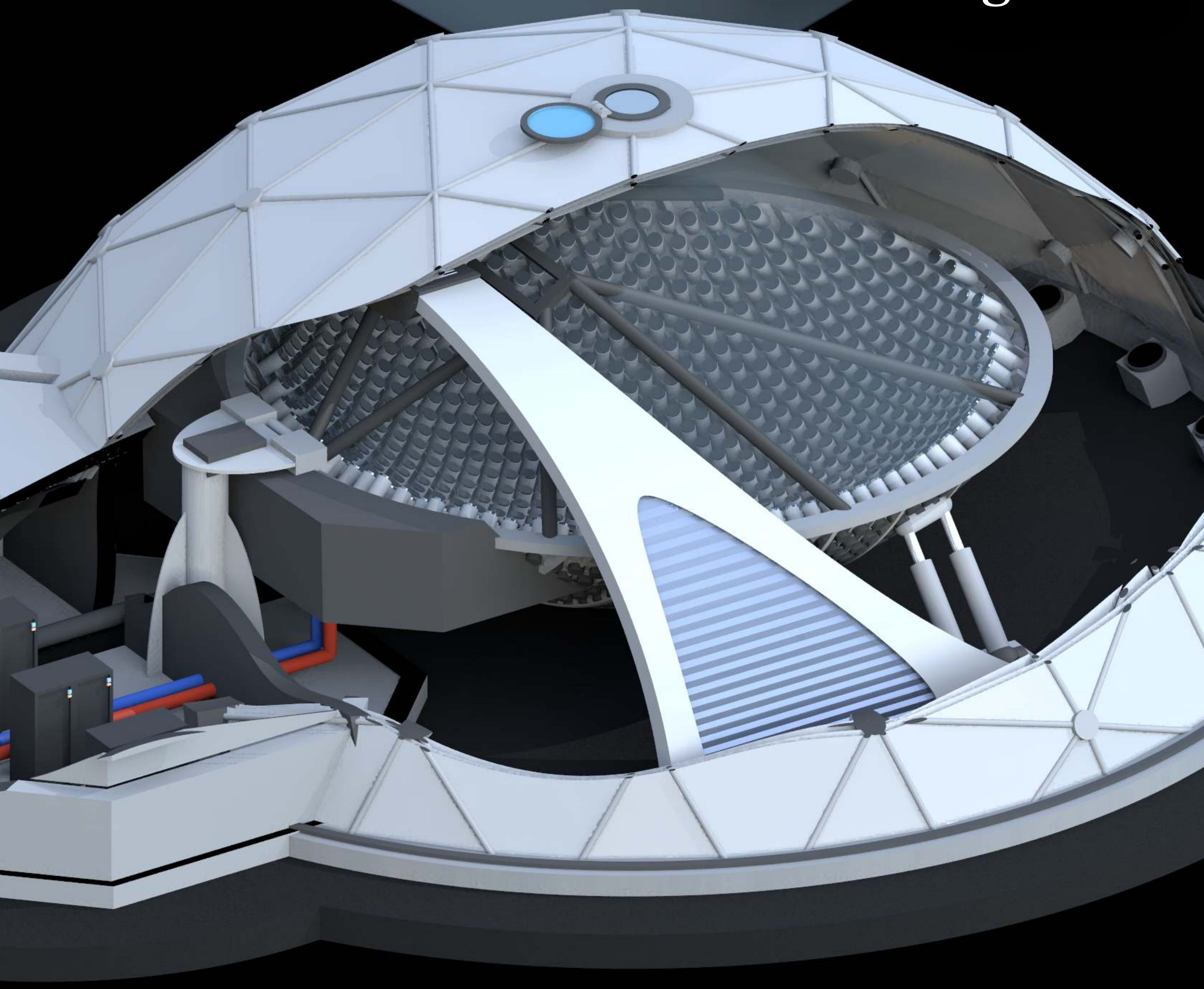
UNC Chapel Hill
Physics and Astronomy
News Magazine



Fall 2022

UNC
COLLEGE OF
ARTS & SCIENCES

FALL 2022

online
physics.unc.edu

Our Department in numbers:

33	Tenure-line faculty
5	Teaching faculty
4	Research faculty
11	Academic support staff
4	Instrument shop personnel
11	Elected Fellows of the APS, AAAS, SPIE, or AIMBE
$15.8M	Annual Research Funding received in 2021-2022
99	Graduate students
10	Postdoctoral scholars
7,120	Annual course enrollment 2021-2022
14,931	Credit hours taught in 2021-2022
210	Majors
48	Bachelor's degrees awarded in Spring 2022

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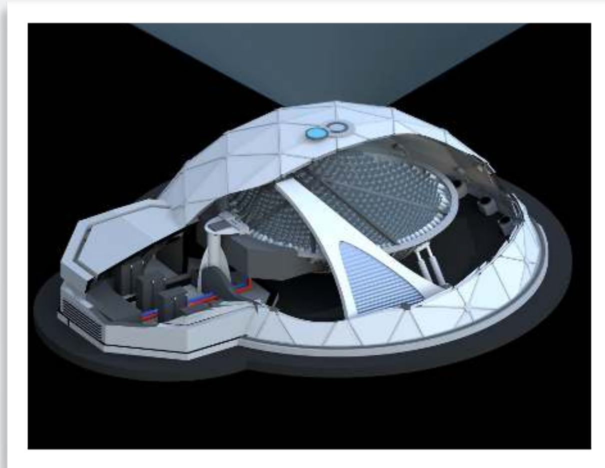

***On the cover**: The design for the Argus Array (see Nicholas Law's article on page 4).*
***Credit**: Nicholas Law*

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Questions? Comments? Contact us: drut@email.unc.edu

From the **Chair**

Thriving in Research and Education
By Frank Tsui

It has been a challenging and exhilarating year in the Department of Physics and Astronomy. We have successfully overcome the limitations imposed by the pandemic, and continued to excel and innovate in research, education, and service.

Our faculty and students are pushing the boundaries of scientific endeavors, unlocking the secrets of the universe, from the cosmos to the smallest building blocks, and everything in between, especially those that directly impact the science and technology of today and tomorrow. We have welcomed two new faculty colleagues to our ranks, Professor Carl Rodriguez, a renowned expert in stellar dynamics, gravitation-wave physics, and computational astrophysics, and Professor and Kenan Jr Fellow Wei Zhang, an internationally recognized expert in quantum information systems, and quantum materials and devices. The new hires will help to further galvanize research and education in our department and university. Our faculty members have substantially increased the external grant support, risen from about $11M in FY 20-21 to more than $15M in FY 21-22. Our research excellence has been recognized, including three NSF CAREER Awards, a Sloan Fellowship, and a Packard Fellowship to our junior faculty ranks, and one distinguished professorship to our senior faculty.

Last spring, we had our first in-person graduation ceremony since the pandemic. We have continued to graduate the highest number of majors in the state of North Carolina, top two in the Southeast, and number 28 in all 760 departments in the U.S., surpassing many bigger departments. We have initiated a comprehensive effort in our students' professional and career development. Our graduates directly contribute to the STEM talent pool of the state and the nation, with the vast majority of them working in engineering and manufacturing, information technology, data science, and biomedical fields.

The department and the CoSMS Institute have successfully organized two international conferences, one on Neutrino and Dark Matter held in Asheville NC, and another on Many-Body Theories in Chapel Hill. We hosted several summer research programs for students at various levels and backgrounds, including the inaugural Astrophysics Program as part of the long running Summer Science Program, attracting dozens of talented high school students from around the world.

I hope you will enjoy reading the stories covered in this issue. If your travels bring you to RTP area, please get in touch with us, and we'd be glad to show you around. As always, thank you for your support.

Best wishes,
Frank Tsui
Chair, UNC-CH Physics & Astronomy

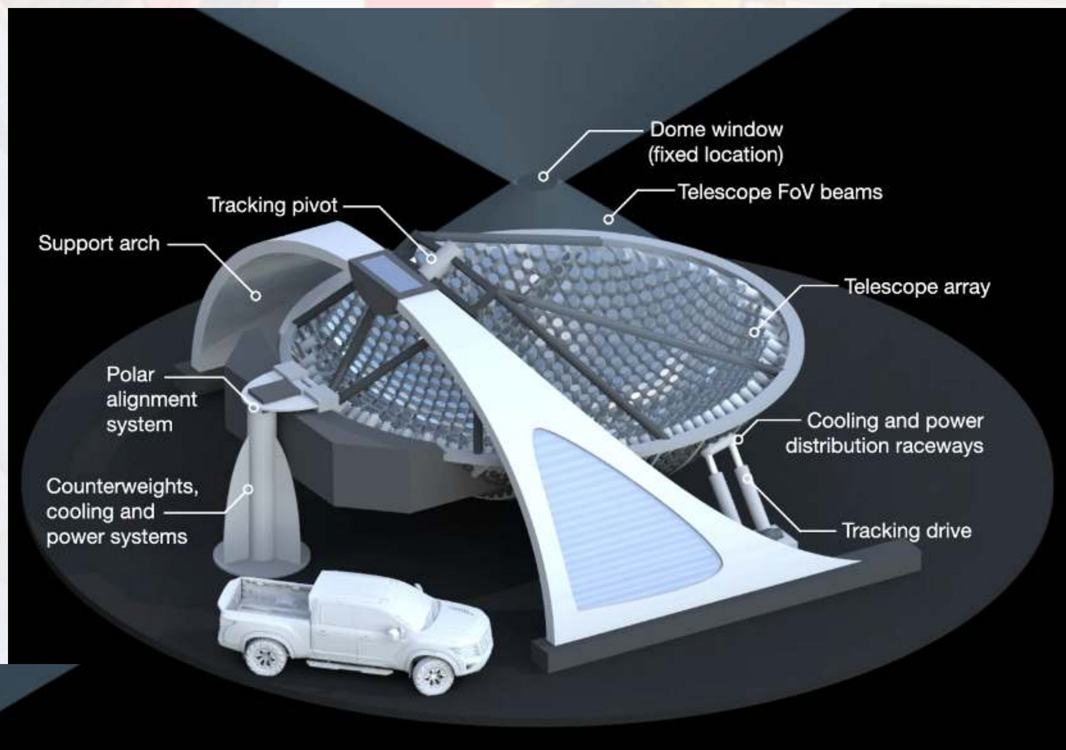
The sky at high speed: developing the Argus Array

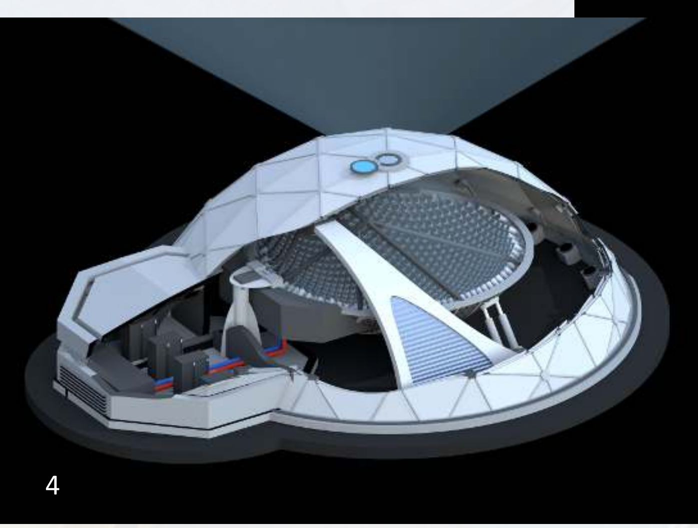
By Nicholas Law

The sky is dynamic and alive. Every day, a dozen new supernovae are detected by telescopes which sweep through the entire sky looking for new events. A dozen more transiting planets are found, orbiting in front of their host stars and blocking the light from them. On faster timescales, countless small bodies in the solar system spin around our star, producing fleeting shadows as they block faraway stars. Fast stellar superflares, far more intense than our Sun can produce, bake the nearby exoplanets we used to think were the best homes for life. And every day thousands of newly-discovered millisecond-timescale radio flashes occur across the sky, their origins mysterious and the subject of much theoretical debate.

This lively universe has been revealed by new technology: sky survey systems which have only recently become possible because of tremendous leaps in consumer digital technology. 20 years ago, a sky survey was ambitious if it expected to cover the entire sky in a period of years. Now, a worldwide suite of telescopes tiles the entire sky every night with images with enough sensitivity to detect nearby supernovae. Soon, the NSF will complete the Rubin Observatory, a billion-dollar 8m-diameter telescope which scans the sky once a week and is capable of detecting by far the faintest extragalactic events yet reached.

At UNC, we are developing new telescopes which will complement the Rubin Observatory and push in a new direction: extraordinarily fast events. Our systems are designed to cover the entire sky every second, 100,000x faster than the best current sky surveys. In doing





The Argus Array's unique design stems from the complexity of keeping a 1000-telescope array operational. A conventional open-air telescope array would have thousands of moving parts and optics exposed to dust and thermal changes, and quickly become impossible to maintain. The Argus Array's design seals all the telescopes into a lab-like environment, with a single moving part to track the sky, and a single small external window to keep clean. Careful thermal control avoids the formation of internal air currents which could affect the array's image quality.

Graduate students installing the first telescope into the Argus Pathfinder array. Left to right: Hank Corbett, Alan Vasquez, Nathan Galliher, Lawrence Machia.

so, they will reveal the new classes of events – the millisecond flashes, the superflares, the distant-solar-system occultation events, and dozens more – that have been hinted at but not explored by the current daily or weekly all-sky coverage. And, as the systems search the entire sky at high-speed for the first time, there is always the electrifying chance of finding something really new – something unexpected and wonderful.

Our new surveys are able to cover the whole sky in each exposure because they are not a single conventional telescope with a narrow field of view, but rather an array of small telescopes designed to tile the entire sky in one go. Because each telescope in the array can be relatively small, it can be mass-produced at far lower cost than an equivalent custom-built monolithic telescope. The hardware for the Argus Array, our flagship design, costs only around $10M, and yet the system would be capable of collecting almost as much light as the billion-dollar Rubin Observatory. The idea of an array telescope is not new, with arrays of up to dozens of telescopes having been built by groups for nightly surveys (including our own Evryscope systems). Argus is, however, at a far-larger scale: 1000 telescopes collecting more light than all previous sky survey telescopes put together, covering the entire sky with a 55 gigapixel high-speed detector array which is 10x larger than any optical camera yet made. This scale and complexity requires a completely new telescope design: a bowl of telescopes, protected within an unchanging lab-like environment, all looking through a single small skylight.

We are prototyping the Argus Array with the Argus Pathfinder, funded by the NSF and Schmidt Futures, and about to be deployed in the Appalachians. Pathfinder's 38 telescope array sweeps across the sky each night, looking for high-speed phenomena. Pathfinder's main targets are superflares from nearby stars, capable of sterilizing habitable worlds over cosmic time. Pathfinder will obtain the first time-resolved light curves and spectra to model the flares' all-important energetic particle releases, which could damage nearby planetary atmospheres. For the largest flares, we will slew NASA's Swift satellite within minutes, to catch extreme-UV and X-ray imaging of the flare as it happens – and directly measure the most important planetary habitability impacts. The full Argus Array, funding permitting, could be covering the entire sky within five years.

Nicholas Law joined the department in 2013, coming from a PhD at the University of Cambridge and postdocs at Caltech and the University of Toronto. His group builds instruments to explore the sky in new ways. Beyond Argus, he is PI of the Evryscope sky survey telescopes, which are deployed in the Andes and the mountains of California. He has also served in leadership roles in the AWCams (the first astronomical instruments deployed near the North Pole); Robo-AO (the first robotic laser adaptive optics system); and the Palomar Transient Factory (a systematic exploration of the night sky). When not bolting telescopes together, Nick can be found building the coolest Lego spaceships with his young sons.

Stars, stellar dynamics, black holes, and gravitational waves

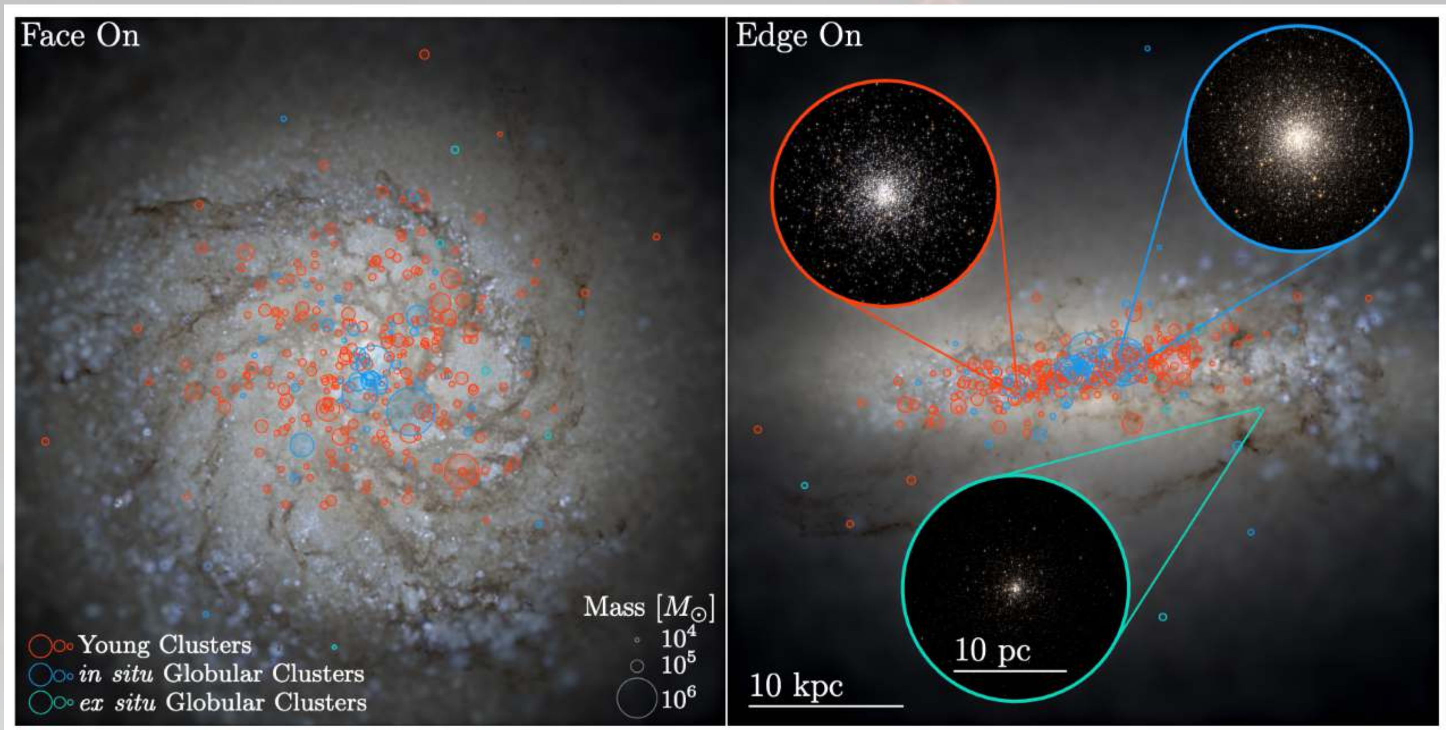
By Carl Rodriguez

My focus is gravity: from the movement of binary and triple stars to the evolution of dense star clusters to the gravitational waves produced by merging black holes. Each of these scales requires a fundamentally different approach. The dynamics of binary stars can largely be analyzed with a pencil and paper, but is complicated by the evolution of the stars themselves. But as the number of stars in a system increases, so does the dynamical complexity. Clusters of stars—such as young open clusters, globular clusters, and the dense stellar clusters in the centers of galaxies—are "collisional" systems, where gravitational encounters between stars cause them to exchange energy, allowing energy to diffuse through the cluster in the same way that energy diffuses through molecules in an ideal gas. But unlike an ideal gas, gravitationally-bound systems have a negative specific heat capacity: when I inject energy into an orbit, the orbit widens and the stars slow down!

This means that no gravitationally-bound system with more than two stars will ever reach equilibrium. As the inner regions of a star cluster collapse into their gravitational potential, the individual stars start moving faster and faster, causing the center of the cluster to "heat up". This sets up an energy transfer from the "hot" core of the cluster to the "cool" outer regions, but because of the negative specific heat, extracting energy from the core only causes it to get hotter and hotter, creating a runaway collapse called the "gravothermal catastrophe", in which the central regions of the cluster become infinitely dense and infinitely small.

Of course, this doesn't happen in real star clusters, where the central regions are largely dominated by the most massive objects in the cluster—stellar mass black holes. When the density of these black holes becomes sufficiently high, it facilitates three-body interactions that produce binary black holes. This production of binaries injects energy into the nearby stars, acting as a power source for the cluster, in much the same way that hydrogen fusion in stars produces the energy to support them against gravitational collapse. And in the same way that nuclear fusion can be detected by the emission of solar neutrinos, binary black hole formation can be detected by the emission of gravitational waves.

A big focus of our group is the production of binary black holes in star clusters, and how they can be distinguished from binaries formed from other pathways (such as massive binary stars). Using large supercomputer simulations of star cluster dynamics, we can trace the evolution of these clusters and the binary black holes they create across cosmic time, creating entire



Globular star clusters (from [Rodriguez et al., 2022](#)) formed from the collapse of giant molecular gas clouds in a high-resolution simulation of a Milky Way-mass galaxy. The left panel shows the face-on view of the galaxy model, with the surviving clusters highlighted in red, blue, and green, while the right panel shows the edge-on galaxy view, along with zoom-in fake Hubble images of three of the surviving star cluster models.

synthetic universes full of gravitational-wave sources detectable by LIGO. Recently our group, with collaborators from Carnegie Observatories, UC Irvine, and the Nice Observatory in France, has begun to explore the formation of these star clusters in high-resolution hydrodynamical simulations of galaxies. This allows us to create a bridge between the largest simulations of galaxy formation and evolution and the binary black hole mergers we see in the local universe.

Surprisingly, even after nearly a hundred gravitational-wave detections, we still don't know where most of LIGO's binary black holes are formed! With postdocs Poojan Agrawal, an expert in massive star evolution, and Ugo Di Carlo, and expert in gravitational N-body simulations, we have started to create a unified framework for binary black hole production across all dynamical scales, from stellar binaries with N=2 stars to massive clusters in galactic centers with N~108 stars. With LIGO's fourth observing run scheduled to start in March 2023, we hope to use these models to understand the origin of gravitational waves! For more information, scan the QR code below.

Carl Rodriguez will be joining the department as an assistant professor in January 2023. Prior to that, he did his PhD at Northwestern University before moving on to postdocs at MIT and Harvard, and spending two years as an assistant professor at Carnegie Mellon in Pittsburgh. Carl is interested stellar dynamics of star clusters and galaxies, how stars form, evolve, and die, and the various gravitational waves and other high-energy transients that they produce along the way. The Rodriguez Group is also broadly interested in developing new ways to approach stellar dynamics, either computationally or analytically, including the development of new high-performance computing software for solving the gravitational N-body problem. When not doing physics, Carl can be found hiking, biking, cooking, climbing, or thinking about trains.

Hybridized-magnon polariton - the mediator for future quantum transduction

By Wei Zhang

As a highly interdisciplinary field, *quantum information science* seeks to understand the transmission and processing of information using quantum mechanics principles. The topic combines Information science with quantum physics, and thanks to the latter, a series of new computing schemes become possible beyond what can be done in classical computation. Recent advances have highlighted the potential of quantum information processors to outperform state-of-the-art high performance computing facilities, for example, Google's 53 qubit quantum computer based on superconducting electronics [**Nature 574, 505 (2019)]**.

In practical quantum devices, information are carried by phase coherent excitations. Therefore, light photons are natural attractive candidates for quantum information processing (**Nobel Prize in Physics, 2022**). In the meantime, quantum technologies based on many other solid state platforms have attracted increasing attention during the last few years, leading to various quantum information processing prototypes and architectures. For nascent quantum technologies to reach maturity, a key step is the development of scalable quantum building blocks: from quantum interconnects and transducers, to sensors at the single quasiparticle level. The development of scalable architectures for quantum technologies not only poses challenges in understanding the coupling between disparate quantum systems, but also presents technical and engineering challenges associated with developing chip-scale quantum technology. Such needs for leveraging the distinct quantum systems and prototypes then trigger new research into necessary quantum mediators. In such a context, an exciting strategy has been explored in the last few years to access through **hybrid quantum systems** those

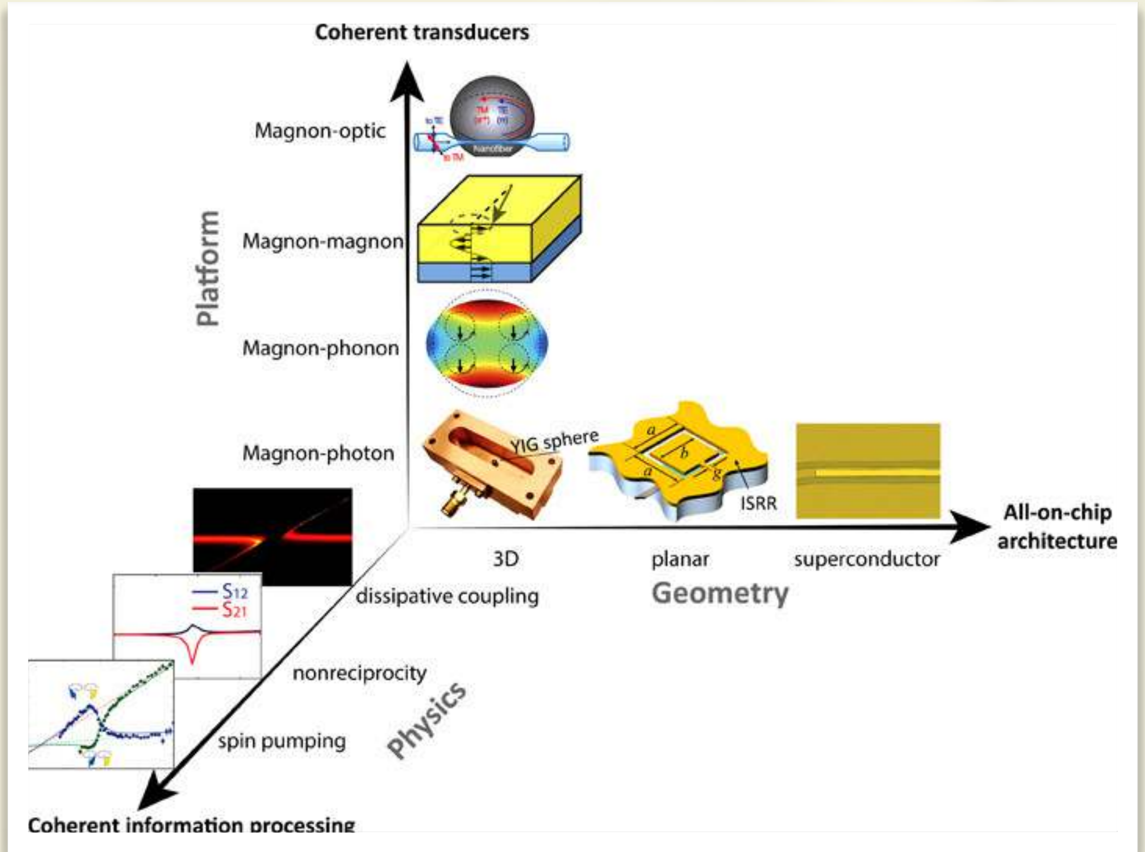


Fig. 1. *Growing directions and goals for magnon hybrid systems. The explorations on geometry, physics, and platform lead to on-chip architecture, coherent information processing, and coherent transduction. J. Appl. Physics* ***128****, 130902 (2020).*

novel capabilities in existing quantum technologies by the combination of distinct physical systems.

A rapidly growing subfield of quantum engineering is associated with magnons. Magnons, or the quanta of spin waves, are the collective excitation of exchange-coupled spins hosted in magnetic materials. Similar to electromagnetic and acoustic waves, spin waves can propagate and interfere, meaning that they can deliver phase information for coherent information processing. Due to the high spin density in magnetic materials compared with individual spins, large magnetic dipolar coupling strengths in the sub-GHz regime can be easily achieved between magnons and microwave photons, which means fast operation and transduction before decoherence. In addition, magnons can provide a wide range of interactions, forming a ***hybridized-magnon polariton***: for example, to mediate coupling between microwave and optical photons via magneto-optic Faraday effects, to interact strongly with phonons due to magnetoelastic coupling, and to couple with single spin in nitrogen-vacancy centers in diamond.

The Quantum Magnonics Laboratory at UNC is currently working on searching a set of hybridized-magnon polaritons and developing quantum magnonic systems that coherently 'talk' to light photon, microwave, acoustic phonon, and qubits, etc. The team is simultaneously exploring new physics, platform, and geometry that may eventually lead to on-chip architecture for coherent information processing and signal transduction.

In the Lab, we manufacture hybrid devices encompassing high quality-factor microwave and optoelectronic resonators that are made from semiconductors, superconductors, and magnetic materials. We also detect their novel magnonic and photonic characteristics by state-of-the-art microwave and optical spectroscopies at a wide range of temperatures down to single digit Kevin.

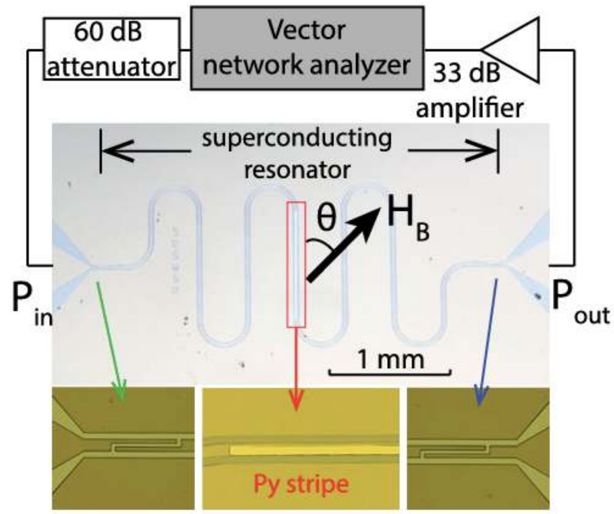
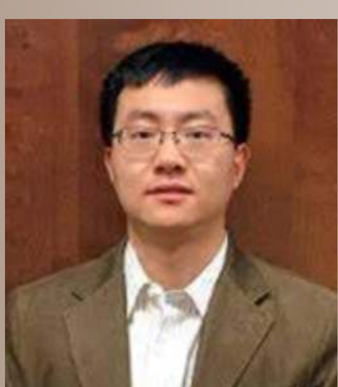


Fig. 2. *On-chip quantum circuit and strong coupling between a superconducting resonator and a magnetic device. Phys. Rev. Lett.* ***123****, 107701 (2019).*

In the future, the lab aims to expand their research scope by actively exploring new hybrid quantum platforms leveraging the vigorous materials synergies in the NC RTP area, including but not limited to, organic-inorganic hybrids, chiral molecules, and novel perovskites. For more information, scan the QR code below.



Wei Zhang joined us in 2022 from Oakland University in Michigan where he was an associate professor in the Physics Department. Before that he was a postdoc researcher at Argonne National Laboratory. Wei got his PhD in Material Science at the University of Washington – Seattle and BS in Physics from Beijing(Peking) University in China. His research focuses on spin-related properties in condensed matter from an interdisciplinary angle encompasses physics, materials, and engineering devices.

Nothingness

By Laura Mersini-Houghton

In my work as a scientist, I have often crossed paths with the question if *nothingness* exists. In physics this concept is known as *the vacuum*. As I write this essay, the celestial beauty of the notes from Bach's St Mathew's Passion fills the room. The first time I heard it performed live was during a concert in Hereford cathedral in England which we attended with a group of colleagues at the end of a conference organized by S. Hawking, devoted to the topic of vacuum. Paraphrasing S. Hawking, the conference was about the question "what breathed fire into those (vacuum) equations to spit a universe out of it?". Listening to it again reminds me of the richness and the incredible story of vacuum.

In modern times, it is inconceivable to perform the simplest operations, whether in mathematics, science, computing, or banking, without using the concept of nothing - of zero. An ancient concept, zero was first conceived by the Sumerians in one of the cradles of civilization that existed from around the fifth to the second millennia BC, in Mesopotamia. It was born out of the necessity of recording transactions made during trade in the lands between the Tigris and Euphrates rivers.

Yet, despite Alexander The Great's conquest of the region, zero was not adopted into ancient Greece and Rome, and generally Europe until the Renaissance, with Toricelli's work on vacuum and the calculus of Newton and Leibniz. The Greek philosopher Aristotle, considered by many to be the founding father of natural sciences, is famously quoted to have said "Nature abhors a vacuum". The ancient Greeks seemed to have a philosophical opposition to using zero as a number. The Far East used the abacus instead of numbers and the concept of zero was not needed.

But a few millennia later this concept made its way into Indian mathematics in the sixth century AD, and it was embraced by Arabic scholars in the Middle East around the ninth century AD, leading to a flourishing of culture of the arts, science, and economy of those civilizations.

In our time we know that Nature actually thrives on vacuum. Research and discoveries in physics rely heavily on the exploration of vacuum. Vacuum is the richest arena where Nature closely guards its secrets.

So far, many key discoveries in our understanding of the universe testify to its validity. Scientists believe that our whole universe came into existence, 13.8 billion years ago, out of a space-time vacuum filled with absolutely nothing, except for a mysterious type of energy, in a blaze of fire known as cosmic inflation. We have strong evidence that the ultimate destination of our universe is another vacuum, a vacuum filled with an energy similar to that at its creation, known as dark energy.

Vacuum energy, be it dark energy which governs the future of the universe, or cosmic inflation energy that determined its past, is stranger than fiction and like nothing else we have ever known. For this reason, it has intrigued and fascinated me sufficiently to devote my working life to its understanding. It is produced out of nothing, out of the very fabric of spacetime: it is a type of energy which maintains a constant density per unit volume of space. As the volume of space time grows with the expanding universe so does the total amount of dark energy. Nobody knows what sources dark energy. In the future, though matter and light will dilute away, dark energy will continue to grow and remain the ultimate "free lunch", the only ingredient left in the universe. Despite the cosmic heat death that awaits our universe, according to our current understanding, it appears that dark energy will continue to be produced out of nothing, *ad infinitum*, in an ever expanding cold, dark and empty universe.

Quantum mechanically, the microscopic vacuum continuously swarms with pairs of particles and antiparticles that flicker in and out existence. The separation of the entangled pairs, for example, pulled out of the space time vacuum by the strong gravitational forces near the horizon of a black hole, leads to Hawking radiation.

Meanwhile the vacuum solutions of Einstein equations in general relativity result in black holes. Black hole pairs, can, at least in principle, be joined by a type of tunnel, or wormhole, known as the Einstein-Rosen bridge, giving yet another vacuum solution. (Nathan Rosen was a professor in our department at UNC when the E-R

***Background image credit**: DALL-E "A vacuum of nothingness before the big bang."*

paper, and the E-P-R paper below, was published).

In the quantum vacuum of black holes, conclusions drawn from Hawking radiation are in strong opposition to those from the vacuum produced by Einstein's theory. This friction is due to the singularity in the center of a black hole, which leads to a major paradox: the information loss paradox. In quantum mechanics, information is never lost and we can collect it in the form of Hawking radiation, but in classical physics, all the information that enters a black hole can never be recovered again - thus the paradox. The objection to quantum entangled pairs of particles in vacuum led Einstein, Podolsky and Rosen to the famous EPR paradox, where the transfer of information between entangled pairs appeared to break the speed of light limit. By now, we understand that entangled pairs cannot transfer classical information.

In a way the EPR paradox was a precursor related to the modern statement of the information loss paradox alongside the problem of the unlikely origin of our universe out of a vacuum. Thus, vacuum takes center stage again: it becomes the arena where the tug of war between the two pillars of modern physics, quantum theory and the theory of gravity, play out. It is the stage where observing Nature we have to take a stance and chose: is the fabric of reality indeterministic subjected to the quantum uncertainty principle at its basic level where anything that can happen, no matter how outrageous, has a non-zero probability to happen; or is the universe deterministic where, if we know all the acting forces on a system then we can determine its evolution with certainty?

Wait a minute, who is observing the universe to decide what happens to it in the future? Truth about physical reality should be objective and independent of who is performing the observations. How can a subjective Observer be avoided? Such questions go back to the discovery of quantum mechanics in Copenhagen in the 1920's and the ongoing debate still keep physicists awake at night.

Yet, undeniably all the particles and light we see around us, (and eventually you and I!), came out of a transition from one quantum vacuum (of higher energy) to another (of lower energy), known in physics as a phase transition from false to true vacuum. The 'mother' of all particles, Higgs Particle, came into being as a result of such a vacuum phase transition (the Nobel prize winning paper by Peter Higgs regarding the Higgs particle was also written while he worked in our department.). All the new materials from nanotechnology to quantum phase of matter are a product of similar phase transitions. At the deepest level, we do not understand the particle physics vacuum either, although we are able capture it quite well in mathematical terms. Yet, all advanced technology, from quantum computing to AI, depends on it.

A tour of the breakthroughs of modern physics is a walk through the struggles of physicists in deciphering vacuum. As we crack open the door to understanding one vacuum, we are faced with a labyrinth of mysteries to the other vacua. My colleagues and I have spent our working lives trying to make sense of it, because, just like the music that unlocks the meaning of infinity in us all, grasping the secrets of the vacuum in our minds holds the key to future discoveries - to claiming this universe our home. Sumerian traders discovered zero out of necessity, and so too will future discoveries in physics cross-fertilize ideas that can be applied in other disciplines, from the economy to the humanities.

Laura Mersini-Houghton joined our department in 2004. She is an internationally renowned cosmologist and theoretical physicist and one of the world's leading experts on the multiverse and the origins of the universe. Born in Albania when it was still under a communist dictatorship, she was awarded a Fulbright Scholarship to study in the United States and is now a regular visiting professor at several universities around the world, including the University of Cambridge. She has been the subject of hundreds of articles in leading popular science magazines and has appeared in documentaries on the Science Channel, Discovery Channel and the BBC.

Will This Asteroid Hit Earth? Teenagers at the Summer Science Program find out.

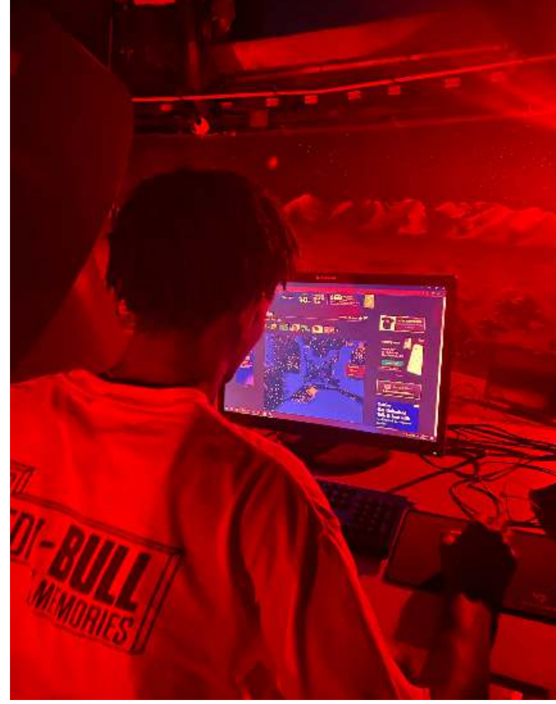
By Michael Hannawald, Academic Director

Over 39 intense days last summer, three dozen of the world's most promising high school science students, from 18 states and three foreign countries, gathered in Chapel Hill for the Summer Science Program (SSP) in Astrophysics at UNC. They spent their nights inside the Morehead Observatory dome in teams of three, using its 24" telescope to take a series of images of their assigned near-earth asteroid. Then in Phillips Hall they measured its precise position in each image and predicted its future path … a classic application of vector calculus.

Besides astrophysics, the students learned that collaborative research is a welcome contrast to competitive high school coursework, and being surrounded by equally bright and interesting peers is rewarding both intellectually and socially. The spirit of cooperation was reinforced by an Honor Code and an absence of exams, grades, or formal credit; their best rewards were the personal growth they experienced and their new global network of peers.

The program's design incorporates values of collaboration and connection, rigor and challenge, trust and respect, inclusivity and support – exactly what high-potential teens need at this critical life stage, just before they apply to college. The experience inspires them to higher confidence and bigger dreams.

Participants stayed very busy learning, working … and having fun. The dense schedule included a Guest Lecture Series, in which scientists and professionals presented on topics not directly related to the research, followed by open-ended interactions. Dr. Nancy Chabot described NASA's "DART" mission, Dr. Adrienne Erickcek presented recent advances in cosmology, UNC's own Dr. Dan Reichart described the worldwide Skynet telescope network he directs, and computer animation pioneer Richard Chuang SSP '74 spoke about "The Infinite Space of Learning".



Old West dorm was the home base for 36 teenagers from around the world at the Summer Science Program in Astrophysics at UNC. They spent their days learning celestial mechanics in Phillips Hall and their nights tracking near-earth asteroids with the newly-renovated 24" telescope inside the dome of Morehead Observatory.

There were also recreational excursions and organized social events, including a talent show. A field trip on the 4th of July to the Durham Bulls party deck was a highlight, a relaxing evening combining baseball, burgers, and fireworks.

"The program's design incorporates values of collaboration and connection, rigor and challenge, trust and respect, inclusivity and support"

SSP was first to use Morehead's 24" telescope following extensive renovations during the pandemic. Cloudy nights notwithstanding, the mood stayed positive, participants worked hard on coding and tracking their asteroids, and in their free time ran integration contests until midnight.

By departure day, the hard work and dedication had paid off. All twelve teams had observed their asteroid and calculated its orbit using Python code they wrote themselves. Capstone calculations with software from Southwest Research Institute revealed that none of the asteroids studied will hit earth; all will eventually be pulled into the sun or slung out of the solar system into interstellar space. On July 20th, everyone headed home and joined a worldwide network of 2,500+ SSP alumni of all ages.

Similar Summer Science Programs are operated by an independent nonprofit (see SummerScience.org) on five college campuses. UNC is the first east coast campus. The program will return to Chapel Hill every summer.

Learn more by following this QR code:

SSP ASTROPHYSICS

UNC '22

On other news...

Beverly Loftin named University Manager of the Year

Beverly Loftin, business manager in the departments of Physics and Astronomy and Applied Physical Sciences in the College of Arts & Sciences, was named the 2022 University Manager of the Year.

The award was presented at the University Manager's Association (UMA)'s annual meeting on May 26. The Manager of the Year Award is sponsored by the UMA and is based on university career accomplishments, both within and beyond normal job responsibilities, or a specific accomplishment made within the previous 12 months that has been of major significance.

Loftin has been with the department of physics and astronomy for 15 years, starting as the HR manager in March 2007 and was promoted to business manager in September 2009, where she has been ever since. As of 2020, she has also been taking on the role of department manager for the applied physical sciences department. Before joining UNC, she worked as the general manager for Marx Industries and Prelude Foam.

Frank Tsui, professor and department chair of the department of Physics and Astronomy, said that she has been an outstanding leader and has always gone above and beyond the call of duty. "*Beverly is a leader who can hold the staff (two departments) together, especially in the face of tremendous challenges, primarily due to pandemic and fiscal constraints*," Tsui said. "*She*

exemplifies what a quintessential best manager should look like, a leader and facilitator who keeps everything afloat within and well beyond her 'normal responsibilities.' In my opinion as the department chair, she is the best manager on the Carolina campus, deserving the Manager of the Year honor."

Graduate Students Pioneer Peer Mentorship Program

Graduate students from Physics & Astronomy and the Department of Chemistry pioneered a peer mentorship initiative, alongside the Graduate School's professional development program in order to better serve incoming graduate students.

In 2020, Department of Physics Ph.D. first-year student Taylor Robinson came to UNC-Chapel Hill during the height of the COVID-19 pandemic and met many others in her graduate student cohort for the first time through a computer screen. The onset of the pandemic compounded the already-rigorous pursuit of a graduate degree; Robinson found support from a student-led peer mentorship initiative that eased the transition from undergraduate to graduate student.

Prior to the pandemic, Department of Chemistry Ph.D. candidate Tayliz Rodriguez, active in a bevy of initiatives on campus that support women and minorities in STEM, saw a need for peer mentorship based on the results of a departmental survey. In 2018, Rodriguez began work, alongside Ph.D. candidate Morgan Clark in the Department of Physics and Astronomy, to outline how a peer mentorship program might be designed and what it might provide to students.

After having taken a workshop in effective mentoring offered by Brian Rybarczyk, assistant dean for academic and professional development at The Graduate School, Clark and Rodriguez reached out to Rybarczyk as they sought to launch a similar initiative in their respective departments. The result is Graduate Achievement Through Mentorship (GrAM), now part of the Allies for Minorities and Women in Science and Engineering organization for which Rodriguez and Clark serve as co-presidents.

Physics Students Win National Recognition for Fourth Consecutive Time

Our local chapter of the Society of Physics Students (SPS) has won an Outstanding Chapter Award from the SPS National Office. This is the fourth consecutive time the chapter has been recognized for its excellence as a top-tier student-led physical sciences organization, a designation given to fewer than 10 percent of all SPS chapters at colleges and universities in the United States and internationally.

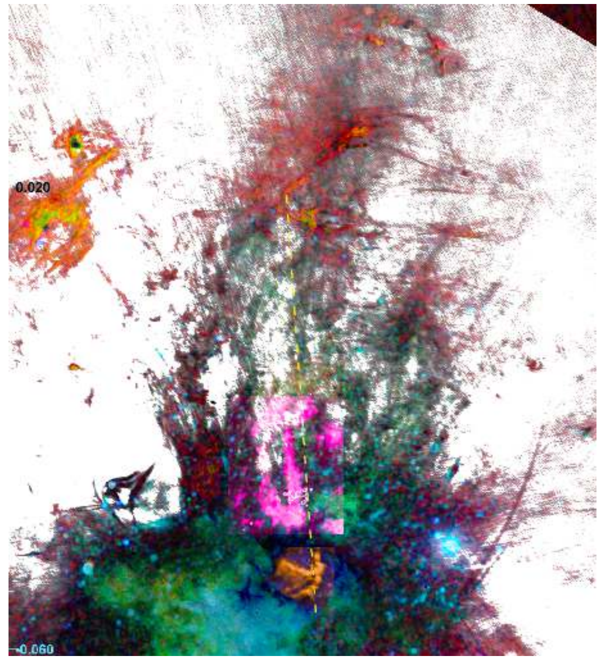
The Society of Physics Students (SPS) is a professional association designed for students and membership is open to anyone interested in physics and related fields. SPS operates within the American Institute of Physics (AIP), an umbrella organization for professional physical science societies.

The SPS chapter at UNC-CH is advised by Prof. Andrew Mann and is led by student officers. The 2020-2021 officers:
President Giovani Leone, B.S. Physics, ’22; Vice President Isabella Ford, B.S. Computer Science, B.A. Physics, ’21; Secretary Tyler Kay, B.S. Physics, B.A. Philosophy, ’22; Treasurer Austin Blitstein, B.S. Physics, B.S. Mathematics, Chemistry Minor, ’22; Events Coordinator Megan Pramojaney, B.S. Physics, Creative Writing Minor, Applied Sciences and Engineering Minor, ’23; Room Manager Nathaniel Badgett, B.S. Physics (Astrophysics Option), ’22.

SPS chapters are evaluated on their level of interaction with the campus community, the professional physics community, the public, and with SPS national programs. The Outstanding Chapter Award recognizes high levels of outreach as well as unique approaches to fulfilling the mission of SPS to “*help students transform themselves into contributing members of the professional community*.”

Recently published: After A Wild Blowout A Few Million Years Ago, The Central Black Hole In Our Galaxy Now Dozes Fitfully

At its center, our Milky Way galaxy has an ancient black hole that over 10 billion years has gobbled millions of suns. Most large galaxies have one, but those holes are too far away to study in detail so their impacts on their surroundings are unclear. However, before gas and dust reach the hole, gamma-rays and charged particles are emitted to great distances. So the escape path once uncovered enables archeology; astronomers can dig through accumulated debris to wondrous artifacts below. Presently our central black hole is very sedate so the route down might have closed up.



Fifty light years across the center of our galaxy. The 4.3 million solar mass black hole is at the center of the yellow “minispiral” near the bottom of the image. Red/orange denote ionized hydrogen, green and blue colors x-rays, and dark filaments trending upward are radio waves. Part of the ALMA molecular flow established by the team is shown in pink. Further observations with ALMA are needed to see if it extends beyond the top shown here.

However, results published in the December 1 2021 Astrophysical Journal by professor Gerald Cecil and collaborators in Japan, Australia, and India provide evidence of recent power surges. “*In 2019 some of us showed that the Milky Way’s central black hole powered up tens of millions of times its current luminosity as it ate a stream of gas a few million years ago*” Cecil noted. That event irradiated a gas plume over 200,000 light years distant from the Milky Way that is still recovering from being hammered by that energetic outburst. Now the new paper reports that the team has found the particle beam of this event, and it is still active at a low level. There’s too much dust along the 26,000 light-year distance to the center of our galaxy for UNC’s SOAR telescope in Chile to penetrate, so to sweep through it the team used the most powerful astronomical facility on Earth — the Atacama Large Millimeter Array (ALMA) of radio telescopes also high in the Chilean Andes. “*We found methyl alcohol and other molecules being dragged along for ten light-years distance in an organized flow from the center*” said Cecil. Unlike many radio and X-ray telescopes, ALMA can map gas motions, so the team could isolate the flow from unrelated gas along our line of sight to establish its orientation and energy. “*The flow is glowing feebly today, but studies by us and others show that at full power it could inflate the huge gamma-ray and X-ray bubbles that we see looming 50,000 light years above and below the disk of our galaxy!*” co-author Alex Wagner of Tsukuba University in Japan noted. The team simulated the flow’s impact on the Milky Way’s gas clouds using large computer clusters at UNC and the Australian National University, obtaining an excellent match. Notes Cecil, “*we plan to map along this flow using ALMA and* *eventually the James Webb Space Telescope. We want to pin down how often and for how long the flow hence our black hole powers up*." Highly magnified images by the worldwide Event Horizon Telescope that includes ALMA may soon reveal the flow's base mere light-hours distant from the black hole to complement the team's study on scales of one to one thousand light years. "*Then we can unravel the history of this exotic but universal phenomenon, and begin to understand how the black hole influenced our Milky Way galaxy*. " said Wagner.

For more information, see **Gerald Cecil *et al* 2021 *ApJ* 922 254**.

Recently published: Direct Neutrino-Mass Measurement With Sub-Electronvolt Sensitivity

A Nature Physics article features a recent discovery made by an international research team that includes UNC Department of Physics and Astronomy scientists. The team has established a new upper limit of 0.8 eV/c2 for the mass of the neutrino – the lightest known particle – a milestone that will impact future discoveries in nuclear and particle physics and cosmology. The consequences of a massive neutrino are profound and may guide the development of an improved Standard Model of Particle Physics. Although their mass is tiny, the abundance of neutrinos contributes an important role in forming the largest structures in the universe, the vast clusters of galaxies, the universe as it appears to us today.

"*Neutrinos were long assumed to be massless until now*," said John Wilkerson, John R. and Louise S. Parker Distinguished Professor, director of the Institute for Cosmology, Subatomic Matter and Symmetries (CoSMS) and one of three UNC-Chapel Hill participants involved in the Karlsruhe Tritium Neutrino Experiment (KATRIN). "*Determining this absolute neutrino-mass scale is vital to our understanding of fundamental interactions, cosmology, astrophysics and ultimately to answering the underlying question on the origin of particle masses*."

Research scientist Tom Caldwell was responsible for data acquisition during the experiment, and postdoctoral research associate Eric Martin also contributed. "*The updated limits on the effective anti-electron neutrino mass from KATRIN's second physics campaign are an exciting new result, an impressive demonstration of the capabilities of the KATRIN apparatus, and the outcome of resolute, coordinated efforts from the international collaboration*," said Caldwell. "*It has been a pleasure to build on the UNC group's KATRIN DAQ efforts, driven by Mark Howe (now retired), and support the KATRIN experiment's DAQ systems*."

*Inside KATRIN, the Karlsruhe Tritium Neutrino Experiment. **Image credit**: Michael Zacher.*

"*I worked on KATRIN from construction through commissioning as a graduate student, and into early data collection as a postdoc," said Martin. "I'm thrilled to see KATRIN advancing our knowledge of neutrinos after these many years of involvement*."

To measure neutrino mass, KATRIN makes use of the beta decay of tritium, an unstable hydrogen isotope. The team was able to determine the mass of the neutrino via the measured energy of electrons released in the decay process. But to do so required a major technological effort. The experiment houses the world's most intense tritium source as well as a giant spectrometer to measure the energy of decay electrons with unprecedented precision. Read the abstract and full text of the published paper here.

For more information, see **Nature Physics volume 18, pp. 160–166 (2022).**

UNC Society of Physics Students Attend SESAPS 2022

This year, from November 3rd to 5th, seven undergraduate students from the UNC Society of Physics Students traveled to Oxford, Mississippi to attend the 2022 annual meeting of the Southeastern Section of the American Physical Society, or SESAPS. The trip was funded by the Department of Physics and Astronomy.

SESAPS gathers physicists from across the southeast to present research and stay engaged with the latest trends in physics research. This year's conference brought UNC undergrads to the

UNC students pose with a newly met friend from the University of Virginia for a selfie.

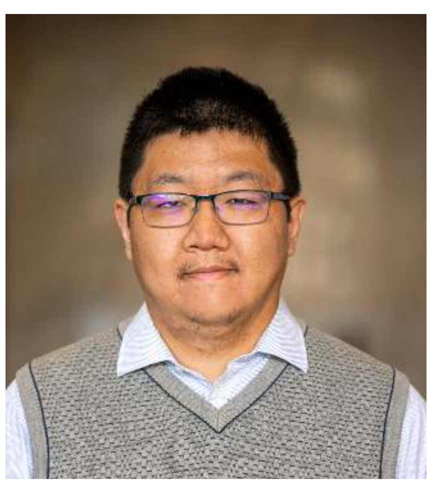
University of Mississippi, where two UNC students presented research talks and one presented a poster.

"*It was exciting; I had lots of fun!*" said Joy Harrison, a junior who attended the conference. In addition to listening to and giving physics talks, UNC students also enjoyed sharing group dinners, attending a graduate school fair, and playing science-themed Jeopardy against students from other universities.

Gary Zhang, the student who planned and organized the trip, stated that he was glad the trip was a success. "*It's important that our students have the chance to experience the universe of physics beyond just UNC,*" he said. "*We belong to a community broader than ourselves, and by interacting with the physics community at events like SESAPS, we get a sense of purpose, a sense of understanding, of why physics matters.*"

Aobo Li Receives the 2023 APS Dissertation Award in Nuclear Physics, and the UNC PARE award.

Aobo is an interdisciplinary experimentalist of artificial intelligence (AI) and neutrino physics. He did his graduate work at Boston University. He did his graduate work as part of the KamLAND-Zen collaboration, searching for neutrinoless double-beta decay with monolithic liquid scintillator detectors. His dissertation formed the early framework of his deep learning algorithm, KamNet, which was a key component in delivering the world-leading search for this decay with KamLAND-Zen 800. His thesis work was recently recognized by the APS with the Dissertation Award in Nuclear Physics "*for the invention of a novel machine learning algorithm that broke down significant technological barriers with monolithic liquid scintillator detectors and, in turn, delivered the world's most sensitive search for neutrinoless double beta decay.*" Aobo joined UNC as a Postdoctoral Research Associate and COSMS Fellow, working with Prof. Gruszko on Germanium detector experiments while maintaining his partial involvement in KamLAND-Zen. Aobo initiated and lead the Germanium Machine Learning (GeM) group, bringing AI solutions to two Germanium detector experiments: Majorana Demonstrator and LEGEND. His research and mentorship work was recently also recognized by the UNC Postdoctoral Award of Research Excellence (PARE), given each year in recognition of the research promise demonstrated by individual postdoctoral scholars.



Recently published: Before the Big Bang: The Origin of the Universe and What Lies Beyond,

by Laura Mersini-Houghton, published July 19th, 2022.

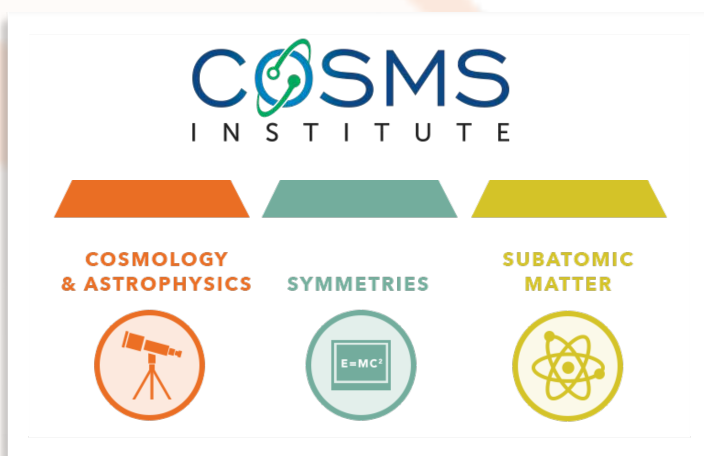
From the publisher's description: "*What came before the Big Bang, and what exists outside of the universe it created? Until recently, scientists could only guess at what lay past the edge of space-time. […] A revolutionary new account of our universe's creation—and a breathtaking exploration of the landscape from which we sprang—from one of the world's most celebrated cosmologists…[…] a mind-expanding journey through the multiverse, "Before the Big Bang" will reshape our understanding of humanity's place in the unfathomable vastness of the cosmos.*"

Laura's book is available from Harper Collins Publishers following this QR code:

In-person CoSMS conferences are back!

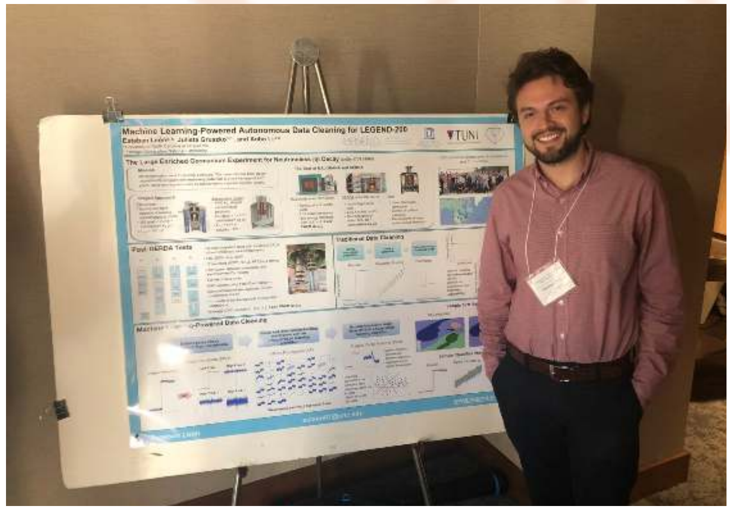
Participants of RPMBT-XXI in front of the Carolina Inn, the conference venue.

As the pandemic subsides, in-person conferences return to CoSMS in the triangle area and beyond. The picture on the right shows the participants of the *21st international conference on Recent Progress in Many-Body Theories* (**RPMBT-XXI**), which took place September 12-16, 2022. The local organizing committee consisted of Prof. Joaquín Drut (UNC) as chair, in collaboration with Profs. Basar (UNC), Nicholson (UNC), Chandrasekharan (Duke), Mitas (NCSU), and Papenbrock (U. Tennessee and ORNL). The conference brought together about 90 experts from around the world to the beautiful Carolina Inn, which served as the main hotel and conference venue. Wide areas of many-body physics were covered, with the new addition of quantum computing and matter (broadly defined). Three awards were given, as follows: The Lenovo laptop award, to the five best student presentations (awarded to **David Jansen** (Georg-August-Universität Göttingen)**, Francesco Marino** (U. Milan and INFN)**, and Megan Moss** (U. Waterloo), for their contributed talks; and **Cristian Apostoli** (U. Milan) **and Tong Shen** (Brown U.), for their poster contributions). The Hermann Kuemmel Early Achievement Award, to **Aavishkar Patel** (Flatiron institute) "for outstanding contributions to the theory of transport in non-Fermi liquids".



Finally, **Antoine Georges** (Flatiron Institute), **Gabriel Kotliar** (Rutgers U.) and **Dieter Vollhardt** (U. Augsburg) were jointly awarded the **2022 Feenberg Memorial Medal** for established work that has significantly advanced the field of many-body physics. The award was given for the Dynamical Mean Field Theory (DMFT) method, now an important tool in the many-body community.

In May, CoSMS organized and hosted the *7th Symposium on Neutrinos and Dark Matter in Nuclear Physics* (**NDM-2022**). The meeting was held May 16-21 in Asheville, NC. One hundred and forty people attended this international conference, which was organized by UNC Profs. Jon Engel and John Wilkerson. For many of the graduate students



***Top**: Group photo from the NDM 2022 Conference held in Asheville. **Right**: Esteban León (UNC) in front of his award winning poster.*

attending the conference, this was their first "in-person" conference, and they expressed their excitement at the opportunity to participate in the meeting. Thanks to generous contributions from CoSMS supporters, as well as Oak Ridge National Laboratory, and Triangle Universities Nuclear Laboratory the conference was able to provide financial support for a number of graduate students and other early career attendees. The evening poster session was quite popular, as students presented their research accomplishments. There were two poster awards: the Best Poster Award went to **Brian Lenardo** (Stanford University) for his poster titled, "Calibrating the nEXO Detector with Dissolved Radioisotope Sources" and the Outstanding Poster Award went to **Esteban León** (UNC) for his poster titled, "Machine Learning-Powered Autonomous Data Cleaning for LEGEND-200". Conference attendees also enjoyed touring the nearby world famous Biltmore Estate as the conference excursion.

The key to CoSMS being able to organize these two conferences was thanks to the dedicated efforts of Sarah Van Heusen, who joined the department in January 2022, as both the Assistant Director of CoSMS and also the Research Project Manager for Prof. Wilkerson's research group. (See Staff Notes below). Sarah was able to successfully navigate the many challenges of resuming in-person meetings as the world has only gradually emerged from the COVID pandemic. Thanks to her expertise with organizing meetings, CoSMS and TUNL were selected to host a national Town Meeting on Fundamental Symmetries, Neutrons, and Neutrinos in December at the Friday Center. This meeting, one of three national community meetings in separate research areas, will provide community input into the U.S. Long Range Plan for Nuclear Science. These long range plans are conducted by the Nuclear Science Advisory Committee at the direction of DOE and NSF every 7-8 years and have been essential to progress of the field. The Town Meeting is being organized by the Division of Nuclear Physics of the APS, with Prof. Jon Engel serving as one of the co-conveners.

CoSMS is in the process of organizing a one day CoSMS Research Symposium to be held in the Research Triangle Park in February 2023. If you are interested in attending, please send an email to Sarah Van Heusen (sarahvh@unc.edu).

2022

The Nobel Prize in Physics

By Jonathan Engel

The Nobel Prize in Physics for 2022 went to **Alain Aspect** from France, **John F. Clauser** from the U.S., and **Anton Zeilinger** from Austria *"for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science."*

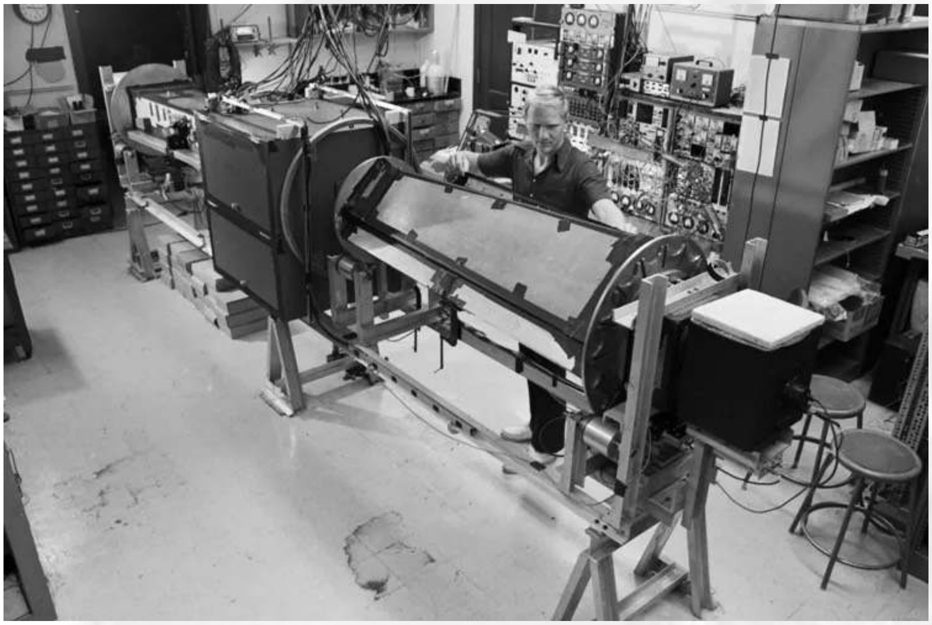
In entangled quantum states, particles do not have their own separate identities. A typical entangled state of photons is a superposition of a simple state in one photon is horizontally polarized and a second vertically polarized, and another simple state in which the polarizations of the two photons are exchanged, so that the first is vertically polarized and the second horizontally polarized. Not only can each photon end up either horizontally or vertically polarized upon measurement --- that can be the case even without entanglement --- but the probabilities for those outcomes also depend on what happens to the other photon, even if it is very far away.

The European Space Agency's Optical Ground Station (OGS) on the Canary Island Tenerife received green laser light from La Palma, 150 miles away, as part of an experiment to teleport photons between the two islands. The teleported photons, infrared and not visible in the picture, were received by a one-meter telescope under the OGS dome. ***Credit****: ing.iac.es .* ***Image credit****: IQOQI Vienna, Austrian Academy of Sciences.*

The intuitive explanation for this dependence is that the behavior of both photons is determined by "hidden variables" that we have no experimental access to but that tell each particle how to behave. Because the photons in entangled pairs must be close to one another when they first become entangled, the variables determining the behavior of the two photons could be correlated, and so could explain correlations in the behavior of the two photons later on, when they are far apart. (This situation would be similar to one in which a parent selects two identical chocolates from a collection of many different kinds, and sends one to each of two children in different cities. When the children open their packages they are guaranteed to find the same chocolates even though the two packages don't influence one another.) In the 1960s, however,

Alain Aspect, John F. Clauser, and Anton Zeilinger

"for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science."



John Clauser with the quantum mechanics experiment that he and Stuart Freedman built to test Bell's theorem in the 1970s.
***Credit**: berkeleyside.org.* ***Image credit**: Steve Gerber.*

John Bell showed that as long a theory with hidden variables sensibly forbids faster-than-light signals that violate the tenets of special relativity (such a theory is called "local") some of its predictions for the results of polarization measurements must be different from those of quantum mechanics.

Clauser was the first to construct a practical test of whether quantum mechanics is correct or whether local hidden variables that determine the results of measurements can be at play in the real world. He created entangled pairs, sent the two photons in opposite directions, and then measured their linear polarizations along different axes. His results strongly supported quantum mechanics over hidden variables. But his experiment had some loopholes, allowing for strange hidden-variables theories in which, for example, themeasurement device affected the photons even before the measurement. Aspect closed this loophole almost entirely by developing a switch that changed the orientation of the devices that measured polarization when the photons were already in flight towards them. Zeilinger expanded these experiments in several directions, e.g. by conducting tests with three entangled photons and demonstrating "quantum teleportation," a phenomenon in which the polarization state of a photon is transferred instantaneously to another photon far away by exploiting the entanglement of a third photon with the one far away.

Procedures like quantum teleportation are leading to applications of the weird correlations implicit in entangled particles. Quantum computing, secure quantum encryption, and networks to connect devices that rely on quantum mechanics to work all exploit entanglement. In the words of Anders Irbäck, Chair of the Nobel Committee for Physics, "*It has become increasingly clear that a new kind of quantum technology is emerging. We can see that the laureates' work with entangled states is of great importance, even beyond the fundamental questions about the interpretation of quantum mechanics*."

For more information, you can turn to Physics Today by scanning the QR code below.

Focus on Grad Research

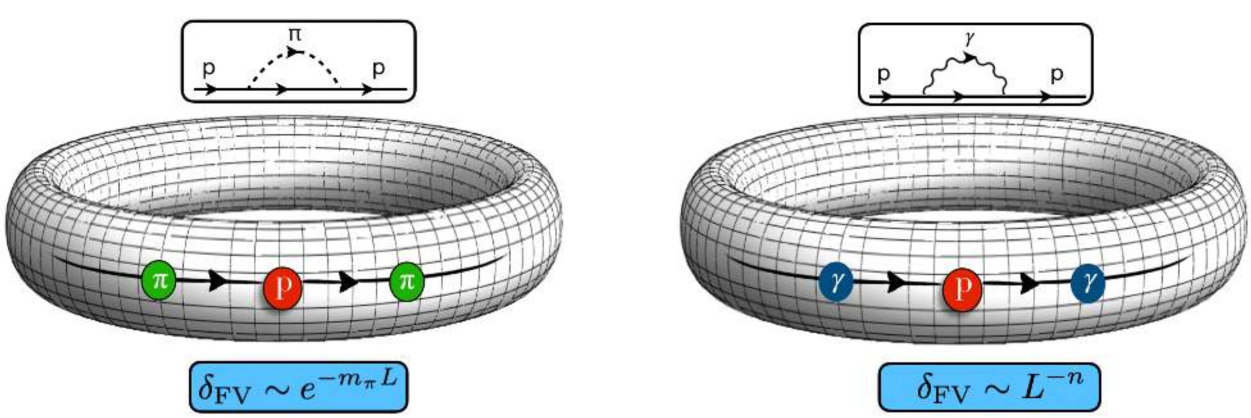
Precision nuclear physics from lattice QCD + QED

By Zack Hall and Amy Nicholson

Can Quantum Chromodynamics (QCD) and Quantum Electrodynamics (QED) play nicely together on the lattice? That is a question lattice theorists have begun to tackle in recent years, as the precision of lattice QCD calculations of hadronic quantities has reached a level where tiny corrections from the electromagnetic (EM) charges of the quarks composing the hadrons comes into play. This level of precision is particularly important when considering precision tests of the Standard Model (SM) in searches for new physics. For example, if experimentalists make high precision measurements of a given quantity, and theorists calculate the same quantity to equal precision from the SM, then any tiny deviations between Nature (experiment) and the SM (theory) indicate some as-yet unknown physics at play. A key example of such a quantity is the interaction between neutrons and the fields giving rise to the weak interactions, which is measured with exquisite precision in ultracold neutron experiments carried out, in part, by physicists at TUNL. The relevant quantity from theory, the so-called nucleon axial charge, has been recently calculated to high precision using lattice QCD by members of our group. In order to push the precision of our calculation to the level necessary to resolve new physics, QED corrections must be incorporated.

Lattice QCD is a computational method which regulates the infinities inherent to Quantum Field Theory (QFT) by "pixelating" space and time, such that there is a smallest length scale, the lattice spacing, to which the interactions between particles are resolved. By also truncating the region of space one is observing, solving the theory is reduced from an infinite-dimensional integral over an infinite set of possible configurations of the fields, to a finite-dimensional, regular integral. Typically, one chooses periodic boundary conditions at the edges of this truncated space, which results in a well-defined analysis of spectra. Unfortunately, issues arise when attempting to formulate QED with the same spatial boundaries.

One important issue is that Gauss's law forbids charged objects within a periodic volume. Picture a circle, which is the equivalent of a periodic volume in 1-D (in 2-D, we would have a torus, so our actual lattices are 4-dimensional tori). If we place a proton on this circle, and draw electric field lines emanating from that proton, the same lines which point outward from the proton will wrap around the circle, and terminate back on the proton. This means that if we draw a Gaussian surface around the proton, all field lines going out from the surface will also come back in,

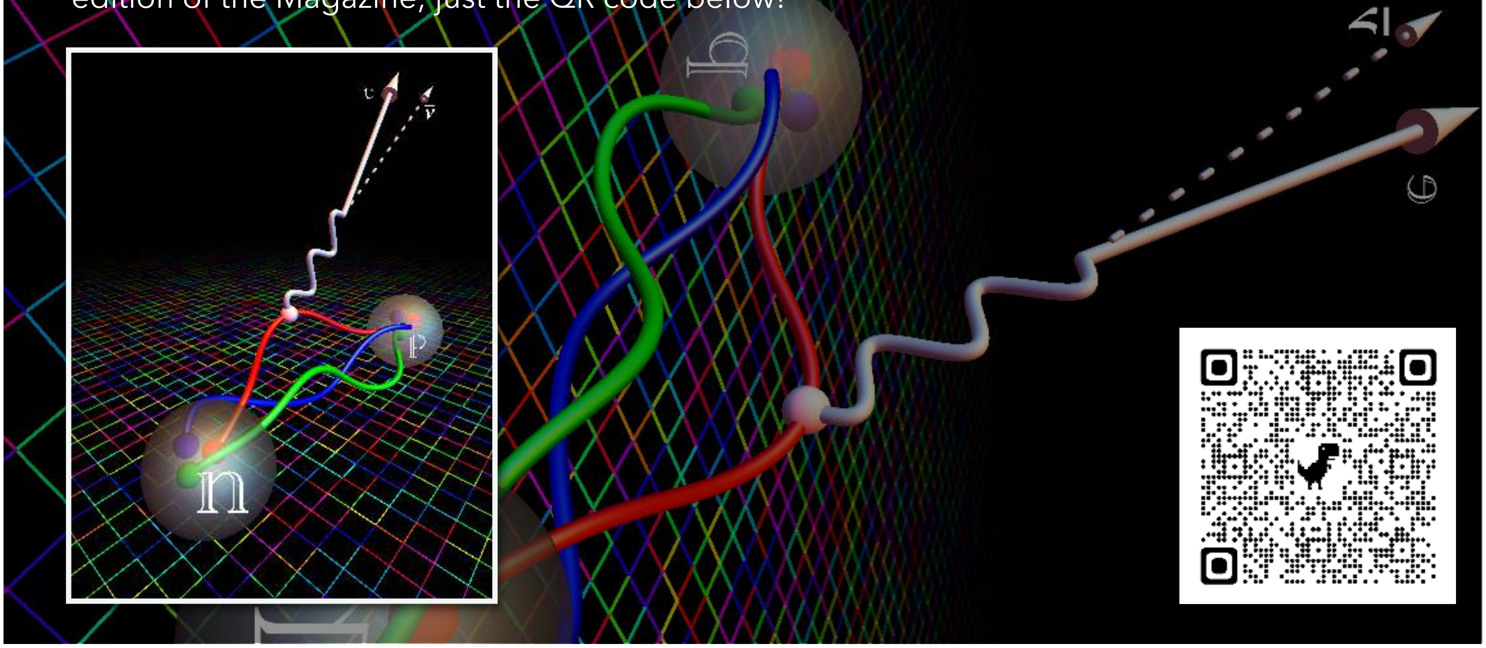


Unphysical effects due to an emitted particle traveling around the finite, periodic box (torus) are typically suppressed exponentially by the mass of the lightest particle in the theory (for pure QCD, the pion) times the box length, L. However, a massless photon (QED) leads to effects which scale as powers of L.

implying there is a net zero charge within the surface, and an inconsistency with our setup. These field lines which wrap around our finite spacetime also lead to issues with systematic errors stemming from the truncated volume. We can estimate these systematics by considering the probability that processes which would otherwise not be allowed, can occur within the finite volume. For example, if any particle within our field theory is emitted by the proton, travels around the circle, and then is reabsorbed by the proton (see Figure), this probability falls off as e^{-ML}, where M is the mass of the emitted particle, and L is the distance traveled. Thus, finite volume systematics fall off exponentially with the size of the volume, and are dominated by the lightest particle of the theory. For QCD, this lightest particle is the pion, with mass ~135 MeV, but for QCD + QED this lightest particle is the photon, which is massless! This leads to grave difficulties in extrapolating to the physical, infinite volume limit.

Previous formulations of lattice QED removed these problematic fields by hand, leading to unphysical theories. More recently, two new formulations of lattice QED have emerged, which lead to physically consistent QFTs: one formulation manipulates the boundary conditions to remove the unwanted fields, but seems to suffer from poor statistical resolution. The other, socalled "massive QED", gives the photon a non-zero mass, and recovers the correct physical limit through extrapolation to the zero photon mass limit. Our research has been to understand this limit: analytically, by performing calculations within effective field theory to determine the functional dependence of observables on the photon mass, and numerically, by performing explicit lattice QCD + QED calculations at different photon masses and volumes, and performing extrapolations to the physical point. Our work has resolved previous issues with the formulation, and highlighted the unprecedented precision with which one can determine QED corrections. After calculating the spectra of a number of hadrons, we have produced the first preliminary, non-zero QED corrections to the nucleon axial charge. In 2023, Zack will be continuing his work on this quantity with the nuclear theory group at Lawrence Berkeley National Lab, through the Department of Energy's Office of Science Graduate Student Research (SCGSR) Program.

Learn more!
Check out Amy's article "Nuclear physics from quarks and gluons on the lattice," in the 2021 edition of the Magazine; just the QR code below!



Focus on Undergrad Research

Studying interfacial water of nanometer scale might lead to geological scale applications

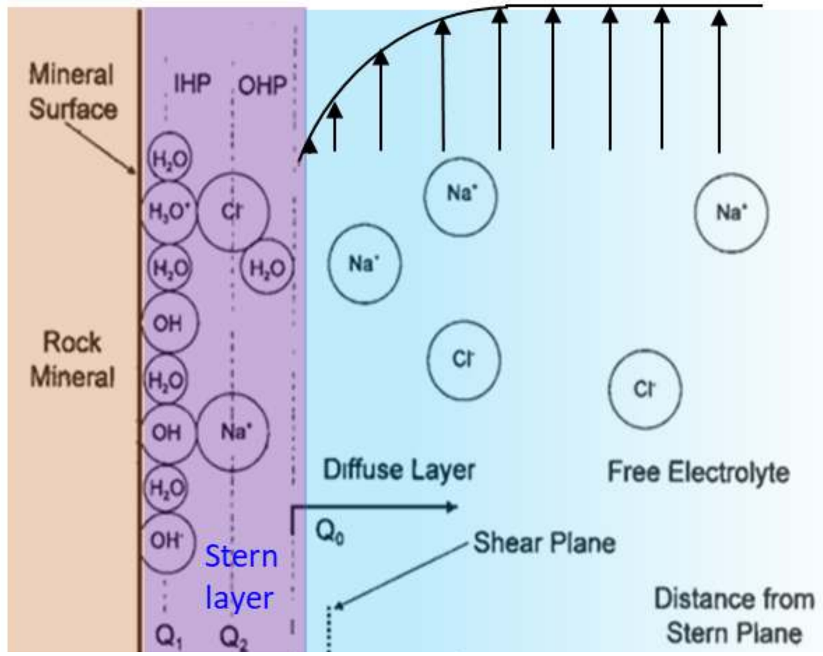
By Yue Wu

Magnus Fonda (left) and Halona Dantes (right) at Prof. Wu's lab.

Magnus Fonda and Halona Dantes, both physics majors entering their senior year this fall, have been conducting research in Prof. Yue Wu's lab. Under the direct supervision and guidance of Dr. Patrick Doyle, Magnus and Halona carried out independent research developing electromagnetic measurement techniques aimed at efficient energy harvesting and carbon sequestration. Their efforts have made significant contributions to projects funded by the Department of Energy, ACS-Petroleum Research Fund, and Advanced Energy Consortium. Both Magnus and Halona's projects involve investigations of the solid-liquid interface. More specifically, they are interested in how aqueous solutions interact with surfaces of porous materials such as rock minerals containing oil and water or rock minerals where CO2 is stored in carbon sequestration.

Magnus' work focuses on developing measurement techniques to determine the wettability of internal surfaces of porous media. Wettability is a surface property that is crucial for efficient oil recovery. Although wettability of an open and smooth surface is trivial to measure, namely by measuring the contact angle of a water droplet on the surface, it becomes a challenging task when the surface is hidden inside porous materials with internal pore structures of micrometer and nanometer scales. Such small pore surfaces, however, can be easily accessed by water molecules in the gas phase. By bringing the internal surfaces into thermal equilibrium with water vapor, the water/surface interaction characteristics (often called hydrophilicity) can be revealed by the water adsorption isotherm. Magnus used the influence of water adsorption on the frequency dependence of the electrical impedance to derive a quantity that is uniquely linked to the surface wettability. In this work, Magnus used a home-made adsorption isotherm apparatus with in-situ impedance spectroscopy probes. He also made various materials with well-defined wettability using chemically induced surface functionalization. This enabled him to obtain a unique function between the internal surface wettability and the quantity derived from the water isotherm/electrical impedance spectroscopy. Magnus' work is of great interest to oil companies aimed at efficient oil recovery.

Halona's work is also related to water/surface interactions. Solid surface in contact with aqueous electrolyte is ubiquitous. Near such interface, electricity can generate fluid flow called electro-osmosis. The reverse is also true, fluid flow generates electricity such as streaming current and streaming potential. This offers a unique way to sense fluid flow using remote electrical detection techniques. Dr. Doyle in our lab showed recently that streaming potential is very sensitive to the presence of CO2 in water. This offers an opportunity for remote sensing using electrical detection tools in CO2 storage in underground porous media. Halona is carrying out systematic studies to investigate various influences on streaming potential such as salinity, flow rates, and CO2 saturation levels. Halona's work could contribute significantly to future technologies in carbon sequestration.



Cation and anion charge separation occurs at the solid/liquid interface with ions immobilized in the fluid layer near the interface, called the Stern layer, due to interactions with the solid surface. Consequently, fluid flow (in the blue region) leads to electric current and electric potential, called the streaming current and streaming potential.

Can one bootstrap the quantum many-body problem?

By Joaquín Drut

Undergrads in the computational quantum matter group at UNC Physics & Astronomy are exploring computer-aided methods of calculating the properties of quantum many-body systems. One of the most intriguing ideas to calculate for such systems is to use the algebraic relations among arbitrary quantum operators to arrive at relations among their expectation values in eigenstates of the Hamiltonian. Throw in the Hamiltonian among the set of operators and you may have interesting connections that may constrain the possible values of the energy levels.

That, in a nutshell, is the philosophy underlying the bootstrap approach to quantum mechanics. If that does not sound simple enough, well, it actually is that simple! Alas, it is not always possible to find closed-form relationships that allow to enforce constraints among the expectation values, so that is what we are currently working on, extending known results for a single particle in 1D to higher dimensions and possibly more particles.

Now, all of that may sound quite cryptic… What is this whole bootstrap idea? Can we explain it more simply? Let's try! In quantum mechanics, one of the essential questions concerns the energy levels of the system you are studying. That tells us something about the structure and interactions which we can potentially measure in an experiment. These energy levels are usually pretty hard to compute, though! Bootstrapping is an idea that tries to get around calculating the energy levels by brute force. Instead, one tries to see how the energies are related to other quantities. If we can find enough relationships and mathematical constraints, then we may have a shot at finding out the levels by enforcing the constraints numerically. So you see, this involves some analytic trickery followed by computational work. The really attractive thing about it is that it may open up a way to compute where a direct approach is only possible with huge supercomputers, if you are lucky! So… stay tuned!

THE SHOP PAGE

Whether you are hunting for exoplanets, searching for the origin of the elements, or disentangling neutrino signals from background noise, you are probably building your own detectors from the ground up, and for that you need help from expert machinists and instrument makers. Thankfully, our Department has its own machine shop, which is in fact the only machine shop on campus. From Phillips Hall 115, Phil Thompson and his crew (William Harris, David Norris, and Cliff Tysor) offer complete professional instrument construction through a variety of services including CNC (programming, turning, milling), manual and electric-discharge machining, welding, sheet metal fabrication, and plastic fabrication. The team machines essential parts for world-class research in multiple areas such as time-domain astronomy (Nick Law's Evryscope), nuclear astrophysics (Christian Iliadis' LENA device), and neutrino detection (John Wilkerson's Majorana experiment).

STAFF NOTES

NEW STAFF MEMBERS!

Jacob Hurst

Academic Affairs Coordinator

Jacob moved here from Montgomery County, Pennsylvania, where he worked in the admissions department for a local community college. He is passionate about a lot of things, but the most important in his view is: continuously striving to be a better human being. He looks forward to working at UNC-CH to help support the Physics and Astronomy Department.

Micah Martin

Executive Assistant to the Chair

I moved from the Seattle area upon gaining my position here at UNC. I have been lucky to live in many places, including abroad. Pre-pandemic, I worked as a cross-country tour guide, showing tourists various destinations. I'm an avid avoider of kale, and I must say hi to every dog I see. I have a bachelor's in public speaking, and I gained my master's in international education earlier this year. I set my sights on working in higher education, and I'm happy to have landed in such a welcoming department.

Sarah Van Heusen

Research Project Manager

I have worked at UNC for over 20 years as a research administrator, mostly in the School of Medicine. Prior to working with Dr. Wilkerson, I took several years off after adopting our beautiful daughter. Coming back to work post COVID has been challenging, but I appreciate the opportunity to work remotely. Especially because I now live on a large farm in Oxford, NC, which is a distance from campus. We have numerous animals, including 14 alpacas, peacocks, ducks, chickens, guinea hens, goats, dogs, cats and a beaver on the pond who is wreaking havoc on our fruit trees.

Pearl Wenqiong Cheng

Public Communications Specialist

At the end of last year, my family relocated from London to Chapel Hill, and we couldn't be happier with our decision. I love living in North Carolina, with its lovely people and incredible nature at our fingertips! My goal is to raise awareness of our institute. Furthermore, I wish for a broader audience to appreciate and gain from physics.

Awards & Graduations

The **Paul E. Shearin Award** was established by W. E. Haisley, Professor Emeritus of Physics, to honor Paul E. Shearin, Professor of Physics, member of the faculty for 36 years, and for 12 years Chairman of our Department. This monetary award is given to the member of the senior class majoring in Physics who is judged most outstanding on criteria of scholarship, scientific insight and professional seriousness. The recipient is selected by the departmental faculty from candidates nominated by the undergraduate major advisors.

The **Daniel Calvin Johnson Memorial Award** in Physics. This award, established in 1960 by Mrs. Mildred Johnson in honor of her husband, Daniel C. Johnson, a former graduate of the department, is awarded annually to the physics major who is judged by the faculty to be the most outstanding student of the junior class.

The **Robert N. Shelton Award**, established in 2001, is given to one or more Physics and Astronomy undergraduate students for excellence in research. The award was first established by Provost Robert N. Shelton.

Outstanding Teaching Assistant Awards
Each year our department recognizes the most outstanding Teaching Assistants (TAs) for their exemplary work. Most TAs provide assistance teaching and grading for our introductory physics or astronomy courses, but some assist with more advanced or specialized courses. In a typical semester we employ approximately 40 graduate students and about 15 undergraduate students to serve as TAs, and we recognize the top 2 or 3 for the department TA award.

Undergraduate Excellence and Achievement Awards
The "Excellence" and "Achievement" awards are two new awards starting in 2022, given respectively for "demonstrated excellence in academics, leadership, and community involvement" and "demonstrated academic resilience."

2022 Awardees

Paul E. Shearin Outstanding Senior Award
Austin Blitstein and Zelong Yin

Daniel C. Johnson Memorial Award
Aaron Miller

Robert N. Shelton Outstanding Research Award
Madyson Barber and Allan Boyuan Li

Outstanding Graduate Teaching Assistant Award
Amy Glazier

Outstanding Undergraduate Teaching Assistant Award
Ellen Hu and Ethan Malin

Undergraduate Excellence Award
Tyler Kay, Xiao-Ming Porter, and Stephen Schmidt.

Undergraduate Achievement Award
Halona Dantes and Alex Morrow

Graduate program 2021 (continued from previous issue)

Ph. D.

Gulden Othman
Evan Ney

M.S.

Timothy Osborn
Taylor Stevenson

Graduate program 2022

Ph. D.

Reece Boston
Nolan Miller
Christian McHugh
Ben Levy
Yaqi Hou
Isaac Waldstein
Brandon Yost

Undergraduate program 2021 (continued from previous issue)

B.S.

Maximilian K. Kremer
Jerrick K. Li

B.A.

James Crisp IV
Hunter K. Fulbright
Kurtis T. Nguyen
Shugo Tanaka

Undergraduate program 2022

B.S.

Nathaniel C. Badgett
Madyson Barber
Daniel Bastawros
Joel I. Bernstein
Austin M. Blitstein
Nicholas D. Boyer
Mark Branham
Paul B. Buttles
Tyler A. Cochrane
Matthew L. Dai
Kayla S. Dutcher
Russell L. Engle
Rylee M. Faraci
Bowen Gu
Gregory Hainline
Zhongxiu Hu
Nikhil S. Kabilan
Tyler V. Kay
Melissa Kissling
Giovanni R. Leone
Boyuan Li
Jeshurun L. Luke
Ethan J. Malin
Makena Maszer
Alex A. Morrow
Gregory J. Murrell
Robert W. Payne Jr.
Francis P. Rivell
Gordon V. Rogelberg
Stephen P. Schmidt III
Cooper J. Schoone
Alex J. Stewart
Addison G. Wilson
Zelong Yin
Owen T. Zook

B.A.

Caitlin Haines
Ethan A. Mcconnell
Duncan F. Mills
Joseph R. Nieto
Caroline A. Smith
Avery Twyman

Congratulations to our most recent Phi-Beta-Kappa inductees!

Lauren R. Behringer
Samantha N. Machinski
Vimaleshwar Palanivelrajan
Cade R. Rodgers
Emma H. Rowe

Phi Beta Kappa is the oldest academic honor society in the United States. It promotes and advocates excellence in the liberal arts and sciences, and inducts the most outstanding students of arts and sciences at select American colleges and universities.

Prof. Jonathan Engel has been appointed **"Phi Delta Theta/ Matthew Mason Distinguished Professor."** Such an appointment is one of the highest honors the University bestows upon its faculty members. The honor recognizes faculty who have achieved distinction in their field or across disciplines. Named distinguished professors are tenured faculty members who are awarded the honorary title with additional salary and research funds.

Professor Engel, a Fellow of the American Physical Society, works primarily to apply nuclear-structure theory to interpret experiments in fundamental physics, so as to better understand, e.g., the nature of dark matter, properties of neutrinos, and the reason the universe contains so much more matter than antimatter. He was the prominent leader of a national 11-institution "Topical Collaboration in Nuclear Theory," funded by the U.S. Department of Energy, on these subjects and this May led a large international meeting on them in Asheville. His research is funded by several grants, from both the Department of Energy and the National Science Foundation.

Prof. Laurie McNeil was one of 3 people **elected from the Council of Representatives of the American Physical Society to join the Board of Directors from 2022-2024**. The Board has overall responsibility for the governance and affairs of APS, including strategy, financial affairs, policies and procedures, and publishing. The Board is made up of the officers of APS (President, President-Elect, Vice President, Past President, Treasurer) and nine members elected by the Council of Representatives to staggered three-year terms. The CEO and Editor-in-Chief of APS are also non-voting members of the Board.

Chris Clemens, Jaroslav Folda Distinguished Professor of Physics and Astronomy, is the new **executive vice chancellor and provost**, as of Feb. 1, 2022. In his announcement, Chancellor Guskiewicz said: "*Chris' deep understanding of the links between rigorous interdisciplinary research, excellent teaching and the value of free inquiry makes him the right person to take on this role at this crucial time in Carolina's history.[…] As chair of physics and astronomy, senior associate dean for natural sciences, senior associate dean for research and innovation in the College of Arts & Sciences, and most recently as the director of Carolina's Institute for Convergent Science and Chancellor's Eminent Professor of Convergent Science, Chris has demonstrated a commitment to the kind of interdisciplinary work emphasized in the University's strategic plan Carolina Next: Innovations for Public Good. As we all work to secure Carolina's role as a leading global public research university, that spirit of creative collaboration will be especially important*."

Prof. Gökçe Başar has received the **Faculty Early Career Development (CAREER) Award** from the **National Science Foundation (NSF)** to support his research on strongly interacting matter in extreme environments. The CAREER Award is the Foundation's most prestigious award given to junior faculty and provides five years of funding. The award will support Prof. Başar's research, which focuses on exploring the phases of matter that occur at a trillion degrees–the temperature of the Universe microseconds after the Big Bang. In such environments, protons and neutrons melt, and their constituents (quarks and gluons) roam freely, forming a peculiar phase of matter called quark-gluon plasma–tiny droplets of which are recreated nowadays in heavy ion collision experiments. Prof Başar's group will develop a new formulation of fluid dynamics that incorporates the novel properties of quark-gluon plasma and build a framework that can be used to computationally study its properties at different temperatures and densities.

Prof. Andrew Mann has received the **NSF CAREER award** to study the properties of infant stars. The NSF CAREER award is one of the foundation's most prestigious awards aimed at assistant professors. The awardees are junior faculty who will serve as academic leaders in both research and teaching, and it includes a grant for both research and outreach activities over a five-year period.

Prof. Mann's research focuses on studying young exoplanets to understand how they evolve over their lifetimes. A mantra of exoplanet research is 'know thy planet, know thy star,' since our understanding of planets is tightly linked to our knowledge of their stellar host. The CAREER grant is aimed at studying the properties (masses, radii, luminosities, and ages) of the youngest stars in the Solar neighborhood. Prof. Mann's team will focus on stars in groups of coeval associations to build generalized relationships between stellar properties and map out how stars change in the early stages of their life. While a key motivation is to better understand planetary systems, the work will inform a wide variety of other research on star and planet formation.

Prof. Robert Janssens has been awarded this year's **APS Division of Nuclear Physics Distinguished Service Award**. The citation reads: "For his exemplary service to the DNP, particularly his extended leadership in the chair line and the nuclear physics community, including as the Director of the Physics Division at Argonne National Laboratory and as Director of the Triangle Universities Nuclear Laboratory.

Prof. Carl Rodriguez, who will join our Department in January 2023, is **one of 20 recipients of the 2022 Packard Fellowships** for Science and Engineering. The fellowship recognizes innovative early-career researchers; it includes $875,000 for research for five years and is designed to provide maximum flexibility and support to scientists and engineers early in their careers.

Carl's work focuses on gravitational waves, ripples in spacetime that were first observed by the Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015. He is particularly interested in the dynamics and evolution of stars and star clusters, and what the gravitational waves they create can tell us about stars and galaxies across cosmic time. See his article on page 6.

Retirements

Gerald Cecil

A theoretical physicist by training, Gerald earned his PhD from U. Hawaii in 1987, working on the kinematics of spatially extended high velocity outflows from the nucleus of M51. He moved on to a research fellowship at the Institute for Advanced Study, Princeton and joined UNC Chapel Hill in 1989. Gerald served as the project scientist for the SOAR Telescope (NOAO [now NOIRlab], Tucson/AZ, 1996-2000), leading preliminary work on the unobstructed optical and telescope design, and co-leading design refinements for contracting and early construction. He served on the South-African Large Telescope board from 2014 to 2020. Gerald's research investigates the internal stellar and gas dynamics within galaxies as clues for their evolution. Most spiral galaxies like the Milky Way show signatures of past or present high-energy outflows emanating from their central regions. These outflows are believed to be driven by gas accretion onto the central super-massive black holes and by winds due to stellar feedback. The outflows are of interest in many astrophysical contexts, such as enriching the circum- and extra-galactic gas, regulating (nuclear) star formation, and possibly helping with accretion of circum-galactic gas as fuel for star formation. Understanding the role of galactic outflows requires detailed spectroscopy across the electromagnetic spectrum of regions where outflows and ambient gas interact. It is this field in which Gerald Cecil broke new ground, identifying signatures of nuclear activity, starting with his earliest papers in 1983 on M51. In 2021, Gerald and his long-term collaborators in Australia identified the remnants of former Seyfert-level nuclear activity in the Galactic center. Most recently, Gerald has been enjoying IR spectroscopy on SOAR and UNC's high-performance computing facilities. Whether stellar structure, observational astronomy, or the BA energy track that he developed, Gerald brought his research experience and interests to the class room, relying on real-world examples and modern applications as teaching material rather than textbooks. The future will see Gerald climbing peaks and exploring The West from his new home in Arizona.

By Fabian Heitsch.

Art Champagne

Art earned his PhD at Yale University (1982), measuring nuclear reactions important for explaining galactic radioactivity and abundance anomalies in primitive meteorites. He was a Postdoctoral Fellow at SUNY – Stony Brook (1982-84) and subsequently became a junior faculty member at Princeton University in 1984. He joined UNC and TUNL as Associate Professor in 1990. He soon started to establish what would become a world-class program in experimental nuclear astrophysics. Art first built the TUNL magnetic spectrograph facility to study astrophysically-important nuclear levels. He then developed the Laboratory for Experimental Nuclear Astrophysics (LENA I) dedicated to direct measurements of key nuclear reactions at stellar energies. His research program was focused on nucleosynthesis in binary star explosions, globular cluster red giants, and AGB stars. He was recognized as a Fellow of the American Physical Society in 1999, was the Edouard Morot-Sir Distinguished Term Professor at UNC during 1996-2001 and became the William C. Friday Distinguished Professor in 2006. Art served as Department chair from 2009 to 2012 and as TUNL director during 2016-2021. He was a convener, chair, and reviewer on numerous committees for funding agencies as well as the APS. In 2019, he shared the Jesse W. Beams Research Award of the Southeastern Section of the American Physical Society for his accomplishments. After retiring at UNC in 2021, Art became a Research Professor, overseeing the construction of the new LENA II facility at TUNL.

By Christian Iliadis.

Jack Ng

Yee Jack Ng, Kenan Professor of physics, received his BS in 1968 at Berkeley and his PhD in 1974 at Harvard under Nobel laureate Julian Schwinger. After postdocs at the Institute of Advanced Study in Princeton and at Stanford University, he joined the UNC faculty in 1978. He has received many honors, including University-wide teaching awards. Jack's early research focused on particle theory and phenomenology, where he made a number of important contributions. These include studies of three jet events in QCD, the physics of heavy quarkonium, and aspects of chiral symmetry breaking. In the 1990s his work began to evolve in the direction of gravity. He has made major contributions to the study of massless spin-two particles, black holes, cosmology and especially quantum gravity. Perhaps Jack's most important work has been on space-time foam, which is the vacuum of quantum gravity. He has shown that space-time foam is detectable through observation of high energy photons and gravitational waves. If the behavior of space-time foam he predicts is discovered, it will be our first observation of quantum gravitational effects. The work of Jack Ng provides our best chance of discovering quantum gravity; hence his work is very likely to affect the future of physics.
By Tom Kephart.

Sean Washburn

Sean started his training in physics at Stetson University before getting his Ph.D. from Duke University in 1982 under the tutelage of Prof. Horst Meyer. There he studied crystalline forms of solid hydrogen. He then moved to IBM Research Division where he joined the group of Richard Webb as a postdoctoral fellow, rising to a permanent member of staff. This was one of the most exciting times for research at IBM, which won two Nobel prizes during Sean's time at IBM. While at IBM, Sean engaged in pioneering experiments on conductance fluctuations, quantum interference, and Aharonov-Bohm oscillations in sub-micron-sized structures which earned him wide recognition in the international condensed matter physics community as well as an IBM Outstanding Technical Achievement Award. Richard Webb, his senior collaborator, received the prestigious Simon Prize (Great Britain) for this work, and acknowledges that Washburn's contributions were crucial, and in many aspects predominant. Sean was then recruited to UNC in 1991 as a senior hire as part of the rebirth of condensed matter physics in the department that started with the hiring of Laurie McNeil several years earlier. After establishing his low temperature physics program at UNC, he partnered with Superfine and the Computer Science Department to develop and apply advanced user interfaces to the tools of nanotechnology. This highly interdisciplinary group studied individual carbon nanotube devices and new applications in biological physics. Together with Otto Zhou and Superfine, he led the first federally funded national center in carbon nanotubes. Sean's passion for research was matched by his devotion to teaching. Students gravitated to Sean, not because he cajoled them with praise, but because his understated manner conveyed his commitment to their success. His unfailing honesty revealed his unwavering pledge to their support. Sean inspired a generation of young faculty, and countless graduate and undergraduate students. In a letter that Sean wrote to the young scholars of Stetson University, he said, referring to a discovery he made while a graduate student: "*Obviously I was very proud of myself, but that wore off in a few days. The addiction to understanding new stuff never has. If I stay lucky, it never will.*"
By Rich Superfine.

Credits

Contributors

T. Branca
P. Cheng
J. E. Drut
J. Engel
Z. Hall
M. Hannawald
F. Heitsch
J. Hurst
C. Iliadis
M. Jensen
T. Kephart
N. Law
M. Martin
L. Mersini-Houghton
A. N. Nicholson
D. Reichart
C. Rodriguez
R. Superfine
F. Tsui
S. Van Heusen
J. Weinberg-Wolf
J. F. Wilkerson
W. Zhang

Design

J. E. Drut

Q&A with Tamara Branca and Jennifer Weinberg-Wolf

In this Q&A section of the Magazine, our director and associate director of undergraduate studies (DUS and ADUS) tell us about their roles.

In your position as DUS/ADUS, I know you have to pay attention to several key aspects of the undergraduate experience in our Department. Which of those do you find to be the most important or challenging ones?

Tamara & Jennifer: The most important aspect of the job is to make sure that all of our students have access to a degree program that meets their academic and career needs and sets them up to be successful beyond Carolina. In addition to the standard BS and BA tracks in Physics and Astrophysics/Astronomy, our department offers several others BA tracks that better reflect the various sectors that employ physicists' post-graduation. Finding the right balance between customizing the degree plan and making sure that standard core physics courses as well as a variety of electives are offered each semester is both an important and challenging task. Finally, making sure all students get timely and track-specific academic advising is a continuous goal of the DUS/advising team and the department. We have assembled a team of five faculty members that offer track-specific academic advising for our majors.

From your experience as DUS/ADUS so far, can you share any insights or trends in undergraduates that we should keep in mind, as a department, when thinking of the next, say, 3 to 5 years?

T&J: The growth of the data science school and degree will be something our department will watch carefully in the coming years. Many people do not realize that the majority of data scientists come from STEM backgrounds, including Physics and Astronomy. Our graduates learn a great deal of mathematics, programming, data analysis, and modeling in the context of scientific applications. More than a quarter of our graduates find employment as data scientists or software engineers after graduation.

Just like the growing interest we are seeing with the new computational physics BA track, data science and the ability to work with large sets of data, is something many of our students will and should be interested in. We need to be flexible and adapt our curriculum (and individual classes) following this trend.

How can we help you?

T&J: Keep your doors open. Faculty are often the first people students talk to when facing a problem. Every faculty member should consider themselves an advisor at some point in an interaction with your students – and if you haven't looked through the current requirements for different degrees, please do so. If you are unsure, ask! We're happy to help navigate the special cases and want to hear about any issues as early as possible.

Volunteer to teach different courses and support early students looking to get into research. We already have MANY more students participating in faculty sponsored independent research than required by their degree track, but we can continue to improve and support the quiet ones or the ones who don't know how to ask.

JOIN US!

At the forefront of physics and astronomy with a financial gift to the department.

The Department of Physics and Astronomy Excellence Fund helps enhance our world-class programs in research and education by providing seed funds for new instrumentation, expanding research and teaching experience of our students, and supporting visiting speakers.

Gifts of any size will greatly increase our ability to support outstanding students and faculty.

To give online, visit **physics.unc.edu/donate/**

To give via check, make your check payable to "The Arts and Sciences Foundation" and include "**101281 – Physics and Astronomy Excellence Fund**" in the memo line.

Please mail your check to:

The Arts and Sciences Foundation
134 E. Franklin Street
CB# 6115
Chapel Hill, NC

***Background**: Summer School Program students track near-earth asteroids with the newly-renovated 24" telescope inside the dome of Morehead Observatory. Find out more on page 12.*

Thank you!

UNC CHAPEL HILL

PHYSICS AND ASTRONOMY

Inside KATRIN, the Karlsruhe Tritium Neutrino Experiment, an international research team that includes UNC Physics and Astronomy scientists, and which established a new upper limit of 0.8 eV/c^2 for the mass of the neutrino. *Read more on page 16.* ***Image credit**: Michael Zacher*

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