

Graduate Studies in

Physics

and

Astronomy

at the University of Oklahoma

INTRODUCTION

The Department of Physics and Astronomy at the University of Oklahoma provides everything talented graduate students need to succeed: faculty members who are national and international leaders in scientific research, a well-designed graduate program that cultivates the skills needed in any technological career, and state of the art equipment for both experiment and theoretical work. This education is provided in the stimulating academic environment of the University, which has lively programs in Politics, the Humanities and Fine Arts. All of these activities take place in a state famous for its low cost of living, its beautiful Spring and Fall weather, and fascinating Native American heritage.

Our department has a relatively young, vigorous faculty of 28 scientists who function in four cohesive research groups: astrophysics; atomic, molecular, and chemical physics; high energy physics; and solid state and applied physics. We also have a program in the National Severe Storm Laboratory. We have a reputation as a department of faculty who are committed to excellence in both research and teaching. Our externally funded research expenditures are running over two million dollars a year and our publication rate is typical of nationally-ranked physics and astronomy departments.

Nearly a third of our faculty has received the prestigious Regents' Award for Superior Teaching at the University of Oklahoma, a truly remarkable record! In addition, our faculty members include a Sloan Fellow, two Fellows of the American Physical Society, four NSF Career award recipients, two State of Oklahoma Gold Medalists for Excellence in Teaching, four OU Presidential Professors, eight Regent's Award winners for Superior Research, an Outstanding Assistant Professor in the College of Arts and Sciences award winner, and one named professorship for excellence in teaching and one in research.

Collegiality is a hallmark of the Department: we have a daily tea, a weekly general colloquium, weekly seminars in our major fields of research, and a variety of social get-togethers. In short, we are a community of scholars. Come and join us!

*For more information see our Web page:
<http://www.nhn.ou.edu>*

THE DEPARTMENT

THE DEPARTMENT'S HISTORY

The Department of Physics and Astronomy has a long tradition in educating scientists, engineers, and science teachers who have distinguished themselves as researchers and leaders in industry and education.

Innovative education programs have been an integral part of this Department since its inception and are still its tradition:

- The Engineering Physics Program, which was the first of its kind when it was begun in 1924.
- The founding of the American Association of Physics Teachers and The American Journal of Physics in the 1930's.
- The New Avenues for Women Program, which was begun in 1971 and has led to a new and exciting way of teaching our freshmen physics.

Our graduates include the current Presidential Science Advisor, one president of a state university, one U. S. Ambassador, five founders of corporations, one famous Arctic explorer, the founder and first editor of The American Journal of Physics, three other journal editors, three inventors, seven research lab managers, seven departmental chairpersons, one Rhodes Scholar, two Guggenheim Fellows, 75 university professors, and more than 500 other people devoted to advancing knowledge and improving the quality of life.

RESEARCH FACILITIES

The Department of Physics and Astronomy, located in Nielsen Hall, includes a number of general research facilities available for use by all. A good in-house library, managed by full-time staff, houses the books and journals needed to support the research and teaching efforts of the Department. There are also ancillary library holdings in the Chemistry/Mathematics and Engineering libraries and in the internationally known History of Science Collection.

The Department maintains state-of-the-art computing facilities. It houses an eight node IBM SP2 parallel supercomputer, for exclusive use by OU researchers. This is supplemented by a network of over 30 UNIX workstations. Hardware and software upgrades are continuously being implemented by our full-time computer staff. On-line access is available to the NSF supercomputer network as well as other supercomputers for those groups with approved projects. Researchers also have access to supercomputer time at Livermore, San Diego, Los Alamos, Pittsburgh, and NCSA. The Natural Sciences Computer Lab houses 30 Pentium-based PC's; it is used for teaching and to meet students' routine computing needs.

There is a well-equipped and staffed in-house instrument shop. The shop staff have machining and designing experience with a wide variety of exotic materials and techniques. In consultation with researchers, they regularly produce state-of-the-art instrumentation. The instrument shop and a full-time electronics technician are available for maintenance and repair of all the Department's research instrumentation. A student shop is also available for less demanding work.

In addition to these general facilities, each research group maintains specialized laboratories and instruments. Construction is currently underway on a new annex that will significantly increase both lecture and laboratory facilities. In keeping with the Department's cooperative environment, individual researchers often borrow or share equipment within and between groups. The astrophysics and high-energy research groups also use the facilities of national observatories and laboratories. In-house research laboratories and instrumentation are discussed under each research group later in this brochure.

GRADUATE STUDIES

GRADUATE DEGREE PROGRAMS

Doctor's Degrees: All PhD degree programs require completion of a 21-hour sequence of core courses and at least 15 additional hours in advanced and specialty courses (listed on page 4). A written Qualifying and an oral and written Specialist Examination must be passed successfully. Formal course work, tailored to the needs of the individual student, is completed with 54 hours of elective courses, seminars, and research, and may include courses outside the Department. Finally, the results of an original body of research must be presented as a written dissertation and successfully defended in an oral Final Examination for the PhD degree. In general, well-prepared graduate students with assistantships spend five years working towards their degree. As their program progresses, they devote increasing amounts of time to research, which often begins as early as the first summer of graduate study.

PhD in Physics: The 36 hours of core, advanced, and specialty courses must be from offerings in the Department of Physics.

PhD in Physics (Astrophysics option): A minimum of 12 hours of the 36 hours of core, advanced, and specialty courses must be astrophysics courses at the graduate level.

PhD in Engineering (Engineering Physics option): At least 36 hours of course work in Physics must be completed, and the general requirements of the College of Engineering must be satisfied.

Master's Degrees: Master's degree programs require completion of 30 hours of courses and preparation of a thesis. Alternatively, 32 hours of course credit suffice for a non-thesis option. A well-prepared student with an assistantship will need a minimum of four semesters to complete the degree.

MS in Physics: Both thesis and non-thesis options are available. For the thesis option, 18 hours of course work from offerings in Physics are required. In the non-thesis option, 20 hours in Physics are required, and the written PhD Qualifying exam must be passed successfully.

MS in Physics (Astrophysics option): Only the thesis option is available. Of the required course work, 18 hours must be from offerings in Physics and Astronomy with no fewer than 6 hours in astrophysics courses.

MS in Engineering Physics: This degree is available under both thesis and non-thesis options. The written PhD Qualifying exam must be passed successfully for the non-thesis option. Each program requires that a significant part of the credit be in Engineering areas outside the Physics category.

DEGREE REQUIREMENTS

The first two years of graduate study usually focus on the required course work, in which a “B” or better must be achieved. A student in one of the PhD programs normally makes a first attempt at the written PhD Qualifying Examination after two semesters of graduate work (two attempts may be made). For thesis-option Master’s degrees, a research advisor must be chosen and a thesis topic selected. For a non-thesis Master’s degree, the written PhD Qualifying Examination must be completed.

Notwithstanding course work and examinations, the most important part of the PhD degree is research in pursuit of new knowledge. Faculty research interests are discussed with first-year students both collectively and individually. During the second year, students discuss research possibilities with faculty members whose interests overlap their own, and often contribute to on-going research.

Doctoral research is a new experience for many incoming graduate students. An ideal time to explore interests and to refine goals in the research setting are provided by the first and second summers of the graduate program. Such early laboratory or theoretical work is strongly encouraged by the Department, and it is often invaluable in assisting the student’s choice of a research advisor. Once this important decision is made, a potential dissertation topic is agreed upon and the student begins thesis research.

The student’s PhD program is outlined with the assistance of a PhD Advisory Committee, assembled by the student in cooperation with his or her advisor. Upon successful completion of the Specialist Examination, this committee is then reconstituted as the student’s Doctoral Committee. Meeting with the student at least once a year, the Doctoral Committee reviews progress and ensures a well-balanced program suitable to each student’s needs. The last step in completing the PhD degree is the final oral defense of the student’s dissertation, consisting of his or her own original research. After the dissertation has been written, and after the reading copy has been approved by the advisor and the Graduate College, the student’s Doctoral Committee schedules the final oral defense of the dissertation.

GRADUATE COURSES

Core Courses:

- Mathematical Methods in Physics
- Classical Mechanics
- Statistical Mechanics
- Quantum Mechanics
- Electrodynamics

Advanced Courses:

- General Relativity
- Quantum Field Theory
- Advanced Topics in Mathematical Methods

Specialty Courses:

- High-Energy Astrophysics
- Extragalactic Astronomy and Cosmology
- Stellar Atmospheres
- Stellar Interiors
- Interstellar Medium

- Atomic and Molecular Physics
- Advanced Atomic/Molecular Physics

- Nuclear and Particle Physics
- Advanced Particle Physics

- Solid State Physics
- Advanced Solid State Physics

Seminar Courses:

- Seminar on Astrophysics (Galaxy Formation; Compact Objects; Supernovae)
- Seminar on Chemical Physics
- Seminar on Nuclear and Particle Physics
- Seminar on Solid State Physics

LECTURES AND SEMINARS

Our permanent faculty is augmented by visiting professors, post-doctoral fellows, and weekly colloquium speakers. Supported by state monies and our own private endowment, the Department plays host to a number of visiting scientists each year. These people are extremely important to our instructional and research programs; their lectures bring the latest developments in their areas of interest to the attention of our students and faculty, and their visits present us with opportunities to exchange scientific ideas.

In addition to the general colloquium, there are seminars run by the research groups within the Department. The solid state physics and the atomic, molecular and chemical physics have weekly presentations. The high energy physics group's weekly seminars are shared with their colleagues at Oklahoma State University via compressed video. The astronomy and astrophysics groups run monthly public presentations and demonstrations of the observatory. There are also informal seminars that meet monthly on teaching, MATHEMATICA, and general topics in theoretical physics.

ASTRONOMY and ASTROPHYSICS

The members of the Astronomy and Astrophysics group are among the leaders of their chosen areas of research. We are one of the largest astrophysics groups within a physics department in the country. The research conducted in our group is interwoven and dynamic, with five focus areas that are complementary to each other.

Supernovae. Supernovae are the explosions of dying stars. Our group is among the top few internationally in supernova research. Baron and Branch are interested in understanding the systematics of how supernovae explode and what kinds of stars lead to what type of supernovae. Baron uses supernovae as a “laboratory” to study the properties of extremely dense matter, neutrino physics, and the initial conditions of progenitor stars. Baron and Branch study the spectra of the expanding supernova atmosphere to determine physical conditions and chemical abundances in the ejecta. Romanishin observes the brightness of a supernova as a function of time, which gives clues to the type of star that exploded, its distance, and the amount of radioactive nickel that was produced in the explosion. Cowan studies the expanding remnants of supernova explosions many years after the explosion has occurred by using the radio emission given off by the expanding shell. Henry studies the chemical composition of such supernova remnants. objects which represent the remnants of the very supernova explosions. We are setting up a “supernova spectrum repository” — a website at which any astronomer can view all of the supernova spectra that we gather from observers, and from which any of the SN spectrum data files can be extracted in a common format. This will make us the “headquarters” of supernova spectra.

Cosmology. The cosmological research in our group is anchored in observational data, and aims at gaining a deep understanding of our universe. Wang’s research focuses on using various independent cosmological data sets (cosmic microwave background anisotropy, galaxy redshift surveys, supernovae) to determine the cosmological parameters that describe our universe, to probe the physics of the very early universe, and to constrain the dark energy in the universe. Baron and Branch study the use of supernovae as distance indicators to remote galaxies in order to determine the age, size, and fate of the universe. Wang, Baron, and Branch study the systematic uncertainties of supernovae as cosmological probes.

Extragalactic Astronomy. Cowan studies properties of radio emitting galaxies such as our own, which may contain a black hole at its center. Henry studies the distribution of chemical elements in spiral galaxies such as our own, in order to study their origin and evolution. Leighly studies Active Galactic Nuclei (AGN). The ultimate power source for AGNs is thought to be accretion onto a supermassive blackhole. Her extensive program involves both observations in the X-ray and theoretical modeling. Romanishin studies various types of AGN as well, including quasars— the most powerful objects in the universe.

Nucleosynthesis. Henry studies the chemical abundances of a variety of emission line objects with the goal of understanding stellar production rates and subsequent cosmic accumulation of elements such as C, N, O, Ne, S, and Ar. Cowan studies cosmochronology and the chemical evolution of the Galaxy. He uses the history of radioactive elements in the oldest stars to study the age of our galaxy and to set limits on the age of the universe.

Observational Astronomy. Romanishin studies the Solar System, in addition to AGN and quasars. He is involved in a program to obtain colors and other photometric properties for faint minor bodies in the outer solar system, including Kuiper Belt Objects and irregular satellites of the Jovian planets. Leighly has an extensive background in techniques and methodology of X-ray observational astronomy. She has been awarded observational time on state of the art X-ray satellites. She has recently expanded her observational work to the optical as well. Cowan conducts observational studies of supernovae and supernova remnants. Branch and Baron are on key observational teams of supernovae. On the basis of scientific merit, our astronomers have significant access to the major ground and space observatories, including the Hubble Space Telescope and the Keck. We use our campus computer-controlled 16 inch (0.4 meter) telescope for student training and certain research projects.

Astronomy continues to be an exciting field with new ideas and new facilities emerging in the dawning year of the new millennium. We welcome the chance to work with motivated and qualified graduate students.

Edward A. Baron
Associate Professor
B.A. 1980 Pennsylvania
Ph.D. 1985 SUNY Stony Brook

I am interested in the physics of supernova explosions, as well as properties of neutron stars and galaxy formation. My research focuses on carrying out detailed theoretical models of the formation of supernovae, the nucleosynthesis that occurs in the supernova explosion, and the transport of radiation in the fast-moving supernova atmosphere. The tools of this research are detailed numerical calculations of both hydrodynamic and radiation transport, as well as detailed models of the nuclear, atomic, and weak-interaction physics that is needed as input for these calculations. Primarily I am interested in understanding the detailed systematics of how a supernova works, what types of stars lead to what types of supernovae, what is the variation in the energy of the explosion, and what are the characteristics of the object that is left behind. I am also interested in using supernovae as cosmological probes, to study the nature of the universe. Supernovae are fascinating systems to study, since all fields of physics are important to their understanding, and one is forever learning new things.

E. Baron, D. Branch, P. H. Hauschildt, A. V. Filippenko, and R. P. Kirshner, *Spectral Models of the Type Ic SN 1994I in M51*, Ap. J., (1999), **527**, 739–745.

E. J. Lentz, E. Baron, D. Branch, P. H. Hauschildt, and P. Nugent, *Metallicity Effects in NLTE Model Atmospheres of Type Ia Supernovae* Ap. J., **530**, (2000), 966–976.

A. Schweitzer, P. H. Hauschildt, and E. Baron, *Non-LTE Treatment of Molecules in the Photospheres of Cool Stars*, Ap. J., , (2000), submitted.

K. Hatano, D. Branch, E. Lentz, E. Baron, A. V. Filippenko, and P. Garnavich, *On the Spectroscopic Diversity of Type Ia Supernova*, Ap. J., (2000), submitted.

E. Baron, D. Branch, *et al.*, *Preliminary Spectral Analysis of the Type II Supernova 1999em*, Ap. J., (2000), in press.

E. J. Lentz, E. Baron, D. Branch, *et al.*, *Analysis of the Type II In Supernova 1998S: Effect of Circumstellar Interaction on Observed Spectra*, Ap. J., (2000), submitted.

E. J. Lentz, E. Baron, D. Branch, and P. H. Hauschildt, *SN 1984A and Delayed Detonation Models of Type Ia Supernovae* Ap. J. (Letters), (2000), submitted.

P. H. Hauschildt and E. Baron, *Numerical Solution of the Expanding Atmosphere Problem*, Jour. of Computational and Applied Mathematics, **109**, (1999) 41–63.

David R. Branch
George Lynn Cross Research Professor
B.S. 1964 Rensselaer
Ph.D. 1969 Maryland

I am working on the interpretation of the spectroscopic, photometric, and statistical properties of supernovae. One goal is to learn how to infer the physical conditions of the ejected matter - the temperature, density, velocity, chemical composition, and mass. By comparing this information with the predictions of theoretical explosion models, we try to find out which kinds of stars produce the various observed supernova types, and how they explode. A related goal is to use supernovae as distance indicators, to measure the expansion rate (Hubble constant), geometry, and expansion rate of the universe.

D. Branch, D. J. Jeffery, M. Blaylock, & K. Hatano, "*Supernova Resonance-Scattering Profiles in the Presence of External Illumination*", Publications of the Astronomical Society of the Pacific **112**, 217 (2000)

K. Hatano, D. Branch, A. Fisher, J. Millard, & E. Baron, "*Ion Signatures in Supernova Spectra*", Astrophysical Journal Supplement **121**, 233 (1999)

D. Branch, "*Type Ia Supernovae and the Hubble Constant*", Annual Review of Astronomy and Astrophysics **36**, 17 (1998).

K. Hatano, D. Branch, A. Fisher, & S. Starrfield, "*New Insight into the Spatial Distribution of Novae in M31*", Astrophysical Journal **487**, L45 (1997).

John J. Cowan

Professor

B.A. 1970 George Washington

Ph.D. 1976 Maryland

I continued my theoretical studies in nucleosynthesis, cosmochronology and the chemical evolution of the Galaxy. Working with one of my students, Debra Burris, we have used data from the Hubble Space Telescope, the Keck Telescope and Kitt Peak National Observatory to make a number of studies of the the formation of heavy elements in explosive environments such as supernovae and how these abundances have changed with time throughout the history of the Galaxy. Also, by comparing the observed and predicted abundances of the long-lived radioactive element in the oldest stars, we are determining the age of the Galaxy, and setting limits on the age of the universe.

I also continued my observational studies of supernovae and supernova remnants. Working with Chris Eck, another student, we have used the Very Large Array (VLA) radio telescopes to detect radio emission from decades-old, extragalactic supernovae, such as SN 1923A in the galaxy M83. This study of supernovae led to a project with another student, Chris Stockdale. We have used the ROSAT satellite to identify X-ray emission coming from the center of the galaxy NGC 7331. This X-ray source is associated with a previously detected central radio source, and may indicate the presence of a massive black hole (MBH) at the center of this galaxy.

C. Stockdale, W. Romanishin and J. J. Cowan, "Discovery of a Nuclear X-ray Source in NGC 7331: Evidence for a Massive Black Hole," *Astrophys. J. Letters*, **508**, L33 (1998)

J. J. Cowan, B. Pfeiffer, K.-L. Kratz, F.-K. Thielemann, C. Sneden, S. Burles, D. Tytler and T. C. Beers, "R-Process Abundances and Chronometers in Metal-Poor Stars," *Astrophys. J.*, **521**, 194 (1999)

J. Cowan, "Supernova Birth for a Black Hole," *Nature*, **401**, 124 (1999)

D. L. Burris, C. A. Pilachowski, T. Armandroff, C. Sneden, J. J. Cowan, and H. Roe, "Neutron-Capture Elements in the Early Galaxy: Insights from a Large Sample of Metal-Poor Giants," *Astrophys. J.*, in press (2000)

J. Westin, C. Sneden, B. Gustafsson and J. J. Cowan, "The r-Process Enriched Low-Metallicity Giant HD 115444," *Astrophys. J.*, **530**, 783 (2000)

C. Sneden, J. J. Cowan, I. I. Ivans, G. Fuller, S. Burles, T. C. Beers, and J. E. Lawler, "Evidence of Multiple r-Process Sites in the Early Galaxy: New Observations of CS 22892-052," *Astrophys. J. Letters*, **533**, L139 (2000)

C. Sneden, G. H. Smith, J. Johnson, R. P. Kraft, J. J. Cowan, and M. S. Bolte, "Neutron-Capture Element Abundances in the Globular Cluster M15," *Astrophys. J. Letters*, **536**, L85 (2000)

Richard C. Henry
Professor
B.A. 1977 Kansas
Ph.D. 1983 Michigan

My research emphasis is the study of the chemical evolution of spiral galaxies. Currently, I am most interested in the abundances of carbon, nitrogen, neon, sulfur, and argon, all as a function of time within spirals. The probes used for this work are planetary nebulae and HII regions. One focus of the planetary nebula studies is the determination of carbon and nitrogen abundances in planetaries, as this provides useful information for assessing the contributions that PN progenitor stars make to the galactic evolution of these two elements. Another focus involves the use of planetary nebulae as abundance probes to map the galactic distribution of elements such as Ne, Ar, and S, elements which are not processed by PN progenitors. Collaborators in these areas include Karen Kwitter (Williams College), Bruce Balick (U. of Washington), and Jackie Milingo (Gettysburg College). Projects using extragalactic H II regions as probes are intended to study heavy element distributions in external galaxies. On this topic work with Mike Edmunds (Cardiff University) is designed to identify and evaluate the important cosmic synthesis sites of the elements carbon and nitrogen, both of which may be forged in intermediate-mass as well as massive stars.

R.B.C. Henry and M.G. Edmunds, *On The Cosmic Origins of Carbon and Nitrogen*, Astrophysical Journal, Sept. 20 issue (2000).

R.B.C. Henry, K.B Kwitter, and J.A. Bates *A New Look At Carbon Abundances In Planetary Nebulae IV: Implications For Stellar Nucleosynthesis*, Astrophysical Journal **531**, 928 (1998).

R.B.C. Henry and Guy Worthey, *The Distribution of Heavy Elements in Spiral and Elliptical Galaxies*, Invited Review, Publications of the Astronomical Society of the Pacific, **111**, 919 (1999).

R.B.C. Henry, K.B. Kwitter, and R.J. Dufour *Morphology and Composition of the Helix Nebula*, Astrophysical Journal, **517**, 782 (1999).

Karen Leighly
Assistant Professor
B.S. 1983 NMIMT
Ph.D. 1991 Montana State University

Active Galactic Nuclei (AGN), recognized by their intense emission that vastly outshines the light of the stars in their host galaxy, are the most luminous persistently emitting object in the universe. My research has focused on a fundamental problem: I seek to understand the origin of their intense emission.

AGN are nearly universally believed to be powered by mass accretion onto a supermassive black hole. AGN emit nearly the same power per logarithmic energy band from infrared to X-rays, and observations at all wavelengths are valuable. My research has primarily focused on X-ray observations since both theoretical and observational evidence indicates that most of the X-rays are emitted very close to the black hole event horizon and therefore the X-rays tell us the most about the central engine of the AGN.

Recently, my work has focused on a subset of AGN known as Narrow-line Seyfert 1 galaxies (NLS1s). These objects were recently recognized to have X-ray emission properties distinct from those of ordinary AGN. The most promising explanation to date for their characteristic behavior is that NLS1s have a higher rate of accretion for their black hole mass compared with ordinary AGN. Since all AGN are thought to be powered by accretion, study of NLS1s, characterized by extremely large rates of accretion, may help us understand AGN emission in general.

One of the interesting things that we have found is that correlations among the X-ray spectral and variability properties of NLS1s exist. On one end of the correlations, typified by very high amplitude X-ray variability, are “extreme” NLS1s. Recently we have discovered that the UV spectroscopic properties of these extreme NLS1s are also characteristic. The observations suggest that in these objects the high-ionization UV emission lines are dominated by emission from an outflow from the nucleus. We postulate that the extreme NLS1s have the highest accretion rates among AGN.

K. M. Leighly and J. P. Halpern, “*HST STIS Ultraviolet Spectral Evidence of Outflow in Extreme Narrow-line Seyfert 1 Galaxies*”, The Astrophysical Journal, submitted.

D. Grupe, K. M. Leighly, H.-C. Thomas and S. A. Laurent-Muehleisen, “*The enigmatic soft X-ray AGN RX J0134.2-4258*”, Astronomy & Astrophysics **356** 11 (2000)

K. M. Leighly, “*A Comprehensive Spectral and Variability Study of Narrow-line Seyfert 1 Galaxies observed by ASCA. I. Observations and Time Series Analysis*”, The Astrophysical Journal Supplement Series **125** 297 (1999)

K. M. Leighly, “*A Comprehensive Spectral and Variability Study of Narrow-line Seyfert 1 Galaxies observed by ASCA. II. Spectral Analysis and Correlations*”, The Astrophysical Journal Supplement Series **125** 317 (1999)

K. M. Leighly, J. P. Halpern, H. Awaki, M. Cappi, S. Ueno and J. Siebert, “*An RXTE Observation of NGC 6300: A New, Bright, Compton Reflection-dominated Seyfert 2 Galaxy*”, The Astrophysical Journal **522** 209 (1999)

William J. Romanishin
Associate Professor
B.S. 1974 Harvard
Ph.D. 1980 Arizona

My research involves the application of optical CCD imaging of astronomical objects using various large and small telescope, along with associated image processing techniques, to a variety of astronomical topics.

Currently, my main topics of interest are: studies of the colors and other photometric properties of minor bodies in the outer solar system, including Kuiper Belt Objects and irregular satellites of the Jovian planets; the accurate measurement of the brightness of active nuclei in active galaxies, particularly those with low luminosity nuclei, where it is difficult to disentangle the light of the nucleus from the light of the host galaxy; study of photometric and astrometric properties of bright asteroids (using the campus telescope); and “target of opportunity” observations of supernovae, using telescope time scheduled for other projects, as well as the campus telescope. A common theme of these projects is to obtain accurate measurements of the observed brightnesses of various astronomical objects, frequently in the presence of contaminating background or foreground light sources.

S. C. Tegler and W. Romanishin, “*Red Snowballs on the Ragged Edge of the Solar System,*” NATURE , submitted July 2000.

W. Romanishin and S. C. Tegler “*Rotation Rates of Kuiper-belt Objects from Their Light Curves,*” NATURE **398**, 129 (1999).

S. C. Tegler and W. Romanishin, “*Two Distinct Populations of Kuiper Belt Objects,*” NATURE **392**, 49 (1998).

W. Romanishin, S.C. Tegler, J. Levine, and N. Butler, “*BVR Photometry of Centaur Objects 1995 GO and 1993 HA2,*” Astronomical Journal **113**, 1893 (1997).

W. Romanishin, T. J. Balonek, R. Ciardullo, H. R. Miller, B. M. Peterson, “*The Galaxy Component and Nuclear Flux Measurements of NGC 5548 from Direct Imaging,*” Astrophysical Journal **455**, 516 (1995).

Yun Wang
Assistant Professor
B.S. 1985 Tsinghua Univ., P.R. China
M.S. 1987 Carnegie-Mellon
Ph.D. 1991 Carnegie-Mellon

I am a theoretical cosmologist. My research is focused on using various independent cosmological data sets to gain a deep understanding of our universe. I have engaged myself in this through three complementary projects:

Cosmic microwave background anisotropy and large scale structure as probes of cosmology. The cosmic microwave background anisotropies (CMB) are signatures of the primordial seeds (matter density fluctuations) imprinted when photons decoupled from matter. The large scale structure in the distribution of galaxies is a direct consequence of the power spectrum of the primordial density fluctuations. I have explored how we can use the upcoming CMB data from the Microwave Anisotropy Probe (MAP) and the large scale structure data from the Sloan Digital Sky Survey (SDSS) to accurately measure the basic cosmological parameters, and the spectrum of primordial density fluctuations. My proposal of parametrizing the primordial power spectrum in a model-independent way will enable us to probe physics in the early universe, and to reliably extract the cosmological parameters simultaneously. The main question I will address in my future research is, how well can we *reliably* probe the early universe physics (in particular, inflation and phase transitions)?

Type Ia supernovae as probe of cosmology. Supernovae are our best candidates for cosmological distance indicators, they provide a unique probe of the dark energy in the universe (the nature of most of the energy in the universe is unknown). I have studied how we can more reliably and efficiently use type Ia supernovae as cosmological distance indicators to measure the cosmological parameters and to constrain the dark energy in the universe. My goal is to establish the potentials and limitations of the use of SNe Ia in cosmology.

Gravitational lensing as probe of cosmology. The images of background galaxies can be distorted by foreground distributions of mass into coherent arclets via gravitational lensing. This weak lensing of galaxies is a powerful tool for mapping the mass distribution in the universe. I am interested in using the weak lensing of galaxies to constrain fundamental cosmological models.

I believe that our understanding of the universe will be significantly enhanced in the next several years. I am very excited to be an active participant in the very dynamic field of cosmology.

Yun Wang and Peter Garnavich, "Measuring Time-Dependence of Dark Energy Density from Type Ia Supernova Data", *ApJ* submitted (2000).

Yun Wang, "Flux-averaging Analysis of Type Ia Supernova Data", *ApJ* **536**, 531 (2000).

Yun Wang, "Supernova Pencil Beam Survey", *ApJ* **531**, 676 (2000).

Yun Wang, David N. Spergel, and Michael Strauss, "Cosmology in the Next Millennium: Combining MAP and SDSS Data to Constrain Inflationary Models", *ApJ*, **510**, 20 (1999).

ATOMIC, MOLECULAR, and CHEMICAL PHYSICS

The Atomic, Molecular, and Chemical Physics group focuses on interactions of atoms, molecules, electrons and photons at low temperatures and low energies, on the order of the binding energies of valence electrons and of chemical bonds. Our programs include both experimental and theoretical projects, many of which entail collaborations within and outside the Department. Combining expertise in several areas of atomic, molecular, and optical physics with an emphasis on chemical physics, our group offers a breadth and range rarely found in either Chemistry or Physics Departments. Recent additions to our group include Eric Abraham and Neil Shafer-Ray. Eric's experimental program in the physics of atoms and molecules at ultracold temperatures, including Bose-Einstein condensates. Neil's experimental program investigates highly controlled scattering of atoms and molecules.

Current specific research areas include chemical reaction dynamics (theory and experiment), the physics of ultra-cold atoms and molecules, including Bose-Einstein condensation (theory and experiment), highly excited states of atoms and molecules including Rydberg states (theory and experiment), low-energy elastic and threshold inelastic scattering of charged particles (theory), orientation and alignment effects (theory and experiment), the determination of potential energy surfaces (theory and experiment), and the study of atoms in magnetic and optical fields (theory and experiment). These programs benefit from ongoing collaborations between experimentalists and theoreticians here at OU, around the country, and around the world.

Our experimental facilities include two complete molecular-beams scattering apparatuses for the study of energy transfer and chemically reactive collisions. Both machines use very sensitive detection of molecules in individual quantum states to probe in detail the dynamics of a molecular collision. Additional experiments use laser probes to study the dynamics of reactions and energy transfer processes, and novel optical traps to cool atoms to ultra-cold temperatures. These experiments complement ongoing theoretical work in electron-molecule collisions, near-resonant energy transfer of Rydberg atoms, dimensional perturbation theory, doubly-excited states of atoms, atoms in magnetic fields, and Bose-Einstein condensation. Our computational facilities include an extensive network of powerful computer workstations, which are freely shared among members of the Department, and an SP-2 super computer. These facilities are used in several experimental contexts and in theoretical research such as ongoing study of processes fundamental to combustion and of CPU-intensive reactive scattering processes.

Since its inception, our group has been regularly funded by such sources as the National Science Foundation, the American Chemical Society, the Office of Naval Research, and the Air Force Office of Scientific Research. We are also pursuing collaborations with local industries. In addition, various members of the group participate in long-term collaborations with scientists from Italy, Australia, Switzerland, Canada, Germany, Israel, Latvia, the United Kingdom, and various laboratories and universities in the U.S. A highlight of the program is a regular, intensive program of visits and colloquia by outside members of the atomic, molecular, and chemical physics community, including our many collaborators.

Eric Abraham
Assistant Professor
B.A. 1991 St. Olaf College
Ph.D. 1996 Rice University

The goal of our research program is to investigate Bose-Einstein condensation of atomic gases, to develop new atom interferometric techniques, to create more accurate and precise atomic clocks, and to trap and study ultracold molecules. We use a variety of lasers and magnetic fields that can cool atoms to a range of temperatures colder than anything else in the known universe (between 10 nanoKelvin and 100 microKelvin.) At these temperatures, the wave-like nature of atoms is enhanced allowing studies of the exotic, quantum-mechanical nature of matter.

Over 70 years ago, Albert Einstein predicted that a gas of non-interacting particles could undergo a phase transition, collecting a macroscopic number of particles into the same quantum state. The gas must be cooled to where the de Broglie wavelengths of the individual atoms overlap. This concept of Bose-Einstein condensation has since been an integral part of the understanding of strongly interacting systems such as superfluids and superconductors. However, BEC in dilute atomic gasses more accurately approximates Einstein's original prediction for non-interacting particles.

Atom interferometry also exploits the wave-like characteristics of matter. In the past few years the field of atom optics has established techniques to manipulate the de Broglie wave of atoms just as light is controlled with conventional optics. Atom interferometers have emerged as powerful tools for fundamental physics measurements (e.g. fundamental constants) and possible technological applications (e.g. rotation sensors for navigation.)

Another area of investigation with practical applications is to improve current atomic clocks. Atomic clocks are important to a wide range of scientific research (astronomy and tests of general relativity) as well as commercial and governmental applications (communications, global positioning systems, and deep space navigation.) While laser cooling and trapping techniques have produced a revolution in atomic physics, it is limited to a few atoms. We hope to extend ultracold trapping techniques to molecules.

This work is a solid combination of both optical and atomic physics. We use semiconductor diode lasers with the latest in optic, fiber optic, acoustic-optic and electro-optic technology. The experiments use Rubidium atoms and take place in ultra-high vacuum at pressures as low as 10^{-11} Torr, and utilize state-of-the-art, as well as home-built, microwave, rf, and DC electronics.

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E.R.I. Abraham, W.I. McAlexander, C.A. Sackett, and R.G.Hulet, "*Spectroscopic Determination of the s- Wave Scattering Length of Lithium*", Physical Review Letters **74**, 1315 (1995).

Michael A. Morrison
David Ross Boyd Professor
B.S. 1971 Rice University
Ph.D. 1976 Rice University

For over two decades, my research group has investigated a wide range of problems in quantum collision theory. Much of our work has explored low-energy scattering of electrons (and positrons) by diatomic molecules, exploring such diverse topics as non-local and many-body interactions such as exchange and correlation, new dynamical theories for near-threshold excitations, model potentials suitable for calculations on large, complex systems, and the determination of accurate cross sections needed for applications such as laser kinetic modeling and the study of planetary atmospheres. In addition, we have worked on multi-step laser excitation of atoms, orientation and alignment effects in electron-atom scattering, and collisions of Rydberg atoms with rare-gas atoms. Typically, we choose problems that entail a blend of formal mathematics and quantum mechanics, numerical algorithms and their computational implementation, and analysis of experimental data.

Our current research includes theoretical studies of dissociative attachment, the extension of density functional theory to bound-free correlation effects in continuum states in electron scattering, and joint experimental/theoretical studies of Rydberg-atom-rare-gas scattering (with Neil Shafer-Ray), of $e - CO_2$ scattering (with Stephen Buckman of the Australian National University), and of laser cooling and trapping (with Eric Abraham).

Vital to our program are our vigorous, continuing collaborations with experimental and theoretical physicists at a variety of institutions, including the Australian National University, the University of Kentucky, the Joint Institute for Laboratory Astrophysics, IBM Research Laboratories, and the Los Alamos National Laboratory. These projects often entail visits of members of our group to other institutions and *vice versa*.

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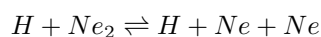
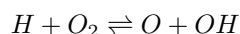
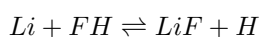
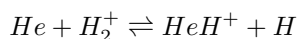
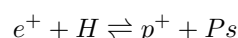
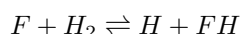
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Gregory A. Parker
Professor
B.S. 1973 Brigham Young University
Ph.D. 1976 Brigham Young University

Chemical reactions dynamics is challenging intriguing and at the forefront of chemical physics. I am interested in accurately solving the time-dependent and time-independent quantal Schrödinger equation for reactive and nonreactive processes.

Over the past decade our research has contributed significantly to the current understanding of reactive scattering. One of the first things found in early one-dimensional reactive scattering calculations were quantum resonances (long-lived collision complexes) that can dramatically affect the reaction probabilities. With new methods developed by ourselves and others, it is now possible to do calculations for triatomic systems of real physical interest. It is becoming clear that quantum resonances dominate many if not most systems in the full three-dimensional space. These quantum resonances are system-specific and very sensitive to the potential energy surface and any approximations made, so the only way to really understand them is *via* accurate quantum dynamics.

Some of the systems of particular interest to us are:



As the last reaction suggests we are currently developing methods for treating three-body recombination processes and collision induced dissociation.

I enjoy interactive collaborations with the experimental group of Professor Neil Shafer-Ray. We can calculate center-of-mass and laboratory cross sections for direct comparison with their experimental observations. Since the interplay between experiment and theory is mutually beneficial it is a real opportunity to have an excellent experimental group in our department with which to collaborate. We also have productive collaborations with theorists at Los Alamos National Laboratory, University of Houston and the University of Perugia, Italy and of course here at OU with Professor Michael A. Morrison.

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Neil Shafer-Ray
Assistant Professor
B.S. 1986 M.I.T.
Ph.D. 1990 Columbia

Our group has recently devised, constructed, and demonstrated an apparatus that explores reactive scattering dynamics with a new level of precision and control. Specifically, we have the ability to measure state-to-state and scattering-angle dependent cross sections of reactive scattering processes. Our apparatus is unique in its ability to continuously tune the collision energy with milli-electron volt resolution. We are using this apparatus to search for highly structured energy-dependent cross sections that would result from long-lived collision complexes (dynamical resonances) occurring in chemical reactions.

Our group is also interested in near-resonance energy transfer that occurs when an excited Rydberg atom collides with a rare-gas atom. Recently Michael Morrison and coworkers have created quantum models of this process that show strongly structured energy-and-alignment dependent cross sections. We are currently planning to measure the energy-dependent cross section for the process $He(18d) + Xe \rightarrow He(19p) + Xe$ to test these exciting predictions.

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N.E. Shafer-Ray, R.N. Zare, "Measurement of Rapidly Varying Electric Fields Through Parity Oscillations in the Rydberg States of Hydrogenic Atoms", *Applied Physics Letters* **69**, 3749 (1996).

Deborah K. Watson
Professor
B.S. 1972 Allegheny College
Ph.D. 1977 Harvard

My group is engaged in the study of fundamental quantum mechanical questions for both simple atomic systems such as helium and most recently for Bose-Einstein condensates. Specifically, we are trying to address these questions using a method called dimensional perturbation theory, in which the Schrödinger equation is solved in an arbitrary number of dimensions. Our philosophy stems from the notion that, just as the two-dimensional world is easier to understand from the perspective of three dimensions, so we believe that we can gain insight into our three-dimensional world using the perspective of higher dimensions. We are presently pursuing several studies, including a detailed look at states of helium as a function of dimension D including the group-theoretic basis for inter-dimensional degeneracies, a study of diamagnetic hydrogen including Rydberg states, and an analysis of properties of Bose-Einstein condensates using trap parameters that approximate current experimental conditions at various laboratories. Our Bose-Einstein work is exploring ways to go beyond the mean field approximation, known as the Gross-Pitaevskii equation, to bring in many-body effects.

Dimensional perturbation theory has thus far been the source of some surprising insight into the dynamics of few-body systems, including electron geometry, classification of doubly-excited states, patterns in helium spectra, and should provide a unique vantage point from which to analyze Bose-Einstein condensation.

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D.K. Watson, M. Dunn, T.C. Germann, D.R. Herschbach, D.Z. Goodson, and J.R. Walkup, "*Dimensional Expansions for Atomic Systems*", *New Methods in Quantum Theory*, edited by C.A. Tsipis, V.S. Popov, D.R. Herschbach, and J. Avery, NATO Conference Book **8**, Kluwer Academic, Dordrecht Holland, p. 83.

HIGH ENERGY PHYSICS

The High Energy Physics group consists of four faculty experimentalists and two faculty theoreticians, several postdoctoral research fellows, and a number of graduate students. Funding for both experimental and theoretical efforts are supported by the Department of Energy and considerable University support.

The goals of the experimental high energy physics group are to search for new physics and to explore the predictions of the Standard Model to unprecedented accuracy. In order to perform this research, we are involved in the $D\bar{0}$ experiment at Fermilab, the CLEO experiment at the Cornell Electron Synchrotron Ring (CESR) and the ATLAS experiment at the Large Hadron Collider (LHC) at CERN. $D\bar{0}$ and CLEO are located at national research facilities which are currently collecting data, while the ATLAS experiment, located at an international research facility, is scheduled to begin taking data in the year 2005. In addition to these three large research collaborations, we are also performing a search for low mass monopoles at the University of Oklahoma (OU).

The $D\bar{0}$ experiment is situated at the Fermilab Tevatron, which produces the highest energy particle collisions in the world. The collisions between the counter-rotating protons and anti-protons allow us to study the strong (QCD) and electroweak interactions through the decays of the produced particles and through their measured angular distributions. Some of the recent results from the $D\bar{0}$ experiment include the discovery of the top quark, a precision measurement of the W mass, and gluon radiation interference effects. In addition, numerous searches for new particles, new forces and discrepancies with the Standard model are all been carried out. A new upgrade is now complete which will greatly enhance the detector's ability. This provides an excellent opportunity over the next few years for new physics discoveries at one of the premier detectors in the world.

The primary focus of the CLEO experiment is to measure properties of the b-quark and its interactions with other fundamental particles of the standard model. Both the production and subsequent decay of particles containing a b-quark are studied, providing deeper understanding of the strong interaction, the weak interaction, and the quantum interference between these two forces.

A search for magnetic monopoles is currently being conducted by a small group of collaborators here at OU. Monopoles created in high energy collisions at the Fermilab Tevatron could be trapped in the detector material surrounding the collision point. We have obtained some of that material and are looking for monopoles using a Superconducting Quantum Interference Device (SQUID) detector. The first run has yielded monopole mass limits on the order of 300 GeV, some three times higher than previous limits for direct searches of accelerator produced monopoles.

Besides the direct physics research, we are also involved in state-of-the-art detector development for $D\bar{0}$, CLEO and the ATLAS experiment. This program, which uses our own facilities at OU, focuses on advanced silicon micro-strip detectors. The excellent position resolution of silicon allows identification of short lived particles and allows us to measure their properties.

The theoretical group is studying non-perturbative aspects of quantum field theory (QFT) and gauge theories. QFT is the basic framework for the description of particle physics, as well as for many other areas of physics. The calculations required today to solve field theories cannot be done by considering relatively small corrections (perturbations) to non-interacting theories of quarks and gluons, for example. In particular, non-perturbative methods are essential to understand the phenomena of strong interactions. Thus new mathematical methods are required, some of which are being developed in our group. In addition to developing new types of perturbative expansions and approximation methods, as well as studying new types of quantum field theories, analytical calculations are being applied to a number of important particle physics topics: quantum chromodynamics (particularly the nature of the running strong coupling constant), quantum electrodynamics, the Casimir effect (vacuum fluctuations) and its applications (to condensed-matter systems, high energy physics, and cosmology), glueballs, Kaluza-Klein theories, topological field theories, and quantum gravity. In addition, new theoretical work on magnetic monopole production and binding is being carried out.

Brad Abbott
Assistant Professor
B.A. 1989 University of Minnesota, Morris
Ph.D. 1994 Purdue University

My research in experimental particle physics has been primarily in two major areas. Recently I was involved in the BaBar experiment at the Stanford Linear Accelerating Center located near the Stanford campus. I was involved in building and commissioning a state of the art silicon vertex tracker for BaBar. This detector was constructed of double sided 300 micron thick silicon with a custom designed radiation hard readout chip. The silicon detector allows the vertices of short lived particles to be determined very accurately, a necessity for studying CP violation. My primary physics interest is working on B physics in order to better understand CP violation. I have been involved in B-mixing studies which, along with $B \rightarrow J/\Psi K_S$, provide a measure of the angle β for the Unitarity triangle.

I have also worked on many analyses studying Quantum Chromo Dynamics (QCD) at the D0 experiment at Fermi Lab. Fermilab, located near Chicago, is the highest energy accelerator in the world. With such high energy, one can probe very small distance scales to search for new physics. My analyses were designed to look for quark sub-structure and to test the current theoretical understanding of QCD.

The new, recently upgraded D0 detector will allow us the opportunity to further exploit the highest energy accelerator in the world. With a new silicon tracker, D0 will be able to explore B physics at unprecedented energies. The next few years will be very exciting as D0 will provide one of the best opportunities available to discover new physics.

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The Inclusive Jet Cross Section in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV, B. Abbott et. al, Phys. Rev. Lett. 82, 2451 (1999); Fermilab-Pub-98/207-E; hep-ex/9807018.

Phillip Gutierrez
Associate Professor
B.S. 1976 University of California–Riverside
Ph.D. 1983 University of California–Riverside

Over past 20 plus years, I have carried out research in experimental high energy physics. The research has taken place at two of the premier high energy physics laboratories in the world, Fermilab near Chicago, and the CERN laboratory near Geneva Switzerland. Currently I am a member of the DØ collaboration, one of two research groups that uses the Fermilab Tevatron, the world's highest energy particle collider. The goal of the research is to study all aspects of proton anti-proton collisions. This includes studying particles that are produced in these collisions, such as the recently discovered top-quark, refining previous measurements to set limits on how well the standard model of particle physics agrees with data. These measurements will ultimately lead to extensions of the standard model, which should help answer such questions as the origin of mass, the asymmetry between matter and anti-matter in the universe, among many others.

At present I am participating in upgrading the current DØ detector, to improve its charge particle detecting capabilities. This includes work with other members of the University of Oklahoma group in developing a silicon vertex detector. I am also participating, along with my current graduate students, in several physics analysis that involve QCD (strong interactions) and electroweak interactions (search for a charged Higgs boson).

For the future, I will be participating in the Large Hadron Collider at the CERN laboratory. This will extend the research that I am currently carrying out at Fermilab.

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S. Abachi... P. Gutierrez... (DØ Collaboration) “*Direct Measurement of the Top Quark Mass*”, Physical Review Letters **79**, 1197 (1997).

Ronald Kantowski
Professor
B.S. 1962 Texas
Ph.D. 1966 Texas

My current interests are in cosmology and effective actions for certain topological quantum field theories and Kaluza-Klein spaces.

I have recently been working on the quantitative effects of mass inhomogeneities on determinations of the cosmological parameters. With collaborators I have found analytic expressions for the Hubble curve for partially filled beam observations in standard cosmology.

With collaborators I am also using the background field method to compute effective actions for certain topological quantum field theories and Kaluza-Klein spaces. To ensure gauge independence of our loop expansions, we have found it necessary to use the effective action of Vilkovisky-DeWitt.

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Chung Kao
Assistant Professor
Ph.D 1990 University of Texas

My research interests are in theoretical high energy physics, astrophysics and cosmology, especially: Electroweak Symmetry Breaking (EWSB), Supersymmetry, Unification of Fundamental Interactions, CP Violation, Dark Matter, and Theories with Extra Dimensions. One of the most important goals of future colliders is to discover the Higgs bosons or to prove their nonexistence. In the Standard Model of electroweak interactions, the Higgs field condenses (disappears into the vacuum), spontaneously breaking the electroweak symmetry and generating masses for the elementary particles. Weak scale supersymmetry is the most compelling extension of the Standard Model to preserve the elementary nature of the Higgs bosons. In most supersymmetric models, the lightest neutralino can be a good cold dark matter candidate if R -parity is conserved. Recently, I have been investigating direct and indirect signatures of new physics in present and future experiments to pursue interesting physics of electroweak symmetry breaking, supersymmetry, CP violation and astrophysics.

Trilepton Signature of Minimal Supergravity at the Upgraded Tevatron, [with V. Barger], Phys. Rev. **D60**, 115015 (1999) [hep-ph/9811489].

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Kimball A. Milton
Professor
B.S. 1967 University of Washington
Ph.D. 1971 Harvard

The interactions that give rise to the structure of atoms, nuclei, and elementary particles are described by quantum gauge field theories. These gauge theories are Abelian in the case of electrodynamics (photons do not interact directly with each other), and are non-Abelian in the case of chromodynamics, the theory of the strong subnuclear force (gluons couple directly with each other). These theories are mostly understood in the weak-coupling regime, where perturbation theory may be applied.

I am primarily interested in developing nonperturbative methods for use in quantum field theories and gauge theories. The programs under active development include the quantum finite-element lattice method, variational perturbation theory, the delta (or logarithmic) expansion applied to symmetry breaking, analytic perturbation theory, and non-Hermitian PT (parity–time-reversal) symmetric theories. Applications are being made to quantum electrodynamics and quantum chromodynamics. Vacuum energy phenomena (the Casimir effect) are being studied in contexts ranging from cosmological to condensed matter systems (Chern-Simons, sonoluminescence).

New theoretical work on magnetic monopole production and binding is being carried out in connection with an experimental search for monopoles possibly produced at Fermilab.

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K. A. Milton and I. L. Solovtsov, “*Can the QCD Effective Charge Be Symmetrical in the Euclidean and Minkowskian Regions?*” Phys. Rev. D **59**, 107701-1–2 (1999).

K. A. Milton, A. V. Nesterenko, and V. V. Nesterenko, “*Mode-by-Mode Summation for the Zero Point Electromagnetic Energy of an Infinite Cylinder*,” Phys. Rev. D **59**, 105009-1–9 (1999).

I. Brevik, V. N. Marachevsky, and K. A. Milton, “*Identity of the van der Waals Force and the Casimir Effect and the Irrelevance of these Phenomena to Sonoluminescence*,” Phys. Rev. Lett. **82**, 3948–3951 (1999).

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C. M. Bender and K. A. Milton, “*A Nonunitary Version of Massless Quantum Electrodynamics Possessing a Critical Point*,” J. Phys. A: Math. Gen. **32**, L87–L92 (1999).

Patrick Skubic
Professor
B.S. 1969 South Dakota State
Ph.D. 1977 Michigan

My area of research is experimental elementary particle physics. My present interest in this field is in experiments which produce particles containing the heavy “bottom” or “beauty” quark (“bottom-flavored” particles). I also have a strong interest in the development of semiconductor detectors for use in high-energy physics experiments, and I am currently involved in several major efforts in the continued development of these detectors.

I am currently involved in an electron-positron colliding beam experiment at the Cornell Electron Storage Ring (CESR). This experiment has been collecting data since 1979, and has produced the world’s first direct evidence for the existence of “bottom-flavored” particles. The experiment uses a large multi-purpose detector called CLEO. It consists of a superconducting solenoid magnet 1 meter in radius surrounded by detector elements which can measure the trajectories of charged and neutral particles. Particles which contain the bottom quark (B mesons) are produced by collisions between electrons and positrons. This process of matter-antimatter annihilation is very useful in producing heavy quark pairs. (Since the “bottomness” quantum number is conserved in strong nuclear interactions, the bottom quarks are produced in pairs.) One goal of the experiment is to investigate symmetry (CP) violation by B mesons as a probe of the fundamental nature of the nuclear force. We have recently observed rare decays of the B meson in which such symmetry violations could occur.

I have also worked within the Department’s high-energy group on the development of semiconductor pixel detectors for a future experiment called ATLAS. This experiment is under construction at the European particle physics laboratory CERN located in Geneva, Switzerland. It is a multipurpose detector to study collisions between protons. A major goal of ATLAS is to discover the Higgs particle, which is thought to be responsible for the generation of the masses of other particles according to current theory. One possible decay mode of the Higgs particle is to four b quarks so our experience with bottom physics may prove useful in detecting the Higgs. The pixel detectors we are developing will be the detector elements closest to the collision point and will provide the best position measurement for charged particles produced in the collision.

A. Anastassov, ... P. Skubic, ..., “*First Observation of the Decay $B \rightarrow J/\Psi\Phi K$* ”, Physical Review Letters **84**, 1393 (2000).

J.P.Alexander, ... P. Skubic, ..., “*Measurement of $B \rightarrow \rho\nu$ decay and $|V_{ub}|$* ”, Physical Review D **61**, 052001 (2000).

Michael Strauss
Assistant Professor
B.S. 1981 Biola University
Ph.D. 1988 University of California, Los Angeles

I am currently a member of the DØ collaboration doing research in Experimental Particle Physics using the Tevatron collider at the Fermi National Accelerator Laboratory. The Tevatron, which produces the highest energy particle collisions in the world, is an excellent instrument for testing the predictions of the Standard Model of elementary particles and fields and to look for experimental deviations from those predictions. My recent research has focused on testing various properties of Quantum Chromodynamics (QCD), particularly

the properties of the gluons within the proton.

The Tevatron is entering a new and exciting era with the completion of the Main Injector and significant upgrades to the DØ detector. With a higher luminosity and a higher center-of-mass energy, we have a possibility of discovering new phenomena which may extend or supersede the Standard Model. Studies indicate that answers to fundamental questions about the nature of mass and the asymmetry between matter and antimatter may be discovered in the near future at high energy physics laboratories.

I have also been involved in testing and developing various silicon microstrip detectors used for finding particle tracks in the DØ upgrade. For years, the University of Oklahoma has been a leader in the utilization of silicon devices for high energy physics detectors and we plan on continuing this effort for the ATLAS experiment currently being built for the LHC.

With the DØ upgrade in the near future, and the ATLAS experiment coming on line soon after that, the future potential for the discovery and observation of new and interesting phenomena in the field of elementary particles and fields looks extremely promising.

B. Abbott, . . . M. Strauss, . . . (DØ Collaboration) "*The Isolated Photon Cross Section in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8 \text{ TeV}$* ", Physical Review Letters **84**, 2786 (2000).

B. Abbott, . . . M. Strauss, . . . (DØ Collaboration) "*The Inclusive Jet Cross Section in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8 \text{ TeV}$* ", Physical Review Letters **82**, 2451 (1999).

B. Abbott, . . . M. Strauss, . . . (DØ Collaboration) "*Search for Charged Higgs Bosons in Decays of Top Quark Pairs,*", Physical Review Letters **82**, 4975 (1999).

B. Abbott, . . . M. Strauss, . . . (DØ Collaboration) "*Direct Measurement of the Top Quark Mass at DØ,*" *DØ Collaboration*", Physical Review **D58**, 52001 (1998).

SOLID STATE and APPLIED PHYSICS

When a large number of particles condense into a fluid or solid, properties (e.g. conductivity or magneto-resistance) and behaviors (like vortices or excitons) emerge that are only indirectly related to the physics of the individual atoms. In Solid State and Applied Physics we not only measure and explain such emergent phenomena, we try to design materials and devices to have the ones we desire. This allows us both to investigate fundamental physics and to develop commercially important applications.

A student in Solid State and Applied Physics must have a thorough understanding of both the microscopic quantum mechanics that underlies the system and the classical macroscopic theories of mechanics, electromagnetism, and statistical mechanics that describe its large scale behavior. This broad background enables students to go on to careers in academia, governments labs, and industry.

Our group focuses on the properties of highly confined electron systems in artificially structured semiconductors. We cover all aspects, from fundamental theory to device fabrication. The experimental emphases are growth of novel materials by molecular beam epitaxy, characterization and nanolithography using scanning probe microscopy (SPM), electrical and optical properties at cryogenic temperatures and in high magnetic fields, and fabrication of microelectronic devices. Theoretical work concentrates on electron-electron interaction effects, electronic band structure of the confined systems, and hot-electron transport and magnetotransport in confined electron systems. Recent successes include the discovery of the two-dimensional metal-insulator transition, and the growth of InSb-based structures with the world's record for room-temperature mobility in semiconductor quantum wells. In addition to this effort in semiconductors, the group also has research efforts in superfluid helium, and in lithium ion conducting polymers.

This research takes place in the department's state-of-the-art laboratories. A dual-chamber molecular beam epitaxy (MBE) system produces artificially structured semiconductors based on the narrow-gap materials InSb and PbTe. These samples and materials obtained from external collaborators are characterized through surface analysis techniques (RHEED, Auger electron and x-ray photoelectron spectroscopies, UHV SPM), high-resolution x-ray diffraction, and cross-sectional SPM. Devices are fabricated in our new cleanroom, which has a host of fabrication, inspection, and characterization tools. Low-temperature experiments are carried out in various cryogenic systems (including a He³ dewar and a dilution refrigerator) with several superconducting magnets (to 17 tesla). A far-infrared laser and a Fourier transform spectrometer are used for optical experiments.

Many of our group participate in the Center for Semiconductor Physics in Nanostructures. CSPIN, one of the National Science Foundation's few Materials Research, Science and Engineering Centers, is a multi-million dollar, interdisciplinary research collaboration between scientists at the University of Arkansas and the University of Oklahoma. Center participants study ways to fabricate small semiconductor structures, via spontaneous assembly and selective area growth, as well as more traditional techniques. They also determine the optical and electronic properties of these structures, and how best to incorporate them into useful devices.

The faculty in the Solid State and Applied Physics group are also in the Engineering Physics Program. The engineering physicist provides the link between the pure scientist and the engineer by applying fundamental scientific theories to the solution of technological problems. As the miniaturization of transistors, lasers, and memory elements continues, an understanding of their operation increasingly requires knowledge of the underlying physics. This trend will only continue in the foreseeable future.

For latest summary of research interests and recent publications, visit our web site at: <http://www.nhn.ou.edu/ouresearch/2solid.htm>.

Ryan E. Doezema
Professor
B.A. 1964 Calvin College
Ph.D. 1971 Maryland

My research interests center on the magneto-electronic properties of semiconductors. The work is focused on the lower-dimensional electron systems formed in synthetically created quantum wells and superlattices. Photonic transitions between quantum levels in the wells, and between magnetic levels induced by strong external magnetic fields, are studied using both a far-infrared, optically-pumped laser system as well as a Fourier transform infrared spectrometer. Our goals include the determination of electron dispersion as well as relaxation processes.

We are especially interested in novel properties of quantum-well systems caused by band structure effects such as mass-mismatch and extreme non-parabolicity. Our work is made possible by the flexibility for designing quantum-well systems with the MBE system as part of the Center for Semiconductor Physics in Nanostructures (C-SPIN). Our experiments concentrate on the narrow-gap system InSb which, as a quantum well material, shows much promise for infrared and laser devices. We have been able to determine the defining characteristics of the binding potentials for these quantum wells (gap mismatch and band offset). Especially exciting is our recent observation of spin resonance in this system and, in asymmetric wells, evidence of spin splitting in zero magnetic field because of strong spin-orbit coupling.

N. Dai, F. Brown, R.E. Doezema, S.J. Chung, K.J. Goldammer, and M.B. Santos, "Determination of the Concentration and Temperature Dependence of the Fundamental Energy Gap in $\text{Al}_x\text{In}_{1-x}\text{Sb}$," *Appl. Phys. Lett.*, **73**, 3132 (1998).

N. Dai, G.A. Khodaparast, F. Brown, R.E. Doezema, S.J. Chung, and M.B. Santos, "Band Offset Determination in the Strained-Layer InSb/ $\text{Al}_x\text{In}_{1-x}\text{Sb}$ System," *Appl. Phys. Lett.* **76**, 3905 (2000).

G.A. Khodaparast, S.J. Chung, R.E. Doezema, and M.B. Santos, "Energy Probe of the Rashba Spin Splitting in Heterostructures," submitted for publication.

John E. Furneaux
Professor
B.S. 1969 U.S. Military Academy
Ph.D. 1979 Berkeley

I am interested in the low-temperature electronic properties of semiconductors - particularly artificially structured semiconductors prepared with molecular beam epitaxy (MBE) and/or photo-lithography. I have concentrated on those properties that involve large magnetic fields.

The major tool for my experimental program is a state-of-the-art superconducting magnet system (to 17 tesla) with a top-loading dilution refrigerator capable of reaching 0.01 K (in collaboration with Professor Murphy), which is optimized and modified for far-infrared spectroscopy (FIR). The FIR sources are a CO₂-pumped molecular gas laser (in collaboration with Professor Doezema) and a Fourier transform interferometer.

We are currently pursuing studies of the interesting properties of ultra-high mobility Si MOSFETs and of the fractional quantum Hall effect. I am also involved in FIR spectroscopy of a number of semiconductor systems including PbTe, other IV-VI compounds, InSb layers produced in the MBE machine, GaAs hetero-structures, and MOSFETs produced in Si and SiGe hetero-structure systems.

I have begun a new effort in lithium ion conducting polymers in collaboration with Professor Frech in Chemistry. We are particularly interested in the interactions between the polymer and the ion conducting salt that can provide insight as to the mechanisms of Li ion diffusion. We are studying these properties by combining two newly available technologies, a state-of-the-art tunable pulsed laser system including an optical parametric oscillator (OPO), and a step-scan FTIR. Other studies of Li polymer batteries are being pursued in parallel with this effort.

J. Hicks, Sophie Raymond, S. Q. Murphy, J. E. Furneaux, and M. B. Santos, "Observation of the Quantum Hall Effect in High Quality InSb Heterostructures", Appl. Phys. Lett., in preparation.

E. H. Aifer, B. B. Goldberg, and J. E. Furneaux, "Tunable far infrared detection by laterally confined quantum wires", J. Appl. Phys., in preparation.

Sabina Abbrent, Jan Lindgren, J. E. Furneaux, Jorgen Tegenfeld, and C. Wendsj, "A Comparative Study of Gel Electrolytes Containing Polar or Non-Polar Polymer Chains", Solid State Ionics, in preparation.

J. E. Furneaux, S. V. Kravchenko, Whitney Mason, V. M. Pudalov and, M. D'Iorio, "Scaling of a Metal/Insulator Transition in a 2D System at B=0", Surface Science **361/362**, 949 (1996).

Whitney Mason, S. V. Kravchenko, and J. E. Furneaux, "Experimental Evidence of the Coulomb Gap in High-Mobility 2D Electron System in Silicon," Surface Science **361/362**, 953 (1996).

Matthew B. Johnson
Associate Professor
B.Sc. 1979 Waterloo
Ph.D. 1989 Caltech

Semiconductor nanostructures such as quantum-wells, -wires, and -dots have led to the discovery and study of new physical processes, as well as to the fabrication of novel “band-gap-engineered” devices. My research involves the use of scanning probe microscopy techniques (SPM) to study the growth, and the physical and electronic structure of molecular beam epitaxy (MBE) grown nanostructures with atomic resolution. To date, scanning tunneling microscopy (STM) on cross-sectionally cleaved III-V heterostructures is used to study heterostructures with chemical, electronic and photonic sensitivity on the atomic scale. Similarly, STMs attached to the MBE systems have been used to study growth surfaces with atomic resolution *in situ*.

Here at OU we have various types of STM instruments including one for cross-sectional studies and one attached to a multi-chamber MBE. My first goal is to use these instruments to further understand the growth of nanostructures on the atomic scale and correlate this information with the optical and electronic properties measured by more macroscopic techniques.

My second goal is to use the SPM instruments themselves to pattern semiconductors so as to fabricate nanostructures and to study the novel properties of these nanostructures. Such nanostructures are the prototypes of the switches that will be used in the next generation of integrated circuits.

K. J. Goldammer, W. K. Liu, G. A. Khodaparast, S. C. Lindstrom, M. B. Johnson, R. E. Doezema and M. B. Santos, “*Electrical Properties of InSb Quantum Wells Remotely-Doped with Si*”, J. Vac. Sci. Technol. **B16**, 1367 (1998).

M. B. Johnson, P. M. Koenraad, W. C. van der Vleuten, H. M. W. Salemink and J. H. Wolter, “*Be δ -doped layers in GaAs imaged with atomic resolution using scanning tunneling microscopy*”, Phys. Rev. Lett. **75**, 1606 (1995).

M. Pfister, M. B. Johnson, S. F. Alvarado, H. W. M. Salemink, *et al.*, “*Indium distribution in InGaAs quantum wires observed with the scanning tunneling microscope*”, Appl. Phys. Lett. **67**, 1459 (1995).

Bruce A. Mason
Associate Professor
B.A. 1980 Oberlin College
Ph.D. 1985 Maryland

My research involves the theoretical study of the properties of electronic systems in semiconductors. This work uses extensive computer modeling of semiconductor structures to understand the electronic states of these systems, and their electron dynamics. This work includes the study of parabolic quantum wells, hetero-junctions, metal-oxide-semiconductor structures and semiconductor quantum wires. I am interested in the electronic transport, optical, and infrared properties of these systems including the effects of magnetic fields and disorder. The techniques used in these calculations include self-consistent local density simulations, many-body Green function techniques, Monte Carlo simulations, and path integrals. I am also interested in the device applications of novel quantum systems for transistors and detectors.

M. F. Khodr, P. J. McCann, and B. A. Mason, "*Effects of Band Nonparabolicity on the Gain and Current Density in EuSe-PbSeTe IV-VI Semiconductor Quantum Well Lasers*", I.E.E.E. Jour. Opt. Elect. **32**, 236 (1996).

C. E. Hembree, B. A. Mason, J. T. Kwiatkowski, J. E. Furneaux, and J. Slinkman, "*Calculated Spin Effects in Wide Parabolic Quantum Wells*", Physical Review B **48**, 9162 (1993).

B. A. Mason and K. Hess, "*Quantum Monte Carlo Calculations of Electron Dynamics in Dissipative Solid State Systems Using Real-Time Path Integrals*", Physical Review B **39**, 5051 (1989).

Kieran Mullen
Associate Professor
B.S. 1982 Georgetown
Ph.D. 1989 Michigan

I am interested in the physics of novel effects in quantum systems. My work to date falls in three broad categories: mesoscopic electronic devices, submonolayer superfluid helium films, and the dynamics of correlated electrons in two dimensions.

“Mesoscopic” systems are those in between the regimes of classical and quantum physics, typically less than a micron across. Experimentalists can routinely fashion devices so small that the electrostatic energy of a single electron can control the flow of current, or in which electrons can travel coherently from one side of the device to the other. The theoretical challenges are to understand how the quantum mechanical effects in the microscopic device couple to macroscopic world of voltmeters and ammeters, and how to take advantage of the novel dynamics for new applications. Schrodinger’s cat is no longer a cute puzzle in nanotechnology; it is a real issue with experimental consequences.

Superfluid helium is an archetype of a macroscopic system displaying quantum mechanical effects. Recent experiments have shown that helium can act as a superfluid even when there is less than a single atomic layer in the film. Such a two-dimensional Bose system is ideal for studying fundamental questions, such the effect of disorder, the dynamics of vortices, and the possible existence of superhexatics and supersolids. The helium system is so well understood experimentally, that it poses a challenging testbed for any theoretical technique.

My third area of interest is an overlap of the above two: the dynamics of electrons when they are confined to a two dimensional plane. This leads to a host of interesting topics including localization, behavior in a strong magnetic field, and the existence of electron “bubbles” called skyrmions. These bubbles are comprised of a dozens of electrons whose spins are twisted into a stable pattern. The pattern is stable due to its topology. Such topological excitations provide a fascinating new way to study many-body systems in an elegant way.

“Thermodynamic Phase Diagram of the Quantum Hall Skyrmion System,” K. Moon and K. Mullen, *Phys. Rev. Lett.* **84**, 975 (2000).

Kieran Mullen, “Geometrical defects in Josephson junction arrays,” *Phys. Rev. B* **60**, 4334 (1999).

K. Moon and K. Mullen, “*Anisotropic transport of quantum Hall meron-pair excitations*”, *Physical Review* **B57**, 1378 (1998).

H. T. C. Stoof, K. Mullen, M. Wallin, and S. M. Girvin, “*Hydrodynamics of Spatially Ordered Superfluids*”, *Physical Review* **B53**, 5670 (1996).

Sheena Murphy
Assistant Professor
B.S. 1984 MIT
Ph.D. 1991 Cornell

Over the last few years, my group has focused on the study of electrons in confined geometries. A two dimensional confinement is achieved when the electrons reside in a thin low bandgap semiconductor sandwiched between layers of a higher bandgap material. Further confinement results from processing the semiconductor sample into wires or dots using lithography techniques. As of late, it is in these reduced dimensional systems that some of the more significant developments in condensed matter physics have been found such as the integer and fractional quantum Hall effect, and quantized conductance in point contacts, to name a few.

At the University of Oklahoma, we have access to a particularly interesting semiconductor system, InSb. This material has an extremely low electron effective mass resulting in high mobility and a very large Lande g factor resulting in large spin effects. My group has been engaged in the study of the quantum Hall effect in this unique system. More recently we have started experiments to study spin injection and spin transport as well.

We perform our experiments at low temperatures (from 10K to 0.01K) and in high magnetic fields (up to 15 Tesla). In addition to our low temperature/high field facilities, we also use the optical lithography facility of the Solid State group. In this facility we can fabricate devices with submicron sized features, package them for our experiments and perform room temperature inspection and characterization. In addition our affiliation with the OU/Arkansas Materials Center gives us access to a number of other magnetic, optical and electronic probes.

S.Q. Murphy, J.L. Hicks, K. Goldammer, S.J. Chung, W.K. Liu and M.B. Santos, "Measurement of the quantum percolation exponent in Coulomb-gap dominated systems", *submitted*.

S.J. Chung, N. Dai, G.A. Khodaparast, J.L. Hicks, K.J. Goldammer, F. Brown, W.K. Liu, R.E. Doezema, S.Q. Murphy, and M.B. Santos, "Electronic characterization of InSb quantum wells", *Physica E* **7**, 809 (2000).

S.Q. Murphy, J.L. Hicks, W.K. Liu, S.J. Chung, N. Dai, K.J. Goldammer, and M.B. Santos, "Studies of the quantum Hall to quantum Hall insulator transition in InSb-based 2DESs", *Physica E* **6**, 293 (2000).

K.J. Goldammer, S.J. Chung, W.K. Liu, M.B. Santos, J.L. Hicks, S. Raymond and S.Q. Murphy, "High-mobility electron systems in remotely-doped InSb quantum wells", *Journ. Cryst. Growth* **201-202**, 753 (1999).

S.Q. Murphy, J.P. Eisenstein, L.N. Pfeiffer and K.W. West, "Lifetime of Two-Dimensional Electrons Measured by Tunneling Spectroscopy", *Phys. Rev. B*, **52**, 14825 (1995).

G.S. Boebinger, S.Q. Murphy, J.P. Eisenstein, L.N. Pfeiffer, K.W. West, and Song He, "New collective quantum Hall states in double quantum wells", *Surf. Sci* **305**, 8 (1994).

S.Q. Murphy, J.P. Eisenstein, G.S. Boebinger, L.N. Pfeiffer and K.W. West, "Many-Body Integer Quantum Hall Effect: Evidence for New Phase Transitions", *Phys. Rev. Lett.*, **72**, 728 (1994).

Stewart Ryan
Associate Professor
B.S. 1964 Notre Dame
Ph.D. 1971 Michigan

My current work focuses on the use of video techniques to enhance physics instruction. Using 3-D computer animation, the Physics Video Project is producing a video series entitled Understanding Modern Technology to illustrate the application of the principals of physics to modern technology. Also in production is a companion series of Physics Video Clips designed to elucidate physical phenomena that evolve in time and thus are not readily illustrated in a static figure. The goal of the Physics Video Project is to enhance learning in introductory physics classes by illustrating the applications of physics and demonstrating concepts that students often have difficulty visualizing or understanding mathematically.

A continuing area of interest is the development of new techniques and instrumentation for use in such fields as materials characterization, non-destructive testing, and energy conservation. A differential, constant-resistance anemometer developed for energy conservation has application in both analytical chemistry and geophysics.

S. R. Ryan, Greg Parker, and Ron Kantowski, "*Understanding Modern Technology: The Audio Compact Disc*", University of Oklahoma, 1998.

T. Xie, S. R. Ryan, and H. J. Fishbeck, "*Proton RBS Measurements of the Oxygen in Heavy-Metal Oxides*", Nuclear Instruments and Methods B **40/41**, 766 (1989).

H. J. Fishbeck, D. J. Rogers, S. R. Ryan, and F. E. Swensen, "*Sourcing Ceramics in the Spiro Region: A Preliminary Study Using Proton Induced X-Ray (PIXE) Analysis*", Midcontinental Journal of Archaeology **14**, 3 (1989).

Michael B. Santos
Associate Professor
B.S. 1986 Cornell
Ph.D. 1992 Princeton

My research interests focus on InSb-based heterostructures for electronic device applications. Since the bandgap of InSb is the smallest of all binary III-V compounds, two-dimensional electron systems (2DES) in InSb quantum wells have several extreme properties: a small effective mass, a large g-factor, a high intrinsic mobility, and a non-parabolic dispersion relation. Using the department's molecular beam epitaxy (MBE) system, my research group fabricates InSb quantum-well structures with $\text{Al}_x\text{In}_{1-x}\text{Sb}$ barrier layers. The room-temperature mobility in these structures is higher than in quantum wells made of any other semiconductor. We are exploring ways to exploit this feature in improved field-effect transistors and magnetic-field sensors. The behavior of our 2DES in the quantum Hall regime (low temperature and high applied magnetic field) is expected to differ from that observed in more commonly studied GaAs-based heterostructures. These fundamental studies are being pursued in collaboration with Professors Murphy and Doezema.

Since the operation of electronic devices depends on the material quality of the heterostructures, my group makes use of *in situ* surface analysis techniques (reflection high-energy electron diffraction, Auger electron spectroscopy, and x-ray photoelectron spectroscopy) and high-resolution x-ray diffraction. With the recent addition of a scanning probe microscope onto the MBE system, we are collaborating with Professor Johnson's group on nanostructure fabrication and studies of the MBE growth process.

S. J. Chung, N. Dai, G. A. Khodaparast, J. Hicks, K. J. Goldammer, F. Brown, W. K. Liu, R. E. Doezema, S. Q. Murphy, and M. B. Santos, "*Electronic Characterization of InSb Quantum Wells*", *Physica* **E7**, 809 (2000).

S. J. Chung, K. J. Goldammer, S. C. Lindstrom, M. B. Johnson, and M. B. Santos, "*A study of factors limiting electron mobility in InSb quantum wells*", *Journal of Vacuum Science and Technology* **B17**, 1151 (1999).

W. K. Liu, K. J. Goldammer, and M. B. Santos, "*Surface Segregation and Compensation of Si in δ -doped InSb and $\text{Al}_x\text{In}_{1-x}\text{Sb}$ Grown by Molecular Beam Epitaxy*", *Journal of Applied Physics* **84**, 205 (1998).

STORM ELECTRICITY

The National Severe Storms Laboratory (NSSL), a federal research laboratory within the National Oceanic and Atmospheric Administration, is located on the north campus of the University. Two senior scientists in NSSL, Drs. MacGorman and Rust, hold adjunct positions with the Department and regularly advise students. Working with NSSL provides students the opportunity to pursue a physics career with emphasis on the atmosphere, which covers a wide range of physical scales. Graduate research opportunities include the electrical properties of precipitation, lightning physics, *in situ* and remote measurements of storm parameters, storm electrification models, lightning data assimilation into weather forecast models, and climatic impacts of weather systems and lightning. More details about the range of topics for experimental and theoretical research on problems in atmospheric physics are described below.

Donald R. MacGorman
Adjunct Associate Professor
B.S. 1973 Rice University
Ph.D. 1978 Rice University

My research focuses on storm electrification: How do storms become electrified? What causes lightning to occur, and what controls where it propagates? How do storm characteristics affect the lightning that is produced? What effects do lightning flashes have on the environment? These and related questions motivate the research in which I have been involved. Experiments to address these issues at NSSL usually involve collecting and analyzing data from existing systems, such as NSSL's radar and three-dimensional lightning strike mapping system, or use numerical cloud models to simulate electrified storms and lightning.

D.R. MacGorman and W.D. Rust, *The Electrical Nature of Storms*, Oxford University Press, 422 pp (1998).

D. R. MacGorman and C. D. Morgenstern, "Some characteristics of cloud to ground lightning in mesoscale convective systems", *Journal of Geophysical Research* **103**, 14011 (1998).

M. A. Shafer, D. R. MacGorman, and F. H. Carr, "Cloud-to-ground lightning throughout the lifetime of a severe storm system in Oklahoma", *Monthly Weather Review*, **128**, 1798, (2000).

W. David Rust
Adjunct Professor
B.S. 1966 Southwestern Univ.
Ph.D. 1973 N.M. Inst. of Tech.

Graduate research opportunities with me are focused in the areas of making measurements of electrical parameters using both the fixed-base instruments and mobile laboratories. Examples include balloon-borne instruments to make storm electricity measurements in and near storms.

D.R. MacGorman and W.D. Rust, *The Electrical Nature of Storms*, Oxford University Press, 422 pp (1998).

M. Stolzenburg, W. D. Rust, and T. C. Marshall, "*Electrical Structure in Thunderstorm Convective Regions 3. Synthesis*," *Journal of Geophysical Research* **103**, 14,097 (1998).

W. D. Rust and T. C. Marshall, "*On Abandoning the Thunderstorm Tripole-Charge Paradigm*," *Journal of Geophysical Research* **101**, 23,504 (1996).

M. G. Bateman, W. D. Rust, and T. C. Marshall, "*A Balloon-Borne Instrument for Measuring the Charge and Size of Precipitation Particles Inside Thunderstorms*", *Journal of Atmospheric and Oceanic Technology* **11**, 161 (1994).

THE ENVIRONMENT

THE UNIVERSITY

Seventeen years before Oklahoma became a state, the University of Oklahoma was founded by the first legislature of the Territory of Oklahoma. The first classes were held in 1892 with 119 students and four faculty members, including Dr. David Ross Boyd, the University's first president. The first two graduates received the degree of pharmaceutical chemist in 1896. The first master's degree was conferred in 1900, and the first doctoral degree in 1929.

More than 175,000 degrees later, annual enrollment is greater than 25,000 on campuses in Norman, Oklahoma City, and Tulsa, including 4,000 graduate students, with approximately 1,830 full-time faculty members.

We enjoy a beautiful campus spread over 1000 acres in the heart of Norman, Oklahoma. Campus buildings are a pleasant mixture of traditional and contemporary — 8 of the 82 buildings were built before 1920. Walkways are shaded by over 2000 trees of 40 varieties and are surrounded by colorful floral landscaping.

The government of the University is vested in the Regents of the University of Oklahoma, and administered by its thirteenth President, David L. Boren. Eighteen colleges headed by academic deans offer 134 undergraduate degree programs, 82 master's degree programs, 51 doctoral programs, professional degrees in four areas, and 36 dual professional/master's programs. The University's annual operating budget is \$657 million.

THE COMMUNITY

Norman residents enjoy the advantages of small-city living along with easy access to the large metropolitan center of Oklahoma City, the state capital. Norman's overall cost-of-living is below the index average; in 1997 the mean cost of an apartment was \$362.

The University community itself offers a multitude of cultural, recreational, and sports activities. For those who enjoy the dramatic arts, the OU School of Drama schedules major productions during the school year and a series of plays and a musical repertory each summer. Also included in the regular season are ballet and modern dance productions. These productions are presented in the striking 700-seat Rupel J. Jones Theatre on campus.

A series of programs is presented at the newly constructed Catlett Music Center, which hosts internationally known artists as well as the University Symphonic Orchestra, Symphonic Band, and other musical groups. Faculty and student concerts and recitals are also scheduled regularly by the OU School of Music are offered during the year.

Museum buffs will find the Oklahoma Museum of National History an intriguing place to visit on campus. The state museum maintains a year-round program of

displays, lectures, movies, and workshops in the earth, life, and social sciences. A new museum building, the largest associated with any state university, will be finished shortly to house the over 5 million items in the collection.

The Fred Jones Jr. Museum of Art, established in 1936, presents more than 30 temporary exhibitions annually. The Museum's diverse permanent collection of nearly 6000 objects includes distinguished works in American painting after 1945, photographs, graphic arts, Oceanic art, ceramics, and Native American painting. Admission is free and films, slides, lectures, as well as tours are available.

The intercollegiate sports scene for men at OU features Big XII football in the fall; basketball, wrestling, gymnastics, indoor track, and swimming in the winter; and golf in the spring. Women participate in intercollegiate basketball, softball, volleyball, tennis, golf, track, and gymnastics. Students receive special rates on all sports tickets. For amateur athletes, OU's intramurals and recreational programs are among the most varied and progressive in the Big Eight. An indoor/outdoor swimming complex, modern physical fitness center, 18-hole golf course, and multiple tennis courts round out the recreational facilities available for student use.

The City of Norman offers a varied range of things to see and do. Little River State Park surrounding Lake Thunderbird, which is within Norman's city limits, is a haven for swimming, water-skiing, sailing, fishing, hunting, and camping. Trail rides, western riding lessons, and hay rides are also available. The Norman and Cleveland County Historical Museum, Firehouse Art Center, Downtown Historic District, and Jacobson House offer glimpses from the state's Territorial Period and Native American culture to modern day art classes and the annual Chocolate Festival. Other Norman traditions include the Medieval Fair, Stage Race and Criterium, Sooner Theatre, May Fair, Jazz in June, Midsummer Night's Fair, Taste of Norman, and Christmas Parade and Fair.

Oklahoma City, 20 miles north of Norman, is another source of cultural, recreational, and sports entertainment. Among the attractions are the Oklahoma Arts Center, the Oklahoma Museum of Art, the Oklahoma City Philharmonic, and Ballet Oklahoma. This major metropolitan center also offers the National Cowboy Hall of Fame and Western Heritage center, the Oklahoma City Zoo, and the Kirkpatrick Omniplex (children's science museum.)

ADMISSION and FINANCIAL SUPPORT

ADMISSION REQUIREMENTS

Applications for admission to the Physics, Astrophysics, or Engineering Physics programs require:

- Official transcripts from all institutions of higher education ever attended;
- GRE scores for both the general and subject exams;
- An official TOEFL score above 600 (old system), or 230 (new system), for students whose native language is not English.

Additional forms to be completed and returned to the Department are:

- A Department of Physics and Astronomy application form;
- Three letters of recommendation;
- A Graduate College application form.

Generally the Graduate College requires an undergraduate GPA of 3.0 (on a 4-point scale) for the last 60 hours of course work, although exceptions are sometimes made at the request of the Department.

ADMISSION PROCEDURE

To receive application forms, please inquire by:

Letter: Admissions Committee – Graduate Secretary
Department of Physics and Astronomy
University of Oklahoma
Norman, OK 73019-0225

Phone: (800) 522-0772, extension 3961 (toll-free)

FAX: (405) 325-7557

e-mail: grad@mail.nhn.ou.edu

Web site: www.nhn.ou.edu

Please indicate which degree program you are interested in and the semester and year you plan to enroll.

Application deadlines are February 1 for the Fall semester, and November 1 for the Spring semester. Overseas applicants may only apply for Fall semester.

Dates and locations of GRE exams in your geographic area may be obtained by writing to: Graduate Record Examinations, Educational Testing Service, Princeton, NJ 08640.

TEACHING and RESEARCH ASSISTANTSHIPS

Graduate teaching assistantships are available to PhD track students on a competitive basis. Teaching assistants generally supervise undergraduate laboratory courses, lead discussion sections in elementary courses, or assist in grading. Loads are adjusted so as to require only 10-15 hours/week, including preparation. Additional summer support, including research appointments, is generally available to those students who request it. Some students are engaged as private tutors during the academic year. Considering the relatively low cost of living in Oklahoma (especially for housing), the academic-year stipends of about \$12,500/academic year are nationally competitive. This is especially true for incomes supplemented by summer teaching or research. Current policy provides all full-time teaching and research assistants with complete waivers for out-of-state tuition, waivers for four hours of in-state fees, and full health care benefits are provided.

Research assistantships and fellowships sponsored by federal agencies are also available. These are usually year-round appointments, and normally require no service of the recipients other than pursuing research towards the PhD.

OTHER FINANCIAL AID

Students who are United States citizens and/or permanent residents may qualify for the University's program of financial assistance which includes scholarships, loans, and part-time employment. An application for a general scholarship based on need is made through the Office of Financial Aid. It should be completed and returned before March 1 for the school year beginning the following Fall.

Additional Departmental and University fellowships offered to qualified students include the prestigious Chun C. Lin Research Fellowship that provides for a \$18,000 per year stipend. The Office of Financial Aid can also provide full information on the national Direct Student Loan Program, the Guaranteed Loan Program, and the College Work-Study Program.