Physics & Astronomy

SPRING 2020 DEPARTMENT NEWSLETTER

College of Arts and Sciences
Department of Physics and Astronomy

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Physics & Astronomy

SPRING 2020 DEPARTMENT NEWSLETTER

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Cover Photo:
The supermassive black hole at the heart of NGC 5548, a type 1 Seyfert galaxy, captured by the Hubble space telescope. Doctoral student Maryam Dehghanian is researching paradoxes in this galaxy (see p. 8).

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Stay connected...

You can keep track of department events, our contact information, and alumni events via the department web page:

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and keep in touch!

Please let us know if your address or contact information changes. Write or call the Physics & Astronomy Department Manager, Suann Reese:

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Greetings from the Department Chairs

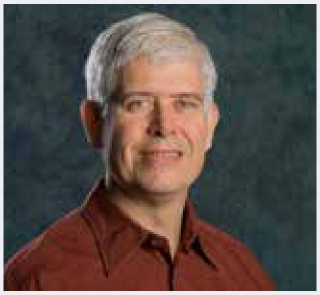
Dear Alumni and Friends,

We hope that this Spring 2020 edition of the Department of Physics and Astronomy's newsletter finds you and yours healthy and well during these uncertain times. We are proud of the high quality newsletters we've produced in a print format in recent years, but this online version provides more immediacy in a period of rapidly changing headlines, while also using fewer resources. As of this writing, we are fortunate to report that, to our knowledge, there have been no reported cases of COVID-19 among our undergraduate majors, graduate students, postdocs, faculty or staff members. The transition of the university to online classes and remote work initially presented many challenges to our teaching and research missions. However, our faculty, instructors and graduate student teaching assistants rose to the challenge, and quickly adapted all of our courses such that they could be delivered remotely (for example, over Zoom). A particular challenge was the online adaptation of our undergraduate laboratory courses for our introductory mechanics and electromagnetism sequences. We would especially like to highlight the heroic work of two of our staff members, Dr. Maxwell Ankrah and Dr. Max Brown, who developed, in a very short period of time, online laboratory modules for these courses using web-based platforms that allow for demonstration and visualization of physics concepts.

Our research mission has also been challenged during these times. Those engaged in theoretical research have lost their ability to have spur-of-the-moment conversations at the blackboard with colleagues, postdocs and students through which ideas for new research directions and solutions to problems often emerge. For the experimentalists, the situation has been quite difficult, as their research laboratories have been closed, thus stalling all experimental work. The experimentalists are now primarily focused on data analysis, simulations and conceptualization of future experiments. Although our in-person seminar and colloquium series of research talks have been paused, we have been fortunate to have had a number of seminars and colloquia from outside speakers presented over Zoom.

Through this all, we remain optimistic and hopeful for the future. As detailed in this newsletter, we have recently added three new faculty members to our department, Profs. William Gannon, Ryan MacLellan and Yuanyuan Su, whose research programs have generated a significant amount of excitement in our department. We are also expanding opportunities to research for undergraduate students and are pleased to announce that we have, under Prof. Christopher Crawford's leadership, received funding from the National Science Foundation to establish a Research Experiences for Undergraduates (REU) summer program in our department; you can read more about that below. Finally, we are especially proud of the accomplishments of our graduating undergraduate majors, master's students and Ph.D. students, some of whom are also featured in this newsletter, and we wish them all the best for their futures.

With best wishes,



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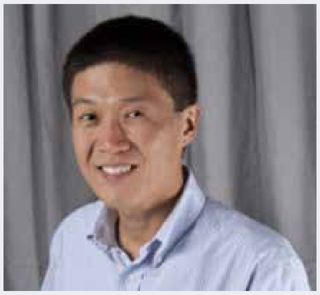

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Highly Competitive Undergraduate Research Grant Awarded by NSF

By Jenny Wells-Hosley

The UK Department of Physics and Astronomy has received its first Research Experiences for Undergraduates (REU) grant from the National Science Foundation (NSF). This highly competitive program will help provide research opportunities for students from regional colleges.

“This REU award is an exciting milestone for our department and for UK,” said Al Shapere, chair of the department. “Just 60 other universities have REU programs in physics, none of them in Kentucky, so this is a distinction that raises our department’s status as a regional leader and sets us apart on a national scale. We are looking forward to partnering with colleges in the region to provide unique, valuable research experiences for their students.”

The $320,000 award will fund up to eight undergraduates each summer for three years (2021-23) to participate in a research program. The program will place an emphasis on underrepresented minorities, students attending community and technical colleges and regional universities in rural Kentucky and Appalachia. By recruiting students from this region and encouraging them to share their summer research experiences with their teachers and peers, the UK team hopes to establish research ties with these institutions and enhance STEM education in the region.

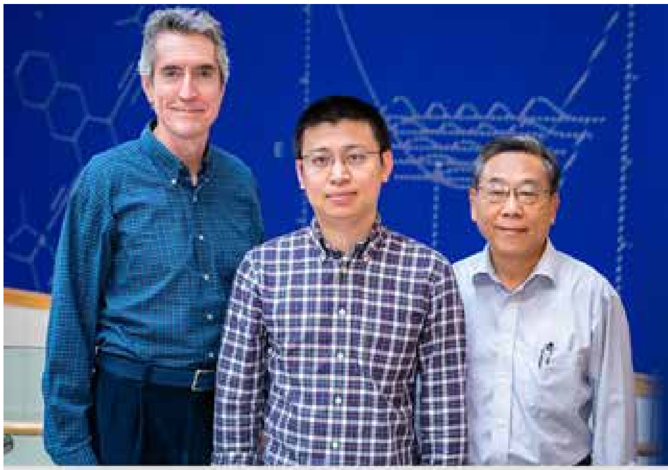
"After years of mentoring our own undergraduates, this grant will allow our department to reach out and build mentoring relationships with institutions in the Appalachian region, and across the U.S.," said Chris Crawford, professor in the department and principal investigator for the REU award. "We hope to inspire students in this region to explore physics research and go on to Ph.D. programs, bringing these opportunities back with them to their local communities."

Selected students will have opportunities to join a research program under one of 11 UK faculty members, work alongside graduate students and postdoctoral students in the lab and produce publishable results in areas of nuclear physics, condensed matter physics and astronomy. Building these student-mentor relationships will also help recruit local talent into the department’s doctoral program. The program, titled “Research in Symmetries,” also will include professional development opportunities through a series of seminars and workshops and course credit in computation and statistical analysis. Social outings and field trips to places like the Oak Ridge National Laboratory will enhance learning. The grant also supports one full-time graduate assistant to serve as a peer mentor and help build a community among the undergraduate participants.

The Department of STEM Education, based in the UK College of Education, is partnering with the Department of Physics and Astronomy to conduct assessment, research and evaluation of the program. Jennifer Wilhelm, professor in the department and co-principal investigator for the award, will conduct research and evaluation of the effectiveness of the mentoring arrangement with the undergraduate fellows, the impact of the REU activities, and the REU students’ development and learning of contemporary physics research content and skills.

“In the STEM Education department, we are just finishing our second funded REU grant,” said Wilhelm. “I plan to apply research and lessons learned from the education experiences to the physics and astronomy REU award; such things include careful pairing with mentors and holding both mentors and undergraduate REU fellows accountable for their learning and development.”

For more information, contact Chris Crawford at c.crawford@uky.edu.



Q & A: UK PHYSICISTS DETERMINE WHAT ACCOUNTS FOR A PROTON'S MASS

A team of researchers from the College of Arts and Sciences Department of Physics and Astronomy has made a discovery that has changed the "elementary textbook" description of protons.

Professors Keh-Fei Liu and Terrence Draper, along with postdoctoral scholar Jian Liang, are co-authors of a study titled "Proton Mass Decomposition from the QCD Energy Momentum Tensor" that was published this past fall in Physical Review Letters. Since then, the study has gained national attention in the world of physics, as its results have opened doors for more calculations and theoretical understanding.

The team recently explained to UKNow exactly what they learned and what it means for their scientific community.

Protons are made up of quarks, but according to your study, there's more to it than that. What else accounts for the mass of a proton?

LIU: The proton is not made of just three quarks as described in elementary textbooks. Besides quarks, the proton is also comprised of gluons which hold the quarks together in the proton. In addition to quark mass, quark energy due to the gluons' motions and interactions also contribute to the proton mass.

LIANG: A gluon is something like glue that binds quarks (and also the gluons themselves) together. All the quarks and gluons are moving very rapidly inside the proton (close to the speed of light), so their energies also contribute to the total proton mass.

LIU: Furthermore, gluon field energy and a quantum anomaly, which does not have a classical analog, also contribute to the proton mass.

What exactly is QCD theory?

LIU: Quantum chromodynamics (QCD) is the fundamental theory of the strong interaction of quarks and gluons. It is analogous to quantum electrodynamics (QED), except there are three color charges instead of one electric charge as for the electron and proton in QED.

LIANG: We sometimes say that a quark can have three kinds of colors (red, green or blue) but these are not actual colors that we can see. QCD describes how the different "colored" quarks and gluons interact with each other and how they constitute the nucleons.

LIU: In addition, quarks in QCD have different flavors, called up, down, strange, charm, bottom and top.

DRAPER: The self-interaction between the gluons makes QCD much more complicated to calculate theoretically. One needs large computer simulations to do the job.

Describe lattice QCD — how does it help scientists understand nuclear physics?

DRAPER: Because of the interaction of the gluons, QCD can be solved by the analytic methods used for QED only when, for example, protons collide at very high energy, such as in particle accelerators. But to determine the properties, such as mass, of a proton at rest, the analytic methods are mathematically intractable. Lattice QCD provides an alternative approach. At the theoretical cost of approximating the continuum of space-time with a grid, or lattice, the number of variables is made finite, and thus the theory is amenable to numerical computation. The tradeoff is that the numerical estimates of physical quantities, such as the proton’s mass, have statistical errors and systematic errors such as those due to finite lattice spacing and volume. Both errors can be reduced to acceptable levels with the expenditure of very large amounts of computer time applied with clever algorithms.

LIANG: One reliable way to tackle these kinds of errors is to use supercomputers to “simulate” the strong interaction with the continuous space-time replaced by a discrete lattice. This is what we call lattice QCD.

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How does this study impact future research in nuclear physics? What other types of studies can now be done as a result of having this information?

LIU: To find out the origin of the proton mass experimentally is one the primary goals of the upcoming electron-ion collider. This work has opened the door for more numerical calculations and theoretical understanding of nucleon structure, including the spin decomposition of the proton in terms of quark spin, quark orbital angular and glue angular momentum, whose measurement is also a leading goal of the electron-ion collider.

DRAPER: Our team has also made the first complete lattice QCD calculation of the proton's spin decomposition.

What is the most exciting part of this discovery?

LIANG: I think the most exciting part is to find out what gives mass to our visible universe. As you might know, the Higgs mechanism gives mass to the elementary particles like quarks and leptons. However, the quark mass contributes less than 10 percent of the total proton mass. Where does the remaining 90 percent come from? This study answered this question quantitatively.

Who funded this research?

LIU: The U.S. Department of Energy. The lattice calculations are carried out in several national labs: National Energy Research Scientific Computing Center (NERSC), Texas Advanced Computing Center (TACC), Oak Ridge Leadership Computing Facility (OLCF) and Brookhaven National Lab (BNL).

By Julie Wrinn

Robert Stokes (Physics BS '64) came of age in the 1960s as part of a generation of American astrophysicists who were energized by the Soviet launch of the Sputnik satellite. He grew up in Ravenna, Kentucky, a tiny city in Estill County built up by the Louisville and Nashville Railroad in 1915.

His father, a dispatcher for the railroad, passed away when Stokes was 16. Although his parents did not have much formal education, they had always hoped he would be able to go to college, and thanks to his mother's dedication and a lot of help and encouragement from the close-knit community, Stokes managed to stay on track for college.

"I had a lot of people who really cared about me," Stokes said. "I had 'extra' parents, scoutmasters, and teachers who had an enormously positive impact on my life. During my junior and senior years in high school, I used to get up very early in the morning to watch Continental Classroom presentations about chemistry and physics on TV. My chemistry teacher often asked to go through what I had learned earlier that day for my class at school—a terrific reinforcement opportunity."

Thanks to scholarships, Stokes enrolled at the University of Kentucky in the fall of 1960. He was fortunate to be part of the first Honors Program group at the school. This group of 30 students participated in a colloquium that exposed them to a wide range of liberal arts subjects. Readings included Plato's "Timaeus," C. P. Snow's "Two Cultures" and "The Copernican Revolution." Stokes said the program broadened his outlook and connected him with lifelong friends who shared an interest in academic excellence.

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With interests in math, physics and chemistry, Stokes originally leaned toward an engineering major, but when confronted with the upfront costs of drafting equipment and other supplies, he decided on physics as a major. During his professional career he managed large engineering organizations and was presented with an “Honorary Engineer” plaque from coworkers.

“One of the wonderful side benefits of the Honors Program resulted from Director Steve Diachun’s frequent dinner parties at this home, where I was introduced to Professor Wendell DeMarcus of the Physics Department,” he said. “This initiated a long and fruitful personal and professional relationship that was very important to my physics career development and success in applying to graduate school.”

Other significant mentors to Stokes during his time at UK were Fletcher Gabbard, Wasley Krogdahl, math professor Vincent Cowling and Wimberly Royster. Another important undergraduate mentor was Arnold Blackburn, an organ professor in the UK School of Music.

“I played piano and took organ lessons,” Stokes said. “I eagerly anticipated my weekly practice sessions on the beautiful Holtkamp organ in Memorial Hall.

"At the end of my junior year at UK, I was selected to be part of one of the first Goddard Institute summer study courses in space science at Columbia University, organized by Robert Jastrow,” he said. “After an intense summer of focusing on planetary astrophysics, our group was treated to a memorable tour of several U.S. space science facilities, traveling aboard a chartered DC-6 aircraft. The tour included visits to the NSF astronomical observatory at Kitt Peak, Arizona; the Marshall Space Flight Center at Huntsville, Alabama (the tour conducted by none other than Werner Von Braun); the NASA launch facility at Cape Canaveral, Florida; and NASA headquarters at Washington, D.C. As a result, my interest in space science was greatly intensified, and when presented with the opportunity to attend graduate school at Princeton, a focus on space science was a foregone conclusion.”

At Princeton, Stokes quickly joined the graduate student cadre led by Professors Robert Dicke and John Wheeler and their junior colleagues Peter Roll, Jim Peebles, Dave Wilkinson, Mark Goldenberg, Kip Thorne and Bruce Partridge. Both Kip Thorne and Jim Peebles have recently been recipients of the Nobel Prize for their work associated with this group.

“My Ph.D. research was part of an early attempt to confirm the theoretical prediction of observable microwave radiation originating from the Big Bang that marked the beginning of the universe.”
“Much of the theoretical work was done by Dicke and Peebles, but there was a need to confirm the detailed spectral characteristics of the cosmic microwave background radiation to discriminate from the competing prediction of a steady state universe model,” Stokes said. “Part of my work entailed the construction of a microwave radiometer and making observations at high altitude.”

The second observational experiment was conducted at an altitude of 11,300 feet in the Colorado Rockies, as shown in the photograph on page 6.

“My subsequent career choices have taken me away from space science to energy technology associated with nuclear and renewable energy and to coal and natural gas conversion technologies. My most recent work involved development of ceramic fuel cell technology ideally suited for creating clean electrical energy from natural gas,” he said.

Stokes retired in 2013 and lives with his family in Golden, Colorado. He stays engaged with the UK Department of Physics and the College of Arts & Sciences and attended the College’s 20th anniversary Hall of Fame festivities in October 2019.

“I was so fortunate to have support from my community as a teenager and the wonderful mentors and opportunities at the University of Kentucky that opened up the world of scientific research and development for me,” he said. “I feel very grateful to UK.”

Robert Stokes graduated from UK with a bachelor’s degree in physics in 1964 and earned his Ph.D. from Princeton in 1968.

MACADAM FELLOW MARYAM DEHGHANIAN'S RESEARCH ON PARADOXES IN GALAXY NGC5548

By Julie Wrinn

Maryam Dehganian earned her undergraduate degree in physics from the University of Kashan, one of the top universities in Iran and ranked first in the country in research productivity. When it came time to pursue graduate work, however, she was attracted to the University of Kentucky for the chance to work with Cloudy, one of the world's most-cited astrophysical computer programs.

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Cloudy is the creation of UK professor Gary Ferland, who began work on it during postdoctoral research at Cambridge University in 1978 and continued developing it after joining UK as an assistant professor in 1980. The program has been open source since 1982 and is updated every other year.

"Since I was interested in computational astrophysics," Dehghanian said, "joining the Cloudy team was a great opportunity for me."

Dehganian is also the recipient of the MacAdam Graduate Excellence Fellowship in Physics, established by longtime UK professor Keith B. MacAdam and his wife, Phyllis A. MacAdam.

"This fellowship gave me the chance to be dedicated full time to my research," Dehghanian said, "and therefore I was able to accomplish milestones that could not be reached otherwise. I have already published two papers, and the third one will be submitted soon. I am also at final stages of preparing a fourth paper. One of the published papers is actually a journal letter. A letter is like a paper, only it is more prestigious."

Dehghanian uses the Cloudy code to conduct photoionization modeling for the disk-wind in active galactic nuclei (AGN) with the aim of studying its effects on the AGN feedback, broad line region (BLR) and absorbing components. The target case is NGC 5548, a type I Seyfert galaxy (z = 0.01717) that is one of the first AGNs to be extensively monitored. It is also one of the first AGN in which the variation of the broad emission line flux was observed. It is approximately 245 million light years away, and the mass of its central black hole can be estimated based on the properties of the emission lines in the core region. It is some 65 million times the mass of the sun. Among astronomers, the accepted explanation for the active nucleus in NGC 5548 is the accretion of matter onto a supermassive black hole at the core.

This object was in an unusual state during the observations (2013 and 2014) and showed anomalous behavior that had never been seen before.

Dehghanian described her work as follows:

"In collaboration with scientists at Space Telescope Science Institute, we work on understanding the abnormal behavior of NGC5548, in which the soft X-ray continuum was heavily obscured by an obscurer. This obscurer made the emission and absorption lines go on a 'holiday' and no longer behave such as they were expected to behave. This phenomenon accounts for a paradox that the standard models cannot explain this phenomenon. NASA committed time on six space-based observatories--XMM-Newton, Swift, NuSTAR, INTEGRAL, Chandra and HST--to conduct an unprecedented observing campaign on NGC 5548. There are also six ground-based observatories that had been used to gather data from this object. The result of dedicating 12 observatories to track NGC5548 is a huge pan-spectral (IR through X-ray) data set.

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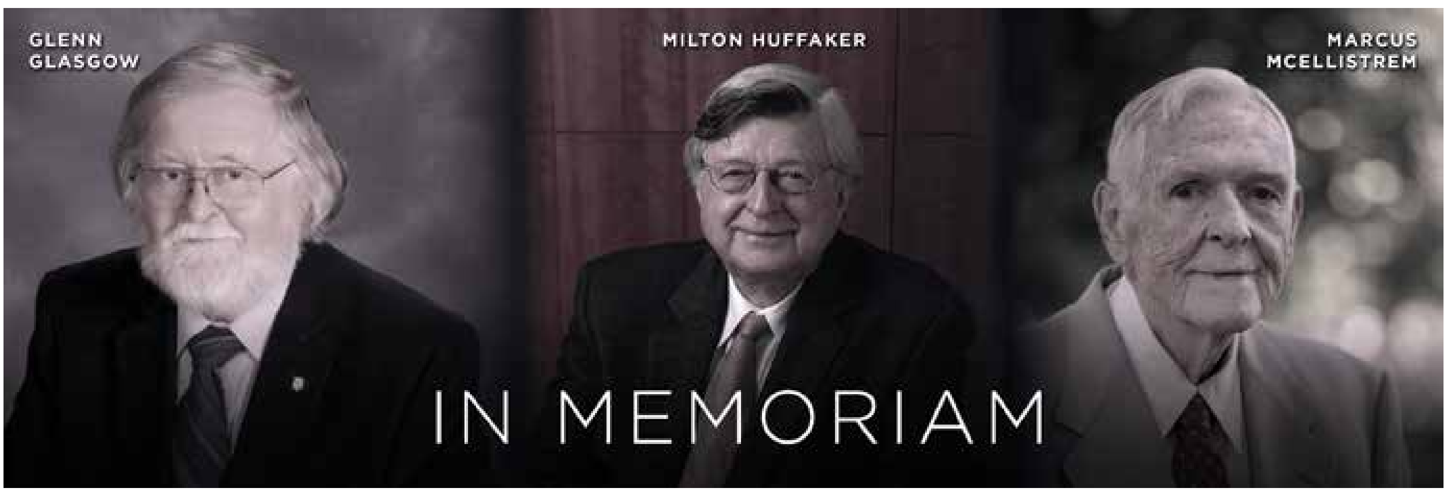
"To find an explanation for what had happened, we need to predict the behavior of the black hole and the obscurer considering a lot of possible scenarios. We mainly use the data taken by Hubble Space Telescope and simulate the holiday that happened in the lines. To be able to model and predict this phenomenon, we need a tool to do numerical calculations. Cloudy is the tool that we use. We produce models of the emission and absorption lines and the obscuration and adapt Cloudy to fully model what we observed, improving the code. As a Cloudy developer, I will incorporate these improvements into next releases of the code. This will benefit other researchers in the field and future space missions as well.
"Cloudy is, in fact, a spectral synthesis code designed to simulate spectra from interstellar matter possibly exposed to an external source of radiation under a broad range of conditions. Cloudy simulates gas ranging from fully ionized to molecular. This makes it possible to predict many observed quantities by specifying only the properties of the cloud and the radiation field striking it. The code is being developed here in Lexington and is publicly available under an open source license, which has a two-year release cycle."

The MacAdam Fellowship, like other forms of graduate student support, provides crucial resources that accelerate the timeline for Dehghanian's degree. After earning her Ph.D., she intends to continue her research as a postdoctoral scholar with the goal of obtaining a faculty position in physics. Meanwhile, her contributions to the Cloudy code will have a lasting impact.

"The developments from my research will be implemented into future releases of Cloudy," she said.



Last year, we mourned the passing of three important individuals who played pivotal roles in the growth of the Department of Physics & Astronomy: Professor Emeritus Dr. Marcus T. McEllistrem II, alumnus Milton Huffaker '57, and alumnus Glenn Glasgow '74.

Marcus T. McEllistrem II was an esteemed faculty member in the department from 1957 until his retirement in 1994. He was a mentor and teacher to generations of students during his distinguished 38-year history at UK. He was awarded the title of Arts & Sciences Distinguished Professor Emeritus in 2008 in recognition of his exceptional scholarly contributions and service to the university, and in 2013 he was inducted into the A&S Hall of Fame. Born in Saint Paul, Minnesota, McEllistrem earned his M.S. and Ph.D. in nuclear physics from the University of Wisconsin, Madison. At UK, he led the design and construction of the Van de Graaff Particle Accelerator Laboratory in Physics, which has been used for research in nuclear physics for over five decades, as well as for Homeland Security and corporate applications. He was awarded over 50 years of research funding from the National Science Foundation and Department of Energy and was an invited guest scientist at many prestigious institutions and laboratories, such as the Brookhaven National Laboratory, Notre Dame University and Bruyères le Châtel, CEA, France. Memorial gifts can be made to the Marcus T. McEllistrem Summer Fellowship Fund to support summer research for outstanding graduate students in the department.

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A native of Wayne County, Kentucky, **Milton Huffaker** was one of the most distinguished alumni in the department's long history, and he forged a close relationship with the department over the past decade. He was a proud alumnus of UK and gave back generously to Physics, creating the Huffaker Scholars and the Coherent Scholars to support graduate students in physics and astronomy. Milton was a scientist who worked with NASA on the Apollo space program. His lunar physics included the creation and direction of laser Doppler systems, significantly impacting the aerospace industry. In 1984, he founded Coherent Technologies Inc. (CTI) to develop Doppler laser radar technology and systems for meteorological and military applications. CTI grew about 30% a year before being acquired by Lockheed Martin in 2005.

Milton's philanthropy helped a number of charitable activities and organizations in the United States and abroad. He co-founded the Second Step Program of the Emergency Family Assistance Association in the mid-1980s and was also founder and chairman of the Realizing Aptitudes Foundation, which assists high school and beginning college students with career guidance. Milton was inducted into the A&S Hall of Fame in 2008, received an honorary doctorate from UK in 2013, and was inducted in UK's Hall of Distinguished Alumni in 2015. He most recently served as a member of the College's volunteer Campaign Committee. Gifts in memory of Milton can be made to the Physics and Astronomy Development Fund.

Glenn P. Glasgow earned an M.S. from UK in 1969 and a Ph.D. in 1974. He left Kentucky to pursue both an academic and medical career in radiation oncology and medical physics, first as a tenured professor of Radiation Physics at the Washington University School of Medicine in St. Louis, then as a tenured professor of Radiation Oncology at the Loyola University Stritch School of Medicine, while also working in the Department of Radiotherapy for Loyola Hospital and the Hines VA Hospital in Maywood, Illinois. Among his proudest professional accomplishments, he was a fellow of the American College of Radiology and a fellow of the American Association of Physics in Medicine, the highest recognitions in his field.

During his 40-plus years of experience in Therapeutic Radiological Physics ('78-ABR) and Health Physics ('82-ABHP), Glenn contributed extensively to his discipline, serving on national committees, including as president of the Midwest Chapter of the American Association of Physics in Medicine, and authoring/co-authoring more than 188 manuscripts, many of which were in his specialty areas of brachytherapy, radiation shielding, facility design, radiation safety, high dose rate remote afterloading, total body irradiation, medical radiation regulations, licensing, quality assurance and program evaluations as well as in general radiological physics. In retirement, he returned home to Kentucky and found a new path, establishing a consulting business providing expert witness testimony.

Marcus McEllistrem, Milton Huffaker, and Glenn Glasgow and were personally and intellectually generous to the department and university, and they will be greatly missed by colleagues, alumni and friends.

Bill Gannon (above left) joined the department as an assistant professor in fall 2019 after earning a B.S. in physics from the University of Michigan and a Ph.D. from Northwestern University. His research interests are in condensed matter physics, correlated electron materials, crystal growth, quantum magnetism, low dimensional magnetism, quantum phase transitions and neutron scattering.

Ryan MacLellan (above center), an experimental nuclear/particle physicist, joined the department as an assistant professor in January 2020. He earned his Ph.D. in neutrino physics at Queen's University (Canada), where he worked with Nobel Laureate Art MacDonald. He then followed this with postdoctoral positions at the University of Alabama and at the SLAC National Accelerator Laboratory before accepting a position as an assistant professor at the University of South Dakota. MacLellan's research program is focused on the search for neutrinoless double beta decay, which would only proceed if the neutrino is a Majorana particle, meaning the neutrino and anti-neutrino are the same particle.

Yuanyuan Su (above right) joined the department as an assistant professor in fall 2019. She earned her Ph.D. at the University of Alabama and completed postdoctoral fellowships at the University of California–Irvine and at Harvard's Smithsonian Center for Astrophysics. Her research focuses on clusters of galaxies, the largest collapsed objects in the universe, using X-ray space telescopes (Chandra, XMM-Newton, Suzaku). She is best known for providing observational constraints on the microphysical properties of the intracluster medium and connecting it with the large scale evolution of galaxy clusters. She also studies AGN feedback at centers of clusters and early-type galaxies using X-ray, radio and EUV observations.

Support the Physics and Astronomy Development Fund

Your gift to the Physics and Astronomy Development Fund will provide critical resources to respond to student needs, attract world-class faculty, and provide innovative opportunities to enable our students to compete in the global marketplace. We explore fundamental questions about nature. Undergraduate majors and graduate students take a complete array of courses with small class sizes that span modern topics in physics and astronomy, and they work closely with faculty researchers in studies of nuclear and particle physics, condensed matter and atomic physics and astronomy and astrophysics.

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