



THE UNIVERSITY
OF IOWA

PHYSICS AND ASTRONOMY





GRADUATE STUDY IN Physics and Astronomy

The Department of Physics and Astronomy at The University of Iowa is a nationally renowned program devoted to teaching and research. Currently, 29 faculty members, two adjunct professors, five emeritus professors, 23 Ph.D. research scientists, four postdoctoral fellows, 70 graduate students, and 66 undergraduate majors are active in research, teaching, and the study of physics and astronomy.

Over the years, the department has achieved particular distinction in space physics. The experimental study of charged particles and electromagnetic fields in space began here and remains a vital area at Iowa today. The Department of Physics and Astronomy has two experiments aboard the Galileo spacecraft to Jupiter, as well as experiments on other missions planned for the coming decade. The acquisition and interpretation of data from these missions will ensure continued prominence for the department.

In addition to its continued vitality in space physics, the department has strong programs in astronomy, astrophysics, atomic and molecular physics, condensed matter physics, elementary particle physics, medical physics, nuclear physics, and plasma physics. A new research program in laser science and quantum optics has been started and is situated in a new state-of-the-art laboratory facility. Van Allen Hall, the department's home, has a number of research laboratories. Faculty members and students also

conduct experiments and observations at national and international laboratories and observatories, such as Fermilab, the Very Large Array radio telescope, and DESY in Germany. The department's computer-controlled optical and radio telescopes are dedicated to student research. This telescope facility, which is unique in the country, is run and maintained by students.

This vigorous research environment benefits the teaching mission of the department. Graduate students participate in all aspects of research, and the department prides itself on a tradition of including undergraduate students in research programs. This research experience, together with sound academic training, has enabled physics and astronomy students to move on to further study or academic positions at the most prestigious institutions in the country.

Finally, the department succeeds admirably in attracting external support for its research programs. Departmental faculty and research scientists obtain approximately \$12 million each year from the National Aeronautics and Space Administration, the National Science Foundation, the Office of Naval Research, the Department of Energy, and other sources. In addition to the other ways in which this funding supports research, it permits the support of many graduate students on research assistantships and the hiring of undergraduate students for work on scientific projects.

PHYSICS AND ASTRONOMY

THE UNIVERSITY OF IOWA
Iowa City, Iowa

ASTRONOMY AND ASTROPHYSICS

The department has a strong tradition of research in radio astronomy, particularly in investigations using radio interferometry. Departmental commitment to the VLBI technique remains strong, with several ongoing projects using the Very Long Baseline Array (VLBA) network of the National Radio Astronomy Observatory. Faculty members and students within the department also make extensive use of the Very Large Array radio interferometer.

Radio astronomy research involves planetary observations, the imaging of extragalactic and stellar radio sources, polarimetry of radio sources, spectroscopy, and observations of molecular clouds and star formation regions. Infrared, optical, and X-ray studies complement radio observations of stellar radio sources. Three of the four faculty members in this group are involved in studies of radio wave propagation through the plasma turbulence in the interstellar medium, interplanetary medium, and solar corona.

The astronomy group also studies a number of topics in the area of theoretical astrophysics. Studies are carried out on the structure of circumstellar envelopes of evolved stars, and how gas and dust interact with each other in the winds of these stars. We are also interested in the formation of molecules in these stars. Another area of interest is theoretical investigations of disks in astrophysics. This is a broad area that includes accretion disks around close binary stars as well as the rings of Saturn. Finally, the astronomy group is involved in research on a number of topics in plasma astrophysics, such as the origin and dynamics of plasma turbulence in the interstellar medium.

The University of Iowa is well situated for research in plasma astrophysics because of its strengths in space physics and plasma physics. The proximity of the space and plasma physics groups facilitates study of processes that might be important in astrophysical settings, and



Image of the nebula NGC 6888 made with the automated telescope on the roof of Van Allen Hall. The image is in the light of the H α transition of the hydrogen atom, and thus reveals ionized hydrogen. The hydrogen emission is from a shell of matter swept up by the wind from the central star and photoionized by its ultraviolet light



Professor Steven Spangler, right, installs a receiver on the radio telescope

that can be studied in detail in the solar wind and the magnetospheres of the Earth and other planets.

Observational research in astronomy is carried out with telescopes of national observatories such as the VLBA, VLA, Arecibo Observatory, and Kitt Peak National Observatory. We believe it is important for astronomy students to receive training and experience in the technical and instrumental aspects of the science. We therefore have established small in-house radio and optical observatories. The optical observatory consists of a fully automated and computer-controlled 7-inch refractor with CCD camera, a full set of filters, and a spectrometer. The observatory has a full set of off-line computers for analysis of the data. The picture on this page shows an image of the nebula NGC 6888 taken in the light of Hydrogen alpha with our telescope. The radio observatory consists of a 4.5-meter antenna with working receivers at 5000 and 1400-1600

MHz, and the hardware for receivers at other frequencies. The philosophy of these observatories is that they provide students with the opportunity for experimentation, adaptation, and instrument fabrication that is not as readily available at expensive and heavily subscribed national observatories. These in-house observatories furnish the opportunity for many projects in electronics, on-line programming, and computer control of instrumentation.

RECENT PUBLICATIONS

"The Mimas 2:1 Eccentric Corotational Resonance in Saturn's Outer B Ring," L.A. Molnar and D.E. Dunn, *Icarus*, 116, 397 (1995).

"Radio Interferometer Observations of Solar Wind Turbulence from the Orbit of Helios to the Solar Corona," S.R. Spangler and T. Sakurai, *Astrophysical Journal*, 445, 999 (1995).

"Radio Emission from Active Late Type Binaries," N.M. Elias II and R.L. Mutel, in *The Realm of Interacting Binary Stars*, J. Sahade, G.E. McCluskey, and Y. Kondo, editors, Kluwer Publishing (1993).

"Observations of the Acceleration Regions of OH/IR Stars," J.D. Fix and M.G. Mulhern, *Astrophysical Journal*, 430, 824 (1994).

ATOMIC, MOLECULAR, AND CHEMICAL PHYSICS

The atomic, molecular, and chemical physics research program is an interdisciplinary effort including faculty from the Department of Physics and Astronomy and the Department of Chemistry. Current research centers on laser spectroscopic studies of gas phase molecular dynamics, and of the structure and dynamics of molecular clusters. The molecular clusters range in size from atomic scale to large clusters approaching the bulk limit of condensed matter. Thus, we may study, on a microscopic level, the transition from simple bimolecular interactions to condensed phase chemical dynamics. Of particular interest are systems relevant to atmospheric physics and chemistry, combustion, and catalysis.

Much of our work involves the study of excited-state molecular collision dynamics, including inelastic energy transfer and chemical reaction. One experimental approach involves the use of laser pump-probe spectroscopic techniques to study the continuum or scattering states of a transient bimolecular reaction complex. These techniques allow a direct probe of the transition state region of a bimolecular reaction complex. Such scattering-state resolved spectroscopic studies are sensitive to the excited state dynamics, giving information about the adiabatic potential energy surfaces of the transient complex, the nuclear motion dynamics, the effect of reagent electronic orbital alignment, and the important nonadiabatic electronic interactions. The dynamical effects that determine the energy partitioning and competitive branching into accessible reactive and nonreactive quenching channels can thus be observed and studied.

A complementary approach to the study of excited state chemical dynamics involves the laser photodissociation spectroscopy of a weakly bound bimolecular precursor complex. This process serves to mimic a

bimolecular "half-collision," but with a restricted range of impact parameters and relative collision energies. This experimental effort couples supersonic molecular beam techniques with time-of-flight mass spectrometry and laser photodissociation spectroscopy. The final-state resolved action spectra give information about the structure and binding in the complex, and can elucidate the nonadiabatic electronic interactions, and dissociation dynamics which determine the microscopic branching into competing energy disposal pathways. Determination of the photoproduct anisotropy and kinetic energy release yields information about the complex lifetime, binding, and energy redistribution which is critical to understanding the chemical dynamics.

It has long been recognized that molecular dynamics can be drastically modified in the condensed phase by bulk-caging effects. Recently, we have observed analogous bulk-like effects even in bimolecular complexes. Thus, our experiments in size-selected molecular clusters also can serve as an ideal experimental laboratory for investigating condensed phase molecular

dynamics and heterogeneous chemistry on a microscopic scale.

Complementary theoretical work is being carried out simultaneously. This includes both efforts to determine the atomic and molecular interactions (the adiabatic potential energy surfaces and the nonadiabatic couplings), and to develop and test quantum and semiclassical models of the collision dynamics, and nonadiabatic theories of line shapes in molecular spectra.

RECENT PUBLICATIONS

"Reaction Dynamics of $\text{Na}^*(4P)+\text{H}_2$: Experiment and Theory," S. Billign, P.D. Kleiber, W.R. Kearney, and K.M. Sando, *Journal of Chemical Physics*, 96, 218 (1992).

"Photofragmentation Spectroscopy of MgD_2^+ ," L.N. Ding, M.A. Young, P.D. Kleiber, W.C. Stwalley, and A.M. Lyrra, *Journal of Physical Chemistry*, 96, 218 (1992).

"Quantum State Selected Photodissociation of $\text{K}_2(\text{B}^1\Pi_u \leftarrow \text{X}^1\Sigma_g^+)$: A Case Study of Final State Alignment in All-Optical-Multiple Resonance Photodissociation," B. Ji, P.D. Kleiber, W.C. Stwalley, A. Yiannopoulou, A.M. Lyrra, and P.S. Julienne, *Journal of Chemical Physics*, 102, 2440 (1995).

"Photofragmentation Dynamics of $\text{Mg}_2(\text{CO})_2^+$," L.N. Ding, P.D. Kleiber, Y.C. Cheng, M.A. Young, W.C. Stwalley, and S.V. O'Neil, *Journal of Chemical Physics*, 102, 5235 (1995).

"Electronic Orbital Alignment Effects in the Reaction $\text{Mg}^*(3p^1P_1)+\text{CH}_4 \rightarrow \text{MgH}+\text{CH}_3$," T.H. Wong and P.D. Kleiber, *Journal of Chemical Physics*, 102, 6476 (1995).



Professor Paul Kleiber in the laser lab

CONDENSED MATTER PHYSICS

Theoretical and experimental research on condensed matter physics involves two faculty members. Areas of research include artificially structured semiconductors, strongly correlated electronic systems, superconductivity, scanning tunneling microscopy (STM), and layered transition-metal-sulfide analogs of the high T_c cuprate superconductors. There is participation in the interdisciplinary Optical Science and Technology Center of The University of Iowa, and collaborations with the Department of Chemistry at Iowa and with a number of programs at other institutions.

Theoretical Condensed Matter Physics

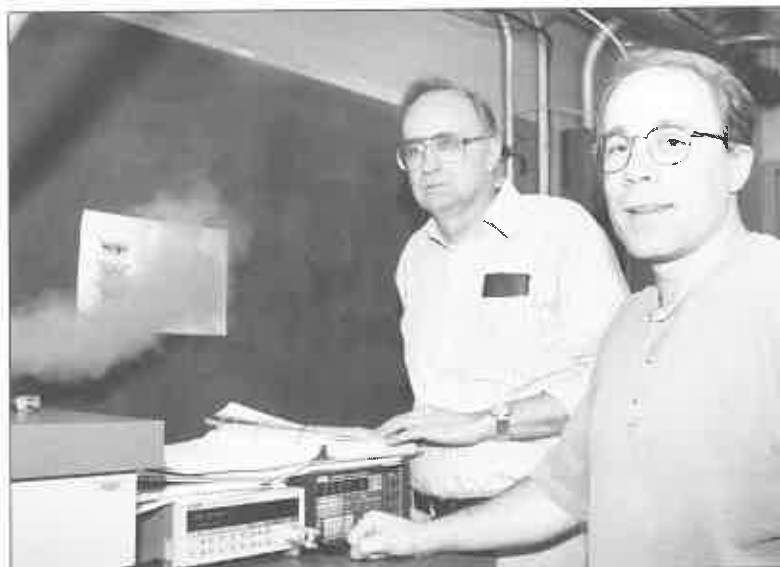
Michael Flatté

The peculiar electronic structure of high-temperature superconductors requires the development of a new phenomenology for samples that are not uniform. A current subject of interest is the theoretical analysis of STM images of the surface of a superconductor with a single inhomogeneity in the field of view, such as an impurity, magnetic vortex, current source, or grain boundary. The current that passes from the tunneling tip to the superconducting surface provides detailed information on the effect of inhomogeneities on the nearby electronic structure in a strongly correlated system.

Efforts in the area of semiconductor nanostructures include investigations of the optical and electronic properties of broken-gap superlattices as well as the lasing mechanism in ZnSe quantum-well blue-green lasers. Work on broken-gap superlattices is done in conjunction with experiments performed by Thomas Boggess, also of the Department of Physics and Astronomy.

John Schweitzer

Present research is an attempt to describe the first-order phase transition from antiferromagnetic insulator to paramagnetic



Professor John Schweitzer and post-doctoral fellow Lee Martinson

metal with decreasing temperature that is seen in a series of layered transition-metal-sulfide alloys that we study in our experimental program. Continuing interests are (1) the treatment of strong correlation effects in the theory of the electronic and magnetic properties of mixed-valence and narrow-band systems, and (2) the quantum dynamics of soliton-like excitations in one-dimensional nonlinear systems.

Experimental Condensed Matter Physics

John Schweitzer

This research involves the synthesis and the structural, electronic, and magnetic characterization of layered ternary sulfides. Initial studies have focused on $BaCoS_2$, $BaNiS_2$, and alloys obtained by chemical substitutions in these compounds. Within this series of materials are simple metals, strongly correlated metals, Mott-Hubbard insulators, paramagnets, antiferromagnets, and spin glasses. A major focus of our studies is the investigation of a unique first-order insulator-metal phase transition that we discovered in a series of sulfur deficient and Co-rich $BaCo_{1-x}Ni_xS_{2-y}$ alloys. This is a structural transition with decreasing temperature from an antiferromagnetic semiconductor to a strongly correlated

paramagnetic metal. Another focus is a search for super-conductivity. These materials have structural and electronic features that are very similar to those of the parent compounds of the high- T_c cuprate superconductors.

We have excellent facilities for the synthesis of these materials and the identification of new structures by single-crystal x-ray diffraction. Measurements of AC and DC susceptibilities are made with a modern SQUID magnetometer that also provides a temperature and magnetic field platform for resistance and Hall effect measurements. In addition, we are collaborating with researchers at other institutions on neutron diffraction, photoemission, infrared spectroscopy, and high pressure measurements.

RECENT PUBLICATIONS

"Lifetime of the Davydov Soliton," J.W. Schweitzer, *Physical Review A*, 45, 8914 (1992).

"Metal-Insulator Transition $BaCo_{1-x}Ni_xS_{2-y}$," L.S. Martinson, J.W. Schweitzer, and N.C. Baenziger, *Physical Review Letters*, 71, 125 (1993).

"Probing Spatial Correlations with Nanoscale Two-Contact Tunneling," J.M. Byers and M.E. Flatté, *Physical Review Letters*, 74, 306 (1995).

"Image of the Energy Gap Anisotropy in the Vibrational Spectrum of a High Temperature Superconductor," M.E. Flatté, *Physical Review Letters*, 70, 658 (1993).

ELEMENTARY PARTICLE PHYSICS

High Energy Experimental Work

Research in High Energy Experimental Physics is being carried out by four faculty members in several experiments with international collaborations. The experiments are carried out at the Stanford Linear Accelerator Center (SLAC) at Stanford University, Fermi National Accelerator Lab (FNAL) near Chicago, Deutsches Elektron Synkrotron (DESY) in Hamburg, and a European laboratory for particle physics (CERN) in Geneva.

Research at Stanford Linear Accelerator Center (SLAC):

A new high-luminosity b-factory in the United States is being constructed at SLAC in order to measure and study CP-violation in the b-quark system. All of the phenomena observed and experimental results measured to date can be explained by the Standard Model, yet the model does not provide many fundamental answers. It is anticipated that the study of the CP-violation will provide a very important window beyond the Standard Model, and perhaps also explain one of the mechanisms of nature's preference for matter over antimatter in our world today. The Iowa group has important responsibilities in building and testing the calorimeter electronics, drift chamber construction, and data acquisition software of both systems. The group is also responsible for the calorimeter electronics calibration. With intimate involvements in the two most important detector systems, Iowa expects to have a lead role in analysis as well. Two graduate students and one postdoctoral fellow are currently involved in this experiment.

Research at Fermilab:

The major effort at FNAL is a new experiment to study charmed baryon spectroscopy with participants from Europe, Asia, and Latin America, using a hyperon beam incident on a fixed target. The experiment will study production and decays of the

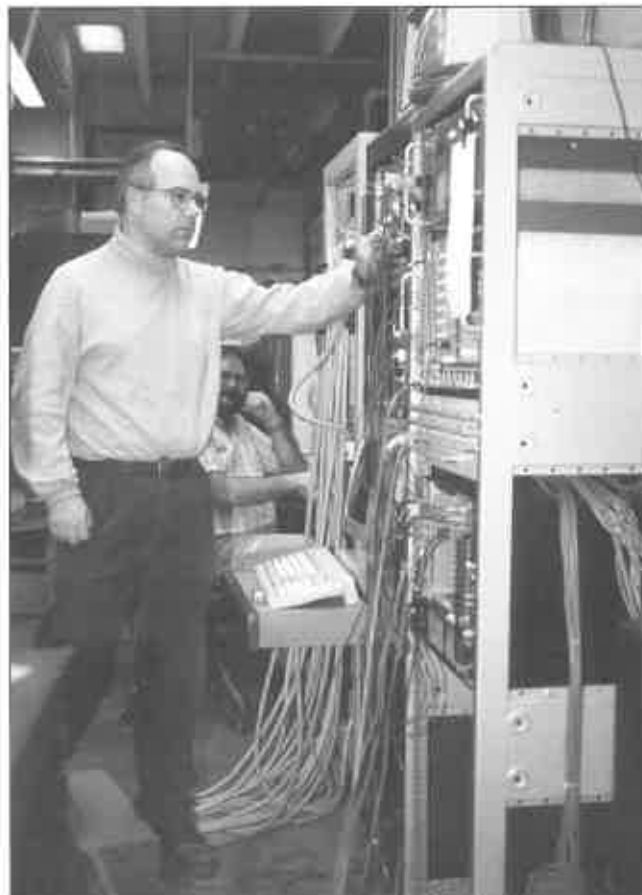
charmed baryons; it also will search for exotic hadrons. The data-taking run began in summer, 1996 and is expected to continue for one-and-a-half years. The Iowa group is involved in both hardware and software efforts. It will provide silicon microstrip detectors and scintillating fiber detectors designed and built at Iowa as well as large area drift and proportional wire chambers. Currently, three Iowa graduate students are involved in this effort.

Analyses of several recently completed experiments are continuing. These include:

- An experiment to study rare nonleptonic radiative decays of hyperons, including measurements of the asymmetry parameter in the decay $\Sigma^+ \rightarrow P\gamma$ and a measurement of the Σ^+ magnetic moment using a new technique employing crystal channeling. The state-of-the-art silicon microstrip detector system, vital to the

experiment, was designed and constructed at Iowa.

- An experiment on spin physics with polarized protons and anti-protons, which produced single and double asymmetry measurements in inclusive production of π^0 , π^+ (π^{+-}), η^0 and Λ^0 particles. The Iowa group was instrumental in the first measurements of the proton at 200 GeV/c in the Coulomb-Nuclear Interference region.
- An experiment on photoproduction of jets to critically test QCD using the Fermilab high energy photon beam on hydrogen and heavier targets. QCD Compton scattering at high x_1 and quark-gluon fusion were studied. Five Iowa graduate students were involved with these experiments, with four having completed their Ph.D. degrees and one expected to finish soon.



Professor Yasar Onel working with the camac electronics for his detector system



Professor Charles Newsom, left, and graduate student Ken Nelson working on detector fabrication

Research at the Deutscher Elektron Synkrotron (DESY):

The HERA electron-proton collider, the first of its kind, has been in operation at the German laboratory DESY in Hamburg since 1992. The Iowa group has been involved in the ZEUS experiment, one of two such ep colliding experiments. ZEUS has a major U.S. involvement. The data thus far has established important milestones in Quantum Chromodynamics (QCD) by revealing deeper knowledge of inner structures of the proton. The parton density in the proton has been observed to rise at low x , (x a scaling variable). The important questions are: Will it get to saturation density, and if yes, how? Iowa has played a leading role in these important measurements.

The Iowa group also has made major contributions in data acquisition (DAQ) and calibration software and building electronics for the ZEUS calorimeter and the upgrade detectors. Two graduate students have completed Ph.D. degrees; presently one a faculty member in Taiwan and the second a postdoctoral fellow working for DESY. Two more are currently working toward a Ph.D. degree with the data. Much higher luminosity and polarized electron beams are expected in the near future.

Research at CERN:

The CMS experiment is one of the two major collider experiments foreseen at the Large Hadron Collider (LHC) at CERN. When completed in 2003, it will search for Higgs boson, technicolor, and supersymmetry in addition to providing information on new quarks, leptons, Z^0 's, and W^+ 's. Currently, the principal focus is on research and development of detector subsystems for CMS, which includes the hadronic barrel calorimeter and the forward quartz fiber calorimeter.

RECENT PUBLICATIONS

"Extraction of the Gluon Density of the Proton at Low x ," M. Derrick, U. Mallik, E. McCliment, M.Z. Wang, S.M. Wang, J.T. Wu, Y. Zhang, *et. al.*, *Physics Letters B*, 345, 576 (1995).

"Measurement of the Cross Section for the Reaction $\gamma P \rightarrow J/\psi P$ with the ZEUS Detector at HERA," M. Derrick, U. Mallik, E. McCliment, M.Z. Wang, S.M. Wang, J.T. Wu, Y. Zhang, *et. al.*, *Physics Letters B*, 350, 120 (1995).

"Measurement of the Branching Ratio and Asymmetry for $\Sigma^+ \rightarrow p \gamma$," S. Timm, J. Langland, E. McCliment, C. Newsom, *et. al.*, *The Physical Review D*, 51, 4638 (1995).

"Analyzing Power Measurement in Inclusive Λ^0 Production with a 200 GeV/c Polarized Proton Beam," A. Bravar, N. Akchurin, J. Langland, Y. Onel, *et. al.*, *Physical Review Letters*, 75, 3073 (1995).

High Energy Theory

Today, the known laws of physics attempt to explain natural phenomena from distance scales larger than a billion light years to distances more than a million times smaller than the typical size of an atom. Remarkably, the phenomena occurring at the shortest distances accessible experimentally can be described using the formalism of quantum field theory with local symmetries, namely gauge theory.

The best known gauge theory is *Quantum Electrodynamics (QED)*. It describes the electromagnetic interactions of electrons and photons. This theory provides predictions in agreement with experiments to more than ten significant digits. *Quantum Chromodynamics (QCD)* describes the strong interactions of quarks and gluons. This theory has a complex large distance behavior which includes phenomena such as the confinement of quarks. Finding calculational methods having an accuracy comparable to *QED* is a challenge for theoretical physics. The weak interactions are described by the Glashow-Weinberg-Salam model. The predictions of this model have received spectacular confirmations with the recent discoveries of W and Z bosons and of the top quark. At the present time, much effort is being spent to develop experiments capable of discovering the Higgs boson. General relativity and other geometrical theories provide a description of classical gravitational phenomena. In many frameworks this may also be called a gauge theory. Finding a consistent quantum theory of gravity is an important goal for many physicists.

The members of the theoretical particle physics group are involved in a variety of problems in particle phenomenology and quantum field theory. These include perturbative predictions of the electroweak standard model and *QCD* for high energy colliders at the Fermi National Accelerator Laboratory and at the

Center for European Nuclear Research (CERN). Field theoretical aspects that are covered include lattice field theory, renormalization group techniques, classical and quantum gravity as related to string theories, and various applications of the theory of group representations.

Perturbative methods are used to probe QCD. The applicability of perturbative QCD to a variety of processes in proton-proton, proton-antiproton, and electron-proton colliders as well as fixed target experiments is being tested. These theoretical tests require calculations at next-to-leading order in the perturbative expansion parameter, the strong coupling constant. A combination of analytical and numerical techniques are used, including symbolic manipulations and numerical integration on the high energy group's computers.

The renormalization group method is an essential tool to understand and describe the large distance behavior of gauge theories and spin models. The practical implementation of this method can be drastically simplified if one considers, as a first approximation, a model where the interactions are self-similar. This approximation allows the calculation of small and large coupling expansions to very large order and their comparison with numerical answers. The perturbative corrections to this approximation in self-similar models are being calculated using analytical and numerical methods. A case of particular interest is the three-dimensional Ising model which is dual to a gauge theory and has been conjectured to be equivalent to a string theory. Another important application being considered is the determination of an upper bound on the Higgs boson.

Other theoretical studies of gauge and gravitational theories in the non-perturbative regime include the use of geometry and topology. These studies

include the study of two-dimensional quantum gravity and its four-dimensional gravity analogue, supersymmetric theories, and string theory that is related to QCD. In conjunction with members of the mathematics department, relationships between representations of infinite dimensional algebras and determinants of Dirac operators on four manifolds are studied as well as anomalies in four-dimensional gravity and the spectrum of certain differential operators.

Theoretical physicists and mathematicians meet weekly for a joint seminar. Topics discussed involve ergodic problems, quantum chaos, and the theory of group representation. A seminar series on topics of interest to theoretical and experimental particle and nuclear physics also meets weekly.

RECENT PUBLICATIONS

"A 2D Inspired 4D Theory of Gravity," V.G.J. Rodgers, *Physics Letters B*, 336, 343 (1994).

"A Study of Fermions on a Cylinder Coupled to Gauge and Gravitational Fields," Ralph Lano and V.G.J. Rodgers, *Nuclear Physics B*, 437, 4 (1995).

"Precise Determination of the Energy Levels of the Anharmonic Oscillator from the Quantization of the Angle Variable," B. Bacus, Y. Meurice, and A. Soemadi, *Journal of Physics A*, 28, L381 (1995).

"The Elusive Asymptotic Behavior of the High-Temperature Expansion of the Hierarchical Ising Model," Y. Meurice and G. Ordaz, *Journal of Statistical Physics*, 82, 343 (1996).

"Evidence for Complex Subleading Exponents from the High-Temperature Expansion of Dyson's Hierarchical Model," Y. Meurice, G. Ordaz, and V.G.J. Rodgers, *Physical Review Letters*, 75, 4555 (1995).

"Ultrahigh-Energy Neutrino Interactions," R. Gandhi, C. Quigg, I. Sarcevic, and M.H. Reno, *Astroparticle Physics*, in press.

"Hadron Collider Limits on Anomalous WWg Couplings," K.R. Barger and M.H. Reno, *Physical Review D*, 51, 90 (1995).

"Relative Distributions of W's and Z's at Low Transverse Momenta," M.H. Reno, *Physical Review D*, 49, 4326 (1994).



Professor Vincent Rodgers and student Bian Nelson discuss how gravitational fields interact with fermions

LASER SCIENCE AND QUANTUM ELECTRONICS

The department has a varied program in laser science, quantum electronics, and photonics. This research often crosses boundaries among disciplines and includes projects within the department that overlap with the atomic and molecular, solid state, and plasma physics groups, as well as projects conducted jointly with the engineering and chemistry departments.

Along with projects in atomic and molecular and plasma physics, which are described on pages 3 and 11-12 in this brochure, our current research includes the development of ultrafast laser sources and measurement techniques, which are capable of both high temporal (<100 fs) and spatial (<1 mm) resolution, and the application of these techniques to the investigation of the nonlinear optical and electronic properties of materials.

Semiconductor microstructures are among the material systems being studied. These are grown by sophisticated techniques, such as molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD), that allow control of material deposition at the atomic level for the fabrication of new synthetic semiconductor materials and structures with novel optical and electrical properties. These, in turn, lead to the development of dramatically improved laser diodes, optical modulators, and high-speed electronic devices and circuits with features of nanometer dimensions. The operation of these, and the development of future devices and systems, will depend on our ability to understand fundamental processes, such as charge transport, scattering, screening, and propagation, which occur over nanometer dimensions and on femtosecond time scales. This is the focus of our research.

Present studies include the use of nonlinear optical techniques to investigate photon echoes, coherent tunneling, quantum beats, dephasing, hot carriers, ballistic transport, cross- and in-well transport,



Professor Arthur Smirl, right, and research associate Osvaldo Buccafusca working in the new laser facility

and space charge formation in such structures. Until recently, most research centered on the near infrared portion of the spectrum, a region compatible with optical fiber communications systems. While this remains an active region for research within the department, we have begun concurrent efforts devoted to extending our capabilities and investigations to shorter (blue-green and ultraviolet) wavelengths and to longer (mid-infrared) wavelengths. The former effort is driven mainly by the desire for compact, short wavelength lasers for high-density optical storage and color display technology; the latter is used for remote sensing, pollution monitoring, and atmospheric communications.

RECENT PUBLICATIONS

"A Review of Optical Limiting Mechanisms and Devices Using Organics, Fullerenes, Semiconductors and Other Materials," L.W. Tutt and T. F. Boggess, *Progress in Quantum Electronics*, 17, 299 (1993).

"Picosecond Investigations of the Excited-State Transition at 532 nm in King's Complex $[(C_2H_5)_2Fe(CO)]_4$ and Synthesized Analogs," G.R. Allan, S.J. Rychnovsky, C.H. Venzke, T.F. Boggess, and L. Tutt, *Journal of Chemical Physics*, 98, 216 (1994).

"Picosecond Measurements of Absorptive and Refractive Optical Nonlinearities in GaP at 532 nm," S. Rychnovsky, G.R. Allan, C.H. Venzke, and T.F. Boggess, *Optics Letters*, 19, 527 (1994).

"Generation of 3-4 mm Femtosecond Pulses from a Synchronously-Pumped, Critically-Phase-Matched $KTiOPO_4$ Optical Parametric Oscillator," S.W. McCahon, S.A. Anson, D.-J. Jang, T.F. Boggess, *Optics Letters*, 20, 2309 (1995).

"Coherent Plasma Oscillations in Bulk Semiconductors," W. Sha, A.L. Smirl, and W.F. Tseng, *Physical Review Letters*, 74, 4273 (1995).

"Degree and State of Polarization of the Time-Integrated Coherent Four-Wave Mixing Signal from Semiconductor Multiple Quantum Wells," S. Patkar, A.E. Paul, W. Sha, J.A. Bolger, and A.L. Smirl, *Physical Review B*, 51, 10791 (1995).

"Scaling of Stark-Shifted Per-Carrier Nonlinearities in Multiple Quantum Well Device Structures," A.N. Cartwright, X.R. Huang, and A.L. Smirl, *IEEE Journal of Quantum Electronics*, 31, 1726 (1995).

"In-Well Screening Nonlinearities in Piezoelectric Multiple Quantum Wells," X.R. Huang, D.R. Harken, A.N. Cartwright, A.L. Smith, J.L. Sanchez-Rojas, A. Sacedon, E. Calleja, and E. Munoz, *Applied Physics Letters*, 67, 950 (1995).

"Intrinsic and Induced Anisotropy of Nonlinear Absorption and Refraction in Zincblende Semiconductors," W. A. Schroeder, D.S. McCallum; D.R. Harken, M.D. Dvorak, D.R. Andersen, A.L. Smirl, and B.S. Wherrett, *Journal of the Optical Society of America B*, 12, 401 (1995).

"Polarization Rotation Modulator in a Strained [110]-Oriented Multiple Quantum Well," D.S. McCallum, X.R. Huang, and A.L. Smirl, *Applied Physics Letters*, 66, 2885 (1995).

MEDICAL PHYSICS AND POSITRON EMISSION TOMOGRAPHY

This is a new area of interest in the department. Students have the opportunity to conduct research in areas in which physics methodology and experimental techniques are applied to solve real-world medical problems. The primary focus at the present time is related to positron emission tomography (PET). This is a diagnostic imaging modality that creates pictures of human tissue function by mapping the kinetic behavior of radioactive tracers as they move and distribute throughout the body. PET encompasses:

- Development of new radionuclide production schemes utilizing high-yield targets and an in-house medical cyclotron.
- Very rapid synthesis of radiopharmaceuticals or radiotracers using predominantly C-11, N-13, O-15, and F-18 positron emitting nuclides.

- Design and fabrication of positron and gamma detection systems for the determination of blood radioactivity concentrations in near real-time.
- Development of algorithms and techniques for creating and analyzing images based on physiological and biochemical parameters of the uptake and distribution of PET labeled tracers within the human body.

The PET Imaging Center is located within the University of Iowa Hospitals and Clinics and contains a fully equipped physics and electronics laboratory, multiple radiochemistry laboratories, a compact medical cyclotron, a machine shop, and extensive computer facilities.

RECENT PUBLICATIONS

"The Effects of the Timing and Duration of Cognitive Activation of O-15 Water PET Studies," R.R. Hurtig, R.D. Hichwa, D.S. O'Leary, L.L. Boles Ponto, S. Narayana, G.L. Watkins, and N.C. Andreasen, *Journal of Cerebral Blood Flow and Metabolism*, 14, 423, (1994).

"V-48: A Renewable Source for Transmission Scanning with PET," R.D. Hichwa, D. Kadmas, G.L. Watkins, S.D. Wollenweber, S. Maniam, L.L. Boles Ponto, J.C.W. Richmond, and J.A. Koeppel, *Nuclear Instruments and Methods in Physics Research B*, 99, 804, (1995).

"Remembering the Past: Two Facets of Episodic Memory Explored with Positron Emission Tomography," N.C. Andreasen, D.S. O'Leary, T. Cizadlo, S. Arndt, K. Rezai, G.L. Watkins, L.L.B. Ponto, and R.D. Hichwa, *American Journal of Psychiatry*, 152, 1576, (1995).

"A New Technique for PET Slice Orientation and MRI-PET Coregistration," T.J. Grabowski, H. Damasio, R. Frank, R.D. Hichwa, L.L. Boles Ponto, and G.L. Watkins, *Human Brain Mapping*, 2, 123 (1995).

"Calculation of Electron Contribution to Energy Escape in BGO PET Block Detector Elements," S.D. Wollenweber and R.D. Hichwa, *The Journal of Nuclear Medicine*, 36, 175 (1995).

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Professor Richard Hichwa with the compact medical cyclotron at the PET Imaging Center

NUCLEAR PHYSICS

Research in nuclear physics currently is being carried out by four faculty members: Edwin Norbeck works in experimental nuclear physics, and Gerald Payne, William Klink, and Wayne Polyzou work in theoretical nuclear physics.

Experimental Research

Experiments are performed at the National Superconducting Cyclotron Laboratory at Michigan State University and other heavy ion accelerators in the United States and Europe. These experiments use ion beams of elements from hydrogen to uranium on targets from carbon to uranium at energies from 50 MeV to 100 GeV.

The reaction products are measured in large detector arrays that include components constructed at The University of Iowa. The emphasis is on understanding the reaction mechanisms involved in the collision process. Computer simulations of these multi-particle reactions are used to better understand the experimental results and to suggest new experimental tests of various reaction mechanisms.

Theoretical Research

Theoretical research is being conducted on a broad spectrum of problems related to the structure and dynamics of few-particle systems. These include systems of interacting nucleons and mesons and systems of interacting quarks. Our goal is to make realistic mathematical models of these systems that can be used as a basis for understanding many-particle systems and the basic interactions between nucleons and between quarks. Part of our research program involves the accurate numerical solutions of the equations that govern these systems. These systems of



Professor Edwin Norbeck discusses nuclear theories with graduate students

equations are large and have complicated asymptotic behavior. They are solved on supercomputers using highly specialized numerical methods that have been developed at Iowa and other institutions over the years. A second aspect of our research involves understanding what happens to these systems at very high energies and very short distance scales. The analysis requires a synthesis of quantum mechanics and special relativity applied to a system of strongly interacting particles.

Professor Payne's research is directed at obtaining a precise understanding of the interactions between nucleons and between quarks. This is done by comparing accurate numerical calculations of the quantum mechanical equations to precise measurements of experimental observables. The computer codes for realistic systems of even three particles are so large that they must be run on supercomputers. Calculations performed at Iowa have shown that the best quantum mechanical models give a very precise quantitative

description of almost all aspects of the physics. The numerical results are used to determine experimental observables that are most sensitive to small corrections due to relativistic effects, subnuclear effects, and few-body forces. They are also important tools for testing the validity of approximation methods that must be used in larger nuclear and sub-nuclear systems.

Professors Klink and Polyzou's research is directed at understanding nuclear and subnuclear interactions at higher energies, where both quantum and relativistic effects are important. Their approach is to formulate quantum mechanical models that are exactly relativistically invariant and simple enough to be solved on a computer. Calculations have been done that apply these methods to the electron scattering off of nucleons in nuclei, quarks in nucleons and mesons, the quark substructure of nucleons and mesons, and the production of particles. Emphasis is on understanding experiments that will

be performed at high energy electron accelerators such as the Thomas Jefferson Continuous Electron Beam Accelerator Facility at Newport News, Virginia.

RECENT PUBLICATIONS

"Relativistic Spin in Point Form Relativistic Quantum Mechanics," W.H. Klink, in *Group Theoretical Methods in Physics, Proceedings of the XIX International Colloquium*, Salamanca, Spain, 1992, and in *Anales de Fisica Monografias*, 2, ed. M.A. del Olmo et al., CIEMAT, Madrid, 466 (1993).

"Nilpotent Groups and Anharmonic Oscillators," W.H. Klink, in *Noncompact Lie Groups and Some of Their Applications, Proceedings of the NATO Advanced Workshop on Noncompact Lie Groups and Their Physical Applications*, San Antonio, Texas, January 1989, 1993, eds. E.A. Tanner and R. Wilson, Kluwer Academic Publishers, Dordrecht, 301 (1994).

"Preparation of CsI(Tl) for Charged Particle Detection," E. Norbeck, L.B. Yang, P. Pogodin, and D. Swan, *Nuclear Instruments and Methods*, A360, 642 (1995).

"Absence of Saturation in Energy Deposition in $^{90}\text{Ar}+^{232}\text{Th}$ Collisions at $E = 15 \cdot 115 \text{ A MeV}$," E.E. Gualtieri, J. Yee, D. Craig, S. Hannuschke, R.A. Lacey, T. Li, W.J. Llope, A. Nadasen, E. Norbeck, R. Pak, N.T.B. Stone, A.M. VanderMolen, J.S. Winfield, G.D. Westfall, and S.J. Yennello, *Physics Letters B*, 357, 7 (1995).

"Benchmark Solutions for n-d Preakup Amplitudes," J.L. Friar, G.L. Payne, W. Glöckle, D. Hüber, and H. Witala, *Physical Review C*, 41, 2356 (1995).

"Assessment of Triton Potential Energy," J.L. Friar and G.L. Payne, *Few-Body Systems*, 19, 203 (1995).

"Vacuum Structures in Light Front Dynamics," F. Coester and W. Polyzou, *Foundations of Physics*, 24, 387 (1994).

"Scaling for Deuteron Structure Functions in a Relativistic Light-Front Model," W. Polyzou and W. Glöckle, *Physical Review C*, 53, 3111 (1996).

PLASMA PHYSICS

Several groups in the department conduct experimental and theoretical research that is focused on basic plasma physics as well as applications to plasma in space, astrophysics, and industry.

One group carries out laboratory experiments to simulate ionospheric plasma processes. Topics under investigation include electrostatic waves similar to those observed in the auroral zone, wave propagation in plasmas with negative ions, double layers, and instabilities. Facilities include double plasma devices and two Q-machines. This work is funded by the Office of Naval Research.

Plasmas of the type that are used commercially in semiconductor manufacturing are also being investigated. Experiments and numerical modeling are conducted to study particulate contamination in radio-frequency discharges. Laser-based diagnostics used in these experiments include laser-induced fluorescence, Mie scattering, and video imaging.

Experimental research on solitons and plasma-wake fields is being done in a number of versatile plasma chambers where the effects of one- or two-dimensional symmetry, the presence of two or three plasma components, and scattering by density gradients are being investigated. In addition, investigations of strong turbulence, caviton formation, and collapse of Langmuir solitons are being done in a large double plasma device.

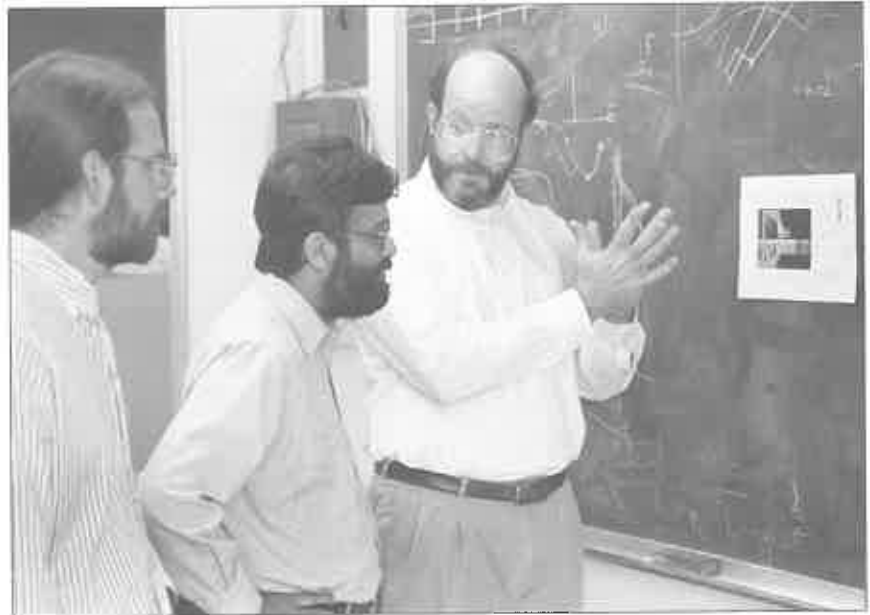
Several of the plasma physics groups are studying dusty plasma. Dusty plasmas are ionized gases containing micron-size particulates that acquire a large electric charge. Such charged grains are found naturally in space and astrophysical plasmas, where they alter or even domi-



Student Chad Thompson working with the plasma physics discharge machine

nate the plasma behavior. Experiments include studies of strongly-coupled dusty plasmas, where the particles arrange themselves in a fixed lattice, analogous to atoms in a crystal or liquid (described in <http://dusty.physics.uiowa.edu>), and Q-machine measurements to characterize the charging of grains at high number densities. Theoretical work centers on basic physical processes of grain correlations and shielding, and waves and instabilities in dusty plasmas. Dusty plasma work is funded by the National Aeronautics and Space Administration, the National Science Foundation, and the Office of Naval Research.

Theoretical plasma physics research is concentrated on fundamental issues that have significant applications to laboratory, space, and astrophysical plasmas. Recently, analytical and numerical studies have been carried out on the subject of magnetic reconnection, nonlinear waves and MHD turbulence, which have important ramifications for fusion plasmas, the Earth's magnetosphere, and the solar corona. In the area of dusty plasma theory, new analytical and particle-in-cell



Professors Craig Kletzing, Amitava Bhattacharjee, and Jack Scudder (left to right) discussing space physics observations

simulations have been carried out to understand correlations and shielding of strongly coupled dust particles.

Fluid turbulence theory is closely related to the subject of plasma turbulence, and it is the subject of new investigations by the plasma theory group. Possible finite-time singularities in symmetric ideal flows is

presently being studied by analysis and simulation. A new method has been developed for the classical problem of Couette flow and its bifurcation to more complicated flow patterns.

The plasma theory group is also involved in analytical and numerical studies of free-electron lasers. Recent investigations have dealt with the suppression of parasitic sideband instabilities and high efficiencies in strongly tapered systems, solitary-wave solutions of the Ginzburg-Landau equation, and the acceleration of electron beams in an inverse free-electron laser.

RECENT PUBLICATIONS

"Elimination of the Sideband Instability in Variable-Parameter Free-Electron Lasers and Inverse Free-Electron Lasers," R.P. Pilla and A. Bhattacharjee, *Physics of Plasmas*, 1, 390 (1994).

"Nonlinear Dynamics of $M=1$ Kink-Tearing Modes in a Modified Magnetohydrodynamic Model," X. Wang and A. Bhattacharjee, *Physics of Plasmas* 2, 171 (1995).

"Self-Consistency Constraints on the Dynamo Mechanism," A. Bhattacharjee and Y. Yuan, *The Astrophysical Journal*, 449, 739 (1995).



Graduate student Tao An (Ph.D., 1996) working with the Q-machine in plasma physics

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"Growth, Sudden Enhancement, and Relaxation of Currentsheets in the Magnetotail: Two-Dimensional Substorm Dynamics," Z.W. Ma, X. Wang, and A. Bhattacharjee, *Geophysical Research Letters*, 22, 2985 (1995).

"Released Status of an Ideal MHD Plasma with Internal Magnetic Field," G. Knorr, M. Mond, and C. Grabbe, *Journal of Plasma Physics*, 53, 373 (1995).

"Structural Analysis of a Coulomb Lattice in a Dusty Plasma," R.A. Quinn, C.S. Cui, J. Goree, J.B. Pieper, H. Thomas, and G. Morfill, *Physical Review E*, 1996, in press.

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"Hilbert Space Methods in Hydrodynamics with Applications to Couette flow," K. Knorr and G. Ströhmer, *Zeitschrift für Naturforschung*, 48a, 679 (1993).

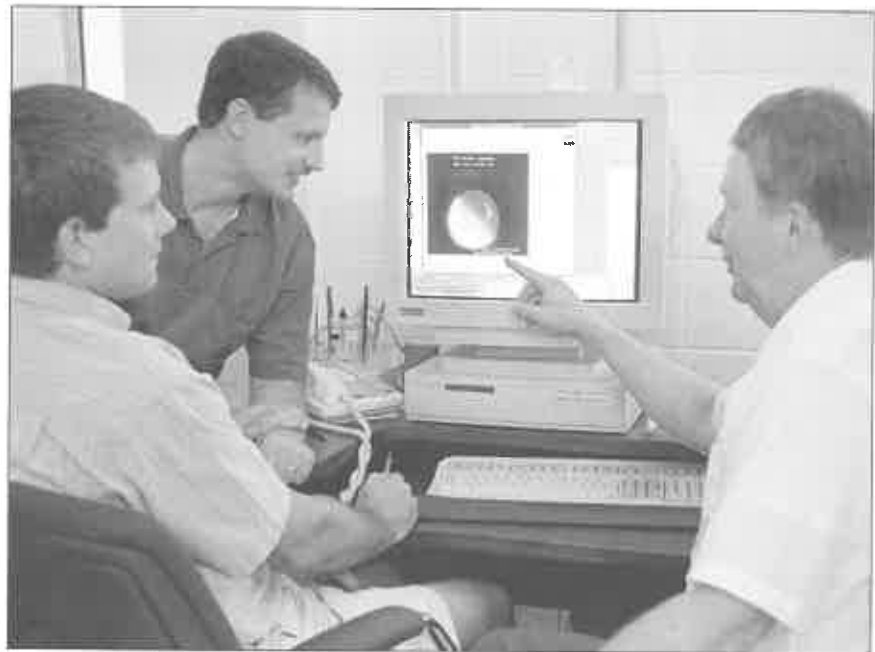
SPACE PHYSICS

The department conducts a major program of experimental and theoretical space physics supported by the National Aeronautics and Space Administration, the Office of Naval Research, and the National Science Foundation. Extensive facilities and engineering and technical staff are available to design, construct, and test equipment for flight in rockets, spacecraft, and the space shuttle, as well as to build complete satellites and perform computerized decoding and analysis of data. Emphasis is on comprehensive observational and theoretical study of the magnetospheres of Earth, Jupiter, Saturn, Uranus, and Neptune; the source regions of the solar wind; the interplanetary medium, including the acceleration and propagation

of energetic particles therein; and the galactic cosmic radiation.

The experimental space physics effort involves measurements of plasmas, plasma waves, radio emissions, cosmic rays, and auroral optical emissions. The space physics group currently has operating instruments on Pioneer 10 now at 65 AU; on Voyagers 1 and 2, now at 63 AU and 48 AU; on Galileo, which is in orbit around Jupiter; and on IMP-8, Geotail, Wind, and Polar, all of which are in orbit around Earth. An instrument is also under development for the Cassini mission to Saturn, which will be launched in 1997.

Space plasma physics mainly deals with the transport, heating, and acceleration of charged particles in planetary magneto-



Professor Louis Frank (right) reviewing images of Earth's northern auroral oval with associate research scientists William Paterson and John Sigwarth



Professor Donald Gurnett, right, and research staff in one of the space physics labs

spheres, the solar wind, and the solar corona. *In situ* measurements by the instruments described above enable research teams to use astrophysical plasmas as natural, self-consistent laboratories for the study of plasma physics.

An active program of research in theoretical space plasma physics is carried out by faculty, research scientists, and graduate students in the department. Topics of investigation include the generation of plasma waves by various distribution functions observed in space, nonlinear behavior of plasma waves, an improved kinetic description of Knudsen regime plasmas, and a number of topics related to the physics of boundary layers in space plasmas. An example of such a boundary layer is the bow shock that separates the solar wind from the Earth's magnetosphere.

In addition to traditional analytic techniques of solving theoretical problems,

investigators in space physics theory employ advanced numerical simulation codes based on Fokker-Planck, magneto-hydrodynamic, and particle-in-cell models. These codes are run on an extensive network of in-house computers and workstations, as well as at NSF super-computer centers in Illinois and California.

RECENT PUBLICATIONS

"Radio Emission from the Heliopause Triggered by an Interplanetary Shock," D.A. Gurnett, W.S. Kurth, S.C. Allendorf, and R.L. Poynter, *Science*, 262, 199 (1993).

"A Review of the Physics of Electron Heating at Collisionless Shocks," J.D. Scudder, *Advanced Space Research*, 15, 181 (1994).

"Direct Detection of the Current in a Magnetotail Flux Rope," L.A. Frank, W.R. Paterson, S. Kokubun, T. Yamamoto and R.P. Lepping, *Geophysical Research Letters*, 22, 2697 (1995).

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"Observations of a MHD Slow-Mode Shock at the Lobe-Plasma Sheet Boundary in the Earth's Distant Magnetotail," J. Seon, L.A. Frank, W.R. Paterson, J.D. Scudder, F.V. Coroniti, S. Kokubun, and T. Yamamoto, *Geophysical Research Letters*, 22, 2981 (1995).

"Early Rocket Observations of Auroral Bremsstrahlung and Its Absorption in the Mesosphere," J.A. Van Allen, *Journal of Geophysical Research*, 100, 14,485, (1995).

"Proton Velocity Distributions in the Magnetotail: Theory and Observations," M. Ashour-Abdalla, L.A. Frank, W.R. Paterson, V. Peromian, and L.M. Zelenyi, *Journal of Geophysical Research*, 101, 2587 (1996).

"Plasma Velocity Distributions in the Near-Earth Plasma Sheet: A First Look with the Geotail Spacecraft," L.A. Frank, W.R. Paterson, K.L. Ackerson, S. Kokubun, and T. Yamamoto, *Journal of Geophysical Research*, 101, 10,627 (1996).

"Micron-Sized Particles Detected in the Vicinity of Jupiter by the Voyager Plasma Wave Instrument," D. Tsintikidis, W.S. Kurth, D.A. Gurnett, and L.J. Granroth, *Geophysical Research Letters*, 23, 997 (1996).

"Twenty-Five Milliampères: A Tale of Two Spacecraft," J.A. Van Allen, *Journal of Geophysical Research*, 101, 10,479 (1996).

"Dreicer Order Ambipolar Electric Fields at Parker's Steady State Solar Wind Sonic Critical Point," J.D. Scudder, *Journal of Geophysical Research*, 101, (June 1996).

"Electrons, Protons, and Planets," J.A. Van Allen, *Icarus* (1996), in press.

DEGREES GRANTED

The University of Iowa offers two advanced degrees in physics: the Master of Science, with thesis or critical essay; and the Doctor of Philosophy, with research dissertation. One advanced degree is offered in astronomy: the Master of Science, with thesis or critical essay. Students who wish to pursue a program in astronomy beyond the M.S. level may qualify for a Ph.D. degree in physics with specialization and dissertation in astronomy or astrophysics. An interdepartmental Ph.D. program is offered in applied mathematical science.

Each graduate student has an individual faculty adviser who oversees the student's academic work and thesis or dissertation research. A typical Ph.D. program requires five years of graduate work.

The University also offers Bachelor of Science and Bachelor of Arts degrees in



Graduate student Bing Ji (Ph.D. 1995), winner of the Spriestersbach Award for best university thesis, with Duane C. Spriestersbach, University of Iowa vice president emeritus

both physics and astronomy. Undergraduate students may pursue double majors in these disciplines, and selected juniors and seniors may receive degrees with honors in recognition of research work they have done with faculty members.

RESEARCH FACILITIES

Facilities for graduate study and research in physics and astronomy are located in Van Allen Hall. The 195,000-square-foot, completely air-conditioned building houses an excellent library, machine shops, well-equipped laboratories, offices, storerooms, auditoriums, darkrooms, classrooms, lecture halls, and seminar rooms. A desk and study area are provided for each graduate student.

The central machine shop is staffed with skilled instrument makers and machinists, and several electronic and machine shops are available for use by advanced students and research staff.

The department has an extensive computer network. All major computers in the department are networked and can access all major networks. More than 20 terminals and auxiliary apparatuses are provided for student use, and additional computing facilities are available at the University's Weeg Computing Center.

Several networks permit access to supercomputers at the National Magnetic Fusion Energy Computing Center, Livermore, California; the National Center for Atmospheric Research, Boulder, Colorado; the National Center for Supercomputing Applications, Champaign, Illinois; and the Los Alamos National Laboratory, Los Alamos, New Mexico.

Professor Robert Muel and students in the astronomy lab



DEPARTMENTAL FACILITIES

Major research facilities in the department are:

- a comprehensive array of low-energy particle accelerators, electronic test equipment, and environmental test chambers and clean rooms;
- an optics laboratory for the development, calibration, and proof testing of instruments for space flight;
- a 17.8 MeV cyclotron for medical physics research;
- a fully equipped high-energy physics laboratory for design, construction, and testing of detectors used in experiments at the Fermi National Accelerator Laboratory and other large facilities around the world;
- twenty-four-inch and 12-inch Cassegrain telescopes at the Riverside Astronomical Observatory, ten miles south of Iowa City;
- a solid-state laboratory with facilities for magnetic susceptibility, resistivity, and

Hall effect measurements at low temperatures; facilities for the preparation of experimental materials;

- several plasma physics laboratories, including a 6-kG Q-machine facility; a variety of multidipole plasma devices and associated computer-based diagnostic equipment used for basic plasma physics research, laboratory simulation of space plasma physics phenomena, and applications to plasma processing of materials;
- The Optical Science and Technology Center, located in the Iowa Advanced Technology Laboratory, with well-equipped, environmentally controlled laboratories housing numerous state-of-the-art ultrafast laser systems. When taken together, the systems currently provide optical pulses with durations ranging from 200 picoseconds to less than 100 femtoseconds, with wavelengths extending from near UV to the mid IR; and a variety of state-of-the-art diagnos-

tic and support equipment such as streak cameras, optical multichannel analyzers, spectrophotometers, computer-controlled data acquisition systems, cryogenic facilities, and polishing facilities. The center also maintains modern molecular beam epitaxy facilities for the growth of novel electronic and photonic materials including artificially layered semiconductors. State-of-the art supersonic molecular beam and coupled laser spectroscopy and tandem time-of-flight mass spectrometer systems are also available for studies of the spectroscopy and dynamics of size-selected molecular clusters.

- Advanced astronomy students also conduct research at the National Astronomy and Ionosphere Center, Arecibo, Puerto Rico; the Very Large Array radio telescope, near Socorro, New Mexico; the Very Long Baseline Interferometry Network; the Very Long Baseline Array; Haystack Observatory, Westford, Massachusetts; Kitt Peak National Observatory, near Tucson, Arizona; the Infrared Telescope Facility, Mauna Kea, Hawaii; and the International Ultraviolet Explorer, Goddard Space Flight Center, Greenbelt, Maryland.



Professor Yannick Meurice (right) talks with theory students

OFF-CAMPUS FACILITIES

Students can arrange to do physics research at the following facilities:

- in nuclear physics at the National Superconducting Cyclotron Laboratory at Michigan State;
- in elementary particle physics at the Fermi National Accelerator Laboratory, Batavia, Illinois; the Los Alamos Meson Physics Facility, Los Alamos, New Mexico; the Stanford Linear Accelerator Center, Palo Alto, California; and the Center for European Nuclear Research, Geneva, Switzerland;
- in ionospheric plasma physics at the National Astronomy and Ionosphere Center, near Arecibo, Puerto Rico.

ASSOCIATED RESEARCH PROGRAMS AT THE UNIVERSITY OF IOWA

In addition to the research programs carried out in the Department of Physics and Astronomy proper, other research and academic programs at The University of Iowa are of interest to physicists. These draw the participation of faculty members in the department and offer physics and astronomy graduate students the prospect of research and interdisciplinary study.

IOWA INSTITUTE OF HYDRAULIC RESEARCH

This internationally recognized institute is a leader in research in numerous areas of hydraulic engineering and fluid mechanics, which are of interest to many physicists and astronomers. The institute occupies its own laboratory building with five modern laboratories. Areas of particular interest to students in physics and astronomy are the institute's research in computational fluid dynamics, studies of boundary layers, turbulence and turbulent shear flow, and active involvement in global climate issues.

CENTER FOR GLOBAL AND REGIONAL ENVIRONMENTAL RESEARCH

Perhaps the science issue most relevant to society in the next decade will be modification of the Earth's climate by human activity, such as release of carbon dioxide and other "greenhouse gases" into the atmosphere, destruction of the ozone layer, and so forth. Study of this complicated area involves sophisticated problems in physics, chemistry, and engineering as well as interdisciplinary synthesis. In recognition of the importance of this topic, The University of Iowa recently established the Center for Global and Regional Environmental Research. Thirty-one faculty members from the College of Liberal Arts and the College of Engineering participate.

Center-related research in the Department of Physics and Astronomy includes the use of millimeter wavelength radio measurements for precise measurement of the stratospheric ozone layer. Work by other faculty members in the center consists of measurements of



The department's rooftop observatory

tropospheric ozone and other urban air pollutants, mathematical modeling of atmospheric chemistry, remote sensing of the Earth's surface, and hydrometeorology.

OPTICAL SCIENCE AND TECHNOLOGY CENTER

The Optical Science and Technology Center of The University of Iowa is a multidisciplinary research center involving faculty from several University departments, including biomedical engineering, chemistry, chemical engineering, electrical and computer engineering, and physics and astronomy. Research areas within the center include ultrafast laser development, photonics and electro-optics, nonlinear optics, materials science, holography, surface science, laser spectroscopy and photochemistry, remote sensing and the detection of trace environmental contaminants, plasma spectroscopy and diagnostics, and the development of optical sensors and diagnostics for a wide range of biomedical applications. A major effort lies in the growth and characterization of novel materials and devices with unique electronic, optical, mechanical, or biological properties. Many of these materials are grown by molecular beam epitaxy or chemical vapor deposition and include artificially layered semiconductors (quantum wells, dots, wires and semiconductor

superlattices). This materials growth effort is enhanced by close interactions with other groups using ultrafast laser scattering techniques for the characterization of important optical and electronic material properties, and efforts aimed at the fabrication of micrometer and nanometer scale structures for optoelectronic devices and integrated circuit applications.

Much of the research is housed in a modern, environmentally controlled laboratory building, the Iowa Advanced Technology Laboratories, devoted primarily to research in areas of optical science and technology. State-of-the-art equipment includes widely tunable ultrafast laser systems, molecular beam epitaxy and chemical vapor deposition growth facilities, UHV surface science facilities, supersonic molecular beam/tandem time-of-flight mass spectrometer systems, holography laboratories, and nuclear magnetic resonance facilities.

MATHEMATICAL PHYSICS

The department conducts a joint mathematical physics seminar with the Department of Mathematics. Topics of interest are operator algebras, harmonic analysis, and topics in relativistic quantum mechanics and quantum field theory. Students may pursue an interdisciplinary degree in applied mathematical science.

FACULTY



BHATTACHARJEE, AMITAVA
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Ph.D., North Texas State University, 1982
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Professor and associate dean for research and development. Observational stellar astronomy, theoretical astrophysics.



FLATTÉ, MICHAEL E.
Ph.D., University of California (Santa Barbara), 1992
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FRANK, LOUIS A.
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KNORR, GEORG E.
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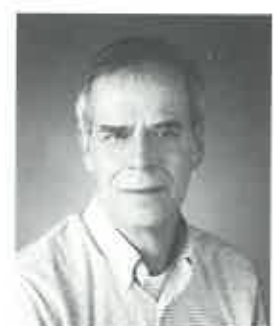
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FACULTY



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SCHWEITZER, JOHN W.
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CARLSON, RICHARD R.
Ph.D., University of
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RESEARCH STAFF

RESEARCH SCIENTISTS

Ackerson, Kent L., Ph.D., University of Iowa, 1972; space plasma physics.

Anderson, Roger R., Ph.D., University of Iowa, 1976; interplanetary and magnetospheric plasma waves.

Berman, David, Ph.D., University of Wisconsin, 1976; optics.

Calvert, Wynne, Ph.D., University of Colorado, 1962; space plasma physics.

Grabbe, Crockett L., Ph.D. California Institute of Technology, 1977; theoretical plasma physics.

Kurth, William S., Ph.D., University of Iowa, 1979; interplanetary and magnetospheric plasma waves.

Menietti, J. Douglas, Ph.D., University of Iowa, 1977; experimental space physics.

Otani, Niels F., Ph.D., University of California, 1986; theoretical plasma physics.

ASSOCIATE RESEARCH SCIENTISTS

Cairns, Iver H., Ph.D., University of Sydney (Australia), 1986; theoretical astrophysics.

Paterson, William R., Ph.D., University of Iowa, 1990; experimental space physics



Student Brita Neller installs a switch on a 6 cm radiotelescope receiver



Professor Amitava Bhattacharjee, center, with members of the plasma theory research group

Randall, Bruce A., Ph.D., University of Iowa, 1972; magnetospheric physics.

Sigwarth, John B., Ph.D., University of Iowa, 1989; experimental space physics.

Wang, Xiaogang, Ph.D., New York University, 1991; theoretical plasma physics.

ASSISTANT RESEARCH SCIENTISTS

Akchurin, Nural, Ph.D., University of Iowa, 1991; experimental particle physics.

Hansen, Paul J., Ph.D., University of Iowa, 1983; theoretical plasma physics.

Moghaddam-Taaheri, Ebrahim, Ph.D., University of Maryland, 1986; space plasma physics.

Ma, Zhiwei, Ph.D., University of Alaska, 1994; theoretical plasma physics.

Ng, Chung-Sang, Ph.D., Auburn University, 1994; theoretical plasma physics.

Masuda, Hiroaki, Ph.D., Nagoya University, Japan, 1988; experimental elementary particle physics.

Cai, Heng Jin, Ph.D., University of Alaska (Fairbanks), 1995; theoretical space plasma.

RESEARCH INVESTIGATORS

Chen, Jing, Ph.D., Johns Hopkins University, 1991; experimental plasma physics.

Hospodarsky, George B., Ph.D., University of Iowa, 1994; experimental space physics.

Martininson, Lee S., Ph.D., University of Iowa, 1994; theoretical solid state physics.

Morgan, David D., Ph.D., University of Iowa, 1992; experimental space physics.

Hamilton, Rowan T., Ph.D., Harvard University, 1996; experimental elementary particle physics.

POST-DOCTORAL ASSOCIATES

Snelling, Michael J., Ph.D., Southampton University (United Kingdom), 1991; experimental atomic, molecular, and optical physics.

Wang, Li, Ph.D., University of Florida, 1995; experimental atomic, molecular, and optical physics.

Walecki, Wojciech, Ph.D., Brown University, 1993; experimental atomic, molecular, and optical physics.

Chen, Xiaoyuan, Ph.D., Strathclyde University, (Glasgow, United Kingdom), 1991; experimental atomic, molecular, and optical physics.

Fittinghoff, David N., Ph.D., University of California (Davis), 1993; experimental atomic, molecular, and optical physics.

Buccafusca, Osvaldo F., Colorado State University, 1996; experimental atomic, molecular, and optical physics.

GRADUATE APPOINTMENTS AND AWARDS

Most of the students who are admitted to graduate study in physics and astronomy are offered research or teaching assistantships. If their progress is satisfactory, students normally continue to receive financial support until they complete their degree objective. Sources of support may also come from various fellowships or award programs at either the University or federal levels.

TEACHING ASSISTANTSHIPS

The initial appointment for a graduate student is usually a teaching assistantship. Most half-time TAs teach three sections of an elementary laboratory under the supervision of the professor in charge of the course. Some may serve as tutors, proctors, graders, or any combination of the four possible assignments. A half-time appointment allows for up to 20 hours of service to the department per week. Duties are arranged to allow the student to take a full load of course work—up to 12 semester hours—concurrently with the assistantship. Stipends for the 1996-97 academic year are \$13,550 for pre-com-

prehensive students and \$14,550 for post-comprehensive students. A few teaching assistantships are available during the summer months.

RESEARCH ASSISTANTSHIPS

Half-time research assistantships are available for many students engaged in Ph.D. dissertation research. The duties consist of work on the student's dissertation along with other work designed to build competence in research. Many students are associated with and supported by research groups before beginning dissertation research. Applicants should indicate the field of study in which they wish to work so that they may be considered for a research assistantship.

All graduate assistants and their spouses are eligible for resident tuition rates. The maximum tuition for the 1995-96 academic year is \$2,934 plus a mandatory health fee of \$44 and a thesis fee of \$60 at the time of degree completion. Graduate student assistants registered in the Graduate College and with at least a 25 percent appointment are eligible to receive the Graduate Student Health Insurance Allowance.



Student Bianca Nelson and graduate student Teh-Hwa Wong (Ph.D., 1996) working in the plasma lab

PLACEMENT OF RECENT PH.D. GRADUATES

1992

Wei Feng, "Analysis of Plasma Wave Interference Patterns in the Spacelab 2 PDP Data"

James Leckband, London Astronomy Unit, Queen Mary and Westfield College, London, England; "Magnetohydrodynamic Wave Associated Plasma Density Fluctuations in the Earth's Foreshock Region"

David Morgan, research investigator, Department of Physics and Astronomy, The University of Iowa, "Landau Damping of Auroral Hiss"

Hsien-Chih Jean, computer programmer, Cadence Design Systems, San Jose, Calif.; "The Relativistic Three-Quark Bound State Problem"

1993

Sharath Ananthamurthy, Professor, Indian Institute of Astrophysics, Bangalor, India, "Alkaline Earth Metla-Rare Gas Energy Transfer Collisions: Experiment and Theory"

Jamie L. Cooney, Research Scientist, Auburn University, Auburn, Ala., "Solitons in Negative Ion Plasma"

Timothy P. Dubbs, SCIPP National Science II, University of California, Santa Cruz, "Measurement of the Branching Ratio and Asymmetry Parameter of the X-Radiative Decay"

Takayuki Sakurai, research assistant, STE-Lab, Nagoya University, Toyakawa, Japan, "Radioastronomical Measurements of Plasma Characteristics of the Solar Corona and the Solar Wind"

Chin-Chun Tsai, post-doctoral fellow, Department of Physics, University of Texas at Austin, "All-Optical Multiple Resonance Spectroscopy of Na2 Using an Ultrasensitive Ionization Detector"

Dmitry Tsintikidis, post-doctoral associate, Hydrologic Research Center, San Diego, Calif., "The Properties of Micron-Sized Particles Detected at Saturn by the Voyager 1 and 2 Plasma Wave Instruments"

Min-Zu Wang, associate professor, Department of Physics, National Kaohsiung Normal University, Kaohsiung, Taiwan, "Calibration of the Zeus Barrel Calorimeter in a Teste Beam and a Direct Measurement of the JIPse Leptonic Branching Fraction"

Wenjun Xu, Hawaii, "Laboratory Studies on the Charging of Direct Grains in a Plasma"

1994

Alessandro Bravar, post-doctoral research fellow, Department of Physics, University at Manz, Manz, Germany, "Measurement of Spin Observable in Inclusive Lambda and Kshort Production with a 200 GeV Polarized Proton Beam"

Lining Ding, Institute of Molecular Science at National Taiwan University, Taipei, Taiwan, "Photofragmentation Spectroscopy of Magnesium Cluster Ion-Molecule Complexes"

George B. Hospodarsky, research investigator, Department of Physics and Astronomy, The University of Iowa, "The Fine Structure of Beam Driven Langmuir Waves"

Hyun-Soo Kim, Department of Science Education, Gyeongsang National University, Chinju, Kyungnam, Republic of Korea, "Ion Wake Fields in a Plasma with Negative Ions: Theory and Experiments"

Lee S. Martinson, research investigator, Department of Physics and Astronomy, The University of Iowa, "Structure and Properties of the $BaCo_{1-x}Ni_xS_{z-y}$ "

Maria Roco, post-doctoral fellow, Zeus Experiment, DESY Laboratory, Hamburg, Germany, "A Measurement of the Proton Structure Function and the First Determination of the Gluon Distribution of HERA"



Professor Edward McCliment, center, and assistant research scientist Nural Akhchurin, left, with graduate students testing detectors in a particle physics lab

1995

Bing Ji, Professional Development Program, Air Products, Allentown, Pa., "Alignment Effects in State-Selected Photodissociation Dynamics and Long-Range Interactions of Alkali Dimers Studied by All-Optical Multiple Resonance Spectroscopy"

Andrew Keller, instructor, Scott Community College, Bettendorf, Iowa, "Lower Hybrid Waves Generated in the Wake of the Galileo Spacecraft"

Jin-Tae Kim, post-doctoral fellow, Department of Physics, University of Connecticut, Storrs, Conn., "Optical-Optical Double Resonance Spectroscopy of K_2 "

Jerry Langland, financial analyst, Applied Financial Management, Chicago, Ill., "Hyperon and Anti-Hyperon Production in P-Cu Interactions with the Geotail Spacecraft"

Anthony Minter, post-doctoral fellow, National Radio Astronomy Observatory, Green Bank, W. Va., "Studying Interstellar Plasma Turbulence Through Precision Farady Rotation Measurements of Extragalactic Radio Sources"

1996

Tao An, programmer analyst, Sony Corporation, San Jose, Calif., "The Effect of Negative Ions in a Magnetized Potassium Plasma"

Paul Erdman, "Optical Absorption of Alkali Metal Vapors at High Temperatures"

Ralph Lano, post-doctoral fellow, Indian Institute of Science, Center for Theoretical Studies, Bangalor, India, "Quantum Gravity: Variations on a Theme"

Paul Lundquist, "Optical Waves in Nonlinear Planar Waveguides"

Gustavo Ordaz-Hernandez, "Scalar Field Theory in the Hierarchical Approximation"

Jongho Seon, assistant manager, Development Department 3, Satellite Business Division, Hyundai Kyounaki-do, Korea, "Observations of Slow-Mode Shocks in Earth's Distant Magnetotail"

Teh-Hwa Wong, "Dynamical Evolution and Energy Transfer in Molecular Collision"

UNIVERSITY CALENDAR

First Semester

Physics & Astronomy

Graduate Orientation

Classes begin

University holiday

Thanksgiving recess begins

University holidays

Classes resume

Classes end

Examination week

Commencement

University holidays

1997

August 22-23

August 25

September 1

November 25

November 27-28

December 1

December 12

December 15-19

December 19

December 25-26

1998

August 21-22

August 24

September 7

November 24

November 26-27

November 30

December 11

December 14-18

December 18

December 24-25

Second Semester

University holiday

University holiday

Martin Luther King convocation

Classes begin

Spring vacation begins

Classes resume

Classes end

Examination week

Commencement

University holiday

1998

January 1

January 19

January 20

March 20

March 30

May 8

May 11-15

May 15

May 25

1999

January 1

January 18

January 19

March 19

March 29

May 7

May 10-14

May 14

May 31

Summer Session

Three-week session

Eight-week session begins

Six-week session begins

University holiday

Commencement

1998

May 18-June 5

June 9-July 31

June 23-July 31

July 3

July 31

1999

May 17-June 4

June 8-July 30

June 22-July 30

July 5

July 30

IOWA'S GRADUATE PROGRAMS

Through The University of Iowa's nationally recognized programs, students master a body of knowledge and ultimately contribute to it through their own scholarship and research.

Iowa's graduate students work closely with a faculty of scholars who are committed to lives of learning. Together, faculty and students work in an atmosphere of academic freedom and intellectual verve that stimulates creative and innovative thinking.

Iowa's graduate programs have both depth and breadth. Iowa's graduate students actively participate in the life of a large and multifaceted university community. They receive specialized attention within their own disciplines while they exchange ideas with people from throughout the University's 10 colleges and more than 90 graduate degree programs.

DIVERSE THOUGHT AND CULTURE

The University of Iowa has a long history of offering learning opportunities for students of all races and backgrounds.

In 1879, only 24 years after the University began continuous operation, the first African American in the country to earn a law degree did so at Iowa. Iowa was the first to offer the M.F.A. degree, and the first recipient was an African-American woman. The first Ph.D.s earned by African Americans in history, music, and political science were at Iowa.

The richness of Iowa's academic environment has resulted in more than 1,800 underrepresented minorities earning degrees at the undergraduate, graduate, and professional levels in the last several years. Recent new efforts directed toward underrepresented groups in higher education have revitalized this endeavor. American students of Asian, African, Latino, and Native American background find many opportunities for support and cultural identification at the University. For more information, contact the Graduate College, Gilmore Hall, 319-335-2144.



EXTENSIVE ACADEMIC SUPPORT

The University Libraries constitute the largest library system of any kind in Iowa and the 27th largest academic/research system in the United States. They contain more than 3 million holdings, including 93,000 rare books, 470 manuscript collections, and 10,000 catalogued manuscript letters. In addition to the Main Library, there are 12 specialty libraries: art and art history, biology, botany and chemistry, business administration, engineering, geology, mathematics, music, physics, psychology, law, and the health sciences.

University scholars benefit from a number of central research facilities such as the Electron Microscopy Facility, the Image Analysis Facility, and the High Resolution Mass Spectrometry Facility.

The Weeg Computing Center provides versatile computing support for the University's academic community. The main computing hardware serves more than 3,000 computer terminals located throughout the campus. Weeg's Personal Computing Support Center provides comprehensive support to campus micro-computer users on an on-call basis.

The University of Iowa Hospitals and Clinics, the nation's largest university-owned teaching hospital, offers unparalleled resources for study and training in the health sciences.

COMMITTED FACULTY

Iowa's faculty members rate high as teachers, scholars, and researchers. In most University departments and colleges, graduate students work one-on-one with faculty mentors. In studios, libraries, and laboratories, they engage in creative endeavors that build toward independent projects initiated by the students.

Faculty members successfully compete for research support, attracting more than \$167 million annually from private and public sources. The University nurtures superior intellectual activity with outstanding facilities, fellowships, and assistantships that attract a critical mass of talented faculty and students.

At Iowa, 60 organized research units complement the activities of academic departments. A few examples are the Center for International and Comparative Studies, the Center for Computer Aided Design, the Alzheimer's Disease Research Center, the Center for New Music, the Cardiovascular Research Center, the Dows Institute for Dental Research, and the Institute for Economic Research.



FINANCIAL ASSISTANCE

Teaching and research assistantships, available in many departments, offer stipends ranging from \$9,500 to \$12,500 for academic year, half-time assignments. Additional support for summer sessions is often available. In the Graduate College, students who hold assistantships pay in-state tuition regardless of their residency status.

The Iowa Fellows Program helps attract extraordinary doctoral students to the University. Twenty to thirty fellowships are available each year, awarding \$16,000 to \$17,000 per year for up to four years plus tuition.

The Graduate Opportunity Scholarship and Fellowship Program and programs through the Committee on Institutional Cooperation offer valuable assistance for minority students.

The cost of living in Iowa City is moderate and comparable to most Midwestern cities. Current financial aid information is available from the Office of Student Financial Aid, Calvin Hall, 319-335-1450.



A LIVELY CAMPUS

The campus caters to pedestrians and bicyclists: it's compact enough to cross in a 20-minute walk. A free ride on a campus bus can halve that time. Entertainment on campus and in Iowa City is geared toward student budgets, with many events offered at no charge.

Iowa City has more book shops, coffee shops, restaurants, record shops, and movie theaters in its downtown area—right next to campus—than you'll find in cities many times its size.

Local service agencies combine with campus programs to provide a wide range of helping services for students and student families.

Hancher Auditorium brings the world's finest musicians, dancers, actors, and entertainers to the University. It is part of the Iowa Center for the Arts, which includes the Museum of Art and cultural/educational programs in music, theatre, art and art history, dance, and literary arts.

Iowa City is alive with festivals and ethnic celebrations. Music, drama, and dance can be found on stage or on street corners. Sculptures adorn campus green spaces and plazas, and works by local artists and craftspeople entice visitors to outdoor markets.

American and foreign film classics are presented at the University's Bijou Theatre at modest rates, and each semester the University community is energized by a full and diverse schedule of lectures, readings, and discussions that bring world notables to campus to interact with students and faculty members.

The University can help put enthusiasts on board a hot air balloon or a sailboat. Weight lifting, tennis, fencing, the martial arts, handball, soccer, rugby, football, spelunking, horseback riding, gymnastics, or golf—Iowa students do them all.

The University's Macbride Nature Recreation Area, located 15 miles from campus, offers hiking, cross-country skiing, sailing, and canoeing.

The University fields 10 varsity teams each for men and women. Iowa is a member of the Big Ten Athletic Conference, and University teams from field hockey to football enjoy fan support from the community and a large region of the state.

WHERE TO LIVE

Campus and community housing options can fit most every need, taste, and budget. University family housing provides efficiency and one- and two-bedroom apartments at affordable rates. Iowa City offers modern apartment complexes, rooms in charming older buildings, trailer parks, and cooperative housing. For off-campus housing information, contact the Campus Information Center, Iowa Memorial Union, 319-335-3055. For information about University family housing, contact the Family Housing Office, Housing Service Building, 319-335-9199.

CHILD CARE OPTIONS

Community Coordinated Child Care, a private, nonprofit agency known as 4-Cs, is a clearinghouse for information about licensed private child care providers, day care centers, preschools, and parent cooperative day care facilities. There are four University-affiliated day care centers overseen by The University of Iowa Student Association Daycare Commission. For information about child care, contact 4-Cs, 202 S. Linn St., Iowa City, IA 52240, 319-338-7684.



UNIVERSITY FACTS AT A GLANCE

Enrollment (1993-94): 27,051, including 6,450 enrolled in the Graduate College.

Colleges: Business Administration, Dentistry, Education, Engineering, Law, Liberal Arts, Medicine, Nursing, Pharmacy, and the Graduate College.

Degree Programs: More than 90 graduate degree programs; more than 56 leading to the doctorate.

Research Funding: Nearly \$2 billion in external funding since 1966; \$167 million in 1993.

Faculty: 1,716 tenure-track faculty members.

History: Founded in 1847 as Iowa's first public institution of higher learning, Iowa was the first public university in the United States to admit women and men on an equal basis.

Location: Iowa City is within 300 miles of Chicago, St. Louis, Minneapolis, Omaha, and Kansas City. The Cedar Rapids Airport, served by national and regional airlines, is a 20-minute drive from campus.

For more information about the University or community, write to the chair of the department of interest or to:

**Office of Graduate Admissions
The University of Iowa
107 Calvin Hall
Iowa City, Iowa 52242-1396**

or call 1-800-553-IOWA

The University of Iowa does not discriminate in its educational programs and activities on the basis of race, national origin, color, religion, sex, age, disability, or veteran status. The University also affirms its commitment to providing equal opportunities and equal access to University facilities without reference to affectional or associational preference. For additional information on discrimination policies, contact the Coordinator of Title IX and Section 504 in the Office of Affirmative Action, telephone 319-335-0705, The University of Iowa, 202 Jessup Hall, Iowa City, Iowa 52242-1316. 48382/48483 2-94

