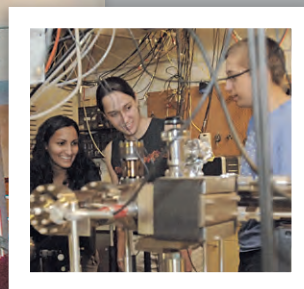
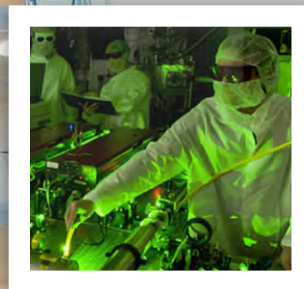
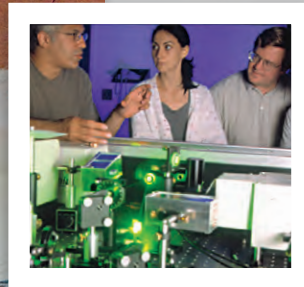
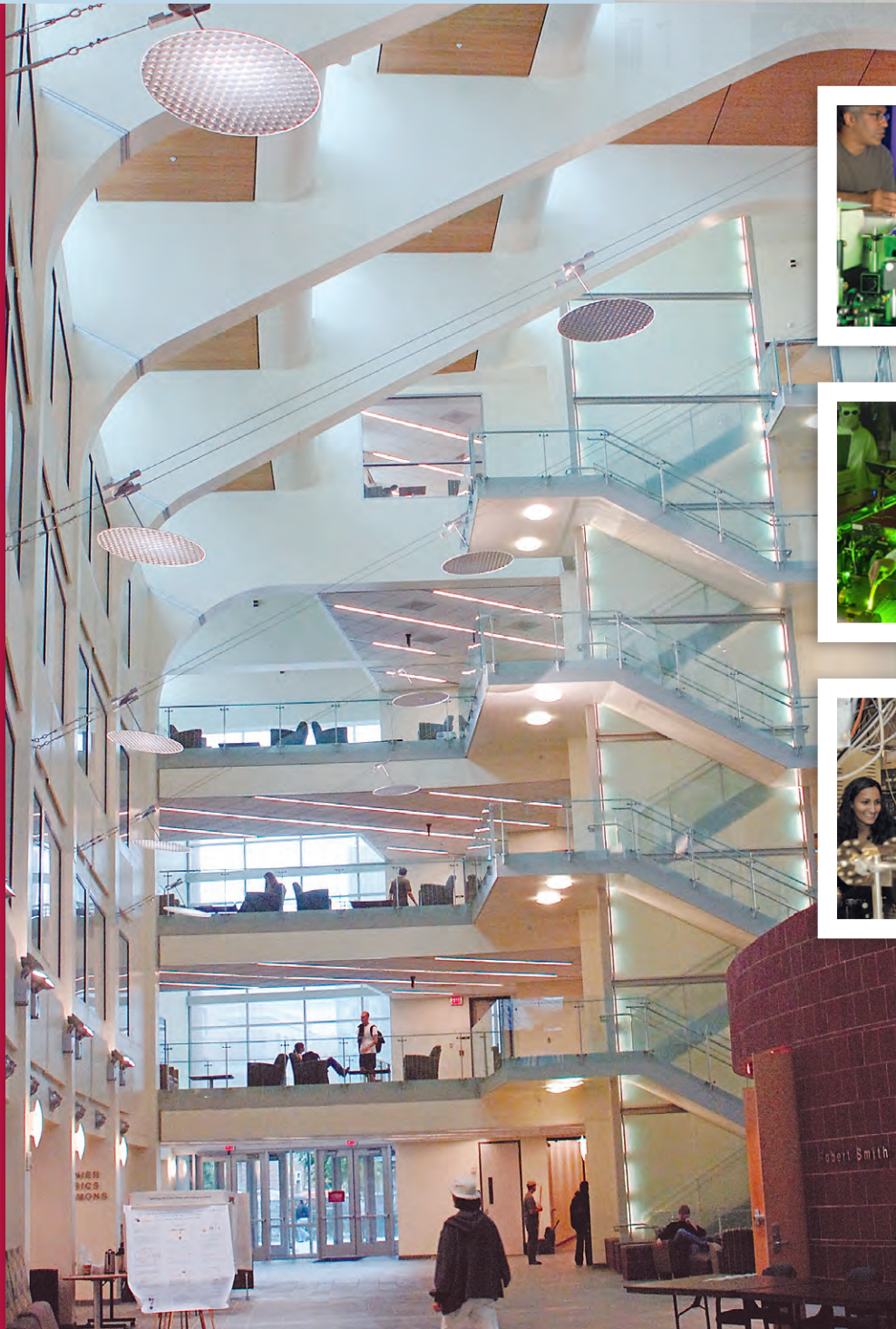
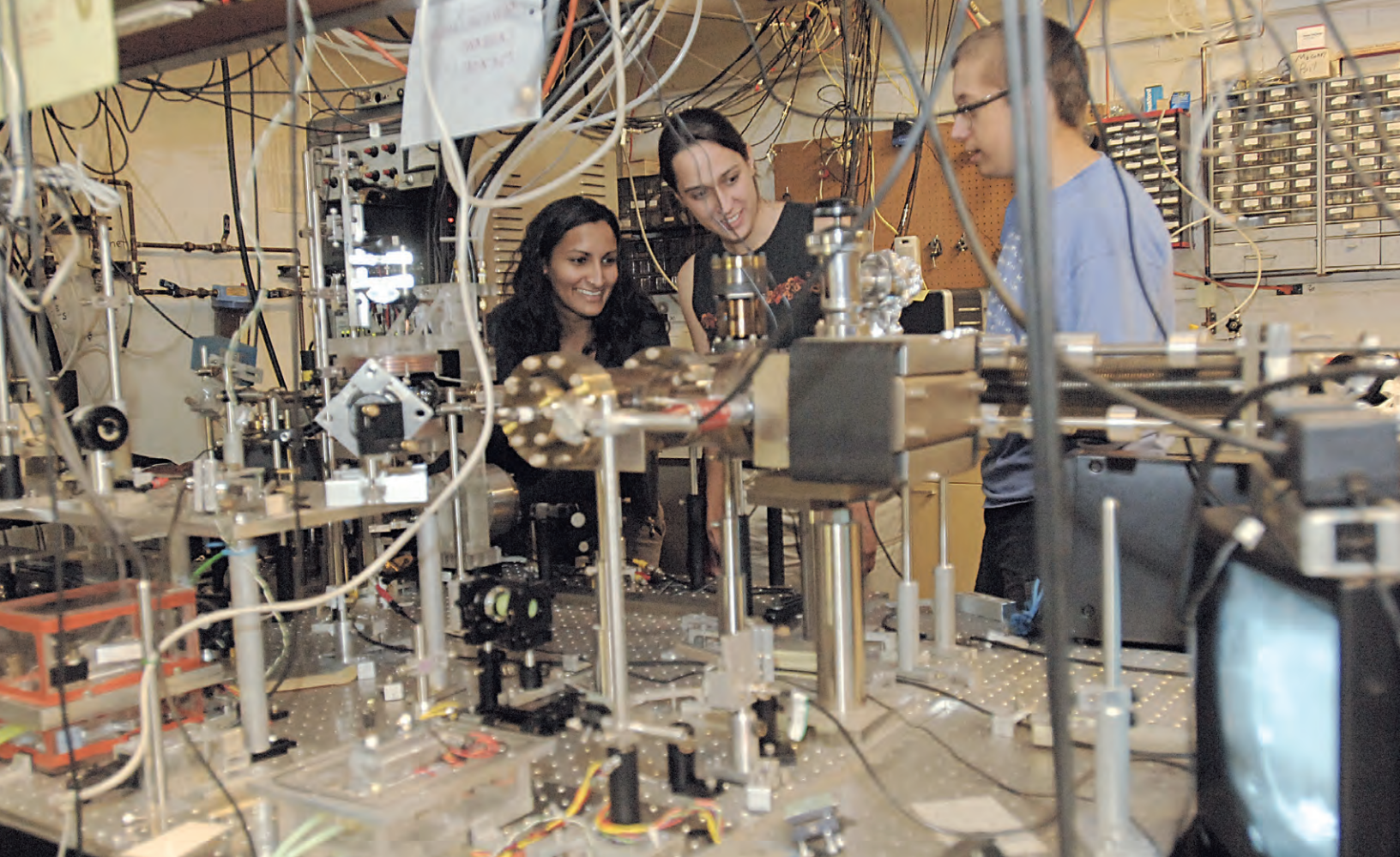


# Graduate Study in Physics



THE OHIO STATE  
UNIVERSITY





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# Graduate Study in Physics



For information about housing and graduate student life  
**[gradadmissions.osu.edu](http://gradadmissions.osu.edu)**

For general information about Columbus  
**[ci.columbus.oh.us](http://ci.columbus.oh.us)**

The Ohio State University  
Department of Physics  
Physics Research Building  
191 W. Woodruff Ave.  
Columbus, OH 43210  
Phone: 614-292-5713  
Fax: 614-292-7557  
[physics.osu.edu](http://physics.osu.edu)

**College of Arts and Sciences**



## Schedule a visit or get more information

We hope this publication helps you find what you need to know about our graduate program in physics and what you can expect to find at Ohio State and in Columbus. If you want more information, or, better still, if you want to arrange a visit to see our facilities and meet the people who could be a part of your graduate education, please contact us at **[gradstudies@physics.osu.edu](mailto:gradstudies@physics.osu.edu)** or **614-292-5127**. To take a virtual tour of campus—or if you are planning an in-person tour—please visit **[osu.edu/visitors](http://osu.edu/visitors)** for more information.





### DEPARTMENT OF PHYSICS APPLICATION

Through a special arrangement, the cost of your application to the physics department is only \$5 to submit. The application may be found on the Admissions website at [applyweb.com/apply/osu/grad\\_files/menu.html](http://applyweb.com/apply/osu/grad_files/menu.html). Please complete the entire application and submit it by December 15. Upon completion of the application, you will be asked to pay the application fee. The fee is normally \$60, but, by supplementing the cost through the special arrangement with the physics department, you will be charged only \$5 when you click “Submit.” Please also see the Step by Step Guide to Admissions on the Graduate Admissions webpage at [gradadmissions.osu.edu](http://gradadmissions.osu.edu), as well as our department’s page with application process information at [physics.osu.edu/graduate-students](http://physics.osu.edu/graduate-students) under the Prospective Students menu.

### Supplementary Materials Required

- Official transcript(s), or a copy of official transcripts, from *all* colleges and universities you have attended. This includes schools you attended for only a short time (even if the transfer credit shows on another transcript).
- Official GRE General and Physics subject test scores sent to institution code 1592. Visit [ets.org/gre](http://ets.org/gre) for more information on GRE tests
- 3 letters of recommendation. Please read program application instructions online at [physics.osu.edu/graduate-students](http://physics.osu.edu/graduate-students) for more information.

- An autobiography or personal statement is required (limit 1-2 pages).
- C.V. or resume (limit 1-2 pages)
- An official TOEFL score is required of international applicants. The TOEFL IBT test is required unless it is not offered in your country. If you do not meet the university minimum TOEFL IBT score (79), you cannot be considered for our graduate program. We cannot waive the TOEFL requirement or consider scores near (but below) the minimum.

### Application Deadlines

We begin to consider applications in the middle of December through January, and usually complete our review process of all applications by mid-February. For the best chance of admission, submit *all* application materials by December 15. (If you take the General GRE in November, it is acceptable if the scores arrive in late December.) All supplementary materials and letters of recommendation must be received by January 1.

If you want to be considered for a fellowship or teaching associateship, please submit a complete application, including all supplemental materials, GRE test scores and letters of recommendation by December 15. If you do not meet fellowship deadlines, you will be considered for support in the form of a teaching assistantship upon the receipt of *all* application materials.



To probe the frontiers of what is known about the physical world, aspiring physicists must have a thorough understanding of the fundamentals of science and mathematics. They also must have adequate means and qualified mentors if they are to fully realize their potential.

**At The Ohio State University** you will find the faculty, facilities and financial support to help you achieve your goals. We offer you a solid foundation in physics that includes course work in a diverse range of specializations covering every facet of contemporary physics research. Our faculty members conduct research in a broad range of areas, including astrophysics; atomic, molecular and optical physics; biophysics; condensed matter physics; high energy physics; string theory; nuclear physics; and physics education research.

Ohio State’s Department of Physics has recruited nationally and internationally distinguished faculty members who have garnered numerous awards. The department is proud to claim two Nobel Laureates and a National Academy of Sciences member, two Max Planck Award winners, four chaired professors, three Distinguished University Professors and 16 winners of young investigator awards, including the Presidential Young Investigator, National Young Investigator and Outstanding Junior Investigator awards.

The most recent ranking of physics departments by the National Research Council places Ohio State (approximately) 24th nationally and 13th among public universities.

This brochure offers a description of our program, our faculty and facilities, as well as the financial aid you may expect to receive at Ohio State as a graduate student in physics. We also invite you to visit us, see the facilities and meet the people who could be a part of your graduate career in physics. More information may be found on our website at [physics.osu.edu](http://physics.osu.edu).





# The Department of Physics at The Ohio State University



**Ohio State** is one of the largest universities in the world. Our large size makes it possible to offer you access to the world-class technology so necessary to advanced study in physics. You get access to the resources of a major research university, while your immediate world revolves around the Department of Physics in the new Physics Research Building, part of the College of Arts and Sciences, Natural and Mathematical Sciences. The department is committed to diversity in science and welcomes members of underrepresented groups. We offer one of the friendliest environments for graduate study in physics anywhere and host a number of social events for graduate students every year, including parties, picnics and receptions.

With 60 faculty, 200 graduate students, 45 postdoctoral associates and a support staff of 50, the department is large enough to provide an excellent research environment and a comprehensive course selection, but small enough to offer you personal attention. We encourage you to visit our campus and talk informally with faculty and graduate students to find out for yourself what kind of people you will be working alongside if you select Ohio State for your graduate education.

## JOIN OUR GRADUATE PROGRAM

By entering our graduate program in physics, you will become part of one of the nation's premier research universities. In 2012–13, Ohio State expended \$934 million research dollars and ranked third among all U.S. universities with approximately \$106 million in industry-sponsored research. Each year, the members of our physics department bring in more than \$15.5 million in research funding, publish more than 200 refereed papers, give hundreds of invited talks at international conferences as well as seminars and colloquia at other institutions and graduate 20 to 30 new PhD students. These numbers quantify the excellence of our young faculty, who are part of a strong, growing department and who pursue a variety of exciting research directions. As part of this program, you will be able to conduct first-rate physics research and receive generous financial support while earning your graduate degree at Ohio State.



## FINANCIAL AID OPPORTUNITIES

Because we select only the highest caliber students for our graduate program, all regular incoming students are offered financial support. Once accepted into the graduate program in physics, you will be awarded one of three types of graduate appointments: a teaching associate (TA) position, research associate (RA) position or fellowship. With any of these appointments, you will receive a monthly stipend plus a full waiver of tuition and general fees.

**Teaching Associates:** Many of our first-year graduate students are supported through their appointment as teaching associates. These appointments ordinarily are made for the academic year (two semesters). Teaching assignments involve a maximum of eight contact hours of combined laboratory/recitation instruction per week. In this appointment, your responsibilities include teaching, grading and giving individual assistance to students. You also will receive training for this position through the department.

After your first academic year, you will be awarded a special research appointment for the summer term, provided you have a satisfactory record of academic work and teaching performance for your first two semesters. Your regular stipend is continued during this summer term, but you will have no teaching duties. This appointment allows you to begin research work early in your graduate program. The stipend for teaching associates is very competitive and is re-assessed regularly. The value of the present stipend will be provided with your offer of admission.

Excellence in graduate teaching is recognized annually with the presentation of the Hazel Brown Teaching Awards, which include a monetary award as well as a certificate of recognition.

**Research Associates:** Graduate research associate positions are available to nearly all advanced graduate students. The stipend is equal to that of a teaching associate. This support is obtained from research grants that have been awarded to individual faculty members from either industrial or governmental sources. As a research associate, you will devote essentially all of your time to dissertation research.

**Fellowships:** A number of prestigious fellowships, including fellowships from The Ohio State University Graduate School and the departmentally funded Fowler Fellowship, are awarded annually to top students. Fowler fellowships include a stipend of around \$27,000 a year for two years. Since these awards require no teaching duties for the first year, fellows take more classes each semester and move more quickly into research. Fellowships are available to students beginning with their first year in the physics graduate program. To apply for a fellowship, check the appropriate box on your application form. To be considered, you must apply by December 15 with all supplementary materials, including letters of recommendation, received by January 1.

## YOUR GRADUATE PROGRAM IN PHYSICS

We have designed the graduate program in physics to give you a solid background in the fundamentals, an understanding of the major fields of current research and an opportunity for in-depth investigations. Working with your faculty advisor, you can tailor your program to meet your own needs and interests, taking into account your particular goals and undergraduate preparation.

In the PhD program, you will devote most of your first year and some of your second year to course work. These courses are designed to strengthen and extend your knowledge of the theoretical foundations of physics and to introduce you to areas of current interest in the field. During the summer following your first year, you will



## Typical Course Sequence

### FIRST YEAR

#### AUTUMN SEMESTER

Physics 6780:	Dept. Research Overview
Physics 7501:	Quantum Mechanics I
Physics 7601:	Classical & Statistical Physics I
Physics 7701:	Analytic & Numeric Methods of Physics

#### SPRING SEMESTER

Physics 7401:	Electromagnetic Field Theory
Physics 7502:	Quantum Mechanics II
Physics 7602:	Classical & Statistical Physics II
Physics 7998:	Graduate Research

#### SUMMER TERM

Physics 8999:	Thesis Research
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### SECOND YEAR

#### AUTUMN AND SPRING SEMESTERS

Advanced Topics Courses,  
Thesis Research

#### SUMMER TERM

Physics 8999:	Thesis Research
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**Advanced Research Courses**

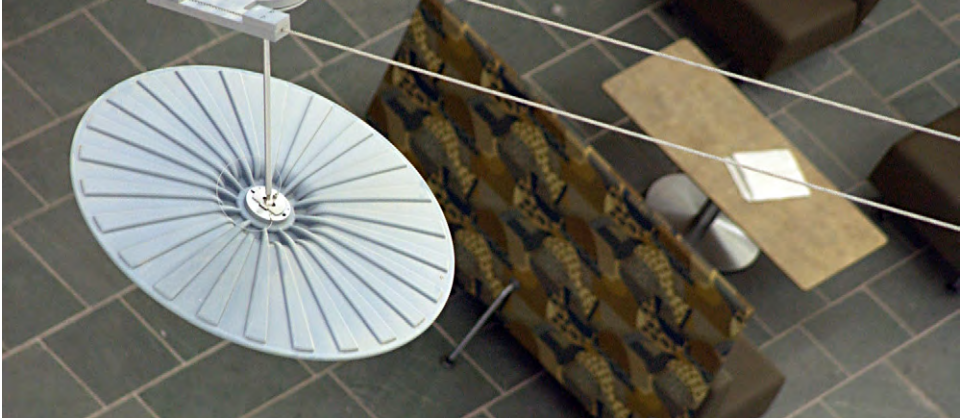
A unique feature and a great strength of our curriculum are the numerous advanced-topics courses at the 6800 or 8800 level. These are courses on topics of current interest in physics taught by faculty working in those areas. Classes are usually small and provide an outstanding opportunity to explore the frontiers of physics in a more informal atmosphere. We typically offer five or more of these courses every semester, except summer. Survey courses (6800 level) are offered regularly on the following topics:

- Astrophysics**
- Atomic and molecular physics**
- Biophysics**
- Condensed matter physics**
- Elementary particle physics**
- Nuclear physics**
- Physics education**
- String theory**

Advanced topics are covered in a series of courses at the 8800 level, which include, but are not limited to, the following:

- Atomic and molecular physics**
- Biophysics**
- Condensed matter physics**
- Continuum mechanics**
- Dynamical systems**
- Elementary particle physics**
- Field theory**
- Group theory**
- Lasers**
- Low-temperature physics**
- Magnetic properties of matter**
- Many-particle physics**
- Nonlinear optics**
- Nuclear physics**
- Phase transitions and critical phenomena**
- Physics education**
- Physics of organic and polymeric materials**
- Spectroscopy**
- String theory**
- Superconductivity**
- Theory of measurement and detection**

You also can study a topic of your choice on an individual basis with a faculty member through Physics 7193.



be encouraged to join one of the ongoing research programs in the department. As mentioned earlier, teaching associates with satisfactory records are offered special summer-term appointments, free of teaching duties, to enable them to take advantage of this opportunity to explore a research area early in their graduate careers.

From your third year on, you will concentrate on carrying out your PhD thesis research with your faculty research advisor. This work culminates in your PhD thesis defense by about the fifth or sixth year.

The resources of the university and of the physics department are available to assist you with job placement after graduation. Recent graduates now have successful careers at colleges, universities, national research laboratories and in industry.

**QUALIFYING AND BECOMING A PHD CANDIDATE**

The first step in becoming a PhD candidate is to qualify via the “core-course requirement.” This is accomplished by taking the six semesters of core courses shown earlier in the course sequence box and achieving at least a B+ average in these courses. Students coming into our program with previous graduate-level course experience may petition to waive some or all of these courses.

After satisfying the core-course requirement, research becomes the center of your PhD program. After working for one or two semesters with your advisor, you will prepare for the candidacy examination. This exam is set by your advisor and advisory committee. It consists of a short paper on a topic related to your research project. Admission to PhD candidacy follows the satisfactory performance on the candidacy examination.

The PhD program concludes with a written dissertation, based upon the scientific advances you made through independent research, and an oral defense of your thesis. The average time for completion of the PhD program is about six years.

**BECOMING A BETTER PHYSICIST**

An important aspect of physics is interaction with other physicists. The Department of Physics at Ohio State encourages advanced students to attend national conferences. It is common for students to present three to four papers at conferences before completing their PhD. The annual Smith Lecture brings internationally recognized physicists—typically Nobel Prize winners—to the department every spring. The weekly colloquia feature easily accessible insight into cutting-edge research in all fields of physics. In addition, each research group also invites collaborators and recognized researchers to present findings in their fields.

Our students publish an average of five papers by the time they graduate, a testimonial to the quality and depth of training they receive. When they graduate, our students are highly competitive in the job market and find employment in many careers, including academics, national research laboratories, teaching, scientific policies and procedure and in industry.

You may contact members of the faculty individually and arrange to meet them if you come to the department for a visit. We appreciate the important role graduate students play in research and are always happy to discuss your needs and concerns.

**RESEARCH OPPORTUNITIES AND AFFILIATED FACULTY**

Diversity of active research areas is one of the great strengths of the Department of Physics at Ohio State. Research spans the entire spectrum of matter, including high energy physics, nuclear physics, atomic and molecular physics, condensed matter physics, biophysics and astrophysics. Research in physics education is another strong, vibrant field at Ohio State. With recent hires and new center funding, we are especially strong in condensed matter physics, high energy physics, nuclear physics, biophysics, astrophysics, AMO, cold atom theory and physics education research. You will find details of the different research groups beginning on page 8.

**FACILITIES AND SUPPORT FOR RESEARCH**

**Computer Support**

The Physics Computer Facility provides computing and networking services to the department’s faculty, staff and students. It has a professional staff of six, assisted by a number of capable undergraduate students. They provide support services as varied as assisting customers in purchasing, installing and operating computer systems to obtaining licenses for distribution of commercial software of interest to the physics community. In addition, they provide maintenance of student computers in physics teaching labs and dedicated labs for undergraduate physics majors and for physics graduate students.

Their goal is to increase the productivity of the department’s employees and students, allowing them to concentrate their energy on physics issues rather than computer support.

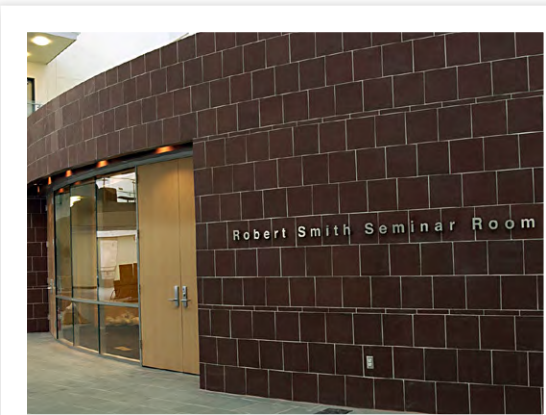
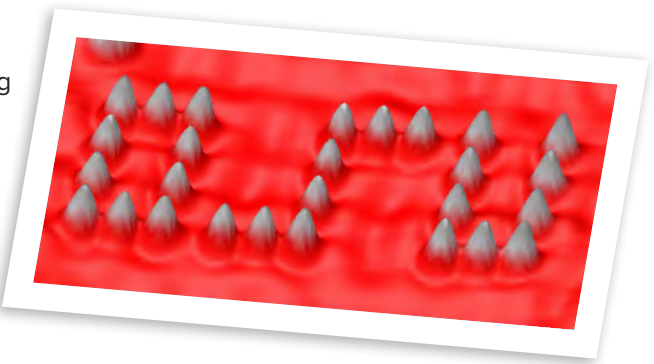
**Laboratory Facilities and Equipment**

While each research group is a separate entity, there are a number of excellent departmental facilities shared by all. These include a well-staffed machine shop, an efficient student shop with supervised training classes, an electro-mechanical shop (electronics design and fabrication, low temperature and optics support), liquid helium and nitrogen facilities and the NanoSystems Laboratory with state-of-the-art focused ion beam/scanning electron microscopy, electron beam lithography, Direct Laser Writer, nanomanipulation, EDS X-ray microanalysis, X-ray diffractometry, SQUID magnetometry, two ambient and one low temperature/high magnetic field atomic force/magnetic force microscopes, two Physical Property Measurement System, new chemical vapor deposition and sputtering/electron beam deposition systems, low temperature magnetotransport measurements and a Langmuir-Blodgett trough monolayer deposition facility. For more information on the NanoSystems Laboratory, visit [ensl.osu.edu](http://ensl.osu.edu).

**Physics Research Building**

The Department of Physics is housed in a 233,739-square-foot, state-of-the-art building with department offices and conference space, as well as 210 laboratory modules. The design features a stunning open atrium and adjoining patio space. Frequent and relaxed interaction is the focus of the open spaces, and highlights on the atrium floor are the Smith Seminar Room and Vernier Physics Commons.

We have recently designated space for a Wellness Room, a private room suitable for breastfeeding mothers or others with mental or physical health needs served by a private, quiet space.

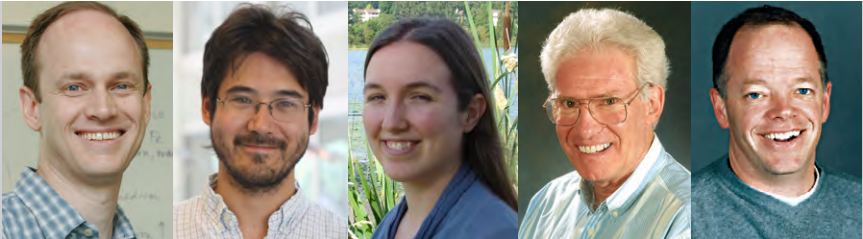




# Research Groups — Astroparticle Physics

## Cosmology and Astroparticle Physics Theory

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John Beacom Christopher Hirata Annika Peter Gary Steigman Terry Walker

### Cosmology and Astroparticle Theory faculty

**John F. Beacom**, Professor  
PhD, University of Wisconsin, 1997  
Neutrinos in astrophysics, cosmology,  
particle physics and nuclear physics  
Gamma-ray astronomy, cosmic rays, dark  
matter and other aspects of particle and  
nuclear astrophysics

**Christopher M. Hirata**, Professor  
PhD, Princeton University, 2005  
Theory and astrophysics of  
cosmological probes  
Cosmic recombination  
Weak gravitational lensing

**Annika Peter**, Assistant Professor  
PhD, Princeton University, 2008  
Dark matter astrophysics  
Cosmology  
Particle physics  
Dynamics of the Milky Way  
Dwarf speroidal galaxies  
Solar system

**Michael Stamatikos**, Assistant Professor  
(Ohio State Newark Campus)  
PhD, State University of New York at Buffalo,  
2006  
Gamma ray bursts (GRBs) in a multi-  
messenger context

**Gary Steigman**, Emeritus Professor  
PhD, New York University, 1968  
Cosmology and the early evolution  
of the universe  
Big Bang nucleosynthesis and the primordial  
abundances of elements  
Constraints on the properties of the standard  
models of cosmology and particle physics

**Terry Walker**, Professor  
PhD, Indiana University, 1988  
Neutrino astrophysics  
Dark matter candidates and their detection  
Big Bang nucleosynthesis

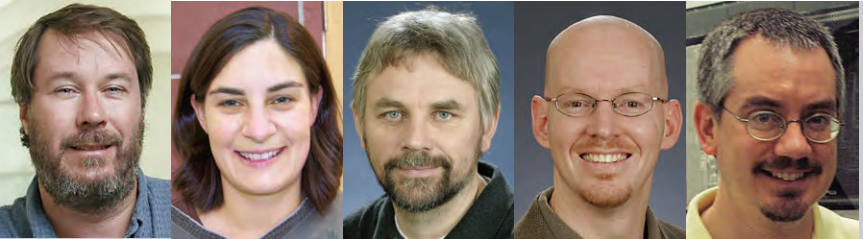
Cosmology and astrophysics probe physics on the very largest scales, endeavoring to understand the history and evolution of the universe along with attempting to reveal the fundamental mechanisms behind its diverse and fascinating constituents. Astroparticle physics seeks to uncover the nature of the participants (elementary particles) and their fundamental interactions on the very smallest scales. The physics department’s Cosmology and Astroparticle Physics Theory group addresses cutting-edge problems on both scales, using the universe to learn about fundamental particle physics and employing what is learned from particle physics to provide a better understanding of the universe and the objects in it. Members of this group, all of whom have joint appointments in the Department of Astronomy, work very closely with their astronomy colleagues, as well as with the physics department’s experimental astroparticle physics group. More information on these interdisciplinary collaborations, which include a free flow of students and postdocs, is available on page 27.

Building on the wealth of observational data accumulated in recent years, the group explores issues of the early evolution of the universe, such as “inflation,” the production and survival of relics from the Big Bang, synthesis of the elements in the first few minutes, connections between the currently observed large scale structure of the universe and the tiny temperature anisotropies in the Cosmic Background Radiation and the nature of “dark Energy.” It is also interested in the more recent evolution of the universe, from star formation and supernovae, to dark matter in the Milky Way and its environs. The observed high energy cosmic rays, gamma rays and neutrinos reveal the presence of galactic and extragalactic cosmic accelerators that directly affect the structure and evolution of the galaxy and the universe and that provide new laboratories for exploring physics at the very highest energies and energy densities. The group is very involved in the Center for Cosmology and AstroParticle Physics (CCAPP), [ccapp.osu.edu](http://ccapp.osu.edu).



## Experimental Cosmology and Astroparticle Physics

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James Beatty Amy Connolly Klaus Honscheid Richard Hughes Brian Winer

### Experimental Astroparticle Physics faculty

**James J. Beatty**, Professor  
PhD, University of Chicago, 1986  
The highest energy cosmic rays  
and neutrinos  
Cosmic ray spectrum, composition  
and anisotropy  
Radio detection of cosmic rays and neutrinos

**Amy L. Connolly**, Associate Professor  
PhD, University of California, Berkeley, 2003  
High energy neutrino astronomy  
Connecting neutrino and cosmic ray  
measurements with astrophysics

**Klaus Honscheid**, Professor  
Dr. rer. Nat. Universitiy of Bonn, 1988  
Dark energy  
(see also Experimental High Energy)

**Richard E. Hughes**, Professor  
PhD, University of Pennsylvania, 1992  
Very high energy gamma-ray  
astronomy with FGST  
(see also Experimental High Energy)

**Brian L. Winer**, Professor  
PhD, University of California, Berkeley, 1991  
Very high energy gamma-ray  
astronomy with FGST  
(see also Experimental High Energy)



Astrophysics and cosmology allow us to test the laws of nature in ways impossible with laboratory and accelerator experiments. These settings involve distances, timescales and energies beyond those possible on Earth. Energetic particles, gamma rays and neutrinos are produced in a wide range of astrophysical contexts. These include supernovae, relativistic jets in active galaxies and black holes and neutron stars. Observations can be used to probe both the astrophysics of the sources and the nature of fundamental physical interactions.

We design and build sensitive instruments to map the expansion history of the universe and to measure energetic charged particles, photons and neutrinos. Detectors are deployed in remote locations such as Antarctica, Chile and rural Argentina, flown on enormous balloons or launched into space. Data is returned for analysis at Ohio State and collaborating institutions. Funding comes from the NSF, NASA and the Department of Energy.

Areas of interest include:  
The highest energy cosmic rays: Cosmic rays with energies of up to 50 joules have been observed. The origin of these particles is a mystery, since it is difficult to accelerate subatomic particles to these energies and to understand how they travel through the radiation backgrounds that fill intergalactic space. We are involved in the Pierre Auger project, building and operating a 3000 km<sup>2</sup> observatory in western Argentina.

Dark energy: Arguably one of the most important and certainly one of the most surprising scientific results of the last decades was the discovery that the expansion of the universe is accelerating. In order to explain this acceleration we are faced with two possibilities: Either 76% of the universe exists in an exotic form called dark energy, that exhibits a gravitational force opposite the attractive gravity of ordinary matter, or Einstein’s very successful theory of gravity, General Relativity, must be incorrect at cosmic scales. We are partners in the Dark Energy Survey (DES) and the Baryon Acoustic Spectroscopic Survey (BOSS) projects, which are designed to probe the origin of the cosmic acceleration and help to uncover the nature of dark energy.

Neutrino astronomy: Neutrinos are weakly interacting particles, so they pass through the universe relatively unimpeded by intervening matter and radiation, making them unique probes of the early universe. However, extremely large detection volumes are necessary to observe the low flux of neutrinos expected at the highest energies. We are involved in the Antarctic Impulsive Transient Antenna (ANITA) and Askaryan Radio Array (ARA) experiments to detect ultra-high energy neutrinos by measuring radio bursts produced when neutrinos interact in the Antarctic ice cap. ANITA is a long-duration NASA balloon experiment and ARA is an antenna array in the early stages of deployment near the South Pole.



# Research Groups — Atomic, Molecular and Optical Physics

## Atomic, Molecular and Optical Physics

physics.ohio-state.edu/~amo



Pierre Agostini



Kramer Akli



C. David Andereck



Enam Chowdhury



Frank De Lucia



Louis DiMauro



Richard Freeman



Daniel Gauthier



Gregory Lafyatis



Douglass Schumacher



Linn Van Woerkom



Brenda Winnewisser



Manfred Winnewisser

Ohio State has long been a center for atomic, molecular and optical physics (AMO physics). The research program in AMO goes beyond traditional spectroscopic studies, encompassing laser physics, ultrafast optical physics, laser-plasma processes, investigations of planetary atmospheres and the interstellar medium and optical cooling and trapping of atoms, network and quantum information sciences. The department enjoys collaborations with strong laser groups in the Department of Chemistry including the Laser Spectroscopy Facility, which is a state-of-the-art laser laboratory. In addition, Ohio State is a leader in ultrafast technologies to study atoms and molecules, ranging from isolated laser-matter interactions to solvent-solute interactions in liquids to laser-induced fusion processes.

Graduate students are a key element in the success of the programs. Many opportunities for research exist within the department, across disciplines and beyond. Graduate students are involved in the following research areas:

- Quantum electronics working with millimeter and submillimeter waves; laboratory astrophysics and upper atmosphere physics; molecular collisions and chemical physics.
- Network science studying the dynamics of networks.
- Using laser light to manipulate the translational degrees of freedom of atoms. Atomic samples at ultra-cold (less than 1 millikelvin) temperatures may be obtained.
- Multiphoton ionization of atoms and molecules.
- Ultrashort laser-plasma interactions.
- Coherent control of atomic systems.
- Propagation of intense laser pulses through solids, liquids and gasses. This involves super continuum generation, intensity dependent group velocity dispersion, plasma generation and other effects.
- High Energy Density Physics, a relatively new field of the experimental study of matter at the extremes of density and temperature. Although not found naturally on earth, it is the most abundant form of matter in the universe: stars ([hedp.osu.edu](http://hedp.osu.edu)).



### Atomic, Molecular and Optical Physics faculty

**Pierre Agostini**, Professor  
Doctorat, Universite Aix Marseille, 1967  
Multiphoton Processes  
Strong field interaction, high harmonic generation  
Attosecond pulses, AttoPhysics

**Kramer Akli**, Assistant Research Professor  
PhD, University of California, Davis, 2006  
QED in extremely intense laser fields  
Laser driven ion acceleration  
High order harmonics from plasmas  
Hot dense & warm dense matter

**C. David Andereck**, Emeritus Professor  
PhD, Rutgers University, 1980  
High energy density physics

**Enam A. Chowdhury**, Research Assistant Professor  
PhD, University of Delaware, 2004  
Short pulse lasers  
Ultra-fast dynamics of solids  
Ultra-intense and high energy density laser matter

**Frank C. De Lucia**, Distinguished University Professor  
PhD, Duke University, 1969  
Quantum electronics, millimeter and submillimeter waves  
Laboratory astrophysics, upper atmospheric physics  
Molecular spectroscopy and collisions, chemical physics

**Louis DiMauro**, Professor and the Edward and Sylvia Hagenlocker Chair  
PhD, University of Connecticut, 1980  
Atomic, chemical and ultrafast optical physics  
Strong field interactions  
Ultrafast laser physics  
Attophysics  
Nonlinear optics  
Short wave length generation  
Quantum control methods  
Many body physics  
Application of fourth generation light sources

**Richard R. Freeman**, Distinguished Professor of Mathematical and Physical Sciences  
PhD, Harvard University, 1973  
Interactions of high powered lasers with matter  
Non-linear optics laser fusion experiments

**Daniel Gauthier**, Professor  
PhD, University of Rochester, 1989  
Network Science Research  
Quantum Information Science Research

**Gregory P. Lafyatis**, Associate Professor  
PhD, Harvard University, 1982  
Laser physics  
Trapping and cooling of atomic particles

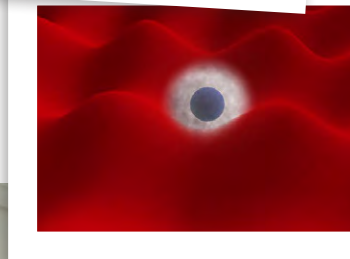
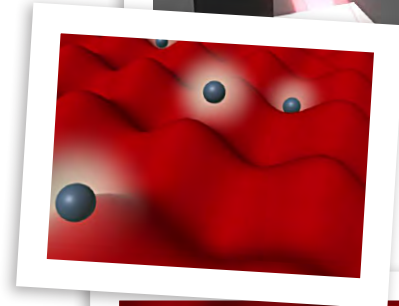
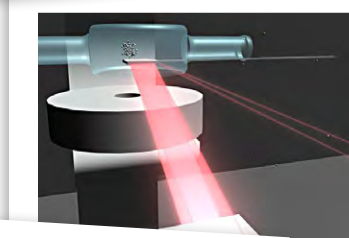
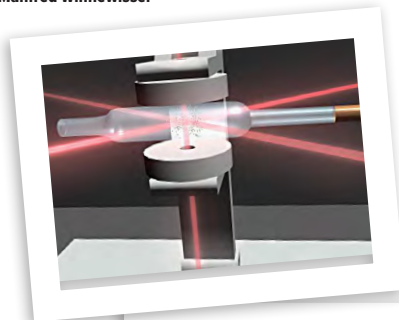
**Chris Orban**, Assistant Professor (Ohio State Marion branch)  
PhD, Ohio State University, 2011  
Laboratory and Astrophysical Plasmas  
Particle-in-Cell and hydrodynamic simulations  
High Energy Density Physics

**Douglass Schumacher**, Associate Professor  
PhD, University of Michigan, 1995  
Ultrafast nonlinear optics  
Intense field laser-matter interactions  
High energy density physics  
Ultrashort laser-plasma interactions  
Nonlinear optics  
Particle-in-cell simulation

**Linn Van Woerkom**, Professor and Associate Provost and Director, University Honors & Scholars Center  
PhD, University of Southern California, 1987  
High-intensity, ultrashort pulse laser-matter interactions  
High energy density physics  
Ultrashort pulse and X-ray physics

**Brenda P. Winnewisser**, Adjunct Professor  
PhD, Duke University, 1965  
Fourier transformer infrared spectroscopy, spectral analysis  
Solid hydrogen  
History of science

**Manfred Winnewisser**, Adjunct Professor  
Dr. rer. Nat., University of Karlsruhe, 1960  
Fourier transformer infrared spectroscopy  
Millimeter and submillimeter spectroscopy  
Reactive and unstable species





# Research Groups — Biophysics, Cold Atom Physics

## Biophysics

physics.ohio-state.edu/~bio



Ralf Bundschuh



C. Jayaprakash



Comert Kural



Michael Poirier



Dongping Zhong

## Cold Atom Physics

physics.ohio-state.edu/~coldatoms  
/coldatomphysics.html



Eric Braaten



Richard Furnstahl



Tin-Lun (Jason) Ho



Mohit Randeria



Nandini Trivedi

### Biophysics faculty

- Ralf Bundschuh**, Professor  
PhD, Universität Potsdam, 1996  
RNA structure: statistical mechanics and quantitative prediction  
RNA editing  
Biological sequence database searches  
Biomolecules  
Bioinformatics
- C. Jayaprakash**, Professor  
PhD, University of Illinois, Urbana, 1979  
Genetic regulatory systems  
Modeling of the adaptive immune system in humans  
Nonlinear ecological dynamics
- Comert Kural**, Assistant Professor  
PhD, University of Illinois, Urbana-Champaign, 2007  
Experimental biophysics and computational biology  
Three-dimensional cell and tissue imaging  
Dynamics of clathrin-mediated endocytosis in living organisms  
Tissue morphogenesis, cell migration and signaling
- Michael Poirier**, Associate Professor  
PhD, University of Illinois, Chicago, 2001  
Chromatin and chromosome structure and function  
Chromatin remodeling  
Mechanisms of molecular machines  
Bacterial population dynamics and diversity
- Dongping Zhong**, Professor  
PhD, California Institute of Technology, 1999  
Femtobiology  
Biomolecular interactions  
Protein dynamics

Biophysics is the application of physical methods to solve problems in biology. At Ohio State we have a young and dynamic group covering experimental and theoretical biophysics with numerous links to other departments and colleges throughout the campus.

The fundamental goal of biological sciences is to understand how life functions. This comprises fascinating questions on many different length scales from the individual molecule over cells and organisms to whole ecologies. Increasingly, answering the truly cutting-edge questions in the biological sciences requires interdisciplinary approaches that combine the traditional methods of biology with the methods developed in the physical sciences.

The current areas of study in the Biophysics group provide many examples of where cutting-edge physical methods are employed to solve important biological problems; e.g., the Biophysics group uses sophisticated femtosecond laser set-ups to observe how proteins convert light into chemical energy or how they repair damaged DNA. The group is able to hold on to individual biomolecules and measure mechanical forces in the piconewton range in order to dissect how the genetic material is organized into the chromosomes, and the group uses cutting edge microscopy and image analysis techniques to study how mechanical forces regulate cellular membrane trafficking during developmental stages of multicellular organisms.

Lastly, it uses the mathematical and computational techniques from statistical physics to interpret the vast amounts of biological sequence data generated, e.g., by the human genome project, and the folding of and interactions between biomolecules, as well as to understand the behavior of the Lake Erie ecosystem and the human immune system.

Most projects of the Biophysics group involve close collaborations with faculty and students from different departments. This enables graduates of the Biophysics group to develop into independent researchers with the experience in both physical and biological methods to answer critical biological questions. Graduates are able to transcend traditional areas so that they interact, collaborate and work with both physicists and biologists.



### Cold Atom Physics faculty

- Eric Braaten**, Professor  
PhD, University of Wisconsin, 1981  
Strongly interacting quantum gases  
Bose-Einstein condensates  
Few-body physics for atoms with large scattering lengths  
Efimov states
- Richard Furnstahl**, Professor  
PhD, Stanford University, 1986  
Effective field theory for many-body systems  
Pairing mechanisms for Fermi gases  
Density functional theory
- Tin-Lun (Jason) Ho**, Distinguished Professor of Mathematical and Physical Sciences  
PhD, Cornell University, 1977  
Fundamental issues in dilute quantum gases:  
scalar and spinor Bose condensates  
Fermi gases with large spin  
mixtures of Bose and Fermi gases  
quantum gases in optical lattices and in rapidly rotating potentials  
boson mesoscopes  
processing quantum information with spinor Bose condensates  
Quantum Hall effect with internal degrees of freedom  
Strongly correlated electron systems  
Quantum fluids
- Mohit Randeria**, Professor  
PhD, Cornell University, 1987  
Strongly interacting quantum gases  
BEC-BCS crossover in Fermi gases  
Optical lattices
- Nandini Trivedi**, Professor  
PhD, Cornell University, 1987  
Fermions and bosons in optical lattices  
BCS-BEC crossover  
Quantum Monte Carlo simulations of cold atoms

The field of quantum gases or ultracold atoms is the fastest expanding and most interdisciplinary field in physics today. The experimental branch of this exciting new field uses the techniques of atomic, molecular and optical physics to study many-body systems consisting of extremely cold-trapped atoms. These are condensed matter systems whose constituents have well-understood microscopic interactions. At sufficiently low temperatures, the large de Broglie wavelengths of the atoms allow these systems to exhibit quantum phenomena on a macroscopic scale. The theoretical branch of this field is completely interdisciplinary, attracting top scientists from atomic, condensed matter, high energy and nuclear physics, as well as from quantum optics and quantum information. The Cold Atom Physics group at Ohio State has established itself as one of the world's top theory groups in this area.

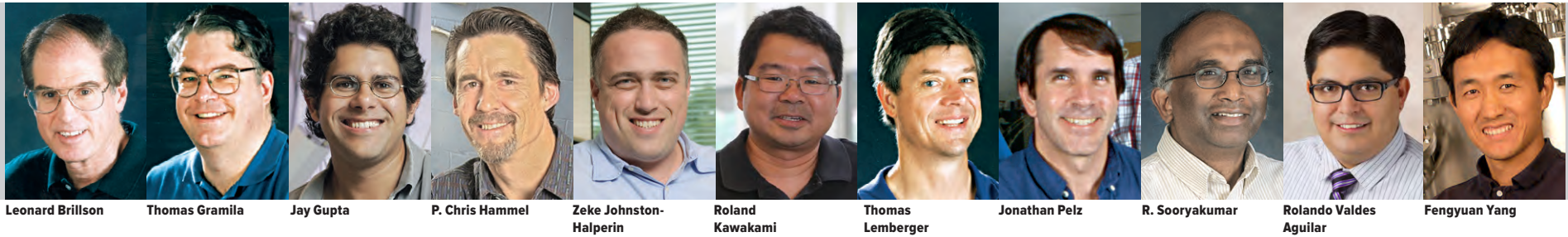




# Research Groups — Condensed Matter

## Condensed Matter Experiment

physics.ohio-state.edu/~cme/CMEfaculty.htm



The largest research area in physics today deals with the diverse and fascinating properties of condensed matter, encompassing metals, semiconductors, superconductors, polymers, fluids and superfluids, magnets and insulators. This area corresponds to the single largest research group in the department, involving 12 experimentalists and eight theorists.

Experimental groups ordinarily consist of a professor, possibly a postdoctoral researcher and several graduate students, with support from a federal source, such as the National Science Foundation or Department of Energy, or from an industrial source.

Group members benefit from each other through sharing of laboratory equipment and expertise, as well as through formal collaborations and materials-related research centers, including the Center for Emergent Materials and the Center for Exploration of Novel Complex Materials (see page 27). There are also a number of excellent shared research facilities located in the Physics Research Building (see page 7).

In addition to strong interactions among the condensed matter experimentalists, a large and active theory group offers expertise in a broad range of subjects. There are about 50 PhD students in condensed matter physics, and at least that many ongoing research projects. They reflect the major directions of current condensed matter research. Some of the problems being investigated are listed below:

- Scanning tunneling microscopy studies of quantum electronic phenomena and atomic scale reactions at surfaces of semiconductors and low-dimensional materials.
- Magnetic and electronic properties of nanoscale magnetic, semiconducting and metallic systems.
- Novel approaches to very high resolution scanned probe microscopy.
- Ultra-high vacuum growth and characterization of complex oxides and other materials with novel magnetic, electronic and thermal properties.
- Magnetic resonance and ferromagnetic resonance force microscopy of novel materials, device structures and nanostructures.
- Optoelectronic, microelectronic and nanoelectronic interface atomic structure.
- Semiconductor interface growth, processing and characterization by ultra-high vacuum surface science techniques.
- Schottky barriers and heterojunction band offsets.
- Raman scattering and magneto-optical imaging of submicron and nanostructures.
- Brillouin scattering studies of magnetic and elastic properties of hybrid structures and membranes.
- Manipulation and control of living cells using magnetic fields and nanostructures.
- Emergent low energy degrees of freedom of complex correlated material systems (quantum matter) using optical spectroscopies with femtosecond and picosecond time resolution.
- Ultrashort pulses of terahertz and infrared radiation to control/modify quantum matter states.
- Spin transport in graphene and other two-dimensional materials.
- Molecular Beam epitaxy of novel magnetic heterostructures.
- Ultrafast optical microscopy and spectroscopy.

### Condensed Matter Experiment faculty

**Leonard J. Brillson**, Professor and CMR Scholar, Department of Physics and Department of Electrical and Computer Engineering  
PhD, University of Pennsylvania, 1972  
Semiconductor interface growth, processing, and characterization by ultrahigh vacuum surface science techniques  
Schottky barriers and heterojunction band offsets  
Optoelectronic, microelectronic and nanoelectronic interface atomic structure  
Solar cells, bioelectric sensors, ultraviolet microlasers  
Ferroelectric/ferromagnetic complex oxides for spintronics and electromagnetic metamaterials

**Thomas Gramila**, Associate Professor and Vice Chair for Administration  
PhD, Cornell University, 1990  
Properties of electronic materials at low temperatures and high magnetic fields  
Two-dimensional electron gases and Quantum Hall effects  
Electron interactions and correlation effects  
Disordered conductors, magnetic properties

**Jay Gupta**, Associate Professor  
PhD, University of California, Santa Barbara, 2002  
Nanoscale studies of organic magnets and conductors  
Evolution of electronic and optical properties in nanoclusters  
Microscopic studies of spin-scattering in semiconductors  
Atomic-scale chemistry on surfaces

**P. Chris Hammel**, Ohio Eminent Scholar and Director of CEM  
PhD, Cornell University, 1984  
Magnetic resonance force microscopy  
Spin electronics and solid state quantum computing  
Nanoscale and multicomponent magnetic systems  
Magnetic properties of endohedral fullerenes

**Zeke Johnston-Halperin**, Associate Professor and Director of ENCOMM  
PhD, University of California at Santa Barbara, 2003  
Spin in reduced dimension  
Study of spin dynamics, scattering and transport in nanoscale semiconducting materials  
Multifunctional magnetic materials  
Development and characterization of magnetic materials with multifunctional properties (magnetization coupled to charge, strain, chemical activity, etc.) for spintronic applications  
Spin injection/detection in heterostructures  
Exploration of spin injection and detection in heterogenous materials such as metal/semiconductor, organic/inorganic, and molecular/bulk heterostructures

**Roland K. Kawakami**, Professor  
PhD, University of California, Berkeley, 1999  
Spin transport in graphene and other two-dimensional materials  
Molecular Beam epitaxy of novel magnetic heterostructures  
Ultrafast optical microscopy and spectroscopy

**Thomas R. Lemberger**, Professor  
PhD, University of Illinois at Urbana, 1978  
Magnetic and electrical properties of films and crystals of conventional and high-temperature superconductors  
Tunneling and transport effects in superconductors  
Superconductor-to-insulator quantum transition fluctuations  
Thin-film fabrication and characterization

**Jonathan Pelz**, Professor and Vice Chair for Graduate Studies and Research  
PhD, University of California, Berkeley, 1988  
Surface and interface science, scanning tunneling, ballistic-electron emission and atomic force microscopies  
Numerical modeling  
Nm-resolution electronic behavior of nanostructures, wide bandgap materials, metal/dielectric interfaces and semiconductor surfaces  
Surface science, scanning tunneling microscopy  
Step dynamics on semiconductor surfaces  
Nanoscale properties of buried wide bandgap semiconductor films and interfaces  
Nanoscale properties of magnetic multilayers  
Atomic scale surface reactions

**R. Sooryakumar**, Professor  
PhD, University of Illinois 1980  
Application and development of spectroscopy probes (Raman scattering, Brillouin scattering and Kerr microscopy) for probing electronic, vibrational, optical and magnetic behavior of novel materials  
Magnetic and spin wave excitations and influence of current injection in hybrid micrometer and sub-micron patterned structures  
Elastic excitations and guided acoustic resonances in confined geometries  
Development of non-invasive techniques for elastic properties of biological tissues  
Photo-induced properties of network glasses

**Rolando Valdes Aguilar**, Professor  
PhD, University of Maryland, 2008  
Terahertz spectroscopy  
Strongly correlated systems  
Ultrafast spectroscopy

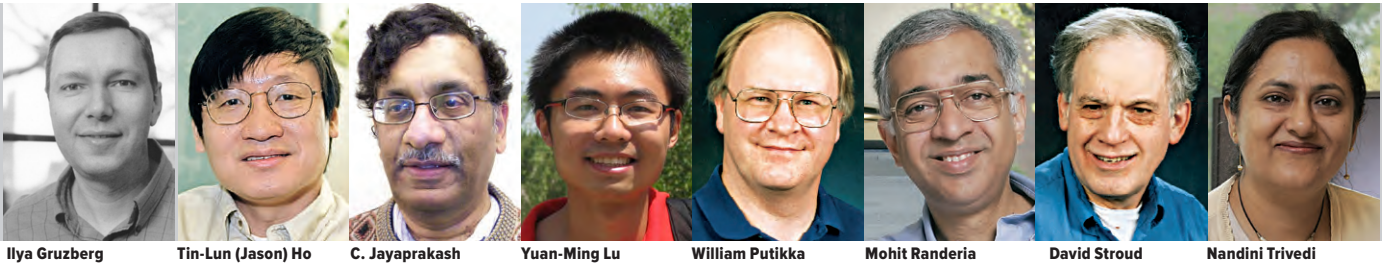
**Fengyuan Yang**, Professor  
PhD, Johns Hopkins University, 2001  
Fabrication and experimental investigation of structural, electronic and magnetic properties of nanostructured materials  
Metallic and oxide epitaxial films  
Spintronics in semiconductor nanowires, including spin injection, spin diffusion and spin detection



# Research Groups — Condensed Matter

## Condensed Matter Theory

physics.ohio-state.edu/~cmt/osucmt.html



The condensed matter theory group is vigorous and diverse, including six faculty, five postdoctoral researchers, about 12 graduate students and several undergraduates. Our strengths include correlated quantum materials, magnetism and superconductivity, ultra-cold atomic gases, quantum Hall effect, topological matter, disordered systems, electronic structure and properties of complex materials.

Members of the group collaborate with each other, as well as with experimentalists in the physics department and faculty in chemistry and the College of Engineering, as well as at other universities and industrial and national laboratories. Group members are supported by the National Science Foundation, the Department of Energy, DARPA, NASA and private industry. Members of the group are actively involved in the OSU Center for Emergent Materials, an NSF MRSEC.

The research environment is friendly and stimulating. A typical research project consists of one or more faculty members, perhaps a postdoc and a graduate student. Students receive close individual attention and, after graduation, have obtained positions with various prestigious employers, such as Harvard, Cornell, Illinois and Brown.

Faculty, postdocs and students are all located on the second floor of the Physics Research Building. Computer facilities are excellent, as there are numerous powerful workstations available to members of the group, as well as links to the Ohio Supercomputer Center and all the national supercomputer centers.

Projects under way include some of the most exciting topics in the field, such as:

- Cold atoms: Bose-Einstein and fermion pair condensates; optical lattices; synthetic gauge fields
- Strong correlations, magnetism and spin orbit coupling in oxides
- High temperature superconductivity
- Quantum Hall effect
- Topological quantum matter
- Quantum phase transitions
- Disordered systems: superconductor-insulator and quantum Hall transitions
- Molecular dynamics and electronic structure of complex, realistic materials

### Condensed Matter Theory faculty

**Ilya A. Gruzberg**, Professor  
PhD, Yale University, 1998  
Quantum condensed matter physics  
Classical condensed matter physics:  
non-equilibrium growth phenomena  
Statistical and mathematical physics

**Tin-Lun (Jason) Ho**, Distinguished Professor  
of Mathematical and Physical Sciences  
PhD, Cornell University, 1977  
Fundamental issues in dilute quantum gases:  
scalar and spinor Bose condensates  
Fermi gases with large spin  
mixtures of Bose and Fermi gases  
quantum gases in optical lattices and in  
rapidly rotating potentials  
boson mesoscopes  
processing quantum information  
with spinor Bose condensates  
Quantum Hall effect with internal degrees  
of freedom  
Strongly correlated electron systems  
Quantum fluids

**C. Jayaprakash**, Professor  
PhD, University of Illinois at Urbana, 1979  
Nonlinear ecological dynamics  
Genetic regulatory systems  
Fully developed turbulence

**Yuan-Ming Lu**, Professor  
PhD, Boston College, 2011  
Topological phenomena in condensed  
matter physics  
Unconventional superconductivity  
Quantum Hall effects  
Frustrated magnets and spin liquids  
Correlated electron materials

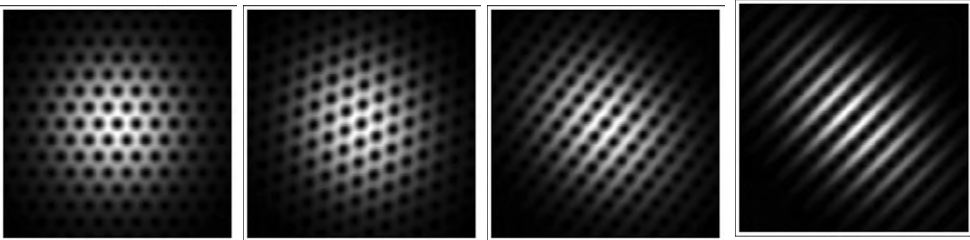
**William Putikka**, Professor  
(Ohio State Mansfield)  
PhD, University of Wisconsin, 1988  
High-temperature superconductivity:  
phenomenological and  
microscopic models  
Two-dimensional strongly  
correlated electrons  
Unconventional superconductivity  
Spin relaxation in semiconductors  
Spintronics  
Semiconductor based quantum computers

**Mohit Randeria**, Professor  
PhD, Cornell University, 1987  
High Tc superconductivity and strongly  
correlated electronic systems  
Angle-resolved photoelectron spectroscopy  
Nanoscale and inhomogeneous  
superconductors  
Quantum gases and BCS-BEC crossover

**David C. Stroud**, Emeritus Professor  
PhD, Harvard University, 1969  
Quantum effects in Josephson junction  
arrays and high-Tc superconductors  
Superconducting qubits  
Magnetic, superconducting and optical  
properties of nanostructured materials  
Ab initio molecular dynamics simulations  
of disordered media magnetic,  
superconducting and optical  
nanostructures

**Nandini Trivedi**, Professor  
PhD, Cornell University, 1987  
Strongly correlated superconducting and  
magnetic materials  
Disorder and interaction driven quantum  
phase transitions  
Fermions and bosons in traps  
Quantum Monte Carlo simulations

**John W. Wilkins**, Ohio Eminent  
Scholar, Professor  
PhD, University of Illinois, 1963  
Molecular dynamics, density functional  
theory, and quantum Monte Carlo for  
dynamics of microstructural transitions in  
metals and semiconductors and designing  
excitations in heterostructures

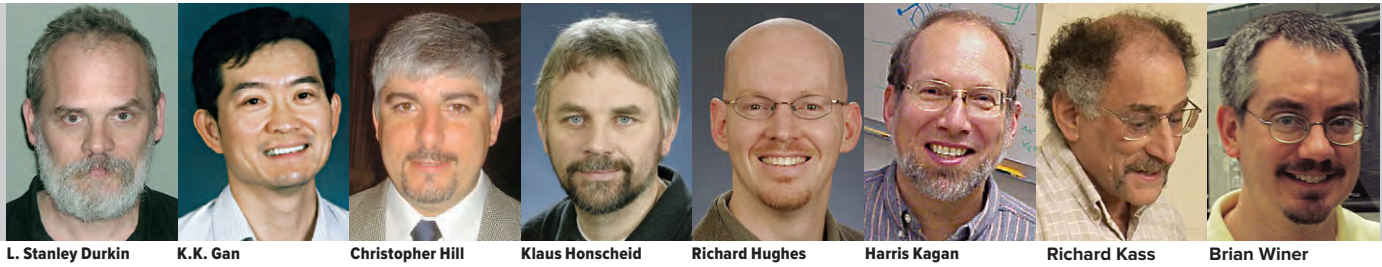




# Research Groups — High Energy

## Experimental High Energy

[physics.ohio-state.edu/research/he\\_experiment.html](http://physics.ohio-state.edu/research/he_experiment.html)



High Energy Physics explores fundamental questions about the nature of our universe. Research in this field seeks to identify the fundamental constituents of matter and uncover the laws that govern their interactions. The current picture of what these building blocks are, and how they work together, is called the Standard Model—a crucial piece of which is the recently discovered Higgs boson. This model, however, has a number of shortcomings (e.g. it does not account for dark matter, dark energy or gravity) that lead particle physicists to search for a more fundamental theory.

Extremely high energy collisions are required to create the new particles that would be evidence of such “beyond the Standard Model” (BSM) physics, and very large particle accelerators are necessary to provide these collisions. The HEE group at Ohio State is involved in two such experiments (ATLAS and CMS) that utilize the largest particle accelerator in the world, the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland. After a very successful Run I of proton-proton collisions at  $\sqrt{s} = 7/8$  TeV during which the Higgs boson was discovered by the ATLAS and CMS experiments, LHC is gearing up for Run 2 that will provide proton-proton collisions at about  $\sqrt{s} = 13$  TeV in 2015. The increase in energy offers the ATLAS and CMS experiments an excellent opportunity to further elucidate the properties of the Higgs Boson, and the potential to observe BSM particles and make significant progress towards the ultimate goal of revealing a more fundamental theory.

There are seven faculty members in this research area, with about 10 postdoctoral researchers, 10–15 graduate students and a supporting staff of engineers and technicians. Faculty members are among the leaders of the international ATLAS and CMS collaborations with Ohio State physicists playing major roles in the design and construction of these experiments as well as making significant contributions to data analysis efforts (including the aforementioned Higgs boson discovery). Funding comes primarily from the Department of Energy and totals more than a million dollars annually.



### Experimental High Energy faculty

**L. Stanley Durkin**, Professor  
PhD, Stanford University, 1981  
Lepton-hadron scattering  
Intrinsic properties of neutrinos  
Search for massive Higgs particles

**K.K. Gan**, Professor  
PhD, Purdue University, 1985  
Physics beyond the Standard Model  
in e-e- and hadron colliders  
High-resolution energy and  
position detectors  
Radiation-hard optical data communication

**Christopher S. Hill**, Associate Professor  
PhD, University of California, Davis, 2001  
Searches for evidence beyond the  
Standard Model  
Studies in the properties of the Top Quark

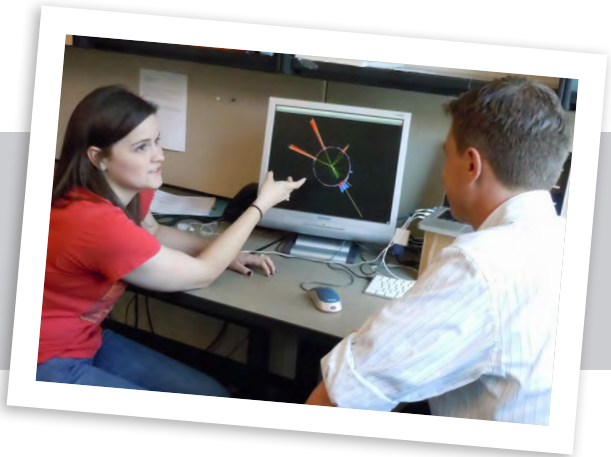
**Klaus Honscheid**, Professor  
Dr. rer. Nat. Universit University  
of Bonn, 1988  
Decay properties of heavy quarks  
Trigger and data acquisition systems  
Experimental cosmology

**Richard E. Hughes**, Professor  
PhD, University of Pennsylvania, 1992  
Astro-particle physics using  
the FGST satellite  
Search for the source of dark matter  
High-energy physics studies using  
proton-antiproton collider  
Study of the top quark  
Development of a trigger track processor

**Harris P. Kagan**, Professor  
PhD, University of Minnesota, 1979  
Electron-positron interactions  
High-resolution energy and  
position detectors

**Richard Kass**, Professor  
PhD, University of California, Davis, 1978  
Electron-positron interactions using the  
BABAR experiment  
High energy hadron interactions using  
the ATLAS experiment  
High-resolution energy and position  
detectors

**Brian L. Winer**, Professor  
PhD, University of California, Berkeley, 1991  
Testing of the Standard Model of  
particle physics  
Detailed studies and measurements of  
the top quark  
Development of DAQ/Trigger Electronics  
Exploring the universe with high energy  
gamma rays  
Searching for dark matter





# Research Groups — High Energy

## High Energy Theory

physics.ohio-state.edu/he\_theory/he\_theory.html



Eric Braaten



Linda Carpenter



Gregory Kilcup



Samir Mathur



Stuart Raby



Junko Shigemitsu

High energy physics is concerned with the most elementary building blocks of nature and the fundamental forces between them. In the 20th century, physicists learned that all matter is composed of a relatively small number of elementary particles called quarks and leptons. They interact by electroweak and strong forces that are mediated by elementary particles called gauge bosons, namely the photon, the W and Z bosons, and gluons. The known quarks, leptons, and gauge bosons and the electroweak and strong forces are all described by a relativistic quantum field theory known as the Standard Model. It includes the electroweak theory, which unites the weak and electromagnetic interactions and has a symmetry that relates the massless photon and the massive W and Z bosons. The conflict between this symmetry and the very different masses is reconciled by spontaneous symmetry breaking, which requires the existence of an additional particle called the Higgs boson. The recent discovery of the Higgs boson provides the last missing particle in the Standard Model.

Relativistic quantum field theory is the basic language of high energy physics. Some aspects of quantum field theory are perturbative—that is, they can be understood in terms of Feynman diagrams. Diagrammatic methods are one of the basic research tools of the group. There are other aspects of quantum field theory that are nonperturbative. A major effort at Ohio State involves solving nonperturbative quantum field theories using lattice gauge theory, a method in which space-time is approximated by a lattice of discrete points. Another research effort uses effective field theories to develop systematic approximations to some nonperturbative aspects of a theory. Another important research direction is the study of supersymmetric quantum field theories, which have a special symmetry that relates fermions and bosons and makes some nonperturbative problems more tractable.

There are many reasons to believe that the Standard Model is incomplete, and that there are other elementary particles and fundamental forces in nature. They include the existence of dark matter, oscillations between different neutrinos, the asymmetry between matter and antimatter in the universe, and the equal strength of the three Standard Model forces at some large energy scale. A major effort at Ohio State is trying to discover the new physics beyond the Standard Model. One possibility is the unification of the three Standard Model forces into a single force, possibly through a supersymmetric quantum field theory that also unifies the elementary particles. Another possibility is that the mechanism for spontaneous symmetry breaking is more complicated than in the Standard Model and involves additional Higgs bosons.

The strong force between quarks in the Standard Model is described by Quantum Chromodynamics (QCD). This quantum field theory has perturbative aspects that can be calculated using Feynman diagrams and also nonperturbative aspects that can be calculated using lattice gauge theory and with effective field theories. A major effort at Ohio State is the study of the heavy charm and bottom quarks and their bound states using lattice gauge theory, effective field theories, and perturbative QCD. The lattice QCD calculations require the use of the most powerful supercomputers, such as are available on campus at the Ohio Supercomputer Center.

Any final theory of physics must incorporate a quantum theory of gravitation. Quantizing gravity has proved to be a difficult problem, but string theory has become established as a consistent theory of quantum gravity. String theory has a rich mathematical structure that is still being explored. A major effort at Ohio State is using string theory to explain the mysterious quantum properties of black holes. Another effort uses string theory to construct extensions of the Standard Model that go beyond quantum field theory.



### High Energy Theory faculty

**Eric Braaten**, Professor  
PhD, University of Wisconsin, 1981  
Quantum field theory  
Heavy quarks and quarkonium  
Effective Field Theory  
Perturbative QCD  
Ultra Cold Atoms

**Linda Carpenter**, Assistant Professor  
PhD, Johns Hopkins University, 2006  
High energy physics  
Higgs physics and supersymmetry  
LHC phenomenology  
Model building  
Phenomenology of weak scale physics

**Gregory Kilcup**, Associate Professor  
PhD, Harvard University, 1986  
Elementary particle theory lattice gauge theory  
Supercomputing

**Samir Mathur**, Professor  
PhD, Tata Institute, 1987  
String theory  
Black holes  
General relativity

**Stuart Raby**, Professor  
PhD, Tel Aviv University, 1976  
Physics beyond the Standard Model (grand unified and supersymmetric models)  
Problems on the interface of particle physics and astrophysics  
Understanding electroweak symmetry breaking and fermion masses  
Working on the construction of realistic models of particle physics, based on 10 dimensional superstring theory

**Junko Shigemitsu**, Professor PhD, Cornell University, 1978  
Lattice gauge theory  
Nonperturbative approaches to strong interactions  
Heavy quark physics  
Tests of the consistency of the Standard Model of particle physics



Star



White Dwarf



Neutron star



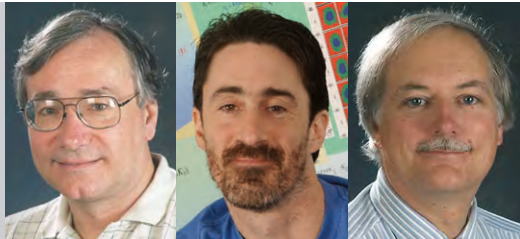
Fuzzball  
= string star



# Research Groups — Nuclear Physics

## Nuclear Physics Experiment

physics.ohio-state.edu/HIRG



Thomas Humanic   Michael Lisa   Evan Sugarbaker

### Nuclear Physics Experiment faculty

**Thomas J. Humanic**, Professor  
PhD, University of Pittsburgh, 1979  
Relativistic proton and heavy ion collisions  
CERN Large Hadron Collider  
ALICE experiment  
Boson interferometry  
Extra-dimensional physics  
Collision model calculations

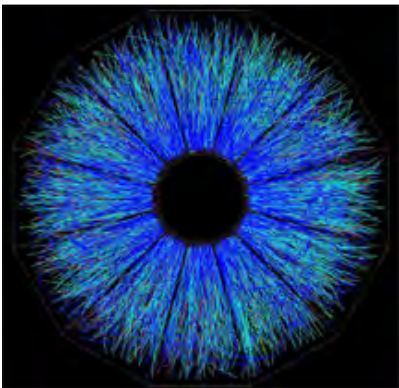
**Michael A. Lisa**, Professor  
PhD, Michigan State University, 1993  
Relativistic heavy ion collisions;  
nuclear equation of state and  
study of quark-gluon plasma  
Collective effects  
Intensity interferometry

**Evan R. Sugarbaker**, Emeritus Professor  
PhD, University of Michigan, 1976  
Spin, isospin character of nucleons in  
nuclear matter  
Neutrino detection  
Relativistic heavy-ion collisions

The Nuclear Physics Experiment group is actively pursuing a wide range of research topics in the field of relativistic heavy ion collisions. The group includes two Ohio State physics faculty, seven physics graduate students and typically several undergraduate students. It is well supported by the National Science Foundation. Experiments are performed at the high energy accelerator facilities at Brookhaven National Laboratory where the Relativistic Heavy-Ion Collider (RHIC) has been in operation since 2000 (STAR Experiment), and at the CERN laboratory in Geneva, Switzerland, where an even higher energy collider, the Large Hadron Collider (LHC), has recently become operational, with new data from heavy ion collisions at the ALICE Experiment already leading to new physics. Each experiment typically involves several graduate students, one or two postdocs, and faculty from Ohio State. Graduate students are involved in every aspect of the work, from equipment design through the actual measurements, to data reduction and analysis, and manuscript preparation. Students acquire many experimental skills such as knowledge and use of electronics and computers and design and use of mechanical equipment. The variety of skills obtained is reflected in the positions obtained by our graduate students after they finish their doctoral degrees. While many are presently in academic positions, others have entered such fields as geophysics, satellite communications and medical physics.

Current physics research topics include:

- Relativistic heavy-ion collisions
- Boson interferometry studies for pion/kaon source sizes
- Nuclear equation of state
- Collective effects and flow
- Study of quark-gluon plasma
- Transverse momentum distributions (pion, kaon, proton, antiproton)
- Monte Carlo simulations of relativistic heavy-ion collisions





# Research Groups — Nuclear Physics

## Nuclear Physics Theory

physics.ohio-state.edu/~ntg



Richard Furnstahl    Ulrich Heinz    Sabine Jeschonnek    Yuri Kovchegov    Robert Perry

The Nuclear Theory group studies a broad range of problems involving the strong interaction. This research includes the direct study of quantum chromodynamics (QCD), the relativistic field theory of quarks and gluons, the connection of QCD to effective theories of the strong interaction at low energies and the manifestation of QCD in the highly compressed and excited nuclear matter created in relativistic heavy-ion collisions. The challenge for nuclear theorists is to develop reliable calculational tools for QCD in the strong interaction regime, to discover and exploit connections with successful nuclear phenomenology and to derive systematic descriptions of QCD in terms of low-energy degrees of freedom (hadrons). Research in the Nuclear Physics Theory group is progressing in each of these areas.

Effective field theory (EFT) and renormalization group (RG) methods have been developed by group members to quantitatively explain how low-energy nuclear phenomenology emerges from QCD. These methods enable systematic and model-independent calculations with error estimates, using control over the degrees of freedom to optimize convergence. Group members are among the leaders in applying EFT and RG to nuclear few- and many-body systems.

Electron scattering is an important probe of nuclei. Insight into the crossover from quark-gluon to hadronic descriptions, which is a major goal of the Jefferson Lab experimental program, is possible only if the model dependence of the theoretical descriptions is under control. Toward this end, group members analyze and interpret JLab experiments in the GeV regime with controlled relativistic calculations, and use RG-evolved operators to analyze high-momentum-transfer processes.

At very high densities and temperatures, such as those in the early universe just after the Big Bang, QCD predicts that strongly interacting matter turns into a quark-gluon plasma (QGP). This QGP also can be created in relativistic heavy-ion collisions, and group members are among the leaders in developing theoretical descriptions for the creation, thermalization and collective dynamical evolution of the QGP and, in collaboration with their experimental colleagues at Ohio State, in applying these theories to experimental data. New techniques are being developed to describe extremely dense gluonic systems, known as the Color Glass Condensate, which can be tested at present and future high energy heavy-ion and electron-ion colliders. In addition, the group has been exploring the connections between strongly coupled quark-gluon systems and new calculational methods, such as AdS/CFT correspondence, emerging from string theory.

Among the nuclear theory group faculty are a Hess-Prize recipient and Distinguished University Scholar, a DOE Outstanding Junior Investigator and Sackler Prize winner, and several APS and AAAS Fellows. In addition, the group typically includes several postdoctoral research associates and three to six graduate students. The group is committed to diversity in science and welcomes members of underrepresented groups. Support for students and postdocs comes from the National Science Foundation (NSF) and the Department of Energy (DOE). Membership of nuclear theory faculty in the DOE-funded UNEDF and JET Collaborations provides students and postdocs with access to international workshops and summer schools where they can broaden their physics horizon beyond the range of locally offered courses.

### Nuclear Physics Theory faculty

**Richard J. Furnstahl**, Professor  
PhD, Stanford University, 1986  
Quantum chromodynamics and nuclear phenomena  
Effective field theories at finite density and/or temperature  
Bazaar approach to physics education research

**Ulrich W. Heinz**, Professor  
Dr. phil. Nat., Johann Wolfgang Goethe University, Frankfurt, 1980  
Relativistic heavy-ion collisions — theory and phenomenology  
Quantum field systems at high temperature  
Thermodynamics and kinetics of quark-gluon plasma

**Sabine Jeschonnek**, Professor  
(Ohio State Lima)  
Dr. rer. Nat., Bonn University, 1996  
Quark-hadron duality  
Short-range structures in few-body systems  
Coincidence electron scattering reactions at GeV energies

**Yuri Kovchegov**, Professor  
PhD, Columbia University, 1998  
Theoretical nuclear and high energy physics  
Theory of strong interactions (QCD) at high energy and high parton density  
Heavy ion collisions and deep inelastic scattering  
Applications of string theory to QCD

**Robert J. Perry**, Professor  
PhD, University of Maryland, 1984  
Quantum chromodynamics  
Light-front field theory  
Renormalization group and effective field theory

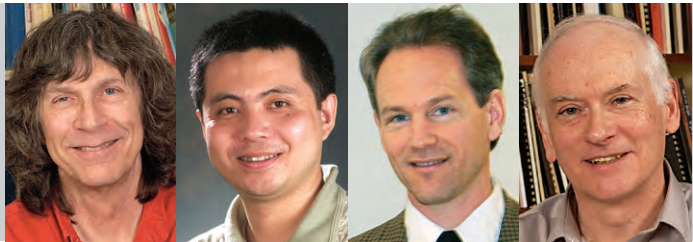




# Research Groups — Physics Education, Interdisciplinary

## Physics Education Research Group

physics.ohio-state.edu/~physedu/



Gordon Aubrecht    Lei Bao    Andrew Heckler    Bruce Patton

### Physics Education Research Group faculty

**Gordon Aubrecht**, Emeritus Professor  
(Ohio State Marion)  
PhD, Princeton University, 1971  
Development of pedagogical spreadsheets  
Revision of curriculum  
Energy issues combined with societal perspectives

**Lei Bao**, Professor  
PhD, University of Maryland, 1999  
Cognitive and computational models of learning process  
Biologically plausible neural network models of cognition  
Model based education assessment theory and technology  
Experimental and theoretical methods for modeling group learning  
Meta-cognitive factors in learning  
Education technology and curriculum for in-class polling and web instruction

**Andrew Heckler**, Associate Professor  
PhD, University of Washington, 1994  
Cognitive origins of student difficulties in physics  
Learning and transfer of abstract and concrete representations  
Hierarchical structure of physics knowledge  
Application of PER principles to the classroom

**Bruce R. Patton**, Emeritus Professor  
PhD, Cornell University, 1971

A unique strength of the Ohio State physics department is that it is one of the few departments in the nation to have a group of faculty and graduate students dedicated to researching how students learn physics and how to improve their learning. Graduate students have a variety of ways to engage with the Physics Education Research group: performing ground-breaking education research in our PhD program, implementing innovative course design as a teaching assistant and participating in a graduate-level course on issues in physics education, which is recommended for all students who aspire to be college faculty members.

The Physics Education Research group has three main areas of focus: cognitive studies, educational assessment and the development of instructional materials and techniques.

#### *Cognitive studies and educational assessment*

What is the nature of students’ understanding of physics? How does this understanding evolve with time? Why is physics so hard? Does a physics course improve scientific reasoning skills? These are some of the questions investigated by the Physics Education Research group. Research includes: cognitive origins of scientific misconceptions, hierarchical structure of physics knowledge, and student learning in upper level and graduate courses. There is also research in computational models of student understanding and apply these to computer-based learning projects. The building and rigorous analysis of educational assessments, in order to more accurately measure and model student understanding, is also an active area of investigation.

#### *Development of educational materials and techniques*

Applying knowledge of how students learn to the design (and redesign) of instructional materials and techniques is a key focus in the Physics Education Research group. We develop course materials at the undergraduate and graduate level, including several projects on computer-based instruction. We also work with other groups in the department to improve learning of cutting edge topics such as materials science.



## Interdisciplinary Opportunities

### COSMOLOGY AND ASTROPARTICLE PHYSICS

A unique environment exists at Ohio State between the Departments of Physics and Astronomy to pursue world-class research at the interface between high energy physics, astrophysics and cosmology. There are about 20 faculty members, 10 postdoctoral fellows and 15 graduate students involved in the Center for Cosmology and AstroParticle Physics (CCAPP). With a yearly CCAPP Symposium, weekly seminars and a daily “Astro Coffee,” this is a lively group with diverse opportunities for students. **ccapp.osu.edu**

### INTERDISCIPLINARY BIOPHYSICS GRADUATE PROGRAM

Biophysics is the application of the principles and analytical approaches of physics to solve biologically relevant problems. Some of the most exciting areas of biology and medicine fall within the domain of biophysics. Students interested in biophysics may major in physics at Ohio State and work with biophysicists within the physics department (see page 12) or they may apply directly to Ohio State’s Interdisciplinary Biophysics Graduate Program and work with one of nearly 90 biophysicists throughout the university. Physics faculty play a strong leadership and educational role in the Interdisciplinary Biophysics Graduate Program and both programs work together to individualize the best opportunities for students interested in this career direction. **biophysics.osu.edu**

### THE CHEMICAL PHYSICS PROGRAM

This is a joint PhD-granting program involving more than 30 faculty from the Departments of Physics, Chemistry, Astronomy, Geology, Medical Biochemistry and Mechanical Engineering. About one third of the approximately 30 students in the program work with advisors in the physics department. **chemphys.chemistry.osu.edu/chemphys**

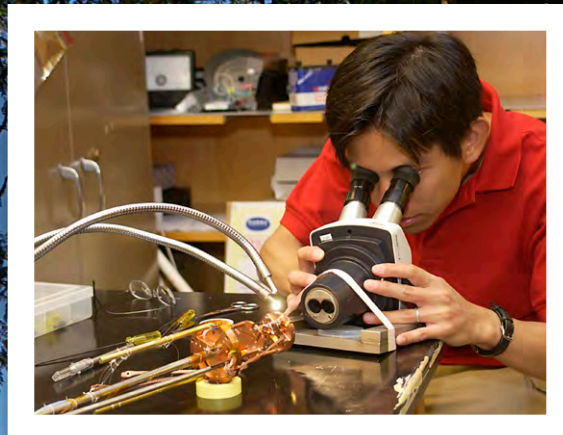
### ENCOMM

The Center for Exploration of Novel Complex Materials (ENCOMM), head-quartered in the Physics Research Building, addresses cutting-edge challenges in understanding and developing complex multicomponent materials. These problems are inherently multidisciplinary and require state-of-the-art facilities. ENCOMM builds teams that can tackle these problems and compete for multidisciplinary block-funded centers (such as the CEM, listed below). ENCOMM meets weekly to identify opportunities and share insights; provides fabrication and characterization infrastructure (see **ensl.osu.edu**); and provides seed funds in fields ranging from DNA dynamics to thermal spintronics. **physics.ohio-state.edu/ENCOMM**

### CENTER FOR EMERGENT MATERIALS

The Center for Emergent Materials (CEM) at Ohio State is a National Science Foundation (NSF) Materials Research Science and Engineering Center (MRSEC) program funded for six years with a total budget of \$18 million. Twenty-five faculty, 30 funded graduate students and six postdocs in CEM comprise two teams tackling cutting-edge problems in magnetoelectronics, computing and information processing. The two MRSEC teams bring an exceptional diversity of capabilities, including advanced microscopy, new materials synthesis, novel materials probes and theory and modeling that are required for this challenging endeavor. Head-quartered in the Physics Research Building and with more than half its faculty and students from physics, the CEM offers outstanding opportunities for graduate students to do cutting-edge research in a highly collaborative environment. **cem.osu.edu**





## Physics Graduate Student Council

[physics.ohio-state.edu/~pgsc/](http://physics.ohio-state.edu/~pgsc/)

The Physics Graduate Student Council (PGSC) is the representative body for physics graduate students at Ohio State. The PGSC is an active and engaged group that advocates and facilitates communication and activities between the department and graduate students on all matters of mutual interest, including grad student representation on several departmental committees. The PGSC holds quarterly meetings and meets regularly with the department chair and vice chairs to discuss issues of concern to graduate students. The council also hosts regular social events (picnics, graduation receptions, etc.), mentors new graduate students (at both individual and group levels), helps publicize graduate student research opportunities, organizes an annual graduate student research poster competition and “core-course” faculty teaching awards and generally enhances the social, academic and research experience for all physics graduate students.

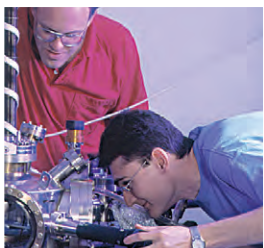
## Society of Women in Physics

[physics.ohio-state.edu/SWiP/](http://physics.ohio-state.edu/SWiP/)

The Society of Women in Physics (SWiP) is an undergraduate and graduate student academic club whose goal is to promote the involvement of, career development for and sense of community among women in the Department of Physics at The Ohio State University. SWiP organizes colloquia and workshops and supports independent outreach programs. Members work closely with undergraduate physics groups and high schools to extend the benefits of outreach activities and to provide mutually beneficial mentor-mentee connections between undergraduate and high school students and SWiP members. In addition, SWiP coordinates annual fundraising events to promote its mission in the broader Columbus community.







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