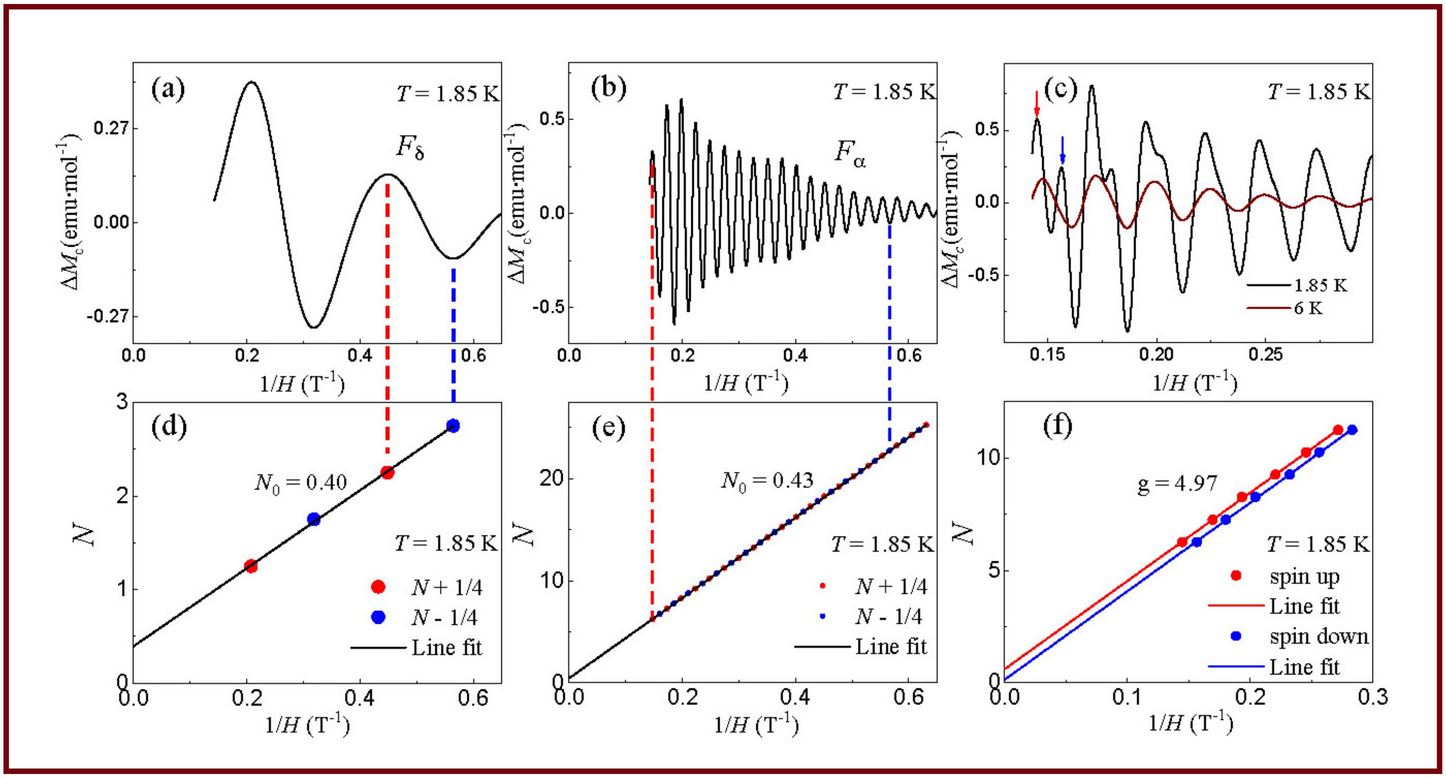
SmartState and John M Palms Endowed Chair and Professor of Physics, Dr. Rongying Jin.

The SmartState Center for Experimental Nanoscale Physics, based in the UofSC Department of Physics and Astronomy, was the first SmartState Center funded after the South Carolina General Assembly passed the Research Centers of Economic Excellence Act in 2002, with Richard A. Webb joining the Physics and Astronomy faculty in 2004 as the first SmartState Chair in South Carolina and the only member of the National Academy of Sciences at UofSC. During his tenure at Carolina, he created a top-quality facility for nanoelectronics research, while simultaneously recruiting five current faculty members to Physics and Astronomy to build the Condensed Matter Physics group. Center personnel have created experimental and theoretical research programs in diverse areas ranging from magnetism to surface science and photonics. Unfortunately, Webb passed away in early 2016, one week after teaching his first class of that spring semester. Over the next two years, the Center kept operating, and to honor Professor Webb, held a series of public lectures that included several members of the National Academy of Sciences and a Nobel laureate. In Fall 2019, the College of Arts and Sciences approved a search for an outstanding physicist to take Webb's mantle and lead the Center. Despite a delay in early 2020 because of COVID-19, the search proceeded and had strong success, recruiting Professor Rongying Jin, formerly in the Department of Physics and Astronomy at Louisiana State University, to UofSC beginning in August 2021.

Passing the Torch

Dr. Rongying Jin, a fellow of both the American Association for the Advancement of Science and the American Physical Society, received her MS in Physics from the University of Shanghai for Science and Technology. After postings at the Institute of Physics in the Chinese Academy of Sciences and as a visiting scholar at the University of Cambridge supported by the British Royal Society, she received her PhD in Physics from the Laboratory for Solid State Physics at ETH-Zürich in 1997. After three years as a postdoctoral fellow at the Pennsylvania State University, she became a staff scientist in the Materials Science and Technology Division at the Department of Energy's Oak Ridge National Laboratory in 2000. After a joint appointment at the rank of associate professor at the University of Tennessee, she joined the faculty of Louisiana State University in 2009 as an associate professor, promoted to professor in 2012. In addition to her prestigious society fellowships, Dr. Jin has received numerous research awards including four awards from LSU and an extension to one of her NSF awards given for special creativity.

Of joining the Physics and Astronomy faculty at UofSC, Dr. Jin says, "UofSC has such strong potential. The opportunity to help the team already in place realize their potential and achieve research excellence in the future was too good a chance to pass up. Webb built a strong program here and I feel that



Topological behavior and Zeeman splitting in trigonal PtBi2-x single crystals – from L. Xing, R. Chapai, R. Nepal, and R. Jin, NPJ Quantum Materials 5:10 (2020). Note that Professor Jin is an editor for NPJ Quantum Materials.

a focus on quantum materials going forward will cement his legacy, one defined by his measurements of the Aharonov-Bohm effect in mesoscopic gold rings. In fact, the explosion in quantum materials arose by identifying the role played by the nontrivial Berry Phase and topology in the Aharonov-Bohm effect. I intend to continue Aharonov and Webb's South Carolina legacy by building a team that creates new understanding of quantum materials and phenomena, taking them from the laboratory to the real world of applications."

A Feast of Quasiparticles at the Quantum Materials Buffet

The dam broke with graphene. The demonstration of linear band structure and massless Dirac fermions in "2-dimensional materials," beginning with graphene and later twisted bilayer graphene, unleashed a renaissance in condensed matter physics with a propagation of novel quasiparticles such as Dirac fermions, Weyl fermions, Majorana fermions, and axions. Some novel quasiparticles can only be found in condensed-matter systems, having no high-energy analogs as constrained by Poincaré symmetry. With the advancement of computation capability, theorists predict thousands of exotic materials that may have nontrivial topology and host novel quasiparticles. However, experimental probe and confirmation has only just begun. A Center with talented scientists combining theoretical and experimental efforts is ideally positioned to discover new quasiparticles hiding inside seemingly ordinary materials. Topological effects might ultimately be everywhere in condensed matter and offer a plethora of ways to develop functional materials and devices with yet-to-be-discovered quantum properties.

Beyond new materials and their quantum properties lies the new realm of Quantum Technologies (QT) where solutions for computation, sensing, and information processing await novel combinations of these materials. Dr. Jin suggests, "Investigations of excitations abounding in condensed matter may ultimately affirm or disprove theories about the kinds of particles that are possible in the universe, while enabling a host of new materials and technologies to advance human society, from addressing climate change, food insecurity, global public health, to national security."

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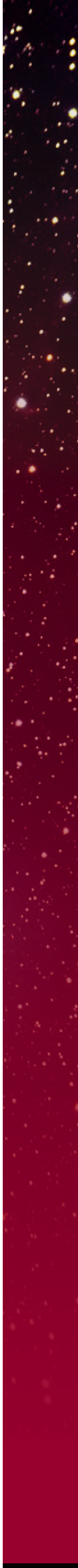


UPDATES FROM THE CHAIR AND DIRECTORS

Message from the Chair — "Love and Strife"

By Michael Dickson

The ancient Greek thinker Empedocles of Acragas postulated that there are four 'roots' of all things—earth, water, air, and fire—and that they are governed by two forces, Love and Strife, which organize the roots into a 'cosmos'. In his cosmology, Love creates attractions between the different roots, while Strife creates repulsion, and these two forces are constantly at work: "this interchange never ceases, at one time all coming together through Love, and at another time rent apart by Strife…the long interchanging never ceasing."

Maybe he was on to something. Last summer, we all thought that things would be back to some semblance of 'normal' this year, but Strife wasn't done with us, and here we are. And here I am, privileged to join the department for a year, and in the midst of the strife of uncertainty, let me hurry to say: Thank goodness for the love! The faculty and staff in Physics and Astronomy have been incredibly welcoming and helpful. Good thing, because we have a lot on our plate, and without some real coming together, it cannot get done. Here are just a few of the things that are on our plate.

This year we are very proud to welcome our new SmartState Chair, Rongying Jin. It is a very busy year for her, getting a laboratory and other facilities outfitted and refitted and retrofitted in a host of ways. It seems sometimes that it is taking forever, but in reality people are working hard, and we are excited for her and everybody working with the SmartState Center for its very bright future. We are also—fingers crossed!—excited to welcome Alexander Monin, who seems finally to have overcome all of his immigration hurdles. He plans to arrive on campus for the Spring 2022 semester.

Several faculty have been working on an overhaul of the department's service courses into a new format, 'Studio Physics'. Motivated and guided by the success of this format at other universities, and aided by an expert from the University of North Carolina, faculty here have developed a plan, and the first course in this format will be offered next Fall. The benefits of an improved experience for students in our service courses will be felt throughout the department.

We are also working on two hires. One is in computational physics, to be associated with the SmartState Center. We already have several promising applications, and we anticipate a successful search, with a new faculty member to join us next Fall. Our other search is for a new chair of the department. This search is an exciting opportunity to bring an excellent scientist to our department, somebody with a track record of success in leadership, and new ideas about how to achieve excellence in teaching and research.

So a lot is going on, and is going on in the midst of the strife that is born of uncertainty and a continued health crisis. Maybe Empedocles was right that Strife will always be with us. I think he was also right about Love.

News from the Director of Graduate Studies

By Matthias Schindler

The past year was far from normal: classes and lab sections were taught online or in a hybrid format, access to research labs was more restricted, and conferences and workshops were limited to online participation. But despite these obstacles, our new and continuing graduate students continued to excel in academics, research, and their teaching of UofSC's undergraduate students.

New Students

After several of our admitted graduate students were unable to join us for the Fall 2020 semester due to restrictions related to the COVID pandemic, we were excited to welcome them for Spring 2021. The new students are Taekuk Hong, Abhinna Rajbanshi, Avyash Sharma Pandit, Volodymyr Shablenko, Nishadi Silva, and Edoardo Vergallo Gazzina. They represent five different countries – a sign of how international the physics community and our department are. We are also happy to see such a strong group of incoming students for Fall 2021: Fatima Elkhatib, Mitchell Halley, Jake Martin, Alexis Osmond, Nibir Talukdar, and Xuecong Wang. In addition, Joanna Blawat and Daniel Duong joined us along with their advisor, Prof. Rongying Jin.

New Graduates

It was a very productive year for many of our students, with seven completed doctoral degrees. Congratulations to Saba Arash, under the guidance of Prof. Wu; Bryan Chavez and Sara FitzGerald, both working with Prof. Crawford; Justin Roberts-Pierel, under the guidance of Prof. Rodney; Thomas Richardson, working with Prof. Schindler; and Iuliia Skorodumina and Nick Tyler, with Prof. Gothe as their advisor, for completing this major milestone! In addition, Brandon Tumeo, working with Prof. Ilieva, completed a M.S. We wish them all the best for their future and hope to stay in touch with them.

Awards

Our graduate students have been very successful in their research as evidenced by several scholarships and awards. Caleb Duff started his first year in the US Department of Defense - Science, Mathematics, and Research for Transformation (SMART) Scholarship for Service Program, while Kyle Lackey continues to be supported by a NASA South Carolina Space Grant Consortium Graduate Research Fellowship. Fawad Kirmani and Chris McLauchlin were the recipients of 2021 Discover UofSC Graduate Poster Awards. In addition, Saba Arash and Thomas Richardson received the Department's Graduate Research Awards and Franklin Adams was the recipient of the Graduate Teaching Award. Congratulations to all of them!

News from the Director of Undergraduate Studies — Misconceptions Are All Around Us

By Jeff Wilson

A common misconception of entry-level students concerns Newton's Third Law, i.e. they don't believe it is true. A few years ago, we administered a standard test called the "Force Concept Inventory" to our intro-level classes. On the pre-test, my students scored only 11% correct on the questions associated with the 3rd Law. After a semester of traditional lecture, they improved to 26%. In the language of education research, 17% of students who didn't understand the concept going in, understood it after taking the course. There were five answers to choose from, so the students were not selecting answers randomly, but were instead, logically reasoning that one of the wrong answers was the correct explanation. The most commonly chosen wrong answer was that larger objects exerted larger forces on smaller objects than vice-versa, with more than 50% choosing that type of wrong answer. My explanations of the correct reasoning were clearly not very convincing to the students.

This is the general problem with misconceptions. A misconception is usually about something you think you already understand, and therefore, you are resistant to efforts to explain to you what you already know. Physics education research tells us that countering misconceptions is hard to do, and standard lecturing is particularly ineffective. The research also points to styles of teaching which have better success. These styles are often interactive and involve a significant amount of action on the student's part, which may involve performing mini demonstrations themselves and making sense of the results, while being asked direct questions, which draw out the discrepancies between the demos (which they can interact with) and common misconceptions.

This brings us around to a big misconception that we have as teachers, which is that lecturing is an effective form of teaching. Our reasoning is strong, after all, since most of our faculty have experienced lecture as their main personal teaching experience. And, if it worked for us, then…

In contrast with our own personal educational experiences, studies involving tens of thousands of students nationwide have shown poor student gains for a wide range of physics concepts, at institutions which use primarily lecture-based teaching methods. The research also found that interactive forms of teaching produced much larger student gains for the same concepts. So, our teaching results, while bad, are not atypical. I would summarize the overall findings of these large studies by using a mangled quote from Winston Churchill, "Lecturing is the best form of teaching, except for all the others."

Recent alumni Alan Rowland (left) and Jonathan Kappel (right) are recognized for excellence in their undergraduate work. Alan received the Nina and Frank Avignone Fellowship Award and Jonathan received the Lovelace Family Endowed Scholarship Award. Dr. Jeff Wilson (Director of Undergraduate Studies) presented these awards to Alan and Jonathan at the 2021 Awards Day celebration, which took place at the Colonial Life Arena in Columbia.

We ultimately couldn't ignore all the evidence pointing toward more effective styles of teaching and so we have begun transitioning our introductory courses to a form of learning called the lecture-studio model. In this type of classroom, students learn by doing, and most of the talking will involve students talking to each other. There is less sitting and listening. Active learning, instead of passive learning. If all goes according to plan, we will be transitioned to active learning for Physics 211 in the Fall. Then, we will have our own experiences to, hopefully, support what the researchers have been telling us.

Congratulations and best wishes to our 2020-2021 graduates!

Joshua Buffum	Fatima Elkhatib
Emma Garrison	Jonathan Kappel
William Marshall	Matthew Moser
Alan Rowland	Ronan Shanley
Camille Yoke	Brooke Ziegenhagen

RESEARCH GROUPS

Experimental Nuclear Physics Group

By Ralf Gothe, Yordanka Ilieva, and Steffen Strauch

The study of the atomic nucleus and its constituents at the quark level is at the core of our research. We are leading experiments at one of the flagship facilities for nuclear physics research in the U.S., the Thomas Jefferson National Accelerator Facility (JLab) that recently has been upgraded to higher energies, and at the Paul Scherrer Institute (PSI) in Switzerland. We have also been responsible for the construction of critical equipment for major nuclear physics experiments at JLab and PSI. Our studies on Quantum ChromoDynamics (QCD) and nuclei are recognized as U.S. nuclear science frontiers, and our research helps to address basic questions such as: what is the origin of confinement and most of the visible mass in the universe, what is the nature of neutron stars, and what are the properties of dense nuclear matter? Answering these and related questions is a complex task requiring dedicated experimental observations and careful testing of theoretical predictions against measured observations.

Currently, our group is comprised of faculty members Ralf Gothe, Yordanka Ilieva, and Steffen Strauch, postgraduates Gary Hollis and Iuliia Skorodumina, graduate students Anne Flannery, Lin Li, Chris McLauchlin, Krishna Neupane, Nicolas Recalde, and Brandon Tumeo, and undergraduate student Benjamin Moses.

Our research and academic activities in the past year continued to be affected by the COVID-19 global pandemic. Foremost, we are glad to share that our group members are currently healthy and safe. We went through a scare when one of us was diagnosed with a COVID-19 infection and was sick for a month. Fortunately, a full recovery followed, and all has been well since. Research wise, we continued to respond to the changing work-related conditions. The partial lift of travel restrictions this summer, allowed us to start catching up with delayed planned hardware work at PSI and JLab. While national and international research conferences are still being held primarily online, cancellations of meetings are no longer occuring and our conference presentations have picked up in volume again. This has been especially important for our students, who could again present their research to the broader nuclear physics community. Not traveling to a meeting location means that we keep teaching and delivering on service work while attending a conference remotely. This has not put an ease on our daily schedules and, as for many many people, the pressure has kept up. All of us share in the collective aspiration to bring life to its pre-pandemic routine and have been contributing to this cause as much as we can.

Even though UofSC opened fully for face-to-face classes this fall, most of our day-to-day research activities are still being conducted remotely, and we expect this to continue until

Figure 1: The Experimental Nuclear Physics Group in the 2021 COVID-shaped environment. Back row (from left to right) - Brandon Tumeo, Iuliia Skorodumina, Anne Flannery, Lin Li, and Krishna Neupane. Front row (from left to right) - Ralf Gothe, Yordanka Ilieva, and Steffen Strauch. Group members working from home or being in class - Gary Hollis, Christopher McLauchlin, Nicolas Recalde, and Benjamin Moses.

restrictions ease up. However, we were again able to take our annual group meeting photograph on campus (see **Figure 1**). Although our weekly group meetings have been held online, work on our analyses projects has continued full steam! We are quite excited to share some new, hot results from our recent experiments at JLab. In one of these, we have measured the resonance excitation cross sections off the bound neutron and a publication of the results is under collaboration review. These highly anticipated results are essential to better understand the flavor-dependence of the strong interaction and to improve models, needed in high-energy physics, to predict neutrino-nuclei interactions. In another experiment, an even higher-energy electron beam smashed into a proton target, which caused a spray of nuclear reactions that were then measured by the new CEBAF Large Acceptance Spectrometer (CLAS12). We will use these novel data to search for new excited states of the nucleon and to probe deeper into the origin of the visible mass in our universe. Krishna Neupane, with the help of Nick Tyler, has already extracted first acceptance-corrected yields for one of the more complicated multi-particle final states to achieve these goals. We are very proud that Dr. Gary Hollis, Dr. Nick Tyler, and Dr. Iuliia Skorodumina have successfully finished their PhD research projects and defended their dissertations.

Using data from another, lower-energy deuteron experiment from the 6-GeV JLab era, Brandon Tumeo observed for the very first time Λ-deuteron elastic scattering events and showed that differential cross sections can be extracted from the data sample with meaningful statistics. We anticipate that these data will shed light on the elusive hyperon-nucleon three-body force that could be key to resolving the hyperon puzzle in neutron stars. Brandon defended his M.S. thesis on this analysis in January and is now pursuing his Ph.D. degree on this topic. He presented results from this research at the 2021 Fall APS Division of Nuclear Physics (DNP) meeting and is planning to do so also at the international Strangeness Nuclear Physics School this December.

Our hardware work on characterizing the gain of small photomultipliers (MPTs), namely Microchannel-Plate (MCP) PMTs in high B-fields (in support of the U.S. Electron-Ion Collider (EIC) project) was deemed mission-critical for JLab and we were given access to the lab this summer to carry out measurements of the newest MCP PMTs on the market. Two of us spent two months in Newport News and gave a countless number of shifts to collect a comprehensive data sample on gain and ion feedback for two models of these devices. The results are quite promising since they show that these PMTs are viable readout options up to B-fields of 2 T, which is the expected magnetic-field environment for at least one EIC Cherenkov detector. Benjamin Moses was responsible for the analysis of these data and presented his results at the Conference Experience for Undergraduates (CEU) at the 2021 Fall DNP meeting (see **Figure 2**).

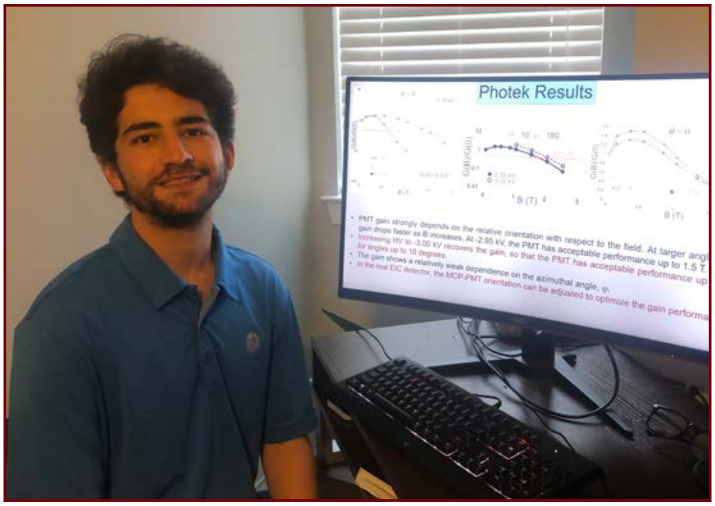


Figure 2: Benjamin Moses preparing his poster presentation on the gain evaluation in high magnetic fields of Microchannel-Plate Photomultipliers for EIC. He was selected to present his research at the 2021 DNP CEU in a nationwide competitive process.

Our NSF-funded Muon Scattering Experiment (MUSE) at PSI will extract the proton charge radius from elastic electron- and muon-scattering off protons. It will directly compare the electron and muon elastic cross-sections at the sub-percent level. Furthermore, using lepton beams of positive and negative charge will allow studying processes in which more than one photon is exchanged in the scattering process. The measurement of two-photon-exchange effects will help overcome theoretical uncertainties in hydrogen-spectroscopy experiments. After more than a year of pandemic-related delay, our group has resumed on-site activity for our Muon Scattering Experiment (MUSE) at the PSI in Switzerland. This past summer, Anne and Steffen received permission from the university and traveled fully masked and vaccinated to PSI to tend to the scintillation detectors built at UofSC for the experiment. Two large frames with 18 detectors each were craned out of the setup. Detectors that showed anything but an ideal response in earlier tests were opened, cleaned, and, where needed, photomultiplier tubes were re-glued to the scintillators. Repaired bars were tested and mounted again on the frames. Further tests and calibrations were performed remotely from Columbia to ready the system for the upcoming beam time in the Fall. We will support the beam time with remote shifts and be back at PSI after the Fall semester. Guided by the results of Lin's simulation work, the collaboration upgraded a calorimeter detector of the setup from a configuration of six-by-six lead-glass crystals to a larger one with eight-by-eight blocks. Lin reported on her work on radiative corrections for MUSE at the 2021 Fall DNP meeting.

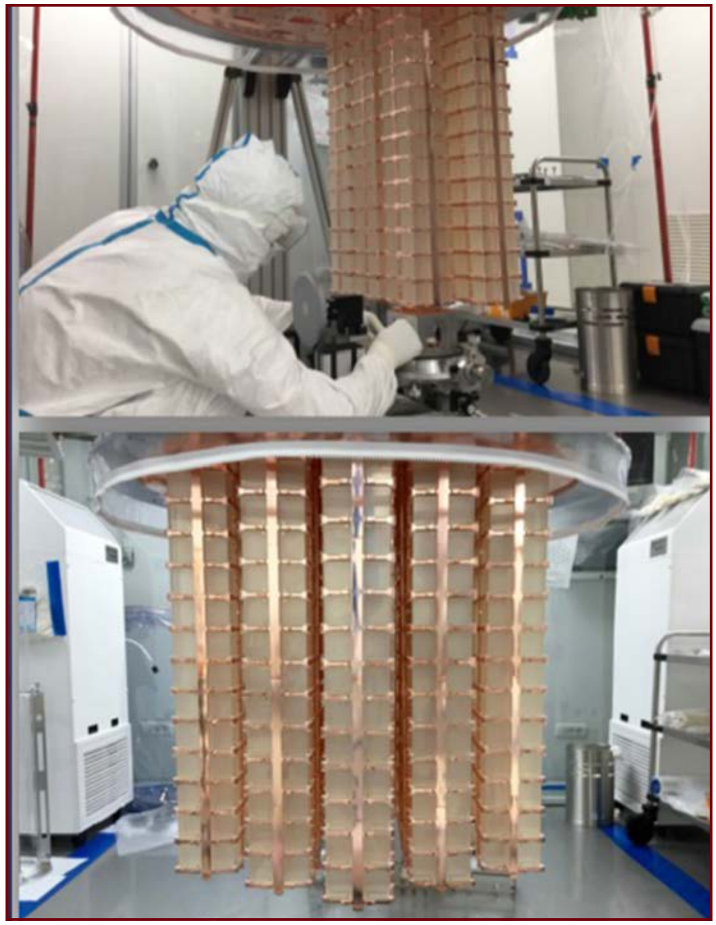


Figure 1: A technician assembles the towers of tellurium dioxide detectors for the CUORE experiment in Gran Sasso, Italy.

Particle Astrophysics Group

By F. Avignone, R. Creswick, C. Rosenfeld, D. Tedeschi, and J. Wilson

This is an exciting time for low background rare event searches conducted deep underground such as neutrinoless double-beta decay ($0\nu\beta\beta$) experiments and dark matter searches. The results from these nuclear physics experiments will bring new possibilities to the understanding of the universe and the role played by neutrinos and dark matter. The UofSC particle astrophysics group continues to play leading roles in international collaborations performing the world's most precise measurements.

D. Tedeschi, F. Avignone, and graduate students T. Lannen and F. Adams are members of the MAJORANA and LEGEND collaborations that are using high-purity Germanium detectors to search for $0\nu\beta\beta$-decay. Searches with germanium detectors hold the current record for the half-life limit and sensitivity. The US Department of Energy considers the measurement of $0\nu\beta\beta$-decay a national priority. The LEGEND-1000 experiment has been chosen to be the premiere US effort and is designed to probe $0\nu\beta\beta$ decay with a 99.7% CL discovery sensitivity, in the ^{76}Ge half-life beyond 10^{28} years, corresponding to a $m_{\beta\beta}$ upper limit in the range of 9-21 meV in 10 yr of live time. The UofSC group will continue with its leadership in data analysis and has begun the development of a new on-campus effort to

Figure 2: Germanium detector strings used in the Majorana Demonstrator to search for neutrinoless double beta decay.

recycle and purify germanium to be used in the construction of detectors for the experiment.

F. Avignone, R. Creswick, C. Rosenfeld, and J. Wilson, and graduate students D. Adams, C. Alduino, and K. Wilson are members of CUORE (Cryogenic Underground Observatory for Rare Events). CUORE is an array of 988 thermal detectors, or bolometers, (3/4 of a ton) maintained at 11 to 15 degrees absolute. It has been searching for the neutrinoless double-beta decay of the isotope tellurium-130 contained in the tellurium dioxide bolometers. The collaboration is publishing results based on one-ton-year of exposure recorded over a period of 3 years. The Department of Energy has also given approval for funding to CUORE's successor, CUPID (CUORE with Particle Identification). The projected sensitivity of CUPID is predicted to be comparable to that of LEGEND-1000. CUPID will be built and operated in the Laboratori Nazionali del Gran Sasso (LNGS), which is located under the Gran Sasso Mountain in Assergi, Italy.

Theoretical Physics Group

Members: Brett Altschul, Vladimir Gudkov, Sapan Karki, Pawel Mazur, Alexander Monin, Harry Oslislo, Thomas Richardson, Abhishek Rout, Matthias Schindler, Luis Suarez

We are excited to announce that after two years of waiting, Prof. Monin is finally set to join the department in person. Professor Monin's research revolves mostly around conformal field theories (CFT). He and his collaborators were among the first to develop a semiclassical method for investigating those theories in sectors with large quantum numbers. Using a Euclidean version of CFT, the method makes it possible to find the spectrum of operators and coupling constants. Currently, Prof. Monin is working on extending the method to theories with Minkowski signature, which can provide information about scattering processes in quantum chromodynamics.

Congratulations to former graduate student Thomas Richardson, who successfully defended his dissertation titled "Large-NC constraints for one- and two-nucleon currents in effective field theory" in Summer 2021. Thomas's research, performed together with Prof. Schindler, has already resulted in two publications and a third manuscript is expected to be completed soon. Thomas has started a postdoctoral researcher position at Duke University, where he will be expanding his research into new directions while also continuing to work with Prof. Schindler. We wish him all the best for the future.

Professor Mazur's research on non-singular black holes a.k.a. gravastars, or dark energy stars, continues to attract the attention (more than 800 citations) of the theoretical and experimental/observational communities of researchers in black hole physics/astrophysics. Professor Mazur has presented his solution for the interior gravitational field of the slowly rotating Kerr black hole at an international conference and a seminar in Europe, and locally at a departmental colloquium.

Professor Gudkov continues to work on projects studying fundamental symmetries in particle and nuclear physics by providing theoretical support for several experimental programs in fundamental neutron physics. This includes the US-Japanese NOPTREX collaboration searching for time-reversal invariance violation in neutron scattering at the J-PARC facility in Japan, an experimental program studying parity-violating effects at Los Alamos National Laboratory, and a search for neutron-antineutron oscillations at the European Spallation Source.

Professor Altschul continues to work on exotic physics beyond the standard model, including the possibility of violations of fundamental symmetries, like rotation symmetry, relativistic boost symmetry, and CPT. He is currently supervising three doctoral students in this area, looking at symmetry violation in quantum field theory, gravitation, and cosmology. Moreover, Professor Altschul has also branched out, and he is now collaborating with a group of scientists at Harvard Medical School on problems in biomedical statistical mechanics, developing new entropy-based algorithms for analyzing the results of large quantities of immune reaction data.

EVENTS, EDUCATION, AND OUTREACH

Figure 1: Jupiter and its moon, Io, as seen from the Melton Memorial Observatory in September 2021.

The Melton Memorial Observatory Re-Opens for Public Viewing

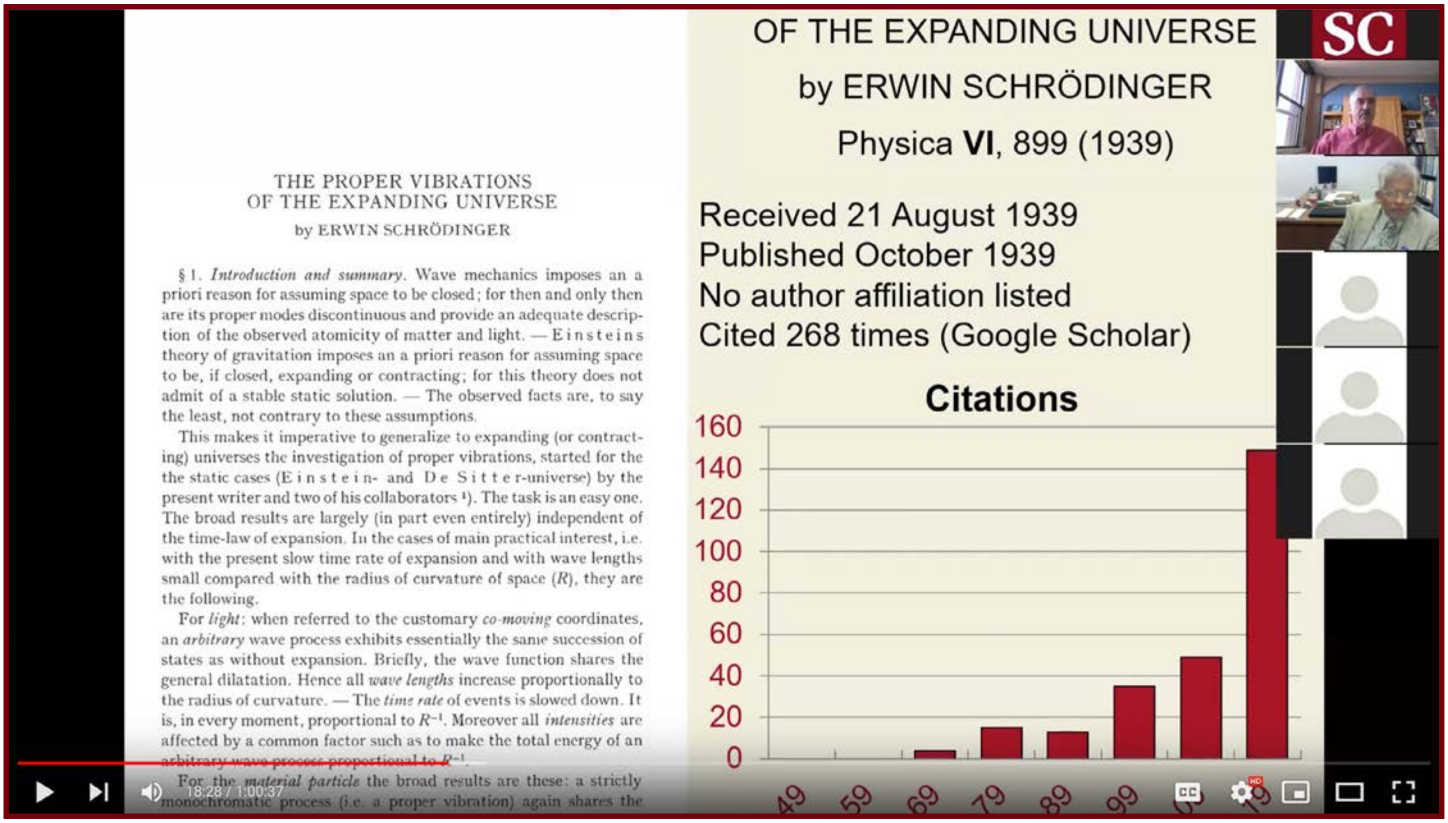
By Martin Bowers

During the COVID-19 pandemic, the Melton Memorial Observatory suspended the practice of hosting guests on clear Monday nights. During this time, we resorted instead to live-streaming on the observatory's Facebook page (*facebook.com/meltonobservatory*). Although the streaming process succeeded in bringing the night sky to our online guests, there's really nothing quite like physically looking through a telescope. We are thus pleased to report that the observatory is once again open for public viewing every clear Monday night!

To meet campus social distancing requirements, we require guests to wear a facemask and have set a limit of no more than twelve guests upstairs at a time (four in the dome and eight on the roof). We use the big 16" Cassegrain scope in the dome and two portable 8" Schmidt-Cassegrain telescopes on the roof to bring the night sky to our guests. Our opening night took place during the university's annual Family Weekend event in late September. We had an enormous turnout with a steady stream of mostly out-of-town guests at our door throughout the evening.

One thing we are doing differently this year is leveraging our video streaming to offer viewing both through an eyepiece and on a live video screen. This enables us to capture images while hosting guests and then later post them online so that remote guests can still experience the event.

An example is shown in **Figure 1**. This image of Jupiter includes the moon Io and its shadow on the surface of the planet. During the evening, we watched the shadow move across the face of Jupiter, capturing a short video stream every 10 minutes. We later processed each stream into a single image using freeware stacking and processing software and then



Dr. Rocky Kolb (University of Chicago) gave a virtual colloquium talk to the Department of Physics and Astronomy, which highlighted the life and contributions of Dr. Erwin Schrödinger, the famous theoretical physicist who developed the well-known Schrödinger equation.

created a video animation by putting 18 individual frames together. The resulting video compresses three hours of real time into nine seconds of video time, clearly showing Jupiter's rotation, Io's shadow transiting the planet, and three moons moving through their orbit. The video is posted on the Melton Memorial Observatory's Facebook page.

We hope you have the opportunity to see us both live and online. Come check us out!

Continuing Colloquia: Presenting in a Pandemic

By Sam Beals

As the effects of COVID-19 continue to shape how we learn, teach, and grow together, we are thankful for departmental traditions that have remained strong in the midst of constant and unexpected change. Over the last year, the Department of Physics and Astronomy pivoted to hosting virtual colloquium presentations via Zoom during our typical Thursday afternoon time slot. Our ongoing colloquium series features a wide variety of notable speakers in various realms of physics and astronomy from across the globe. Since last Fall, we have had the pleasure of extending invitations to leading scientists such as Dr. Rocky Kolb (University of Chicago), Dr. Lawrence Ford (Tufts University), Dr. Robert Cava (Princeton University), a number of our very own from UofSC, and more. Many of these talks have been recorded and uploaded to YouTube, which has provided added flexibility for those who cannot attend. Each speaker brings a wealth of scientific knowledge to these talks, and we are very pleased to continue offering virtual colloquia for the foreseeable future.

During this period of time where many of us seek opportunities to gather together, our hope is that these virtual talks encourage a unique sense of community both inside and outside the department as well as provide a chance to explore and discuss various topics at the forefront of current physics and astronomy research. Of course, we hope to return to a face-to-face format in the near future and perhaps even implement a hybrid model for viewing upcoming presentations.

For more information on past and upcoming colloquia as well as accessing recorded talks, please visit our website at ***uof.sc/physicscolloquia***. We hope to see you on Zoom for our next colloquium!

STUDENT SPOTLIGHT AND ALUMNI NEWS

STUDENT SPOTLIGHT

Answering a Question with a Question

By Fatima Elkhatib

As a native South Carolinian surrounded by University of South Carolina graduates, my path was set out for me from the beginning: I was going to become a Gamecock. In my elementary and middle school years, I dreamed about all kinds of careers from working as a high school teacher to launching into space as an astronaut. While thinking about my career choices and imagining my future self, I knew that no matter what dream I chose to pursue, the University of South Carolina was where they'd come true.

Growing up, I was always fascinated by how things worked and why they moved the way they did; somehow it seemed like I had always chosen physics. Ever since I began solving math equations and physics problems, my favorite part of it all had been putting a box around my answer. It might sound trivial, but after completing an entire problem, working through derivations, plugging in numbers, and re-checking the work, drawing a box around the answer was the most satisfying and empowering part. The box I drew was my seal. It was the confidence I had in my answer - the proof in the pudding. A couple of years into college, I realized I was putting question marks next to my answers instead of drawing boxes around them. At first, I was devastated. I no longer knew what I was doing. At least that was what I thought. I began to realize that those unbearable question marks lead me to asking more questions and reaching out to my classmates and professors for help. They empowered me, a studious youth who equated asking questions with an inadequate understanding of a concept, with the knowledge that questions are the key to delving deeper into the understanding of a concept.

As an undergraduate student, I wasn't sure what I wanted to do with my degree. Majoring in physics presented a lot of opportunities, and each was just as intriguing as the other. To resolve this, I decided that my research would determine the direction of my career path. Scrolling through the research groups on UofSC's webpage, I was instantly hooked on the topic of astronomy. I got to work consulting with professors and was presented with a number of different astronomy projects to choose from. The dimming and reddening of quasars due to the dust in foreground galaxies was the one I found most fascinating. I felt like I was given the opportunity to be one of those scientists I had read about as a girl, the ones pouring over books, charts, and looking deep into telescopes trying to find the answers to questions most people never even bother to ask. I simply could not turn down that opportunity. While it may sound complicated, the concept is relatively simple. A quasar, the very luminous nucleus of an active galaxy, emits light that we can see. However, on its way to us, the light passes through and is absorbed by dust in other galaxies that lie between us and the quasar, making it appear redder and dimmer than it actually is. In my research, I calculate the effects of interstellar reddening and extinction, or dimming, to study the properties of the dust in the galaxies that the light passes through, comparing it to dust in our galaxy, the Milky Way. Understanding dust and its properties helps with understanding the physical processes connected with star formation.

In my senior year, I started looking at graduate school options. Making my way to class among the trees and nearly tripping over one of the brick stones one day, I knew I couldn't leave UofSC; it had become my home. Beyond that, I was presented with opportunities I could never be thankful enough for - opportunities I would not turn down. My undergraduate research director offered me a position as assistant to her graduate school research group. I am fortunate to have such an opportunity - I will get my master's and PhD at my university doing the thing I love, all on a full ride. Last semester, I graduated cum laude in my class, proudly waving my Bachelor of Science degree. I know I won't stop here.

Since graduation, I have been calculating phosphorus column densities, working with zinc lines, comparing published oscillator strengths, and most recently, analyzing the different elements in a gas cloud with respect to hydrogen. There are times when I take a step back in what can be only described as pure contentment and wonder at how happily unexpected all of this is. Before attending the University of South Carolina, I was compelled to learn more about the world around me, from the tiny atoms and quarks to the vast universe around us. Throughout my years as an undergraduate student, my perspective of everything has changed dynamically. Yesterday, I was worried about finding the answers to things for myself, but today I ask the questions and seek the answers for others.

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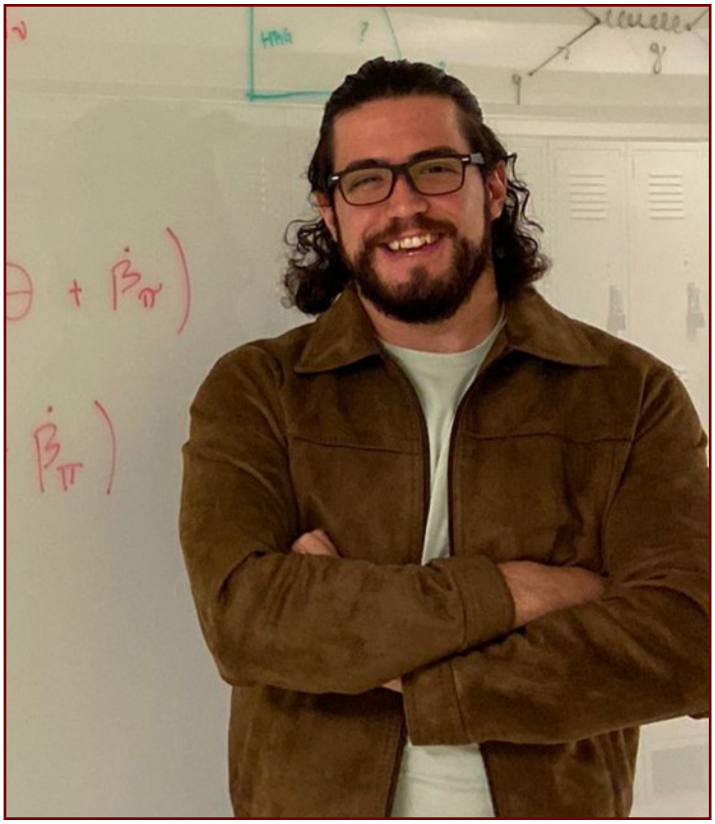

A Question of Scale

By Travis Dore

As an 18-year-old fresh high school graduate, beginning college over 700 miles away from home with an undecided major, I could not possibly have conceived what the trajectory ahead of me would entail and where I would be today. I didn't put much thought into where I would be going to a university other than making a financially sound decision while also going to school away from home. Regardless of where I could be, I am absolutely certain that where I am now is a result of my professors and mentors at the University of South Carolina who constantly embodied a vehement passion for physics and an unwavering care for students. In fact, throughout my time as an undergraduate, I was never at the top of my class in physics, but I had a deep passion for learning and a knack for asking questions. It's always been clear to me that my professors at Carolina noticed and fostered this with a personal touch that I don't believe I would have received anywhere else. Every professor I encountered seemed to have the students' best interest in mind as they taught their classes and mentored. It was a fundamental component of my growth and development as a young physicist which helped me cultivate the courage that I needed to continue my studies. After graduating from USC with my bachelor's degrees in both physics and philosophy, I began to pursue a Ph.D. in physics at Rutgers University.

Starting at Rutgers, I found myself in a familiar position in that I was again undecided on exactly where I wanted my studies to take me. I was convinced that I would be doing experimental physics because I liked the idea of working closely with real physics experiments and didn't believe I had the necessary background to work on the theoretical side. I didn't realize how often graduate students change their direction. I was persuaded by some fellow classmates to at least talk to some professors who worked in theory and because of this, I stumbled into the office of Dr. Jacquelyn Noronha-Hostler, a new hire who started at Rutgers the same year that I did. Jaki told me about her work in nuclear theory, specifically relativistic heavy-ion collisions. These are experiments done at the Large Hadron Collider at CERN and the Relativistic Heavy-Ion Collider at Brookhaven National Laboratory. When colliding two heavy nuclei (e.g., Pb) at high energies, experiments create a system so energy dense that quarks and gluons are deconfined and eventually thermalize into a state of matter called the quark gluon plasma. Amazingly, we can use relativistic viscous hydrodynamics to model the evolution of the bulk of the system, which has reproduced and predicted a plethora of experimental data. Therefore, these experiments also allow us to explore the phase diagram of strongly interacting matter. Crucially, we use our theoretical models, such as hydrodynamics, to interpret experimental data and learn about many-body strongly interacting systems both in and out of thermodynamic equilibrium. The interdisciplinary nature of the field has allowed me to ask deep and meaningful questions from many different areas of physics and I continue to ask and research the answers to these questions daily.

Currently in my fifth year of my Ph.D. program, I have since advanced to doctoral candidacy and transferred with my advisor to the University of Illinois Urbana-Champaign. I have learned so much and gained a great deal of experience over the past (almost) decade since I started my undergraduate degree at Carolina. However, I would be lying if I said at any one moment, I felt like I knew exactly what I was doing. On shorter time scales, I find myself feeling as if my career is turbulent and driven by chaotic or even stochastic dynamics. After all, so much that got me to exactly where I am now happened just by chance. On longer time scales, a steady picture of growth begins to emerge, and it is clear that my own hard work along with invaluable guidance from caring and more senior professionals has allowed me to be where I am, in a more general sense. This year, I am beginning to apply for postdoctoral appointments and fellowships while feeling ready to start the next phase of my physics career.

There were so many professors who made lasting impressions on my development as a young physicist in their classes. This feels like the right time to say "thank you" for every lecture, for all of the time spent in office hours, for every thoughtful answer to my (sometimes out-of-left-field) questions, and for all of the challenging but worthwhile courses. I would especially like to thank Dr. Sanjib Mishra, who took me seriously as a young undergraduate researcher as well as Dr. Ralf Gothe, who had the patience of a saint while I spent many hours in his office not just working on homework and asking questions, but also asking for career advice, and sometimes just hearing some of his stories. So much in physics comes back to the important question of scale. In my own life, I find that somewhere between the turbulent day-to-day and the long-time "big picture" limit, is exactly where I find my satisfaction as a physicist.

To South Carolina...and Beyond!

By Justin Pierel

My path to becoming a graduate student in the Department of Physics and Astronomy at UofSC was long and circuitous. A career in astronomy never seemed possible in my rural Maine childhood home, where students were encouraged at school to pursue more "practical" career paths. The future consideration of graduate school was never mentioned, and, in the end, I went to college intending to pursue an engineering degree.

I ended up graduating from Bowdoin College with my bachelor's degree in mathematics in 2014, and quickly abandoned a consulting career path to instead accept a position in the Earth Science Division DEVELOP Program at NASA LaRC. Being at NASA was a transformative experience that left me with the single goal of having a career in astronomy, and I finally broke into the space sciences when the Cassini CIRS team hired me in 2015 as a research assistant. At that point I knew I wanted to go to graduate school for astronomy, so I began communicating with potential advisors and programs around the country while studying the atmospheres of Jupiter and Saturn.

Eventually, I joined UofSC in 2016 because I had the opportunity to immediately contribute as a research assistant to work related to supernovae and gravitational lensing with Dr. Steve Rodney. Throughout my graduate career, I had an excellent experience working with fellow students, and thoroughly enjoyed the research opportunities I was given. In 2020, I completed a master's degree in physics with a thesis focused on the cosmological potential of gravitationally lensed supernovae discovered with the upcoming Nancy Grace Roman Space Telescope. Then, this past spring, I completed my PhD with a dissertation aimed at preparing for next generation telescopes by providing new models and methods for supernova cosmology research in the coming decade.

Soon after graduating from UofSC, I joined the Space Telescope Science Institute (STScI) at Johns Hopkins University as a postdoctoral fellow, where I am continuing my work on supernova cosmology with current and future data. Although my position has been fully remote up to this point, I am moving to Washington, D.C. very soon and am excited to spend some time in the office on a hybrid work schedule for the foreseeable future!

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Space Elements imaged by Alex Mowery from the Melton Observatory