ΦYAST ΦLYER

The Homer L. Dodge Department of Physics and Astronomy

Grant Biedermann joins the faculty

This fall, Grant Biedermann joined our department as the Homer L. Dodge Professor of Atomic, Molecular, and Optical Physics. Grant is coming from Sandia National Laboratories in Albuquerque, New Mexico where he has been on staff for eleven years.

Grant graduated from OU in 2001 with an undergraduate degree in engineering physics, where he first did research in atomic physics as part of the department's capstone program. He received his Ph.D. from Stanford University with Mark Kasevich in 2007 for innovative work in atom interferometry using ultracold atoms. He then began at Sandia in 2008 as a Senior Member of the Technical Staff and was promoted to Principle Staff in 2013. Concurrently, Grant began advising Ph.D. students as an Adjunct professor at the University of New Mexico in 2011 and later as a Research Associate Professor in 2015. Grant greatly enjoys working with students, and he wanted mentoring and teaching to be a bigger part of his career, making the move to OU an ideal professional opportunity.

At Sandia, Grant developed experiments in the areas of precision metrology via coherent control of atomic matter waves, and quantum information science with ultracold neutral atoms. Often, the national laboratories serve an important role of bridging the gap between scientific learning and applications. As such, he developed new techniques to enable metrological applications of atom interferometers. The success of his efforts has recently led to a large research program to advance these quantum technologies for field applications, i.e., sensing and navigation. He also found ample opportunity for basic research with matter wave interferometers. For example, he demonstrated the self-interfering nature of matter wave interferometry with a textbook, single-atom experiment that clearly shows the build-up of an interference fringe, one atom at a time. In parallel, he established important foundational work in the area of quantum information science. He led efforts to develop quantum control of multi-atom systems and pioneered the first demonstration of an entangling Rydberg-dressed interaction between the spins of cesium atoms, which can have important uses in quantum many-body physics and quantum computation.

(*continued on page 9)*

From the Chair

In last year's newsletter I stated that I expected the second year to be easier than the first year since I would know what to expect on the administrative side. What I learned from that prediction is to never underestimate the ability of administrative work to overwhelm everything else. Nonetheless, a number of departmental successes where achieved and I was able to maintain progress in my research program.

The highlight of the year was the dedication of the new Dodge Physics Complex (comprised of Nielsen Hall and the new Lin Hall) which took place on October 13, 2018. This provided an opportunity to honor the Avenir Foundation and Prof. Chun C. Lin the two major donors of the new state-of-the-art NIST A laboratory building. The dedication provided an opportunity for faculty to reunite with many of our alumni and with members of our Board of Visitors. The event lasted all day, starting in the morning with speeches by OU administrators followed by a tour of Lin Hall with a display of posters showing departmental research and culminating in an evening gala at the Sam Noble Museum of Natural History where a good time was had by all.

The quantum initiative that was put together by the AMO and condensed matter groups has now blossomed into an OU initiative. This initiative led to a $16M donation from the Avenir Foundation, a $2M appropriation for FY 2020 from the state legislature, an increase in graduate student stipends for the incoming class of graduate students, and last year our department was allowed to conduct three faculty searches, which later became four searches. The three initial searches (AMO and condensed matter experiment, and AMO theory) lead to two hires, experimentalist Dr. Grant Biedermann who will hold the Homer L. Dodge chair in AMO physics and Dr. Robert Lewis-Swan an AMO theorist. The condensed matter search will continue this coming year. In addition, a targeted search for a director of the new Center for Quantum Research and Technology (CQRT) took place; this search will also be continued this coming year and for the time being Professor Alberto Marino will serve as the interim director. The CQRT was dedicated in a ceremony that took place the afternoon of Oct. 25, 2019. As last year, I thank Dean Wrobel who has been a champion for our department, Provost Harper and VPR Hewes who have also been very supportive of our efforts.

For the coming year, three new faculty searches were approved. One in AMO experiment, one in condensed matter experiment, and one in either AMO or condensed matter theory. This is in addition to the two searches continuing from last year for a total of five searches. We expect to have a very busy year ahead of us.

Our students continue to excel. This past year H. Day was named a Goldwater scholar for which we congratulate her for this achievement. In addition, many of our students reached the milestone of receiving their diploma both at the undergraduate and graduate level. Congratulations to all.

Beyond classroom teaching, the most important role of the department is the acquisition of new knowledge and the training of students in the research techniques needed to acquire it. Even though it is clear that the goal of the Ph.D. program is designed to develop independent researchers, it is important that our undergraduates also have an opportunity to participate in our research program, which is the case for many of our undergraduate majors who work in our research labs and on projects in theoretical physics. Our faculty have roughly 65 grants with expenditures of $3 million dollars, which funds our research and allows our students to participate in major research projects in both theoretical and experimental physics and astronomy. The experimental work is performed at labs both local and elsewhere including at the CERN Large Hadron Collider, various telescopes around the world, in our local labs in atomic, molecular and optical physics, and in condensed matter physics. Finally, I want to congratulate three of our young faculty members who were awarded NSF Career Grants. The three are Professors Nate Kaib, Alberto Marino, and Arne Schwettmann.

The department will be hosting two conferences this coming year. We will be one of the 13 sites hosting the annual APS Conference of Undergraduate Women in Physics whose goal is to help undergraduate women continue in physics by providing them with the opportunity to experience a professional conference, provide information about graduate school and professions in physics, and have access to other women in physics of all ages with whom they can share experiences, advice, and ideas. The conference will take place January 17 through January 19 2020 and is being organized by Prof. Doerte Blume and graduate student Amber Roepe. We will also be hosting the 13th International Conference on Interconnections between Particle Physics and Cosmology May 18 through May 22, 2020, which is being organized by Prof. Kuver Sinha.

We look forward to a very busy and productive year. I would like to personally invite any of our alumni and friends to drop by the department any time and visit with me or any of our faculty.

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Lin Hall Dedication

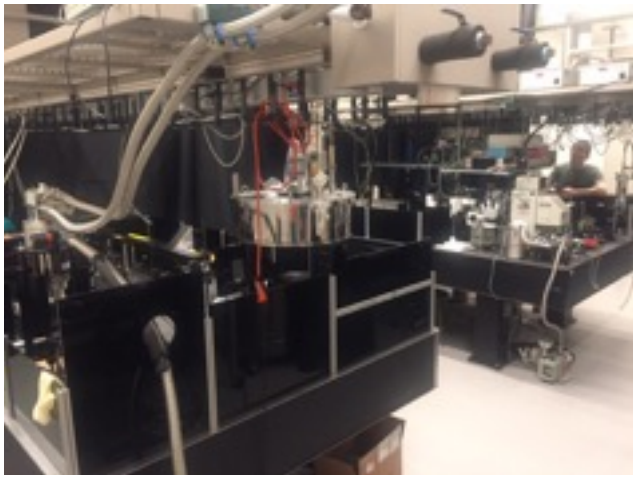
Lin Hall, part of the Dodge Physics Complex, was dedicated on Oct. 12, 2018 in recognition of Chun C. Lin, an OU professor of physics from 1955 to 1968. It contains more than 18,000 square feet of world-class research space and is one of only a few buildings in the world to meet the NIST-A requirements on vibrations, temperature, humidity, and electromagnetic interference.

Since that time, members of the department (both the atomic, molecular, and optical physics groups and the condensed matter physics groups) have begun the process of moving into the new facility. By the summer of 2019, nearly all the faculty, graduate students, and postdocs have moved into new offices on the second floor. The labs take longer to move. Because experiments can take months or years to complete, many faculty (and their students finishing degrees) wish to complete current work before moving equipment and apparatus into the new space. One faculty member that has completed the move is Dr. Ian Sellers, who does experimental condensed matter research on novel materials and structures for the next generation of solar cells.

While his current experiments don't take advantage of all the NIST-A level of environmental control, he is excited about what it offers for the future. Dr. Sellers, his postdocs, and his students already appreciate the new facility's layout, how it handles plumbing and power, and the use of the utility corridor. The new building, designed from the ground up as modern laboratory space, is already a leap forward in research environment. By August, they had completed their first manuscript from data taken entirely in the new facility.

Dr. Sellers said moving into the new building wasn't terribly onerous. The transition provided additional advantages. Vince Whiteside, a postdoc working in the Sellers group said it provided the opportunity to optimize the setup. As experiments evolve and pieces added, they aren't always optimal in the new configurations. While it's not something one would shut down the lab to do if it weren't moving, the reorganization makes the experiment more efficient and the lab more productive.

Several people have commented on the improved working environment on the second floor. Professor Sellers mentioned having everyone together and not hidden in separate parts of Nielsen Hall greatly increases the population you see and interact with every day, especially in the summer with most of the undergraduates gone. He also noted better group cohesion with people in the same place and predicted improved productivity across groups. This will only increase as more of the experiments migrate to the new building.



Left: Graduate Student Collin Brown works on the experiment in Dr. Ian Sellers's Lab in Lin Hall. **Right**: Lin Hall and the new Dodge Physics Complex.

Women in Physics Year-in-Review

The 2018-2019 school year was a big one for Women in Physics (WiP)! They started off the school year by hosting a booth at the Oklahoma EPSCoR Women in Science Conference in October 2018. WiP held many professional development luncheons with topics from overcoming your fears of public speaking, given by Dalaki Livingston M.A., and shared experiences from some of our esteemed colloquium speakers. We also visited a GED program for adults and spoke to their children about what it means to study physics when they get older.

In January 2020, our department will be one of the 13 sites hosting the APS Conference for Undergraduate Women in Physics. The local organizing committee, run by Chair Amber Roepe and Faculty Chair Doerte Blume, are very excited to host this important conference for our undergraduate women, and those in surrounding states. For more information, please visit http://www.ou.edu/cuwip

Interested in more WiP activities? Follow-us on twitter at @OUWomenInPhys

Lunar Sooners Outreach

Lunar Sooners had an absolutely fabulous 2018-2019 academic year, with total of 32 events, including 19 private star parties, 9 Soonertariums, and 4 demo events. We hosted the Lin Hall inauguration star party for the Board of Visitors and other distinguished guests on October 13th outside Sam Noble Natural Science Museum. In 2019, the new observatory on the third floor of Lin Hall finally opened - with twelve new 8" telescopes and one 14” telescope inside the full functioning dome. Nine permanent mounts for the telescopes have been set up on the roof for the Astro 1514 labs, Wednesday night public star parties, and Lunar Sooners private events which began to happen at new observatory starting Spring 2019 semester. Lin Hall observatory is wheelchair accessible and the old observatory on Asp Ave. is still used as a backup venue for Lunar Sooners events and for some Astro 1514 sections. Lunar Sooners along with the OKC Astronomy Club co-hosted the total lunar eclipse viewing on January 20, 2019 with around 500 visitors in attendance and telescopes set up by Norman North High School, Norman High School, OKC Astronomy Club and Lunar Sooners. We thank our previous officers for their great work (Hora Mishra, Joseph Choi, Nick Reynolds, Kyra Dame, and London Wilson) in the past year and congratulate our 2019-2020 officers: Hora Mishra, Brett Bonine, Nick Reynolds, and Joseph Choi.

Photo from left to right, back row: James Derkacy, Nickalas Reynolds, Joseph Choi, Brett Bonine, Evan Rich, Jordan Van Nest, Kellen Lawson, front row: Renae Wall, London Wilson, Hora Mishra, Kyra Dame

OU physicists awarded European Physics Society prize

The CDF and DZero collaborations, the latter of which includes several current and former OU physicists, were awarded the 2019 High Energy and Particle Physics Prize from the European Physical Society for "the discovery of the top quark and the detailed measurement of its properties." This prestigious prize is awarded every two years for outstanding contributions to the field. OU made substantial contributions to the DZero experiment, without which the discovery would not have been possible. Faculty members Brad Abbott, Phillip Gutierrez, Patrick Skubic, and Michael Strauss oversaw the work of seven PhD students, six postdoctoral research associates, and a research scientist (Horst Severini) on the DZero experiment.

The discovery of the top quark was announced jointly by the CDF and DZero collaborations in 1995. At the time, the top quark was the only remaining matter particle predicted by the standard model yet to be observed. Discovery was made challenging by the large mass of the top quark, which necessitated careful analysis of billions of high-energy proton-antiproton collisions produced by the Tevatron at Fermilab in Illinois. The large mass of the top quark is also what makes it so fascinating; it is the heaviest of all known fundamental particles, with a mass at the electroweak scale.

In addition to discovering the top quark, the CDF and DZero experiments performed a number of important measurements of its properties. The top quark mass was measured with a precision of 1%. The cross section for production of a top-antitop pair was measured with a precision of 10%. The production of a single top quark is much rarer, being mediated by the weak interaction. However, the CDF and DZero collaborations also later observed this production mode, thanks in part to significant work from an OU postdoc (Supriya Jain).

The OU group continues to study top quark properties today, using collisions produced by the Large Hadron Collider at CERN. Recently, Phillip Gutierrez and postdoc Muhammad Alhroob published the first 3-sigma evidence for the production of a single top quark in association with a Z boson, which is also mediated by the weak interaction. Along with graduate student Dylan Frizzell, they are now finalizing a publication with incontrovertible >5-sigma observation of this process.

From left: EPS Chair of High Energy and Particle Physics Barbara Erazmus, CDF co-spokesperson Giorgio Chiarelli, DZero co-spokesperson Paul Grannis, DZero co-spokesperson Dmitri Denisov. Not pictured: CDF co-spokesperson David Toback. Photo courtesy of EPS Conference

Student Awards

Homer L. Dodge Departmental Awards

Dodge Outstanding Sophomore	Dodge Outstanding Junior	Fowler Prize
Tanner Legvold	Matthew Welty	Matthew Peters

Physics and Astronomy Awards

Undergraduate Student Awards

J. Clarence Karcher Award

Nathaniel Lydick
Visal So

Duane E. Roller Award

Claire Riggs

Elijah Robertson

Lukas Stone

William Schreiver Award

Nathaniel Gunter
William McNulty
Jacob Moser
Katherine Sloan
London Willson

Outstanding Graduating Senior

Dustin Gier
Gavin Jergensen

Graduate Student Awards

George Kalbfliesch Award

Amber Roepe

Neil Shafer-Ray Award

Wending Huang

Homer L Dodge Fellowship

Joseph Hyunseop Choi

Nielsen Prize

Matt Clement

Hamidreza Esmailpour

Physics Final Fling 2019

This last May saw the third annual "Physics Final Fling," an expansion of the traditional departmental award ceremony into an afternoon of events. The slate of events started with a photo-shoot of the entire department, including the undergraduates, graduates, and faculty immediately followed by a buffet of snacks. After eating the crowd was ushered into NH 170 for the undergraduate and graduate student awards. Professor Wisniewski was the recipient of the 2018-2019 Kantowski Bear Award, for "Grateful Dead powered astronomy". Immediately after this, the department held its third ever Alec Montec Norris Memorial Quiz Bowl for the entertainment of all.

Prof. Kieran Mullen acted as quizmaster, posing challenging trivia questions on Physics, OU, and popular culture (E.g. "What is the first letter in the alphabet NOT used in a two-letter abbreviation of an element?", "Name four restaurants on the OU campus NOT in the Memorial Union.") In addition to the undergraduate, graduate and faculty teams this year the office staff joined the competition. The official scorekeeper was William Spain, from the Provost's office.

The competition was fierce, with the undergraduate team of Cora Ann DeFranschesco, Colin Riggert, and Kevin Robb edging out the graduate students by a single point. The faculty team claimed that their loss was due to injuries sustained during the contest and vowed to win next year.

Hannah Day Named Goldwater Scholar

Hannah Day was named a 2019 Goldwater Scholar. The prestigious scholarships are awarded on the basis of potential and intent to pursue research careers in mathematics, the natural sciences, or engineering. Day, a National Merit Scholar majoring in both physics and math, is from Topeka, Kansas. She is a member of the Honors College and has a 3.98 GPA. In 2017, she was awarded the Physics Merit Scholarship Award and earned a Mathematics Scholarship the following year. In 2018, she also was recognized as the Outstanding Sophomore in Physics. In addition to her academic achievements, Day is a member of the Math Club and Physics Club, and enjoys practicing her language skills as a member of the French Club. She is also a member of OU's Concert Band and is active in Chi Alpha Student Ministries.

Day intends to earn a doctorate in theoretical physics and to study physics beyond the Standard Model (made up of ideas concerning quantum mechanics, relativity and Einstein's gravity), especially as it relates to gravity. Her research activities have included working in Kimball Milton's lab, which was devoted to the study of properties of the stress tensor. She also worked with Ralph Lehnert at Indiana University, exploring the motion of light and developing methods to measure the effects of the Lorentz violation upon light.

Summer Research for Undergraduates

Summer of 2019 was another successful year for the Research Experience for Undergraduates (REU) program in the Homer L. Dodge Department of Physics and Astronomy. This 10-week program, from May 28 to July 31, involved 12 undergraduates from other schools and 7 OU students working with faculty in all our research groups. Research topics ranged from Bose-Einstein condensates and solar cells to Higgs boson decay and simulations of galaxy formation. Details about the 2019 REU program are online at: https://www.nhn.ou.edu/~abbott/REU/photos-2019.html.

Center for Quantum Research and Technology (CQRT) Established

The Homer L. Dodge Department of Physics and Astronomy is excited to announce the creation of a new research organization, the Center for Quantum Research and Technology (CQRT). The CQRT will be based in the newly-constructed Lin Hall, as part of the Dodge Physics Complex, and will capitalize on the expertise of the current atomic, molecular, and optical (AMO) and condensed matter (CM) physics groups. The CQRT's mission will be to make OU a world leader in quantum technology by excelling in basic research and pursuing applications enabled by its discoveries. It will train the future workforce for this emerging field, while establishing meaningful partnerships with industry.

The development of quantum mechanics in the 1920s started a technological revolution that led to many of today's ubiquitous electronic technologies, including computer chips, lasers, the global positioning system, and the technology that supports all aspects of the internet. Recent progress in exploiting superposition and entanglement—two fundamental aspects of quantum mechanics that are not utilized in today's technologies—is creating a second quantum revolution. Entirely new fields are being created (quantum information processing and quantum simulation) and others transformed (secure communication and high-precision sensing). The systems involved in this revolution vary widely from photons, atoms, and spins (AMO systems) to mesoscopic superconducting, semiconducting, and nano- mechanical structures (CM systems). To take full advantage of quantum resources, these systems must work together to harness their complementary properties.

Over the next decade, quantum-based devices will begin to replace current classical ones. For example, ultra-precise atomic clocks and quantum cryptographic systems with absolute security are already commercially available. Start-up companies that focus on quantum technology are proliferating. Even established tech companies, such as Google, IBM, and Microsoft, have prominent efforts in quantum computing, and many countries are making significant investments in this emerging field. Economists predict that the global quantum technology industry will have annual revenues of $80 billion by 2030 and $1.3 trillion by 2040.

Congress is launching a 10-year National Quantum Initiative, a coordinated Federal program to accelerate research and development of quantum-based technologies. While the most famous quantum technology, quantum computation, attracts the most attention, other fields (e.g., quantum communication, quantum simulation, and quantum sensing) have immediate practical applications and revolutionary potential, and will be the initial focus of the CQRT. Developing these quantum technologies requires meeting fundamental challenges across a wide diversity of systems, necessitating close collaborations between both the AMO and CM fields.

To further grow the center, the Homer L. Dodge Department of Physics and Astronomy will conduct searches for five new faculty members next year to participate in the new center: the director of the CQRT and Homer L. Dodge Chair in AMO or CM physics, a tenure-track Assistant Professor or Associate/Full Professor in experimental quantum physics with a research focus in AMO physics, two tenure-track Assistant Professor or Associate/Full Professor positions in experimental quantum materials or quantum physics with a research focus in CM physics, and a tenure-track Assistant Professor or Associate/Full Professor in theoretical quantum physics with a research focus in AMO or CM physics.

Experimental research on promising quantum systems can only be carried out in precisely-controlled environments. Lin Hall and the Dodge Research Complex maintains a level of vibration, temperature, humidity, and electromagnetic control equal to or better than any university facility in the US. This state-of-the-art research environment will support the highest level of experimental inquiry and serve as a powerful recruiting tool to attract talented scientists.

The University of Oklahoma celebrated the creation of the CQRT with a dedication ceremony on Friday, October 25, 2019.

Continued from page (1), **Grant Biedermann joins faculty**

Building on this foundation, the theme of Grant's research at Oklahoma will be perfecting control of large and complex quantum systems and the ensuing exploration of new phenomena. In particular, he will be developing an experiment to create large entangled spin states of neutral atoms and investigating new possibilities for high-fidelity quantum control and measurement. His near-term experimental goals include demonstrating a matter wave interferometer with multiple entangled atoms and developing techniques to study the interplay of robustness and complexity in large entangled systems.

Being at a national laboratory like Sandia gave Grant a unique experience and perspective not possible elsewhere. He brings that expertise to Oklahoma, making him an excellent fit for the new center in quantum research and technology; his research goals are in alignment with the center's direction, and his experience compliments others in the department. With the addition of Lin Hall and the creation of the new center focused on quantum research and technology, he said it is an incredibly exciting time, and that the physics department at OU is "poised to do great things."

When not in the lab, Grant enjoys spending time outdoors with his wife Katie and their children Elaine and Fiona. In New Mexico, they would often camp and fish in the mountains and they look forward to similar adventures in Oklahoma and the vicinity. He also enjoys snowboarding, rock climbing and soccer, and he is excited to re-experience Oklahoma football in person.

Faculty Research

Astronomy, Astrophysics and Cosmology

Eddie Baron's Eddie Baron's supernova numerical radiative transfer group is proceeding apace. Malia Jenks defended her dissertation in the Spring, while her husband held their six week old son. Her paper on the analysis of the Nearby Supernova Factory data, is currently under internal review. We hope to submit it to a journal soon. Postdoc Andrea Cristini has decided to return to the UK, but we look forward to welcoming Vera Passegger as a new postdoc in November. Third year student James Derkacy has been driving our observational effort on APO and now Gemini as well as working on Extremely Luminous Supernovae models and some Type Ia projects. Sarah Stangl just finished her first year and is working at Los Alamos this summer. Incoming graduate student Anthony Burrow is working on a project as part of the Carnegie Supernova Project and learning the vocabulary. Undergrad London Wilson is working with Mukremin Kilic's group this summer to get exposure to observational techniques, but we expect her back in the Fall. Eddie thoroughly enjoyed his sabbatical, he spent the Fall at the University of Aarhus, Denmark and made trips in the Spring to Florida, Aarhus, Hamburg, Stockholm, and Boulder.

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Nathan Kaib's group recently published works, led by graduate student Matt Clement, showing that an orbital instability among the outer giant planets in the early solar system can explain the mass difference between Mars and Earth as well as the structure and low mass of the asteroid belt. Also, postdoctoral researcher, Billy Quarles, led a paper showing that this orbital instability could not have taken place more than a few tens of Myrs after solar system formation, as the Kuiper belt's self-stirring hastens any potential outer solar system instability. Kaib led a publication showing that a recently proposed undetected planet in the distant solar system should generate a subpopulation of Kuiper belt objects on highly inclined orbits that is not seen, casting doubt on the planet hypothesis. Finally, Kaib was awarded an NSF CAREER grant for additional studies of the formation of the Kuiper belt and exoplanet systems.

Mukremin Kilic's group has produced two PhDs this year. Drs. Paul Canton and Kyra Dame defended their theses in December 2018 and July 2019, respectively. Paul has worked on the initial-final mass relation using stellar remnants in open clusters of stars, and Kyra has searched for transiting planets in the habitable zones of white dwarfs. Renae Wall has submitted her first author paper on calibrating NASA's GALEX Mission, and Alekzander Kosakowski has been driving our observational efforts using OU's Apache Point Observatory 3.5m telescope, SOAR 4m telescope in Chile, and Gemini 8m telescope in Hawaii. Alek is working on two first author papers from these observational projects. We had a great REU student, London Willson, who analyzed the Zwicky Transient Facility data to identify short period eclipsing binary white dwarfs. We also had two other excellent undergraduate research students, Sara Paugh and Andrea De La Torre, looking for variable systems using NASA's TESS mission. Our group is strengthened by the addition of a new graduate student from the incoming class of 2019, Adam Moss.

Karen Leighly's SimBAL group has had an active year. Two papers were published, one introducing the code and a second investigating the nature of partial covering in Broad Absorption Line quasars. Leighly, graduate student Joseph Choi, and undergraduate student Ryan Hazlett presented posters at the 233rd American Astronomical Society meeting. Many exciting excursions were taken during summer 2019. Choi attended the 2019 Cloudy workshop in Lexington, Kentucky. Undergraduate student Collin Dabbieri visited SimBAL collaborator Gordon Richards at Drexel University to work on the problem of finding FeLoBAL quasars in the SDSS. Undergraduate student Collin McLeod presented a poster at the 2019 AstroInformatics meeting at CalTech on his work with graduate student Alex Kerr (on loan from Kieran Mullen) to develop a variational autoencoder to generate quasar spectra. Leighly and SimBAL collaborator Don Terndrup attended the 2019 PICUP (Partnership for Integration of Computation into Undergraduate Physics) Development workshop at UW River Falls.

John Wisniewski's group continued to investigate topics in circumstellar disks, exoplanets, and stellar astrophysics. Evan Rich and Steven Silverberg successfully defended their PhD dissertations and advanced to postdoc positions at the University of Michigan and MIT respectively. Graduate student Kellen Lawson led a paper that used machine learning to identify stellar flares in sparsely sampled data sets. It is probably not surprising that the official mascot of Lawson's **Py**thon **V**ariable **A**ssessment with **N**on-linear Template Optimization (PyVAN) software developed for this work is Wisniewski & Munshi's pug, Ivan. Graduate student Maria Schutte, incoming graduate student Anthony Burrow, REU student Erick Powell, and undergraduate Matthew Peters continued working on several papers investigating the Be star population in M31 and in Galactic open clusters.

Atomic, Molecular and Optical Physics

The **Blume** group has been busy during the past year working on NSF funded research. Postdoc Dr. Qingze Guan studied density oscillations of expanding two-atom systems in collaboration with Prof. Jochim's group from Heidelberg University. The work, published in Physical Review Letters in early 2019, was selected as an Editors Suggestion and highlighted in the magazine Physics. Postdoc Dr. Jianwen Jie finished his interferometer paper, which carefully analyzes the performance of an SU(1,1) interferometer for different initial states within the undepleted pump approximation. Undergraduate student AJ Yates has been making excellent progress on developing Monte Carlo treatments of helium clusters and Samuel Bayliff joined the group as an REU student in summer 2019. Qingze, Jianwen and graduate student Jugal Talukdar presented their work during the annual DAMOP meeting in Milwaukee. Jugal additionally attended the B2/ITAMP winterschool on many-body cold atom systems in Arizona. Doerte Blume was also busy traveling. In addition to attending DAMOP, where she served as the Chair of the Education Committee that put on a one-day student symposium, Doerte presented invited talks in Shanghai in November 2018, at Temple University in April 2019, in Zhuhai and Hong Kong in June 2019, and in Frankfurt in September 2019.

Eric Abraham's group is currently working at the interface between ultracold atomic physics and quantum optics. With graduate student Matthew Holtfrerich, we study electromagnetically induced transparency using atomic gases of rubidium cooled to tens of micro-degrees above absolute zero.

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We utilize laser beams that have non-zero orbital angular momentum, an exploit the extra degrees of freedom for possible advances in optical communication and cryptography. A senior capstone student, Visal So, started graduate school at Rice University. Another undergraduate, Andy Schramka started a new experiment with me exploring classical entanglement, where we entangle light modes and polarization in a mathematically similar way to atoms and spin, but with entirely classical fields. We are moving our experiments into Lin Hall and are terribly excited about the new facility.

Deborah Watson has continued to investigate the dynamics behind the emergence of collective behaviors such as superfluidity. Normal modes, selected by the Pauli principle, were found to play a role in creating and stabilizing the superfluid behavior of ultracold fermions in the unitary regime. Using analytic expressions for these normal modes, the evolution of their macroscopic collective behaviors as a function of N, as well as the microscopic motions underlying these behaviors, have been analyzed. Normal mode behavior is ubiquitous in nature, occurring at all scales in the universe from nuclear physics to cosmology. Understanding the dynamics of collective behavior could help in constructing systems that support this special behavior. This work is supported by NSF.

Arne Schwettmann's group received a NSF CAREER award that is funding a 5-year research program in ultracold atomic gases starting in June 2019. The group acquired many data on ultracold spin-changing collisions for sensing applications using OU's first and only Bose-Einstein condensate (BEC), a gas so cold that it behaves like a single quantum object. Graduate students Shan Zhong, Qimin Zhang, Isaiah Morgenstern and Hio Giap Ooi compared their experimental data to theoretical supercomputer calculations in a new collaboration with OU Prof. Doerte Blume's group. Undergraduate students Dana Peirce (REU) and Cameron Cinnamon (REU) built a sophisticated magnetic field control circuit to cancel unwanted fields from the moving building elevator and other sources. The group presented their progress at DAMOP, Milwaukee, WI.

Alberto Marino's group continues working on the control and characterization of quantum states of light to enable quantum enhanced devices. Graduate student Javad Dowran and postdoc Aye Win developed a measurement apparatus to extend our previous work on quantum enhanced sensing to a parallel configuration; graduate student Tim Woodworth is finalizing experiments to determine the ultimate precision in transmission measurements with quantum resources; graduate student Saesun Kim has developed techniques to generate quantum states of light on resonance with atomic systems; while graduate student Gaurav Nirala visited our collaborators in Brazil as part of our joint work on novel techniques to characterize quantum states of light. Two new students, Kit Leonard and Umang Jain, have also started working in the group. Over the last year the group published papers in Optics Express, Physical Review A, and Optics Letters, and a review article on quantum enhanced sensing in ACS Photonics. In addition, invited and contributed talks were given at several international conferences, such as DAMOP, SQuInT, Quantum Optics IX, LAOP, SPIE Photonics West, and SIPQNP. The group's work on quantum enhanced plasmonic sensing was recognized as one of the main achievements in Optics and Photonics in 2018 by Optics and Photonics News, the monthly news magazine for The Optical Society of America.

Condensed Matter Physics

Daniel White works to make experiences in physics courses more engaging and effective for students. With the help of diagnostic assessments and frequent student surveys, he determines what life science students have learned and what they have found frustrating in their physics classes, using the results to guide modifications to lecture notes and course materials. He has also helped coordinate moving two introductory teaching labs into new rooms and is looking into ways to make those labs more student-led in the hopes of improving student problem solving and data analysis skills. To improve the experience of majors in our department, he has worked on developing a survey for graduating seniors to better assess their subjective thoughts on their education.

Since January of 2019, **Bruno Uchoa** has been on sabbatical leave as a visiting scholar at the University College London in the UK, where he has ongoing collaborations with different theoretical groups, and more recently as a visitor at the University of Illinois at Urbana - Champaign. In the past year, Bruno's group published four papers, one as a regular article and two as Rapid Communications in Physical Review B, and another one in Physical Review Letters, which was the subject of an OU press release. Bruno gave invited talks at multiple institutions, including the University Paris-Sud in Orsay, and University of Cambridge, among several others. His group has been working on the novel properties of twisted graphene bilayers, a fascinating novel class of strongly correlated superconductors that may unveil some of the mysteries of high temperature superconductivity.

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Bruce Mason continues his work on an NSF-funded project to provide more authentic and engaging learning experiences for life science students taking an introductory physics class. The Living Physics Portal, https://www.livingphysicsportal.org now in beta, provides a place for faculty to find and share high-quality resources that apply physics to authentic biological problems. (As a counter-example, a cat sliding down a frictionless inclined plane is NOT an authentic biological problem.) This project, led by the American Association of Physics Teachers, is a collaboration of leading curriculum developers and researchers in this field. Mason brings his experience in educational digital libraries and online communities to the design and development of the portal. He is currently leading the editorial process reviewing the submissions to the portal and helping authors with this process.

High-Energy Particle Physics

Brad Abbott is continuing his work on the ATLAS experiment working on various analyses. Along with P. Gutierrez, H. Alhroob, and D. Frizzell, the cross section has been measured for the production of a top quark in association with a Z boson and a paper is expected soon. Graduate students J. Lambert and D. Wilbern are currently resident at Argonne National Laboratory working on readout for the upgraded ATLAS pixel detector and searching for evidence of tri-boson production and vector like leptons with P. Gutierrez, grad student J. Muse and postdoc M. Marjanovic. B. Abbott continues to help run the REU program where 18 students were involved in summer research.

During the past year, **Howard Baer's** group made contributions to the European Strategy for Particle Physics update, related to the properties of future hadron colliders required to discover natural supersymmetry. They found that the soft dilepton plus jet signal from direct higgsino pair production should be accessible at the high-luminosity LHC, while an LHC energy upgrade to 27 TeV or beyond might be needed to discover gluinos and top squarks. They also generated a new Z(24) discrete R-symmetry solution to the SUSY mu problem, which also generates Peccei-Quinn symmetry (needed to solve strong CP problem) and R-parity (needed to stabilize the proton). Further work on the string theory landscape was highlighted by comparing stringy naturalness to conventional naturalness. Stringy naturalness predicts a Higgs boson with mass 125 GeV and sparticles beyond the present LHC reach.

Phillip Gutierrez's research group has had a productive year: Graduate student Q. Wang completed his dissertation on a search for dark matter particles and vector-like top quarks. The results of his dissertation are published in the Journal of High Energy Physics. Postdoc M. Alhroob and graduate student D. Frizzell are leading the effort to finish and publish the results of a measurement of electroweak production of a single top quark in association with a Z boson. A draft of the paper is moving through the ATLAS collaboration approval process. In addition, D. Frizzell is writing up his dissertation, expecting to graduate by the end of the fall 2019 semester. M. Marjanovic, a postdoc who recently joined the group, and graduate student J. Muse are working on a search for vector-like tau leptons. They are also setting up the production testing facilities for the new silicon pixel detector to be used during the operation of the upgraded high intensity LHC.

During the 2018 - 2019 year, **Kuver Sinha** published on several different topics: (a) the search for axions and dark photons in the vicinity of neutron stars; (b) methods to use gravitational waves to study exotic astrophysical compact objects and constrain dark sectors; (c) studying phase transitions in the early Universe using complementary approaches based on collider physics of the Higgs sector and gravitational waves. Kuver is working on several new ideas: using beam dumps to constrain new parameter regions of axions, studying the emission of dark sector particles during neutron star mergers, and using ultra intense lasers to look for dark photons. He is also pursuing ideas in string phenomenology to understand the scale of supersymmetry breaking using statistical arguments, after incorporating moduli stabilization. Other topics of interest include studying dwarf galaxies for signals of dark matter (in collaboration with Ferah Munshi), and studying particles with long lifetimes at particle detectors (in collaboration with John Stupak).

Professor **Mike Strauss** is working with two graduate students, David Shope and Nate Grieser, investigating decays of the Higgs Boson to two W Bosons. Shope and Strauss are measuring the decay properties of the discovered standard model Higgs particle to determine if they fit precisely with the predictions of the standard model. Grieser and Strauss are searching for other types of Higgs particles with higher mass, as predicted by various theories including Higgs doublet models.

John Stupak continues to lead three exciting efforts within the ATLAS collaboration; a physics analysis group composed of 60+ people focused on unconventional searches for beyond the Standard Model physics, a task force studying the reconstruction of novel detector signatures, and a forum related to long-lived particles. Stupak and postdoc Giuliano Gustavino are finalizing a search for dark matter in the so-called mono-jet topology. Stupak, Gustavino, and graduate student Amber Roepe are also developing a novel search for decays of the Higgs boson to long-lived particles, which decay within the ATLAS tracker.

Kaib and Schwettman win NSF CAREER Awards

OU Astronomy Professor Nathan Kaib was the recipient of a National Science Foundation CAREER Award for research on planet formation and evolution.

It is thought that protoplanets, the bodies that eventually gave rise to planets, formed by a process known as accretion during the early life of our Solar System. This process cannot, of course, be studied directly. Little is known about how accretion proceeds at different distances from the Sun. Professor Kaib's work will address questions of Solar System development by using sophisticated computer modeling techniques. His team will also reassess the development of the giant planets and the Kuiper Belt of the outer Solar System.

Professor Kaib will use a GPU-accelerated N-body code to directly simulate the construction of rocky protoplanets via runaway and oligarchic growth. The same code will be used to build a self-consistent model of the dynamical evolution of the early outer solar system. Finally, he will use a new N-body algorithm to understand the interplay between planetary and triple star dynamics within the Alpha Centauri and other multiple star systems.

He will also establish astronomy and planetary science education programs at the Sam Noble Museum, Oklahoma's natural history museum. He will design classroom programs for visiting school groups as well as adding to the museum's catalog of Discovery Kits, which can be loaned free of charge across the state.

OU Physics Professor Arne Schwettmann was also the recipient of a NSF CAREER Award for research on ultra cold atoms.

By cooling a gas to ultracold temperatures near absolute zero (below minus 273 degrees Celsius) and trapping it in the center of a vacuum chamber, collisions between atoms in gases can be controlled and used to develop new technologies such as quantum-limited sensors for impurities. An ultracold gas behaves like a single quantum mechanical object, a matter wave. Collisions still take place in the matter wave, but they now happen in a predictable fashion. In a sodium matter wave, the collisions can be controlled precisely via microwave radiation. The colliding atoms behave like small magnets with magnetic north and south poles determined by the direction of their atomic spin. During collisions, atoms experience each other's magnetic fields and change their spin directions. As they change directions, the atomic spins become correlated with each other at the quantum level, a phenomenon known as quantum entanglement. Quantum entanglement is useful when atoms are used as sensors. All entangled atoms react to external influences in unison, increasing the sensitivity of a sensor.

Schwettmann’s research project will use controlled collisions in sodium matter waves to study quantum-enhanced sensing and other quantum technologies. This project will study the role of impurities and will also explore differences and similarities compared to experiments with entangled beams of light. The research will improve our experimental understanding of quantum technologies based on matter waves under realistic conditions, in the presence of loss and impurities. This has practical applications for development of robust quantum-enhanced sensors, for development of quantum-enhanced probes for ultracold gases, and for improving our understanding of how we can control spin in matter waves at the quantum level.

Brad Abbot Named Presidential Professor

OU Physics Professor Brad Abbott is the recipient of the 2019 Brian and Sandra O'Brien Presidential Professorship. Presidential Professors inspire their students, mentor their undergraduate and/or graduate students in the process of research and creative scholarly activity within their discipline, and exemplify to their students (both past and present) and to their colleagues (both at OU and within their disciplines nationwide) the ideals of a scholar through their endeavors in teaching; research and creative scholarly activity; and professional and university service and public outreach.

Marino Wins James and JoAnn Holden Faculty Award

Professor Alberto Marino is the recipient of the James and JoAnn Holden Faculty award. The James and JoAnn Holden Faculty Award recognizes outstanding faculty who inspire freshman and sophomore students through their willingness to teach, encourage and support students' transition into higher education.

Members of the Homer L. Dodge Department of Physics and Astronomy, May 2019. Photo by Hugh Scott.

Please consider making a donation to the Homer L. Dodge Department of Physics and Astronomy

Your donations to our General Fund are used to support such critical departmental activities as physics and astronomy conferences on the OU campus; high-profile colloquium speakers; programs for women and minorities; outreach; alumni reunions; faculty and student research; postdoctoral fellows; graduate research assistants; and newsletter publication. The two major immediate needs are the building and a buy-in to a national telescope. Remember, what you give to the department stays in the department. Go to https://www.nhn.ou.edu/friends-alumni/donate for details.

Nielsen Hall, home of the Homer L. Dodge Department of Physics and Astronomy

Foucault pendulum, located in the Nielsen Hall atrium, where tea is served each weekday from 3:30 to 4:00 pm.