# Quantum Leap

University of South Carolina
Department of Physics and Astronomy

2022

## Message from the New Department Chair

*By Alexey Petrov*

Welcome to another year of *Quantum Leap*! This is my first newsletter as the Chair of the Department of Physics and Astronomy. I am excited to start a new chapter of my life at the University of South Carolina! Before properly introducing myself, I would like to thank Interim Chair Michael Dickson for his selfless service to the Department. Last year was not easy, and I would like to acknowledge Michael's leadership as the university transitioned back to in-person teaching and research activities.

As I mentioned, I am new to the Department, to the University, and to the South! I came to the University of South Carolina from Wayne State University in Detroit, where I spent 21 years as a professor, following postdoctoral appointments at Cornell and Johns Hopkins. My research specialty is theoretical particle physics. In particular, I am interested in questions related to the physics of quarks and leptons, the matter-antimatter asymmetry of the Universe, and applications of effective field theories. I look forward to working with USC physicists on these and related problems. I do enjoy teaching: my favorite classes are classical and quantum mechanics.

There are several new and exciting developments happening in the Department this year.

First, we are proud to welcome new faculty to the Department! Our newest tenure-track faculty is a computational condensed matter physicist, Dr. Sai Mu. He comes to South Carolina from the University of California Santa Barbara and will be associated with our SmartState Center. We also welcome two professional-track faculty, Dr. Alice Churukian and Dr. Bram Boroson, who come from the University of North Carolina at Chapel Hill and Clayton State University respectively.

Dr. Churukian is leading an effort to overhaul the department's service courses into a new "Studio Physics" format. This format has proven to be superior in teaching physics at other universities. The first studio classroom has opened for students this Fall, and two more are on the way. We are very excited about this development – please stop by to see the new studios!

It is known that graduate education is not only about taking courses but also about "learning the craft." This does not only mean learning one's research specialty but also having a broad picture of what is happening in physics and astronomy. Besides the usual Colloquium series, the department now runs a Condensed Matter Physics (CMP) seminar and a journal club, as well as a Nuclear, Astro, and Particle Physics (NAPP) seminar. While CMP and NAPP seminars are designed as professional talks, colloquia are reserved for graduate-level presentations by visiting experts in their fields. We encourage everyone to attend our colloquia and seminar series.

This would be an important year for the Department as we chart our way forward by developing a long-term strategic plan. The committee, headed by Mas Crawford, has their work cut out for them! The Department is poised to address its challenges and grow both in size and in its research, educational, and outreach activities. In addition, we are working on creating two new undergraduate majors in the department! Several outreach programs are also in the works. We hope those initiatives will help us better serve the people of the great state of South Carolina! We would love to hear from you, whether you are far away or nearby. If you are in the vicinity, please stop by!

Alex Petrov

Alexey A. Petrov

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# SPECIAL ARTICLE

## Science that Captures the Popular Imagination: Stereo Sound Picks Up an Extra Dimension!

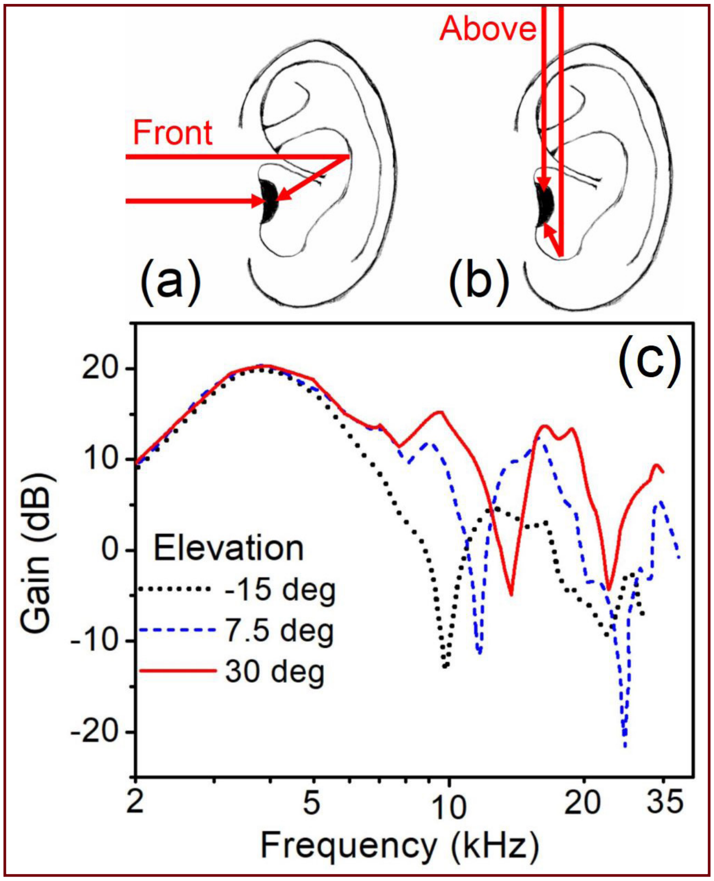
*By Milind Kunchur*

Physics is often viewed as an intimidating and abstract subject, and not many of its topics are easily communicable and relatable to the general public. However, the science of sound and its perception/reproduction is an effective way to break the ice with a lay audience. Despite its century old existence, audio reproduction is still surprisingly poorly understood and is filled with many contentious and controversial claims because of the lack of a rigorous scientific foundation. Consequently, consumer audio systems typically bear a distant resemblance to live music. However unbeknownst even to many music and audio professionals, there is a regime known as “high-end audio” (HEA) that achieves a strikingly realistic portrayal of instruments in a three-dimensional space. Dr. Kunchur's research is demystifying HEA by developing incisive physical measurements, sensitive psychophysical tests, and a quantitative understanding of auditory neurophysiology and memory hierarchy. The work required bridging together several disciplines including acoustical physics, musicology, auditory biology, neuroscience, psychology, and engineering.

One historical result published in the past year is the first proof—in the 70-year history of stereo sound—that two-channel stereo is three-dimensional, not just one- or two-dimensional as is often believed. From a naive physics point of view, one might expect the sound wave fronts from two speakers to add like vectors within the plane including the listener, producing apparent (phantom) sound locations at different azimuthal angles in a horizontal plane. This would produce 1D sound with no depth or height differentiation. However, the summation of sounds does not take place physically but does so neurologically. If a recording made with just two microphones is reproduced through two speakers cleanly—with minimal distortions, especially of the temporal kind—the brain has all the information it needs to create a 3D phantom space. In HEA, this ghost-like phenomenon is referred to as "soundstaging" and "imaging”.

In other work, Dr. Kunchur used his condensed-matter (solid-state) physics expertise in fast-signal techniques and novel measurements to demonstrate by far the smallest audible audio-system change on record. This result—"Cable Pathways Between Audio Components..." published in the Journal of the AES (Audio Engineering Society) —also shed light on the roles of short-term and long-term memories in comparison processes, and thus explained why previous blind testing over many decades had failed. The JAES held a Zoom roundtable open to all AES members to promote an open discussion of the surprising results, and Dr. Kunchur received congratulatory emails from the AES president and the chair of the AES Technical Committee on High-Resolution Audio.

These results are being hotly discussed on forums and YouTube channels on audio (e.g., ***"Audio Cables: Scientific proof on impact of sound?"*** and ***"Scientist Finds Measurable Difference in HIFI Audiophile Cables ! PROOF"***). Dr. Kunchur has been invited to appear as a guest on their shows and to collaborate with them in producing a series of educational videos. A related educational exhibit was also produced for the South Carolina State Museum. Next time you are in town, contact Dr. Kunchur for a mind-blowing audio demonstration!




*Standard HRTF (head related transfer function) based mechanism for how the auditory system differentiates the elevations of sound sources. (a) and (b) The delays (and hence interference) between direct and pinna-reflected paths depend on the direction of the sound. (c) This leads to notches and other features in the spectrum as shown in these measurements (Rice et al. Hear. Res., vol. 58, pp. 132–152, 1992)., which are analyzed by pyramidal neurons in the DCN (dorsal cochlear nucleus). This HRTF mechanism fails to explain elevation spatialization in unprocessed stereo sound and also natural localization for narrow-band and low-frequency sounds.*

# UPDATES FROM THE DIRECTORS

# News from the Director of Undergraduate Studies

*By Jeff Wilson*

We have had an exciting year. Michael Dickson, as interim chair, watched over the department as we did an external search for a new chair. We regard such a search as implicit permission for us to reformulate our department. The search succeeded and Alexey Petrov will be our chair for the foreseeable future. In addition to Alexey, and as a start to our reformulation, we were able to recruit and hire a new senior instructor, Alice Churukian, who will be taking a leadership role in our undergraduate program.

We have several big projects underway involving our undergraduate program. Our conversion to a lecture/studio teaching format is underway and we are offering our calculus-based intro course, Physics 211, in that mode right now. Alice Churukian has been leading this effort as one of the creators of a similar course at the University of North Carolina at Chapel Hill. Next fall will see the conversion of Physics 212. That process will continue with Physics 201 and 202 (algebra-based physics) in the following years. We are developing a plan with the College of Arts and Sciences to perform the renovations needed to convert our existing lab space to the studio classrooms we will need for these courses.

Other projects under discussion involve some potentially popular additions to our program. Astronomy has long been a strong interest for our incoming students - both at the undergraduate and graduate level. We have an Astronomy minor for undergraduates, but our new chair has tasked us with investigating a major in Astrophysics. This could result in a significant expansion in the size of our undergraduate and graduate populations with only a modest investment in building up our Astrophysics research group, which is currently undersized relative to the high level of student interest. We have a significant group of faculty investigating and supporting this expansion effort.

Quantum computing is one of the hottest and fastest developing areas of physics right now. We have several groups of faculty who are investigating how best to develop a program of study to introduce students to the ideas of qubits, quantum entanglement, and "spooky" action. Faculty in the Departments of Mathematics and Computer Science are working on their own courses related to information science that could potentially complement our developments on the quantum computing side. A properly designed program could thus have large multidisciplinary appeal and attract new students to our department.

The American Physical Society has identified many areas where physics departments can offer skills that can help improve career outcomes for students. One of the areas suggested by the EP3 study group (Effective Practices for Physics Programs) for more emphasis is computational skills: *"Knowledge and skills in programming, simulations, and modeling are needed by physics graduates in a variety of careers."* This is an idea that has resonated with several faculty members who have considered embedding computational problems and techniques in several of our introductory and intermediate courses. We are hoping to give our students well-practiced skills to take with them, and we have tentatively chosen to focus on Python as our primary programming tool. Our goal is for students to become comfortable with computational tools and to see them as a normal companion to their continuing physics careers.


*Benjamin Ranson (Class of 2022) received the Nina and Frank Avignone Fellowship Award. Dr. Jeff Wilson (Director of Undergraduate Studies) presented this award at the special Awards Day celebration on April 21, 2022 at the Colonial Life Arena in Columbia. Benjamin is now a first-year graduate student at Johns Hopkins University (Baltimore, MD).*

Last year might have been exciting when compared to recent history, but it looks like the fun is just getting started.

**Congratulations and best wishes to our 2021-2022 Graduates!**

Tyler Anonie
Robert Griffin
Ethan Mahan
Benjamin Moses
Benjamin Ranson
Raymond Schmidt

# News from the Director of Graduate Studies

*By Matthias Schindler*

Getting a graduate degree in physics and astronomy is more than taking classes and sitting in one's office doing research. It often involves interacting with a variety of other scientists, taking shifts at labs far from home, participating in conferences and workshops, and learning about physics outside one's own specialized field by attending colloquium talks. With universities and lab facilities getting back to in-person participation, our graduate students finally get to experience these important aspects of their education again.

**New Students:**

We are happy to welcome the latest cohort of graduate students to the Department: Jean-Joseph Benoit, Daniel Hancock, Corey McAllister, Karthik Gananath Putha, Paras Regmi, Ananthavishnu Santhigiri Unni, and Cameron Walker. Four more students are set to join us in the upcoming months: Mohammadali Khosravi, Myo Maung Maung, Deepak Sharma, and Ahmad Zia Sherzad. Myo Maung Maung has been selected as a recipient of the USC Presidential Fellowship, the most prestigious doctoral award at the University.

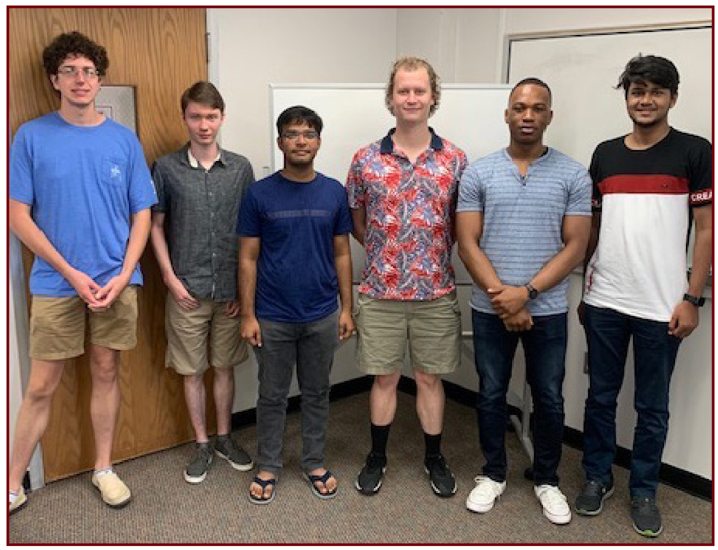
**Awards:**

Once again, our graduate students continue to excel in their research and teaching, with several of them receiving external and internal awards and scholarships. Caleb Duff has started his second year in the US Department of Defense's Science, Mathematics, and Research for Transformation (SMART) Scholarship for Service Program, while Kyle Lackey is now in the fourth year of a NASA South Carolina Space Grant Consortium Graduate Research Fellowship. Franklin Adams received a 2022 Discover USC Graduate Student Poster Award. Sapan Karki was the recipient of the departmental Graduate Research Award, and David Edwins and Edoardo Vergallo Gazzina received Graduate Teaching Awards. Congratulations to all for their outstanding accomplishments.

**New Graduates:**

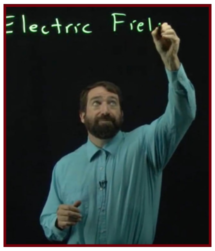
Despite the difficulties of the last few years, several of our graduate students successfully completed their studies and graduated. The Ph.D. recipients are Douglas Adams under the guidance of Dr. Avignone, Vincent Dowling working with Dr. Pershin, Lin Li working with Dr. Strauch, and Rahman Mohtasebzadeh with Dr. Crawford as his advisor. Jinsun Kim completed her M.S. degree working with Dr. Pershin. Congratulations to the new graduates and we are looking forward to hearing of their future successes.

*Winners of our departmental Graduate Student Awards (April 2022): From left to right: Dr. Matthias Schindler (Director of Graduate Studies), Edoardo Vergallo Gazzina (Teaching), David Edwins (Teaching), Sapan Karki (Research).*



*New graduate students in the Fall 2022 cohort: From left to right: Cameron Walker, Corey McAllister, Karthik Gananath Putha, Dan Hancock, Jean-Joseph Benoit, Vishnu Santhigiri Unni. Not pictured: Paras Regmi.*

# Dr. Bram Boroson



Dr. Bram Boroson received his Ph.D. from the University of Colorado. He has done postdoctoral research at NASA and the Harvard-Smithsonian Center for Astrophysics. His research is in the field of high energy astrophysics, mostly with a focus on accreting neutron stars and black holes in binary systems. This work involves modeling the accreting gas flows, inferring them by means such as Doppler tomography, eclipse mapping, reverberation mapping, and testing hydrodynamic simulations against spectral line variability. Dr. Boroson uses observations from UV and X-ray telescopes. He has also worked on extragalactic X-ray astronomy, finding a scaling relation from IR to estimate the contribution from blended accreting binaries to the total X-ray emission (including hot gas) from elliptical galaxies.

**Current research projects include:**

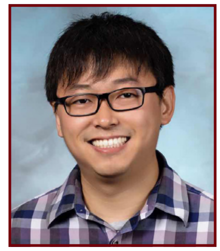
- Reporting the results of a coordinated observing campaign to determine and compare the broad-band spectra (Spectral Energy Distributions) of a sample of X-ray binaries, including a variety of neutron star and black hole systems.
- Fitting variable UV emission lines in the Cygnus X-2 accreting neutron star system to models including accretion disk winds. The emission line profiles of these systems often show only one peak instead of the double peaks expected from accretion disks, and scattering in an accretion disk wind may explain this.
- Searching through X-ray all sky monitor data for undiscovered periodicities. These may be the result of eclipsing orbits in poorly known X-ray sources, or more mysterious "long term periods" often attributed to accretion disk precession.
- Developing hydrodynamic simulations of accreting X-ray binaries, with particular focus on the complex interaction of the X-rays from the compact object and a line-driven stellar wind. In the past, Dr. Boroson's research has compared the results of similar simulations with observed UV and X-ray emission. Dr. Boroson is developing new high performance GPU computing simulations to compare with new observations.

# Dr. Alice Churukian

Alice Churukian comes to us from the University of North Carolina at Chapel Hill where she was a Teaching Associate Professor in their Department of Physics and Astronomy. While there, she was a major contributor to the development and implementation of their fast-track, high-school science teacher preparation program. She was instrumental in the renovation of several teaching spaces into active-learning environment classrooms and was a member of the development team responsible for the transformation of their introductory physics courses into a student-centered, active-learning format using research validated pedagogy. She brings her expertise in educational practice in the physics classroom and course re-development to our efforts of adopting the Lecture/Studio format and adapting the curricular materials she helped develop at UNC as we work to improve our introductory physics courses. See "Breathing New Life into the Introductory Physics Courses" for more detail.

Dr. Churukian earned her bachelor's degree in physics from the College of Wooster (Wooster, OH) in 1991 with a senior independent study thesis in non-linear dynamics. She continued in this field at the University of Wisconsin – Milwaukee earning a Master's degree in physics in 1994. She then became the science department at Thaddus Stevens College of Technology (Lancaster, PA), where she became intrigued by the disconnect between the teaching and learning of physics in her students and decided to pursue Physics Education Research. After a one-year visiting position in the physics department at Juniata College (Huntingdon, PA), she went on to earn a PhD in Physics Education Research (PER) from Kansas State University in 2002. There her research involved the development, implementation, teaching, and evaluation of the New Studio (now called Lecture/Studio) approach to teaching calculus-based introductory physics. After earning her PhD, she was a Visiting Assistant Professor of Physics at the College of Wooster and an Assistant Professor of Physics at Concordia College in Moorhead, Minnesota prior to becoming a Carolinian.

# Dr. Sai Mu



It is my great honor to join the Department of Physics and Astronomy and I am looking forward to building the computational physics group and working with our colleagues in the department on novel quantum materials for practical applications. Nowadays, advanced quantum materials have attracted much attention due to their promise of wide-ranging applications and many emergent exotic properties that arise from electrons, lattice vibrations, topology, magnetism, disorder, and their couplings. Understanding the fundamental phenomena associated with and driven by those quantum mechanical effects is a central topic of condensed matter physics, and underpinning many advanced technologies. Computational physics plays a crucial role in developing a fundamental understanding of the physics of quantum materials, in improving the properties of existing materials, and in the discovery of novel materials. Employing density functional theory (DFT) – the workhorse of materials properties calculations, my research addresses electronic structure, transport, magnetism, and the couplings between different degrees of freedom within various condensed materials, ranging from correlated transition metal insulators and alloys and to novel semiconductors.

More specifically, I envision my group developing in the following three research directions:

1. **Unfolding the effect of disorder on fundamental excitations of quantum materials**

   Chemically disordered alloys have played a critical role in human advancement since ancient humans discovered that the addition of small amounts of tin to pure copper produced an alloy – Bronze – that bestowed great practical advantages. Today, disordered alloys are commercially ubiquitous and underpin many advanced technologies. Indeed, disorder often leads to profound effects on the underlying electronic, magnetic and vibrational excitations – effects that are in turn manifested in improved physical properties ranging from electrical and thermal transport to mechanical strength, corrosion resistance, and radiation tolerance.

   In magnetic disordered systems, site-diagonal disorder is thought to have a major effect on material properties, whereas *off-diagonal* disorder is thought to be a secondary effect that is often overlooked or oversimplified. The importance of the *entire* off-diagonal disorder was revealed by my research based on the phononics of concentrated alloys. Expecting similar effects on the spin system, I plan to investigate the impact of *full* disorder on electronic structure, spin interactions and spin excitations – such as magnons and skyrmions – in quantum electronic materials, particularly 2D materials and novel antiferromagnets for spintronic applications. We will also use deep learning methods to study disorder effects on various magnetic interactions, assisting novel materials discovery with targeted materials properties.

2. **Quantum defects in solids for quantum information science**

   Identifying and designing materials for use as qubits, the basic unit of quantum information, is a critical step in the development of a quantum computer. Defects in semiconductors are promising platforms to realize qubit. A promising qubit realization is through a deep level defect in wide-band gap semiconductors due to the localized electron energy levels with paramagnetic spin states. We will work on identification of the deep center defects and their excited states in wide bandgap semiconductors. Method development will be carried out to accurately describe their excited states. In addition, spin qubits based on shallow donors provide promising quantum information techniques with significant potential scalability. We will devise an accurate approach to calculate shallow donor properties, and to extend this method to efficiently represent the Rydberg state in solids for shallow donor applications in quantum information. With the ability to precisely describe the defect states for quantum information, an inverse design of spin qubits will be studied with the help of *artificial intelligence*.

3. **Phononics and spin-phonon interaction in quantum spin liquids for quantum computation**

   Quantum spin liquids are magnetically disordered states with long-range quantum entanglement that can host localized and itinerant Majorana fermions. Many researchers focus on the magnetic interactions; however, little attention has been paid to lattice vibrations and their coupling to the spin system. I'll continue working with the neutron team in Oak Ridge National Laboratory to study the lattice vibrations of spin liquid candidate $RuCl_3$ and other quantum Van der Waals magnetic systems. With a precise description of lattice vibrations, isolated magnetic response in several interesting observables (heat capacity, thermal hall conductivity, etc.) can be sorted out. For quantum computation applications, the development of defects and layer stacking, as well as their effects on spin-phonon interactions, will be investigated.

I look forward to developing many fruitful collaborations with my colleagues in our department and other departments across the USC campus, and also look forward to recruiting some energetic graduate and undergraduate students.

# News from the SmartState Center for Experimental Nanoscale Physics

*By Rongying Jin*

Thanks to great teamwork, Prof. Rongying Jin has successfully relocated her research laboratory to the SmartState Center for Experimental Nanoscale Physics. While some instruments require further testing and new equipment is yet to arrive, Jin's research is already well in progress. She is especially proud of collaborations with colleagues within the Center and the Department of Physics and Astronomy. Shown in Figure 1 is the collaborative work between her and Prof. Scott Crittenden, which was recently published in *NPJ Quantum Materials*. She looks forward to many such future accomplishments and collaborations.

The successful recruitment of Prof. Sai Mu will further broaden the Center's research horizons. His expertise lies in computational condensed matter physics, which can play a crucial role in developing a fundamental understanding of the properties of existing materials and in the discovery of novel materials. His research spans many subfields of condensed-matter physics including spintronics, power electronics, optoelectronics, and quantum information science. Please see his article in this same issue.

While it is still under construction, our ***website*** regularly provides updated news. For example, the Center hosts a weekly Journal Club talk (scheduled by Dr. Bryan Chavez) or an invited Condensed Matter Physics Seminar (scheduled by Prof. Rongying Jin).

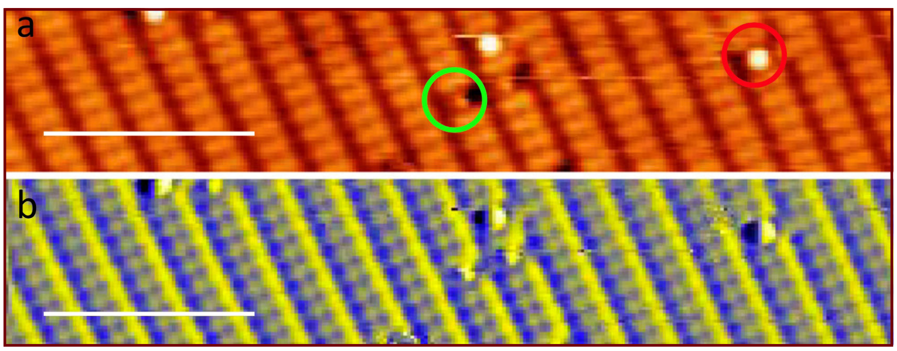



***Figure 1:*** *Scanning tunneling microscopy on two terminations of topological semimetal $BaMnSb_2$ (the white bar represents 4 nm): (a) the Ba layer and (b) the Sb-Mn-Sb slab. Both terminations form dimers, leading to modified surface properties compared to its bulk counterpart. This work is published in **npj Quantum Materials** 7, 85 (2022).*

# News from Milind Kunchur

Professor Milind Kunchur continues his efforts in the three areas of auditory-neurophysiology/audio, condensed-matter physics, and physics education. Results from the first were described earlier in this newsletter. His work in condensed-matter physics, in particular that related to vortices in superconductors, continues to be a benchmark in the field and was prominently featured in 2022 in the *Elsevier's Encyclopedia of Condensed Matter Physics* (see **Figure 1**).

Dr. Kunchur continues with his development of teaching methods and promotion of physics education through the SACS-AAPT (South Atlantic Coast Section of the American Association of Physics Teachers) for which he serves as the 2022-2023 vice president. Kunchur also serves regularly as head judge at the Central SC Science and Engineering Fair and at the Junior Science and Humanities Symposium (JSHS), both of which are competitions for high-school student research. The winners of the first are sent to ISEF (International Science and Engineering Fair) and winners of the state JSHS are sponsored to compete in the national JSHS in Albuquerque, NM.

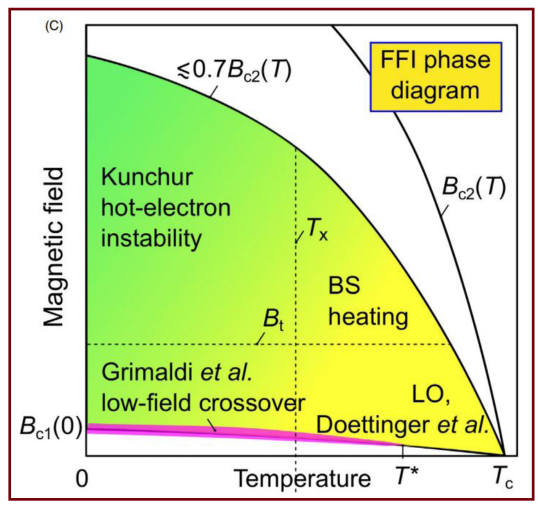



***Figure 1:*** *Principal regimes of the superconducting mixed state. This figure was published in the chapter "Fast dynamics of vortices in superconductors" (by Prof. O. V. Dobrovolskiy, University of Vienna, Austria) in Elsevier's Encyclopedia of Condensed Matter Physics (https://doi.org/10.1016/B978-0-323-90800-9.00015-9).*

# 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), 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, graduate students Anne Flannery, Chris McLauchlin, Krishna Neupane, Nishadi Silva, and Brandon Tumeo (see **Figure 1**).

With the easing of restrictions related to the SARS-Cov-2 pandemic in the past year, conducting research is moving back to an in-person format. As of this summer, all our graduate and undergraduate students are back in the office full-time, and we have started to again travel to conferences, experiments, and collaboration meetings. We are excited to be able to share with you new and important result from our experiments at JLab. We measured and extracted information on the first radial excitation of the Delta resonance that, before, has only been theoretically predicted. With our data, we could confirm the prediction, which underlines how the experimental and theoretical understanding of the strong interaction becomes more refined year after year. In a more recent 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 has already extracted first normalized yields for one of the more complicated multi-particle final states to achieve these goals. He and Alexis Osmond, who joined us this summer, are currently exploring how an energy and luminosity upgrade would be a unique opportunity for an extension of our program. Krishna has presented his recent results both at JLab and at this year's DNP meeting.

In another JLab experiment, deuteron nuclei were used as the target, and in a tiny fraction of the spray of nuclear reactions, a charm quark-antiquark pair, called J/ψ meson, was produced. The production of this particle is quite interesting since it serves as a clean tool to study the properties of gluons inside the nucleus. In the past year, our effort was focused on refining our methods to extract the J/ψ signal from the collected data and to prepare the data for another processing with optimized reconstruction efficiency. We will continue to study the gluon content of light nuclei in the era of the U.S. electron-ion collider (EIC), which is currently being designed. In the past year, the baseline detector (called ePIC) for the EIC project was selected in a competitive process involving three detector proposals. While we have been contributing to the characterization and selection of readout photosensors for the DIRC detector in ePIC and are a founding institution of the ePIC Collaboration, we have invested a significant amount of effort in the development of a second detector for EIC. Such a detector will not only support the discovery potential of ePIC, but will broaden the physics reach of EIC in areas not accessible to ePIC, such as studies of rare isotopes and light nuclei. In collaboration with other institutions, we submitted a proposal for the development of a muon detection system based on the one constructed for Belle-II. If supported, we will study the scintillator material and readout photosensors for the system. Ultimately, our goal is to construct the muon detector in our detector lab on campus that was developed for the FTOF and MUSE scintillators. Undergraduates Nitin Gupta and Vansh

***Figure 1:*** *Members of the Experimental Nuclear Physics Group. In the front row from left to right: Christopher McLauchlin, Krishna Neupane, Nishadi Silva, and Brandon Tumeo; in the back row: Ralf Gothe, Yordanka Ilieva, and Steffen Strauch. Anne Flannery was supporting the MUSE experiment at the Paul Scherrer Institute when the picture was taken.*

Nagpal worked on summer projects in support of our EIC efforts. Nitin Gupta has been accepted to present his study of the effect of Copper versus Aluminum material for the second EIC detector solenoid coil on muon detection at the 2022 Fall meeting of the Division of Nuclear Physics of the American Physical Society (APS). Vansh Nagpal will present his J/psi event generator development at the 2022 Meeting of the Southeastern Section of the APS.

We continued the data analysis of our low-energy deuteron experiment from JLab. After Brandon Tumeo observed the very-first-in-the-world Λ-deuteron elastic scattering events in 2021, he was joined in summer 2022 by MS student Nishadi Silva and undergraduate Alexander Nelli on this project. Nishadi is extracting the yield of inclusive Λ photoproduction, whereas Alexander quantified the amount of proton-deuteron elastic scattering events in the same data sample. Both studies will provide input for the estimate of the probability of Λ-deuteron elastic scattering and are important for the overall progress of the project. 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 presented this research at the Frontiers and Careers in Nuclear Physics meeting as well as at the Gordon Research Conference.

Our group has been making key contributions to the Muon Scattering Experiment (MUSE) at PSI. The experiment will measure cross sections of electrons and muons that scatter elastically off a proton target. The data will allow us to directly compare μp and ep interactions, extract the proton charge radius, and study two-photon exchange effects. The experiment has provided many research opportunities for our undergraduate and graduate students. We could give many of them the opportunity to work abroad, on-site at PSI. The highlight of this year's activity was the successful completion of Lin Li's Ph.D. work. In her thesis, Lin studied systematic uncertainties of MUSE cross-section measurements from radiative corrections. MUSE does not measure the magnitude of the final-state electron or muon momentum, and the experimental yield thus includes all events with particle momenta above the detection threshold. That threshold dependence is a potential source of significant uncertainties in the size of the radiative corrections for electrons. Lin carefully studied this threshold dependence with Geant4 Monte Carlo simulations. Employing realistic event generators, she showed that the uncertainties from radiative effects can be largely reduced by rejecting events that are accompanied by the production of initial-state radiation. Her findings were instrumental and prompted the collaboration to include a photon detector downstream of the hydrogen scattering target and informed the optimization of the overall detector size.

# Axions and the Strong-CP Problem

*By Rick Creswick*

Yanwen Wu, Mas Crawford, Frank Avignone, and Rick Creswick have teamed up to construct an experiment dubbed the **F**abry-**P**erot **A**lp **S**earch (FPAS) to directly detect axion-like particles, or ALPs. While the fundamental physics question we want to address falls firmly in the area of particle astrophysics, Professors Wu and Crawford have generously contributed their expertise in quantum optics and laser physics to make FPAS possible.

Axions arose within the standard model of strong interactions to solve a long-standing question, "Why is the neutron dipole moment so small?". Current experimental bounds on the neutron dipole moment are 10 orders of magnitude smaller than what might be expected, requiring fine tuning of the parameters of the standard model. The 'unnaturally' small value of the parameter required for the theory to be consistent with experiment is called the Strong CP Problem.

In 1977, Peccei and Quinn introduced a new symmetry into the standard model that solves the Strong CP problem. Shortly after, Weinberg and Wilczek showed that spontaneous breaking of this symmetry leads to a new pseudo-scalar particle, the axion. In the intervening years, other extensions of the standard model have led to pseudoscalar bosons generically called axion-like particles, or ALPs. ALPs couple to photons, electrons, and quarks and they appear in many different contexts in cosmology, and astrophysics as well as particle physics, but, at the moment, they are purely hypothetical. For the past 40 years, there has been an intense effort to either discover ALPs or rule them out, some of which is summarized in **Figure 1**.

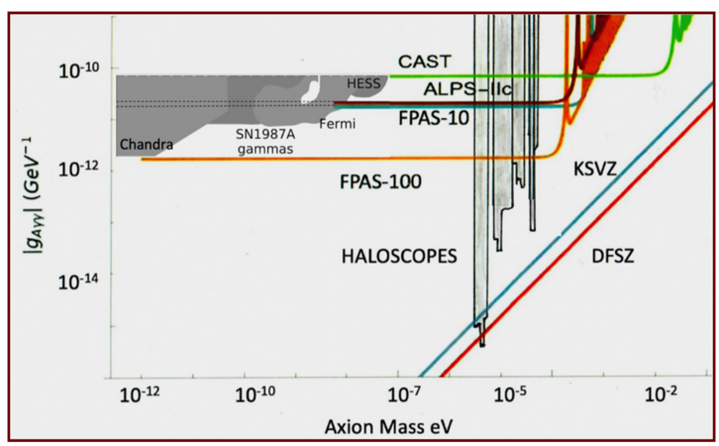



***Figure 1:*** *ALP parameter space. Peccei-Quinn axions lie in the band between the lines labeled KSVZ and DFSZ. ALPs with parameters in the region above the green curve labeled CAST have been excluded by the CAST experiment. ALPs IIc and FPAS 10 indicate the sensitivity of the proposed experiments ALPs IIc and FPAS 10 (FPAS with a 10m cavity). FPAS 100 indicates the sensitivity possible with a 100 m cavity.*

In addition to solving the Strong CP problem, ALPs created in the Big Bang are a leading candidate for dark matter. Current estimates are that 84% of all the mass in the universe is dark matter, and yet we do not know what form this matter takes. We know dark matter only through its gravitational effects on the large-scale structure of the universe, galactic clusters, and individual galaxies.

ALPs have also been invoked in explaining the Pair-Production Anomaly in which very high energy gamma rays emitted by active galactic nuclei are observed on Earth. These gamma rays *should* collide with the extra-galactic background light producing electron-positron pairs and never reach detectors on the Earth. And yet they do! A possible explanation of how this could happen is that the photons convert to ALPs in the magnetic field of their source, propagate unmolested through intergalactic space, and then reconvert to photons in the magnetic field of the Milky Way.

FPAS is designed to look for the unmistakable signature of the coupling of ALPS to the electromagnetic field through the scalar product of the electric field of a photon and a fixed magnetic field. As shown in **Figure 2**, FPAS takes linearly polarized light from a laser and passes it through an electro-optical modulator (EOM) causing the polarization to precess at a known frequency. The light then enters a Fabry-Perot cavity embedded in a strong uniform magnetic field. The cavity is essentially a pair of parallel super-mirrors that reflect the light back and forth within the cavity, extending the optical path length from 1m to 446 km. As photons traverse the magnetic field, some of them convert to ALPSs leading to a periodically modulated dichroism. The sensitivity of FPAS is very competitive with second-generation experiments like IAXO and ALPs IIc for a 10m cavity (FPAS 10) and is considerably better for a 100m cavity (FPAS 100).

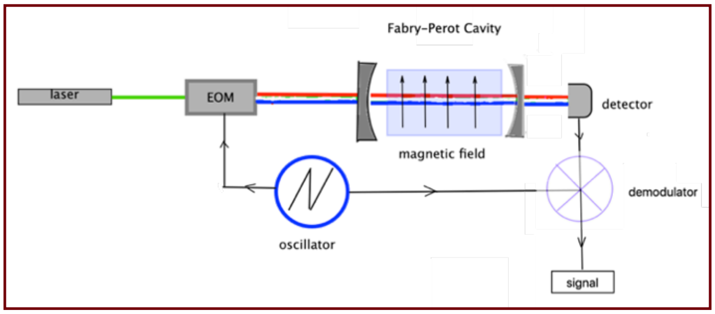



***Figure 2:*** *A highly over-simplified view of FPAS. Light from the laser passes through an electro-optical modulator (EOM) and then enters the Fabre-Perot cavity where photons are converted to ALPs in the magnetic field (indicated by the black arrows). The intensity of the light that emerges from the cavity has an intensity modulated at the driving frequency of the EOM.*

# Theoretical Physics Group

In 2022, the Theoretical Physics group welcomed Dr. Alexey Petrov, who is not just the new chair of the department, but also a distinguished particle theorist. Moreover, after some COVID-related delays, Dr. Alexander Monin was finally able to join us full-time on campus.

In the meantime, Dr. Matthias Schindler has been continuing his research into the strong interactions between protons and neutrons. In principle, these forces are described by the underlying theory of quantum chromodynamics (QCD). However, calculations of the interactions between protons and neutrons directly from QCD remain extremely challenging. Dr. Schindler studies how symmetries and theoretical extensions of QCD can be used to gain a better understanding of the main features of the nuclear forces. These insights help in determining how to best allocate resources for future experiments and computational investigations.

Dr. Brett Altschul, working with three doctoral students—Sapan Karki, Harry Oslislo, and Abhishek Rout—is studying the Lorentz and CPT symmetries that underpin Einsteinian relativity. Experimental tests of special and general relativity (for example, testing whether the maximum speeds for all particles are really the same as the speed of light in vacuum) are very important to our understanding of fundamental physics, and interest in them has picked up a great deal in the twenty-first century. Moreover, even if relativistic Lorentz invariance is actually an exact symmetry of real-world physics, studying the kinds of exotic theories that can account for violations can lead to important new insights into the structure of quantum mechanics. In that vein, Dr. Altschul and Mr. Karki published a series of papers in 2022 demonstrating that certain kinds of quantum-mechanical corrections in interacting quantum field theories can have additional layers of structure which had not previously been appreciated.

Dr. Altschul was also recently invited to submit a Perspective article about tests of relativity for publication in *Europhysics Letters*, the flagship journal of the European Physical Society. For some of the most natural violations of relativity involving electrons and positrons, there are competing bounds coming from high-energy astrophysical observations and laboratory tests with optical atomic clocks, and the Perspective discussed the advantages and limitations of both these approaches and how they may evolve in the future.

# EVENTS, EDUCATION, AND OUTREACH

## Breathing New Life into the Introductory Physics Courses

*By Alice Churukian and Jeff Wilson*

Introductory Physics courses often get a bad rap. They are boring, the lecture and laboratory are unrelated (they are, in fact, separate courses), and student performance is low. It was time to make a change. After many meetings, discussions, and research, it was decided to adopt and adapt the Lecture/Studio Format and associated Curricular Materials developed at the University of North Carolina at Chapel Hill.

What, you say, is Lecture/Studio? Originally developed at the Kansas State University and, independently, at the Colorado School of Mines, the Lecture/Studio format is a hybrid of the traditional lecture/laboratory/recitation format and active-engagement formats such as Workshop Physics, Studio Physics, and SCALE-UP. In the traditional format, students would attend three 50-minute (or two 75-minute) lectures, possibly one 50-minute recitation, and one 110-minute laboratory each week. Content across the two or three components was frequently decoupled such that it was possible for a student to be expected to do a laboratory experiment on a topic which had not yet been introduced in lecture. The Lecture/Studio format rearranges the in-class time so students attend two 50-minute lectures and two 110-minute studios per week. Lectures and studios are interleaved such that students attend a large lecture section (100 - 250 students) on Monday mornings led by a faculty member and a smaller studio section (~ 50 students) on Monday or Tuesday led by a combination of faculty (the lecturers), graduate students, and undergraduate students. The process is repeated on Wednesday and Thursday. We refer to each lecture and its associated studio as a module. Friday mornings are reserved for an optional question and answer (led by a faculty member) session similar to a group office hour, and for exams. This format provides a highly coherent course structure that closely integrates the lecture and studio activities and all instruction is provided using best practices supported by Physics Education Research.

Implementation to the new format was put on hold during the pandemic but rejuvenated during the Fall 2021 term. A classroom (Jones PSC 208) was renovated over the summer to facilitate active-engagement and group learning. The room now has six round tables which can accommodate three groups of three students each, many whiteboards on the walls, two projectors and screens (on opposite facing walls) and a “teacher station” off to the side. We began teaching Physics 211: Essentials of Physics I in August 2022 and have plans to roll out one course per year with Physics 212: Essentials of Physics II starting in Fall 2023, followed by Physics 201: General Physics I and then Physics 202: General Physics II. We plan to renovate several of the current teaching-laboratory spaces into active learning spaces (a.k.a. Studio Rooms) preceding the rollout of Physics 212 and Physics 201. We are only halfway through the first semester, but students are more engaged and, anecdotally at least, feeling like they are learning physics and even enjoying the class! Hopefully this trend continues and we will have great things to report next year.

*Graduate student Jean-Joseph Benoit assists two students during a recent session in our new Studio Physics environment.*

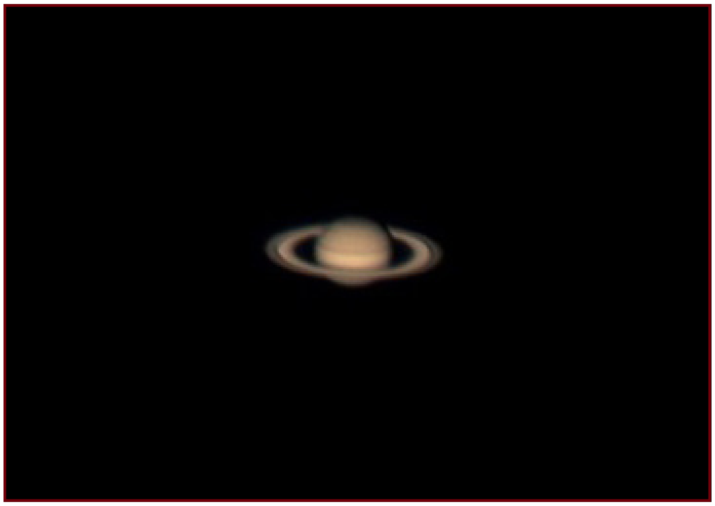


***Figure 2:*** *Saturn.*

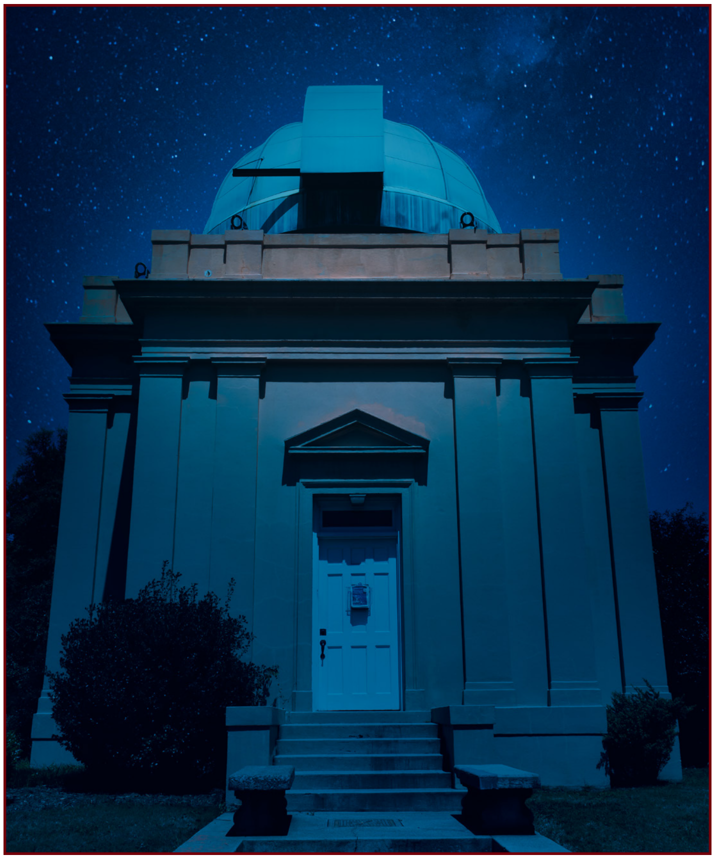


***Figure 1:*** *The Melton Memorial Observatory. Photo credit: Jack Allen (College of Arts and Sciences).*

## Nonagenarian of the Night

*By Martin Bowers*

Built in 1928, the Melton Memorial Observatory (see **Figure 1**) has served as a teaching and research tool for more than nine decades. Although the observatory functions as an astronomy laboratory on most weeknights, Monday evenings are reserved for public viewing sessions.

The observatory houses a 16” Cassegrain telescope that sits atop a truly impressive mount. Although currently operated by a modern computer-controlled drive system, the mount itself and the telescope it holds are all original equipment. This instrument continues to provide stunning views of celestial objects.

The Fall 2022 semester features the planets. Although Saturn and Jupiter have been our feature objects, Uranus and Neptune are also on the menu and Mars is about to make an appearance. **Figure 2** contains an image of Saturn recently taken through a 6” refractor.

Our public viewing sessions are conducted every clear Monday evening when classes are held. Current operating hours are 8:00-10:00 p.m. We post updates every Monday morning on the observatory’s ***Facebook page***. To learn more about Melton, please visit ***http://uof.sc/melton***. Come join us!

# The Society of Physics Students is Back in Black (and Garnet)

The SPS exists to help students transform themselves into contributing members of the professional community as well as aid in students navigating the physics curriculum. Coursework develops only one range of skills. Other skills needed to flourish professionally include effective communication and personal interactions, leadership experience, establishing a personal network of contacts, presenting scholarly work in professional meetings and journals, and outreach services to the campus and local communities. We also acknowledge that it is not easy to complete a physics degree. As such, our members who are in their junior and senior years make sure to take time to help newer students both cope with the stress of classes and learn what they should be learning from their courses. Even for members who are not physics majors, this club is a way to participate in physics outreach around Columbia and keep up to date with events occurring within the physics community.

Every week, SPS hosts “Power Hour” on Wednesday evenings, where students gather to work on their physics assignments and get and give help between each other. On Thursdays, SPS hosts “Tea Time,” where students can take a break from their heavy coursework and decompress with game nights, movie nights, and physics experiments. SPS is also planning on attending physics conferences in other states where members of the club will get to experience presentations on research projects and connect with other students involved with physics from around the country. Some of these conferences even include tours of different universities, which give students information about various graduate programs and available research opportunities.

SPS offers a multitude of different resources to help students academically such as providing a room in the basement level of the Jones Physical Sciences Center, where students can study or work in a calm environment. The room also includes a whiteboard and a blackboard.

**2022-2023 Society of Physics Student Officers:**

- **Alyssa Bagby**, sophomore Physics major and Mathematics and Astronomy double minor. She had a summer internship researching specific atmospheric electric field changes that could predetermine an occurrence of lightning at the Savannah River National Laboratory (Aiken, SC).
- **Andrew Boldy**, fifth year Physics, Mathematics, and Psychology major minoring in Neuroscience. Found a passion for particle and nuclear physics and is writing his senior thesis on the theoretical framework of gauge theories as they relate to nuclear and particle physics under the direction of Dr. Matthias Schindler.
- **Caleb Fairchild**, senior Physics Major. Transferred from USC Aiken during his sophomore year and discovered a passion for particle physics since beginning his physics classes and research at USC. He attended a REU program during the summer of 2022 at Rutgers University (New Brunswick, NJ) studying Higgs Boson to double b-jet and two Muon decay through the CMS detector at the Large Hadron Collider.
- **Dayton Proffit**, sophomore Physics major with an interest in nuclear physics and engineering. He volunteers at the Melton Memorial Observatory here on campus.
- **Martin Salomon**, sophomore Physics major and Mathematics major. He is a TRIO student that has an interest in theoretical and mathematical physics. He works as a Supplemental Instruction (SI) Leader for Calculus II (MATH 142) courses here on campus.
- **Natalie Truman**, sophomore Physics and Geological Sciences major and Astronomy minor. She is a long-time employee of Roper Mountain Science Center (Greenville, SC). The Roper Mountain Science Center is home to one of the largest telescopes in South Carolina – a 23 inch refractor formerly belonging to Princeton University. During the period when the telescope was stationed at Princeton, Albert Einstein was there!

*Society of Physics Students members at their weekly “Power Hour” and “Tea Time” meetings during the Fall 2022 semester.*

# Midway Physics Day Returns: Reaching the Next Generation Through Applicable Science

*By Sam Beals*

It's October in the capital city of Columbia. The weather (usually) gets cooler, Ferris wheels and roller coasters suddenly appear in the skyline off Assembly Street, and the familiar scents of corn dogs, elephant ears, and candy apples fill the air. This can only mean one thing - the South Carolina State Fair is back in town! After much anticipation, our department's annual tradition, R.L. Childers Midway Physics Day, returned to the State Fair in 2022 following a three-year hiatus due to COVID-19 concerns and many school activities and field trips being temporarily paused. At Midway Physics Day, our departmental faculty, staff, and students bring a wide variety of "real physics" demonstrations to a captive audience of high school students and teachers from across South Carolina. These demonstrations include singing rods, jumping rings, liquid nitrogen, and many more!

To prepare teachers for the big day, long-time Midway Physics Day veterans Dr. Jeff Wilson (USC), Dr. Dave Tedeschi (USC), and Mr. Tom Sunday (A.C. Flora High School) led a training event for both new and returning teachers to help them maximize their time at the event with students. Topics discussed included preparing a lesson plan and other instructional activities in advance, being selective when choosing rides to analyze for data collection, and informing the group about useful measurement tools such as Arduino Science Journal, which is an exciting app that transforms a student's smartphone into a pocket-sized laboratory! This event is always a fantastic opportunity for teachers to network with one another as well as share strategies and best practices for the upcoming Midway Physics Day.

This year, we welcomed nearly 2,800 students from 52 South Carolina schools to a new location at the State Fair, which was the Pepsi Place Stage. Stationed in the center of the fairgrounds, this environment is typically used for concert performances and was a bit different from our usual tent. However, there was plenty of open space for everyone to participate in the demos and we all enjoyed a beautiful autumn day teaching physics concepts together! For many of our USC volunteers, this was their first time serving as a "mentor" at Midway Physics Day while others who have assisted before jumped right back in after several years without missing a beat. Following the demos, our participants applied what they learned on popular fair rides and were given a chance to collect various data points for their analysis assignments, which were based on the scientific principles they encountered at Midway Physics Day.

One of our department's primary objectives with this event has always been to present these demonstrations in fun, engaging,


*Graduate student Jake Martin (right) explains the concept of magnetic braking using the induced eddy currents demonstration.*

*Two graduate students, Govinda Kharal (left) and Daniel Duong (right), teach nearby students about the principle of electromagnetic induction as they prepare to launch aluminum rings into the air. Photo credit: Jack Allen (College of Arts and Sciences).*

and relatable ways to get students excited about science and better understand how the physics topics they are learning about in their classes can be applied in the real world. High schoolers who attend Midway Physics Day and similar experiences during their academic journeys may even find themselves attending the University of South Carolina in a few years and possibly pursuing careers in STEM fields down the road!

A special thanks goes out to our energetic USC Midway Physics Day mentors as well as Nancy Smith and her wonderful team at the ***South Carolina State Fair*** for ultimately making this event possible for nearly three decades. We were also thrilled to welcome a special group of local volunteers from Thorlabs Spectral Works, an active research and development division associated with Thorlabs' Optics Business Unit in Newton, New Jersey. Over the last few years, TSW has established a robust presence here in Columbia and is dedicated to giving back to the community, especially regarding scientific outreach efforts. TSW even brought their own demonstration this year and several of their staff members are graduates of the University of South Carolina as well! We are very grateful for the expertise and ongoing support from Cory Dolbashian, Adam Fisher, Cali Harvell, Izlen Peksenar, Heath Smith, and Jason Williamson. Thank you again to all who contributed this year! To learn more about Midway Physics Day, please visit our website, ***go.sc.edu/midwayphysicsday***. We look forward to seeing you again in 2023!

# STUDENT AND ALUMNI SPOTLIGHTS

# STUDENT SPOTLIGHTS

## My REU Experience

*By Caleb Fairchild*

My name is Caleb Fairchild and I am a senior physics major at USC Columbia. I had a very rough start to my schooling experience and I worked throughout college to sustain myself. This made it very difficult to find the time and money for a research internship early in college. However, in my junior year, I became determined to find an internship that fit my needs. This is when one of my professors pointed me to REU opportunities.

REU stands for Research Experiences for Undergraduates. It is a program sponsored by the National Science Foundation for undergraduate students. The NSF typically pays upwards of $6,000 for undergraduates to perform research at various locations around the country for a full summer. Going into this experience, I was afraid that I was underqualified. I had never performed any research before. The most I had done was work in a laboratory class environment on experiments originally performed centuries ago. I felt like imposter syndrome patient zero when I received my acceptance email to say the least.

I applied to nearly twenty REU programs and I was accepted by the REU program at Rutgers University located in New Brunswick, New Jersey. I spent my weekends taking the train into New York and I spent my weeks working on research for an experiment with the CMS (Compact Muon Solenoid) detector at the Large Hadron Collider. My first few weeks were rough in terms of how much catching up I had to do. I heard several new words I had never heard of before and nodded along when someone casually mentioned a Higgs Boson as if I totally knew what that meant. I did not know much about particle physics at the time, but I knew that it was relevant to medical physics, which I was interested in pursuing. However, I studied particle physics in my free time and I caught up to a point where I was comfortable asking questions in no time.

During my time at Rutgers, I met several other physics majors performing research. We spent afternoons eating dinner together and exchanging our plans and hopes for graduate school. Bonding with other physics majors was extremely important because it showed me that I was not alone in my experiences. Online schooling during the COVID-19 pandemic caused me to feel somewhat removed from other physics majors, and, after learning how important forming bonds with students was to my investment in physics itself, I was motivated to join the University of South Carolina's chapter of SPS (Society of Physics Students) to help provide that same experience to other students.

At the end of the summer, we presented our research in the form of posters and slides. I was asked many questions about my research and I surprised myself with how many questions I was able to answer compared to how many I was able to answer at the beginning of the summer. I came out of this experience determined to go to graduate school with a newfound passion for particle physics.

I am not writing this article for a professor, a homework assignment, or for a magazine. I am writing this article for the physics student who believes they may not have what it takes like I did and I want that student to know that they are capable. I want this student to know that it is okay to not know things. Knowing everything is not the point of being a physicist. The point is not knowing but being driven to find answers anyways.

## Hunting for Ghosts Underground

*By Nibir Talukdar*

Located in a small city called Leeds (in South Dakota) are four giant 17 kton liquid argon tanks (in layman language) sitting quietly about a mile underground to catch these ghosts. The magnitude of the size of each tank/detector can be visualized as the size of a Boeing 737 airplane. There are approximately 780 tons of rocks that shield these detectors from the atmospheric ghosts. About 70 billion of them are passing through your body every second and these ghosts are called neutrinos. Neutrinos are light particles that interact "weakly" with matter; hence we need massive detectors to detect them. This experiment is called the Deep Underground Neutrino Experiment (DUNE) and the neutrino group at USC is collaborating with this experiment. Our group is majorly involved in the SAND subdetector and leading the inner tracker construction of SAND in the ND complex of DUNE.

I come from a small city called Guwahati, which lies in the peripheries of the northeastern part of India. My state, Assam, is one of the largest tea producers in the world. My day starts with a cup of Assamese tea. I also keep some tea bags in my office. If anyone wants to try it, they are always welcome to stop by my office. In India, almost each state has its own language, but Assam has several languages due to people of different tribes living throughout the state. Although my native language is Assamese, I can speak four languages in total. It is a beautiful place and we live close to nature. However, we have limited resources as far as the study of physics and its allied subjects are concerned. Self-learning played a vital role in my understanding of physics. The hurdle caused by limited Internet connectivity and study materials did not deter my love for the subject, and, instead, it strengthened my will to acquire more knowledge on the subject.

Although I was interested in physics, I decided to pursue engineering in my undergraduate studies. My first impression of the degree was not so positive. I was not really interested in the courses that I was taking and I felt that I had made a wrong decision. The curriculum in India is not as flexible compared to the United States, which made it feel like a point of no return for me. However, there are some things in life that are not in your control and you must accept it. Toward the end of my sophomore year (during March 2019), I took one more chance to revive my interest in physics and I started emailing different professors asking for internship opportunities. I was not sure about which field to pursue, so I sent around 30-40 emails to various faculty. The only professor who replied to me was Prof. Bipul Bhuyan from the Indian Institute of Technology Guwahati. Prof. Bhuyan specializes in experimental particle physics. This was like winning the lottery for me and this played a pivotal role in deciding to aim for a PhD. This internship really helped me develop a temperament for research and understanding the dos and don'ts of this process.

In December 2019, I joined the Indian group working on DUNE. Upon joining, I met Prof. Roberto Petti (USC) as he was collaborating with the group for the SAND detector. DUNE, being in its construction phase, provides a wide area of research from detector R&D, electronics, software development, computational analyses, physics studies, etc. It was also during this period that COVID-19 began and disrupted normal day-to-day life, but research really helped me to stay focused and motivated. I remember shifting my daily schedule to match the time zone of that in the US so that I could work together with my colleagues in the States. I became a night owl for quite some time, but I can say that everything was worth it. I presented my work in the global SAND group meetings in front of various eminent scientists and researchers. As an undergraduate student, that was indeed a big thing for me. This series of events ultimately made me realize that I wanted to have a career in research.

Working with Prof. Petti was a really great experience and I decided to join USC for my PhD to work under him. He is not just a good researcher, but also an excellent mentor to me. I graduated in May 2021 and joined the Department of Physics and Astronomy in August 2021. The department here is really welcoming to students and does good research in various fields. The first few months in the US were quite challenging for me from cooking my own food, getting groceries, teaching undergraduate labs, taking graduate classes, and setting aside time for research while maintaining a personal life. Learning to balance these things properly will set you apart and make you a good researcher and person. Also, culture shock is a big factor for international students. However, if you can go through this phase, you can learn many aspects about yourself, which will broaden your thinking and perception. Having dinner with your family, talking to people in your native language, and attending festivals from your culture matter greatly when you are in a foreign country, which makes you feel grateful for the small yet important things in life.

Lastly, I can say that I am really in a strong place to pursue research and the Department of Physics and Astronomy provides a very good atmosphere for people like us to grow as researchers. The PhD journey has been nice so far and I hope to become a good researcher after finishing this program. I am also involved in various science outreach programs in areas such as my hometown, which have limited resources for scientific education, and I hope to give back and contribute to these places in the long term.

# ALUMNI SPOTLIGHTS

## A View from Outside

*By Cory Dolbashian*

I never thought I would be writing an article about myself in a general sense like this, so instead of having some grand enigmatic opening statement, I think I will just start like this. My name is Cory Dolbashian, and if you have any Armenians in your life, you will quickly pinpoint my ethnicity from my last name. I am proudly 100% Armenian and raised in one of the more Armenian-suffused regions of the country: Southeast Pennsylvania.

Without dwelling too much on my undergraduate tenure at Slippery Rock University, I graduated with a BS in Physics and, of course, was faced with the most common question: do I find a job or go to grad school? At this point in my life, I hardly even knew what a "physicist" was except for "weird math problem solver," and as you may have guessed, I decided to go to graduate school. I applied to many places but heard back from few (thanks to my rather lackluster Physics GRE scores, I am sure). One particular school that I applied to, but didn't hear back from, was USC. Thankfully, while attending the APS March Meeting that year, I happened to meet someone that many of you already know: Yaroslaw Bazaliy. He was sitting at a table with a humble trifold poster targeting future graduate students. I went over and asked him about my application, and he responded, "I look at all applications and I didn't see yours," or something along those lines. Apparently, said poor GRE scores never made it through to the departmental office. In the meantime, Dr. Bazaliy was more than happy to give me a few physics problems on the spot to quiz me. Apparently, if Dr. Bazaliy happens to stump you at a conference with some impromptu math problems, it just means he cares because shortly after that conference, I received an acceptance letter in the mail.

Graduate school was a whole different experience when compared to my small undergraduate school. Colleagues from all over the world, more demanding professors, and, of course, research. The experience was simultaneously frustrating, gratifying, rage-inducing, and dare I say…fun! After making it through coursework and the qualifying exams (thankfully on the first try), I decided on which field of research I was going to pursue. At this point in my life, I wasn't the strongest mathematician, nor was I particularly good at coding (if you are a grad student in any physics field, do yourself the largest favor and pick up a programming language), I decided that experimental "table-top" physics was likely where I'd find the most success. This landed me in Dr. Crawford's lab working with some novel materials and an even more novel characterization method. I graduated with my Ph.D. during the onset of the pandemic in April of 2020.

With a shiny new Ph.D. in physics, I found that jobs did not seem to be growing on trees or falling into my hands as I thought. After what felt like ages (months in reality), I managed to find a position as an application engineer with Thorlabs. While the job isn't the hardcore-long-term type of problem solving that a postdoc would do, every day has been an unexpected new challenge. While at this job, I have also come across an invaluable piece of information: every single professional career in the world is important and often more difficult than we as physicists will appreciate. As physicists, we are sometimes so focused on ourselves and the difficulty of our hyper-focused-ultra-niche project that we can't possibly imagine anything being as important or difficult. Being a new hotshot experimental physicist, I was humbled by my pathetic knowledge of other adjacent fields in physics and engineering. All in all, I am very grateful to have had the opportunity to be a part of USC's Department of Physics and Astronomy and pursue such a fun degree in experimental physics.

# The Graduate Student: An Unexpected Journey

*By Thomas Richardson*

Many of the best things in my life sort of happened to me rather than me initiating them. That is how I ended up in Mainz, Germany for a postdoc as a family of three. While growing up in a smallish town in South Carolina, I always had big plans but I never understood just how far physics and the help of the University of South Carolina would take me. Indeed, I have exceeded my childhood goals with a significant amount of help from the USC Department of Physics and Astronomy. Of course, a great deal of effort was put forth on my part, but each major step happened in an unforeseen way.

I came to USC in the fall of 2016 after becoming the third person in my family to earn a college degree. Until this point, earning a Ph.D. seemed like a pipe dream. Still, the notion was not very well-formed after I arrived considering I had no clue what I wanted to do regarding research. I only knew I wanted to do theoretical physics since my undergraduate classes revealed to me that I am not cut out for experiment.

Eventually, I knocked on Fred Myhrer's door, and he agreed to begin teaching me the fundamental tools I would need as a theorist. Shortly after that, Prof. Myhrer suggested that I speak with Matthias Schindler about possible projects. Prof. Schindler guided me through several topics that later formed the basis of my dissertation on effective field theory for few-nucleon systems. Simultaneously, I decided it would be a good time to get married; thankfully, my soon-to-be wife thought so, too. To some, the first year or two of graduate school was not an obviously convenient time for marriage. However, the value of my relationship with my wife ultimately made me a better student and physicist as I wanted to work quickly and do things well in order to spend time continuing to invest in our relationship. Moreover, we were able to carve out many meaningful experiences as husband and wife that helped strengthen our bond. After two years of marriage, my wife and I made our first trip to Europe, one of these meaningful experiences, so I could attend a summer school in Italy. On the plane, I finally understood the fact that physics and the investment of USC in me could enable us to experience things for which many in my family did not have the opportunity.

A little further into my USC experience, COVID-19 struck the globe. I did not see my classmates or Prof. Schindler face-to-face for over a year. Then, after the first year of COVID passed, I defended my dissertation. Three weeks later, my daughter was born. Two more weeks later, we moved to Durham, NC.

Needless to say, this was a chaotic period, and no rational person would ever time these events in the way they occurred. Yet, this is what happened and I would not change it if I could. Becoming a father pushed me to become a better physicist in the same way my marriage has.

Now, the road that started in Columbia has led me to a postdoc position in Germany; a personal wish that I had several years ago but put on the back burner of life until it did not seem feasible. I am starting some work related to the muonic atoms program at Paul Scherrer Institute in Switzerland as well as conducting some other projects related to Beyond the Standard Model physics in low-energy systems. My USC experience saw and influenced several of my milestones: marriage, a Ph.D., moving across the Atlantic, and the birth of my daughter. I firmly believe that none of these life events would be quite as significant to me without my time in the Department of Physics and Astronomy. Because of the preparation I had at USC and the investment from the faculty, I now have the opportunity to provide a life I dreamed of when I was a child for my own daughter.

# Reach for the Stars

*By Krystal Rolon*

*Krystal Rolon prepares to open the Gould Observatory for a STEAM open house on October 14, 2022. The school's Astro-Physics 155mm telescope aims toward the Sun with a white-light filter to provide guests with a safe view of solar activity.*

I graduated from the University of South Carolina in May 2019 with a Bachelor of Science in Physics and a minor in Astronomy. I am currently a teacher at Glenelg Country School in Maryland, where I have a fantastic opportunity to teach everything I love: physics, astronomy, and robotics. I call these things my three "pillars" and they are foundational to who I am.

The University of South Carolina was the most significant piece of what allowed me to be where I am now. During my first year, I entered as a Capstone Scholar and had a great Resident Mentor who brought the campus to life for me. My floormates were ambitious and energetic. I was encouraged to go to everything, whether it was a movie in the Russell House or a free event on campus, and I enjoyed it immensely. One of those journeys brought me to the Melton Observatory. I remember recognizing a fellow physics major while stargazing and how our conversation became philosophical. Why study physics at all? Where would it lead us later in life? I came to the University of South Carolina with a drive to better understand the natural order of the world around us. I was not so concerned about where it would take me afterward.

The Department of Physics and Astronomy not only provided me with academic tools but an experience that grew me as a person. I tried to be as involved as possible, including volunteering for Midway Physics Day each year, attending weekly colloquiums, and joining two research groups. I had great relationships with a few professors who inspired my passion and supported me while I was a student. Academically, I was an average student, much to the frustration of some of my physics professors. I did find additional support through the Supplemental Instruction (SI) program and hundreds of hours of peer tutoring. Dr. Wu inspired the revival of the Society of Physics Students (SPS) chapter on our campus, and the group did extraordinary things. We slowly renovated our beloved "dungeon" into a study and social space for physics majors. I remember how much time I spent with my peers trying to finish lab reports and arguing over solutions to homework problems. The SPS chapter also brought students closer together through events and shared activities. One project involved building this fantastic trebuchet for a pumpkin throwing contest hosted by the College of Engineering and Computing. I loved every minute of my time with the club and gained many leadership skills.

In an interview, I was quoted saying, "Physics was my major, but astronomy was my passion." It is true, but entirely by accident. I did not go to the University of South Carolina with the intention of becoming so involved in astronomy. Dr. Rodney's lectures were so engaging that I wanted to take more classes and do more. My love for it all took off with volunteering at the Melton Observatory for fun. I loved the stargazing aspect, but what truly inspired me was the energy I felt explaining the cosmos to guests. No matter how small, every question was a great entry point for a whole world of discussion. The skills I gained from volunteering led to my position as an Observatory Educator at the South Carolina State Museum's Boeing Observatory. I would sometimes talk to hundreds of people a day about the Sun. I learned to make science accessible to anyone at any age. Today, I have restored an observatory on my school's campus, and I am currently creating an entire space science library of activities for students, families, and the greater community. None of what I am doing now would be possible without my time at the Melton Observatory.

I must thank my lucky stars for the wonderful people who supported me during my time at the University of South Carolina. The particle physics and astrophysics research groups that I participated in as an undergraduate were incredibly rewarding. The classes were challenging and adequately prepared me for the problems I solve now. The people were exceptional and a huge part of my journey. I hope to continue my work in physics and astronomy for many years.

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*Space Elements imaged by Alex Mowery from the Melton Observatory*