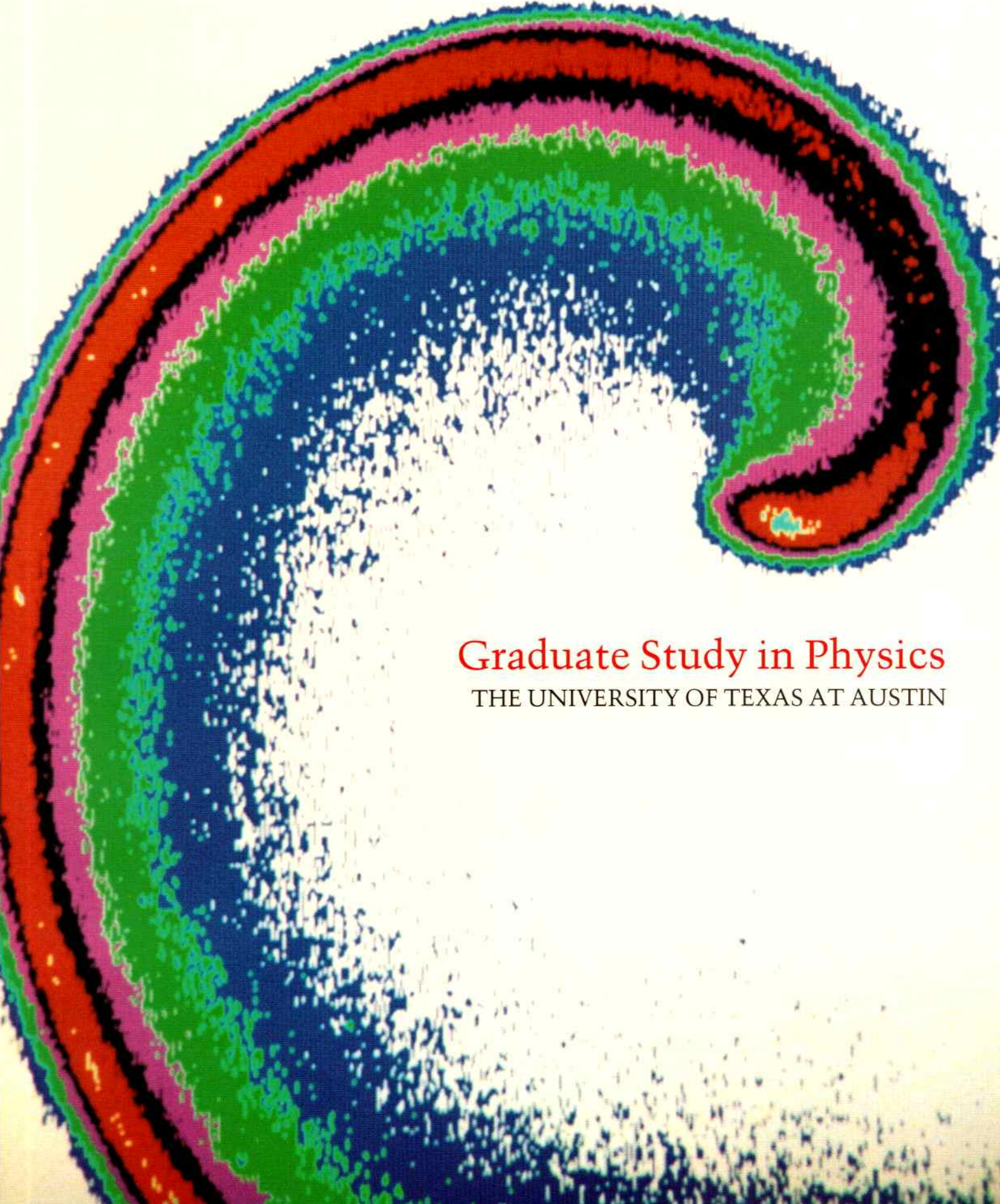


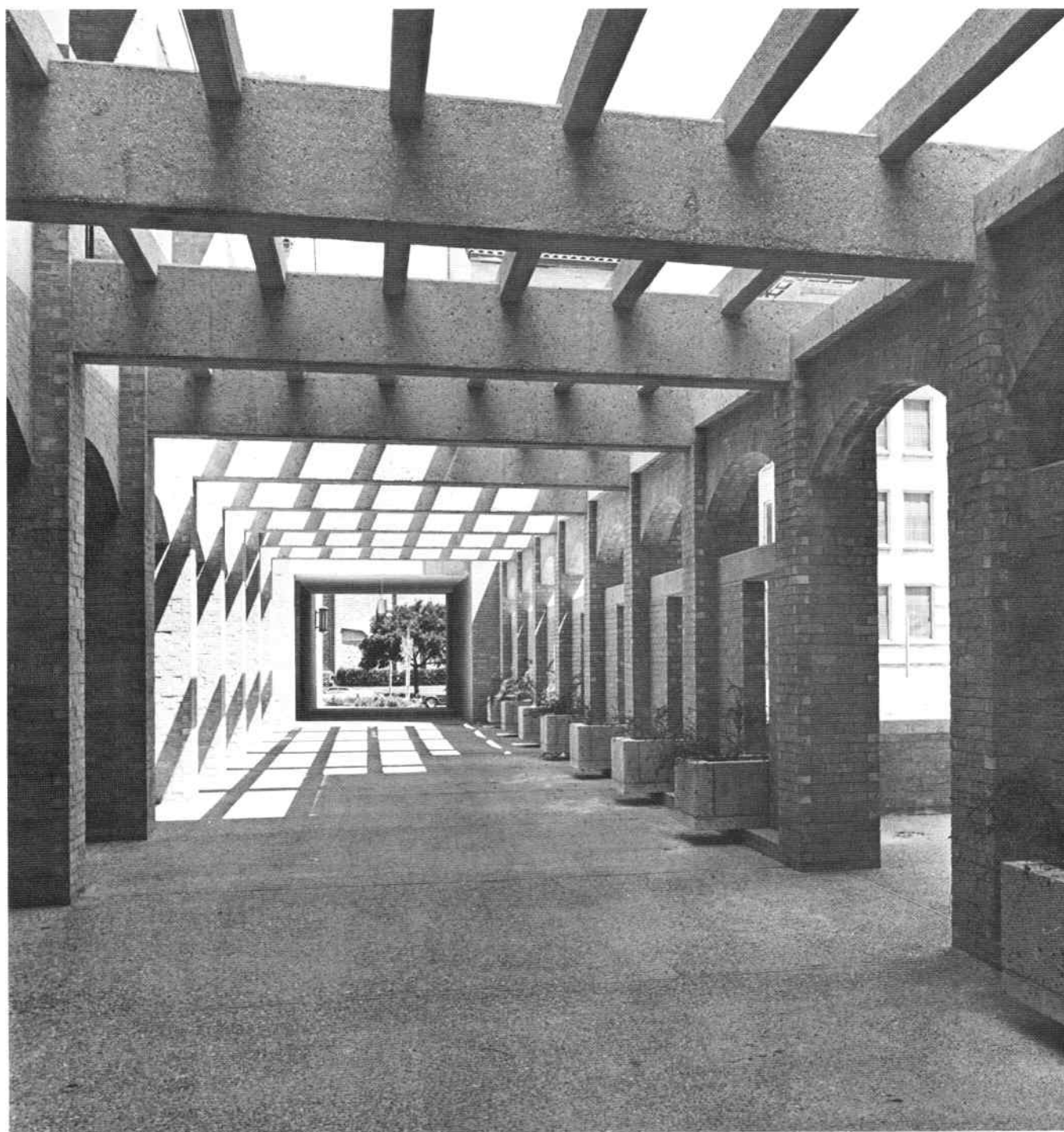


Graduate Study in Physics

THE UNIVERSITY OF TEXAS AT AUSTIN

Cover: Photograph of a rotating spiral pattern that formed in an initially uniform chemical reaction-diffusion system. The colors correspond to different concentrations of one of the chemical species. (Experiment in the Center for Nonlinear Dynamics.)

Published, Spring 1991.



GRADUATE STUDY IN PHYSICS

at The University of Texas at Austin

*C*ONTENTS

The University	5
The Department of Physics	6
Areas of research	7
Atomic, Molecular, and Quantum Optics Physics	7
Classical Physics	10
Condensed Matter Physics	11
High Energy Physics	16
Medium Energy and Nuclear Physics	18
Nonlinear Dynamics	21
Physics Education	24
Plasma Physics	25
Relativity, Cosmology, Quantum Gravitation, and Relativistic Astrophysics	29
Statistical Mechanics	31
Theoretical Particle Physics	33
Departmental colloquia and seminars	36
Ongoing collaborations	36
Admission	37
Degree requirements	39
Financial assistance	40
Course offerings	43
Tuition, fees and expenses	45
Housing	45
Living in Austin	46

THE UNIVERSITY

The University of Texas at Austin is a coeducational institution which formally opened in September, 1883. Since then, U. T. Austin has grown into one of the largest public universities in the nation. In 1990, total student enrollment was approximately 50,000 at the Austin campus, with about 12,000 of them in the Graduate School. At present, over 2,000 faculty teach courses in 16 colleges and schools, and supervise master's and doctoral work in over 50 fields of study.

A comprehensive research university, U.T. is especially proud of its libraries, which contain over five million volumes and are a vital national resource center for Latin American, Texan, 20th century British and American literary materials. The internationally famous Benson Latin American Collection draws scholars from all over the world who research the history, politics, and literature of Latin America. There are other major collections such as the Lyndon Baines Johnson Presidential Library and the Humanities Research Center. Several specialized branch libraries of the University of Texas General Libraries System serve specific academic areas such as law, biological sciences, chemistry, and other disciplines including a branch for Physics, Mathematics and Astronomy. Located near the research or teaching facility served, each library houses a variety of technical journals and comprehensive reference materials.



The University of Texas Tower

The University of Texas grounds include the original forty-acre campus in central Austin, the 390-acre Balcones Research Center located several miles north of the main campus and the 400-acre Brackenridge Tract situated between Lake Austin and Town Lake. The University also operates the Marine Science Institute on the southeast coast of Texas at Port Aransas and the McDonald Observatory in the Davis Mountains in West Texas.

To meet the advanced computation needs of researchers working in disciplines such as physics, computer sciences and mathematics, The University of Texas at Austin maintains up-to-date computing facilities. The University Computation Center offers some of the most comprehensive computing services of any research center in the U.S. Some of the systems available for faculty and student research include two instructional UNIX systems, an Encore multiprocessor system and two Alliant FX/4 minisupercomputer systems. A VAX 11/780 provides advanced graphics capabilities. And for computing in the sciences, the Computation Center maintains two Control Data Cyber 170/750 computers. The University of Texas System Center for High Performance Computation, located at the Balcones Research Center, supports a modern CRAY computation facility. All University of Texas computers are linked by a comprehensive telecommunication network which permits transfer of data from system to system.

THE DEPARTMENT OF PHYSICS

The Department of Physics is located in Robert Lee Moore Hall, a seventeen-story complex also housing the Mathematics and Astronomy Departments. The TEXT Tokamak fusion reactor is located four floors below street level and has helped make the University of Texas an important center for fusion research. R. L. Moore Hall also contains research facilities for over sixty faculty and student researchers as well as a variety of technical support shops/groups (machine, cryogenic, electronic repair, electronic design, and computers). And on the ground floor, the Kuehne Physics-Mathematics-Astronomy Library maintains a collection of more than 47,000 volumes along with subscriptions to about 700 periodicals.

Remote terminals located in various laboratories throughout the building provide access to the University's computation system. The Department supports the latest computer systems which are available for research and development, text-processing, and networking with other computer systems. The Physics faculty, research staff, and students all have access to these computer systems. Most research groups also have their own dedicated computer systems.



Robert Lee Moore Hall

From its early beginnings at The University of Texas at Austin, the graduate program in physics has grown to a current enrollment of over 300 graduate students working in the Department and in eight different Centers. These Centers are: The University of Texas Theory Group, headed by Nobel Laureate Steven Weinberg; the Center for Nonlinear Dynamics, headed by Harry Swinney; the Institute for Fusion Studies, headed by David Baldwin; the Fusion Research Center, directed by William Drummond; the Center for Particle Theory, directed by Duane Dicus; the Center for Relativity Theory, directed by Richard Matzner; and the Center for Statistical Mechanics, directed by Nobel Laureate Ilya Prigogine.

The Department of Physics is continually improving its research and teaching programs. Recent improvements in research include an upgrade of the TEXT Tokamak, used by the Plasma Physics group, as well as the formation of a High Energy Physics group. This last group and the Plasma Theory group are working together with staff from the Superconducting Super Collider now being built in Texas. This facility will provide exciting new research opportunities. In addition, new appointments have greatly expanded the capabilities in Condensed Matter Theory and Experiment, and in Atomic, Molecular and Quantum Optics.

AREAS OF RESEARCH

Active research is carried out in a diverse range of fields in physics. The main areas of research are listed below together with faculty and staff/research personnel in each particular area. Interests of the faculty and staff are noted, together with brief biographical information. Some representative publications from each group are also given.

ATOMIC, MOLECULAR, AND QUANTUM OPTICS PHYSICS

Experimental work in atomic and molecular physics involves the quantitative investigation of the properties of energy states and the mechanisms for energy transfer in atomic and molecular systems. Problems are drawn from areas of current and fundamental interest in upper atmospheric physics, plasma physics, electron physics, chemical physics and astrophysics. There are eleven faculty, two postdocs, and approximately 30 graduate students.

Electron diffraction is used to study molecular structures from simple diatomic molecules to biological compounds to accuracies better than 0.001 angstroms. Systematic studies of the thermal vibrational averaging of the structure parameters give access to the molecular potential functions. The elastic cross sections are Fourier analyzed, and charge density functions are determined. The inelastic scattering intensities are compared with theoretical predictions emphasizing correlation effects in molecules. The newest developments target the extension of electron scattering to optically pumped electronic excited states of atoms and oriented molecules. A new apparatus has been designed and built which will be able to determine the rest mass of the electron antineutrino to better than 2eV. The endpoint of the beta spectrum of T_2 will be measured with an electrostatic tandem spectrometer arrangement.

The dynamics of gas-surface interactions are being studied using molecular beam and laser techniques. Emphasis is placed on understanding the importance of internal molecular degrees of freedom such as rotational, vibrational or electronic excitation, in the scattering of a molecule from a solid surface. Laser excitation is used either to prepare a molecule in a selected quantum state prior to interaction with a surface, or to measure the distribution of quantum states populated in a sample after interaction with the surface.



Students working in the quantum optics laboratory.

Novel investigations of molecular interactions are based on collision-induced infrared and Raman spectra which are "forbidden" at low gas densities. Molecular two- and more-body interactions induce broad lines at high densities, with a width given by the reciprocal interaction time. These profiles provide new information on the molecular interactions. Collision-induced emission and scattering of light, along with a number of other optical and dielectric properties of matter are studied. Collision-induced processes are significant for astrophysics in all regions of high density, for excimer and multi-photon processes, and for determining the infrared opacity of the atmospheres of planets and cool stars.

Interactions among atoms and molecules are being studied following multiphoton laser excitation. Using high resolution dye lasers, precise spectral line shapes are obtained and interaction potentials are extracted. The dynamics of excited state systems are also probed using an amplified picosecond laser. Current experiments are investigating reactive excitation transfer from xenon excimers to chloride dopants. Attempts are being made to use nonlinear Raman processes (CARS, SRGS) to study the structure and reactions of molecular ions.

Techniques have become available which allow for the control of the interactions of light with a small number of atoms. The application of ion trapping techniques to such problems has opened up many exciting directions for research. At The University of Texas, we have developed a novel linear ion trap which can confine a small string of ions and is especially well suited to quantum optics studies. Another area of research is low-energy manifestations of elementary particle theories which could be tested using the high precision techniques of atomic physics.

A powerful femtosecond (10^{-15} second) laser source is used to study the physics of atoms in super-intense light fields. Under these extreme conditions, the optical electric field exceeds Coulombic atomic binding fields, and ionization becomes a tunneling process rather than a perturbative dipole transition. The goal of the experiments is to reach a fundamental understanding of ionization rates and energies under strong field conditions, especially through measurements of spectral shifts in the light field itself. Theoretical investigation covers a broad range, running from necessarily approximate studies of the very large systems of interest to organic chemists, to highly accurate first principle investigations of simple atomic systems. Significant advances are being made in the application of group theory and group algebra to electronic and nucleonic systems, as well as in extensions of perturbation theory.

Faculty

Bengtson, Roger D.

Professor. B.S., Nebraska, 1962; M.S., Virginia Polytechnic Institute, 1964; Ph.D., Maryland, 1968. Atomic transition probabilities, Stark broadening, plasma physics.

Downer, Michael

Associate Professor. B.A., Rochester, 1976; M.A., Oxford, 1978; Ph.D., Harvard, 1983. Femtosecond spectroscopy.

Fink, Manfred

Professor. Vordiplom, Diplom, Dr., Technische Hochschule Karlsruhe, 1958, 1963, 1966. Electron diffraction, neutrino physics.

Frommhold, Lothar W.

Professor. Dipl. Ph.D., Dr. Habil, Hamburg, 1956, 1961, 1964. Atomic and molecular physics.

Heinzen, Daniel J.

Assistant Professor. B.S., M.I.T., 1981; Ph.D., 1988. Trapped ions.

Keto, John W.

Professor. B.S.E., Michigan, 1968; Ph.D., Wisconsin, 1972. Reaction and radiative processes of excited atoms and molecules, laser spectroscopy, high power lasers.

Matsen, F.A. (Al)

Professor of Physics and of Chemistry. B.S., Wisconsin, 1937; Ph.D., Princeton, 1940. Quantum mechanics, groups and linear algebras.

Raizen, Mark G.

Assistant Professor. B.Sc., Tel Aviv, 1980; Ph.D., Texas, 1989. Experimental quantum optics and ion trapping.

Robertson, William W.

Professor. B.A., Texas 1941; M.A., 1949; Ph.D., 1955. Experimental atomic and molecular spectroscopy, gaseous electronics, reactions in decaying plasmas, environmental effects on spectra.

Scherr, Charles W.

Professor. B.S., Pennsylvania, 1949; M.S., Chicago, 1951; Ph.D., 1954. Theoretical quantum-mechanical studies of high accuracy on simple systems.

Sitz, Greg O.

Assistant Professor. B.A., Rice University, 1981; Ph. D., Stanford University, 1987. Experimental studies of the dynamics of gas-surface interactions.

Postdoctoral Research Staff

Xie, Shang-Di

Ph.D., Shanghai University. Atomic and molecular physics.

Trisnadi, Jahja

Ph.D., Texas, 1989. Atomic and molecular physics.

Some Recent Publications

"Investigation of Low-Frequency Fluctuations in the Edge Plasma of ASDEX", R.D. Bengtson, A. Rudyj, A. Carlson, L. Giannone, *Proceedings of 16th European Conference on Controlled Fusion and Plasma Physics, Venice, Italy* **13B**, Part I (1989), 27.

"Electron Thermal Confinement Studies with Applied Resonant Fields on TEXT", R. D. Bengtson, A. J. Wootton, M. E. Austin, J. A. Boedo, et. al., *Nuclear Fusion* **29**, 547 (1989).

"Direct Inelastic Scattering of N_2 from Ag(111). II. Orientation", G.O. Sitz, A.C. Kummel, J.C. Tully and R.N. Zare, *J. Chem. Phys.* **89**, 2572 (1988).

"Observation of a Speed-Dependent Collisional Inhomogeneity in H_2 Vibrational Lines Profiles", R. L. Farrow, L. A. Rahn, G.O. Sitz and G. J. Rosasco, *Phys. Rev. Lett.* **63**, 746 (1989).

"Ultrafast Laser Probing of Interband Absorption Edges in 3D and 2D Semiconductors", M. C. Downer, D. H. Reitze and G. Focht, *SPIE* **1282**, in press (1990).

"A New Class of Ultraviolet Femtosecond Sources", M. C. Downer, G. Focht, P. Williams and T.R. Zhang, *Proc. SPIE*, **1041**, 162-166 (1989).

"Cross Sections and Spin Polarizations of Electrons Elastically Scattered from Oriented Molecules (DH3I)", R. Fink, J.A. Ross and M. Fink, *Z. Phys. D-Atoms, Molecules and Clusters*, **11**, 231-238 (1989).

"Elastic Electron Scattering Cross Sections of Oriented and Aligned Molecules", M. Fink and A. Mihill, *Z. Phys. D* **14**, 77 (1989).

"An Electron Diffraction Study of Alkali Iodide Vapors", J. G. Hartley and M. Fink, *J. Chem. Phys.* **86**, 6053 (1988).

"Polarized Electron Impact Ionization of Metastable Helium", G. Baum, M. Fink, W. Raith, H. Steidl and J. Taborski, *Phys. Rev.* **A40**, 6734 (1989).

"Radiative Lifetimes and Collisional Deactivations of Two-Photon Excited Xenon in Argon and Xenon", M.R. Bruce, W.B. Layne, C.A. Whitehead and J.W. Keto, *J. Chem. Phys.* **92**, 2917 (1990).

"Raman Induced Kerr Effect Spectroscopy Using Pulsed Lasers", J. Borysow, R.H. Taylor and J.W. Keto, *Opt. Comm.* **80** (1988).

"Reactive Quenching of Two-Photon Excited Xenon Atoms by Cl_2 ", M.R. Bruce, W.B. Layne, E. Meyer and J.W. Keto, *J. Chem. Phys.* **92**, 420 (1990).

"Test of the Linearity of Quantum Mechanics by RF Spectroscopy of the $^9Be^+$ Ground State", J.J. Bollinger, D.J. Heinzen, W.M. Itano, S.L. Gilbert and D.J. Wineland, *Phys. Rev. Lett.* **63**, 1031 (1989).

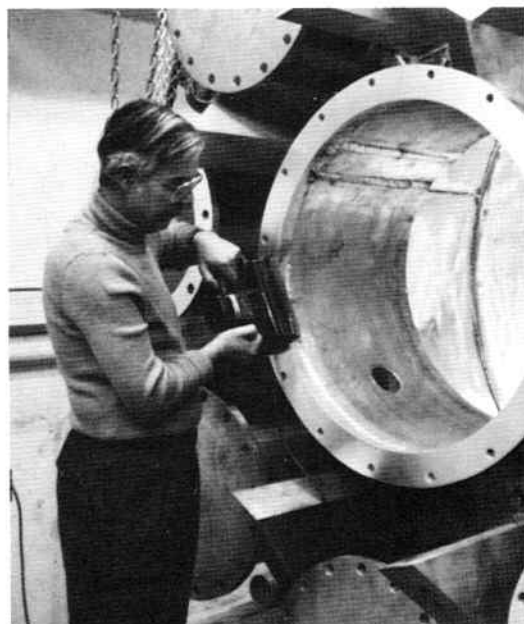
"Quantum Zeno Effect", W.M. Itano, D.J. Heinzen, J.J. Bollinger and D.J. Wineland, *Phys. Rev.* **A41**, 2295 (1990).

"Quantum-Limited Cooling and Detection of Radio-Frequency Oscillations by Laser-Cooled Ions", D.J. Heinzen and D.J. Wineland, *Phys. Rev.* **A42**, 2977 (1990).

"Normal-Mode Splitting and Linewidth Averaging for Two-State Atoms in an Optical Cavity", M.G. Raizen, R.J. Thompson, R.J. Brecha, H.J. Kimble and H.J. Carmichael, *Phys. Rev. Lett.* **63**, 240 (1989).

"Comment on Nonlinear Magneto Optics of Vacuum: Second Harmonic Generation", M.G. Raizen and Baruch Rosenstein, *Phys. Rev. Lett.* **65**, 2744 (1990).

"Ionic Strings in a Linear RF Trap", M.G. Raizen, J.C. Bergquist, W.M. Itano and D.J. Wineland (to be submitted to *Phys. Rev. Lett.*)



Professor Fink building large scattering chamber

CLASSICAL PHYSICS

The University of Texas is a major national center for research in acoustics. This is an interdisciplinary program involving faculty and graduate students from the Departments of Aerospace Engineering, Electrical Engineering and Mechanical Engineering as well as Physics. Some areas of investigation include sound propagation in the atmosphere, nonlinear acoustics, acoustical properties of musical instruments, transducer design and underwater acoustics. Some of the work in the latter area is performed at The University of Texas Applied Research Laboratories facility (ARL), located approximately five miles north of the main campus. This laboratory has a staff of approximately 500 people working primarily in the area of underwater acoustics. The research at ARL covers topics such as long-range propagation of low-frequency sound and design of high-frequency high-resolution sonars. ARL facilities include several large experimental tanks, a transducer fabrication laboratory and a large testing laboratory located west of Austin on Lake Travis. ARL offers good employment opportunities for students in the graduate program in acoustics.

Another program in the Department involves research on electromagnetic wave propagation problems, especially as related to measuring and reducing electromagnetic emissions from electronic equipment.

Faculty

Antoniewicz, Pete R.

Professor. B.S., North Carolina, 1959; M.S., Purdue, 1964; Ph.D., 1965. Surface and interface physics; electromagnetic wave propagation and transport properties in solids and liquids.

Blackstock, David T.

Professor of Mechanical Engineering. B.S., Texas, 1952; M.A., 1953; Ph.D., Harvard, 1960. Nonlinear acoustics, medical acoustics.

Gavenda, J. David

Professor of Physics and Education. B.S., Texas, 1954; M.A., 1956; Ph.D., Brown, 1959. Conduction electrons in metals using ultrasonic and electromagnetic waves.

Gleeson, Austin M.

Professor. B.S., Drexel, 1960; M.S., Pennsylvania, 1963; Ph.D., 1965. High energy acoustic sources.

Griffy, Thomas A.

Professor. B.A., Rice Institute, 1959; M.A., 1960; Ph.D., 1961. Theoretical medium/high energy physics; underwater acoustics.

Hamilton, Mark F.

Associate Professor of Mechanical Engineering. B.S.E.E., Columbia, 1978; M.S., Penn State, 1981; Ph.D., Penn State, 1983. Nonlinear acoustics.

Nolle, A. Wilson

Professor. B.A., Southwest Texas State University, 1938; M.A., Texas 1939; Ph.D., M.I.T., 1947. Musical-instrument physics; underwater acoustics.

Some Recent Publications

"Extracorporeal Shock Wave Lithotripsy", L.A. Crum, C.C. Church and D.T. Blackstock, *Physics Today* **42**, 54 (1989).

"Atmospheric Acoustic Noise as a Function of Altitude", T.A. Griffy and E.L. Hixson, *J. Acoust. Soc. Am.* **85**, 1089 (1989).

"Dynamic Compressibility of Poly (Vinyl Acetate) and Poly (Methyl Methacrylate): Effects of Molecular Weight", T.-S. Lin and A.W. Nolle, *Polymer*, **30**, 648 (1989).

"Noncollinear Interaction of Two Sound Beams from Displaced Gaussian Sources, with Application to Parametric Receiving Arrays", M.F. Hamilton, T. N. Tjotta and S. Tjotta, *J. Acoust. Soc. Am.* **82**, 311 (1987).

"Effect of Source Type and Orientation on the Rate of Falloff of Electric Fields", J.D. Gavenda, *IEEE 1987 Int. Electromagnetic Compatibility Symposium Record, Atlanta*, 338 (1987).

CONDENSED MATTER PHYSICS

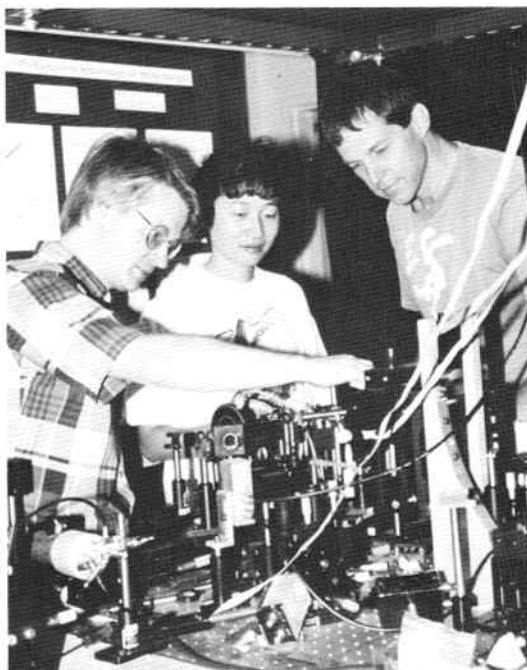
Sixteen faculty, nine postdoctoral associates, and approximately 50 graduate students are engaged in a broad program of research in condensed matter physics. Major group efforts include work in surface physics, thin film magnetism, phase transformations, high- T_c superconductors, semiconductors, heavy fermions, femtosecond processes in condensed matter and nonlinear dynamics.

A broad range of spectroscopic techniques are being used to investigate the relationship between structure and magnetism at surfaces and in novel materials grown by molecular beam epitaxy. Low energy electron diffraction, scanning tunneling microscopy and electron forward scattering are used to study film growth and characterize atomic level structure and coordination of epitaxial thin-film structures. Several spin sensitive probes, including spin-polarized photoemission and magneto-optical techniques, are used to probe structure-dependent magnetic properties including magnetic transition temperatures, coercive forces and anisotropy. Surface dynamics and structure are studied using inelastic electron scattering to measure surface phonon properties and discrete vibrations at surfaces. Electronic properties of bulk materials, thin films, and epitaxial films are studied using spin- and angle-resolved photoemission at The University of Texas beamlines at the National Synchrotron Light Source.

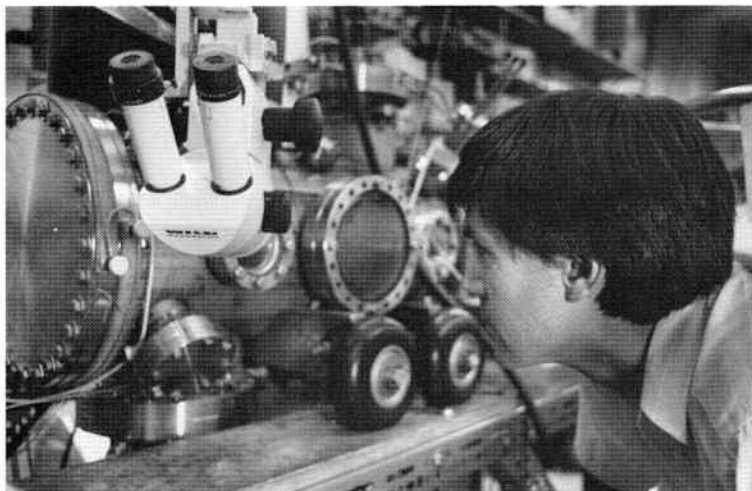
A parallel and complementary theoretical program exists which adds important capabilities to these experimental efforts. First principle calculations of the structure and electronic properties of thin films and superlattices including III-V semiconductors are carried out using the University of Texas CRAY Computer. Theoretical, structural, and lattice dynamical calculations of crystal bulk, surfaces and interfaces are carried out with the dual goal of studying intrinsic properties of these systems (e.g., the relationship between bulk and surface structural transitions) and interpreting results of surface scattering experiments with electron energy loss spectroscopy and helium scattering. This work includes full lattice dynamical studies of the high- T_c superconductors and their phonon related properties.

Theoretical and experimental research is being conducted on phase transitions and critical phenomena. Dynamic and static properties near phase transitions in liquid crystals are being studied from the theoretical point of view. Ultra-thin (1-10 atomic layer) magnetic films representing a class of structures which approximate ideal two-dimensional systems are being studied both experimentally and theoretically. Finite size scaling and critical exponents in ultra-thin magnetic films using optical and polarized electron techniques are being studied.

Femtosecond laser spectroscopy is used to heat solids to extremely high temperatures, characteristic of molten or plasma phases, on a time scale short enough that the material remains at solid density. The material properties and potential applications of these hot, dense phases are then probed optically on a



Prof. Mike Downer with students and postdoc



*Professor de Lozanne's
tunneling microscope*

femtosecond time scale. The poorly understood liquid phases of highly refractory materials such as carbon are created by heating the solid beyond 5000 K within 100 femtoseconds, then probing the optical properties of the liquid before evaporation or ablation occurs. At metal surfaces, solid density plasmas are created and the evolving electron temperature is probed by femtosecond photoemission methods. Parallel experiments at lower excitation levels utilize femtosecond laser sources to investigate short-lived surface states, carrier dynamics in semiconductors, and electrical pulse propagation in high-speed integrated circuit structures.

Superconductivity is being studied in its most novel manifestations, namely high T_c , heavy fermion, and organic materials. Synthesis of bulk and thin film samples is possible by conventional techniques and by sophisticated multi-source evaporation. Compositional studies of these materials are used to elucidate the basic mechanisms of superconductivity. These samples are characterized by x-ray diffraction, scanning electron microscopy (SEM) with energy dispersive analysis, transport measurements in fields up to 8 Tesla, and SQUID magnetometry. Unique capabilities are provided by several low-temperature scanning tunneling microscopes (STMs), one of which operates in a dilution refrigerator at temperatures down to 0.043K.

STMs are also used to study semiconductor surfaces and junctions in ultra high vacuum. A powerful combination of SEM and STM generates and measures structures with 10 nm linewidths. Novel effects have recently been discovered in similar nanostructures. Such nanostructures are important in understanding the transition between mesoscopic physics and atomic physics.

Other areas of interest include electron transport properties in metal crystals, which are being studied using ultrasonic and electromagnetic waves, as well as the effects of complex molecular adsorbates on photo threshold, second harmonic generation and other surface related optical processes. Theoretical work is also proceeding on several questions related to pattern formation dynamics. Some issues under investigation include how water flowing over a flat surface can form a river network, why fast cracks leave behind ragged surfaces, and how irregularity affects their velocity.

The research is supported by contracts/grants from NSF, NASA, DOE, Air Force Office of Scientific Research, The Robert A. Welch Foundation, British Petroleum, and Joint Services Electronics Program. Total support was in excess of \$2,000,000 for 1989-1990.

Faculty

Antoniewicz, Pete R.

Professor. B.S., North Carolina, 1959; M.S., Purdue, 1964; Ph.D., 1965. Surface and interface physics; electromagnetic wave propagation and transport properties in solids and liquids.

de Lozanne, Alex L.

Associate Professor. B.S., Purdue, 1976; Ph.D., Stanford, 1982. Scanning tunneling microscopy; nanostructures, thin films and devices; high temperature superconductors.

de Wette, F.W.

Professor. B.S., Utrecht (The Netherlands), 1947; M.S., 1950; Ph.D., 1959. Theoretical studies of crystal surfaces and thin films; lattice dynamics of high-temperature superconductors.

Downer, Michael

Associate Professor. B.A., Univ. of Rochester, 1976; M.A., Oxford, 1978; Ph.D., Harvard, 1983. Femtosecond spectroscopy in condensed matter.

Erskine, James L.

Trull Centennial Professor. B.S.E.E., 1964; M.S.E.E., 1966; Ph.D., Washington, 1973. Experimental solid-state physics; thin-film magnetism; surface phonons.

Gavenda, J. David

Professor of Physics and Education. B.S., Texas, 1954; M.A., 1956; Ph.D., Brown, 1959. Properties of conduction electrons.

Kleinman, Leonard

Professor. B.A., Univ. of California (Los Angeles), 1955; M.S., 1956; Ph.D., Univ. of California (Berkeley), 1960. Density functional theory, pseudopotential theory and energy-band theory; superlattices.

Marder, Michael P.

Assistant Professor. A.B. Cornell, 1982; Ph.D., Univ. of California (Santa Barbara), 1986. Theoretical investigations of pattern formation, nonlinear dynamics.

Markert, John T.

Assistant Professor. B.A., Bowdoin College, 1979; M.S., Cornell Univ., 1984; Ph.D., 1987. Magnetism and superconductivity in oxides and heavy fermion systems; high temperature superconductivity; high pressure research.

McCormick, William D.

Professor. B.S., California Inst. of Technology, 1953; Ph.D., Duke, 1959. Nonlinear dynamics; experimental condensed matter physics.

Niu, Qian

Assistant Professor. B.S., Peking Univ., 1981; M.S., Univ. of Washington (Seattle), 1983; Ph.D., 1985. Condensed matter theory; field theory; superconductivity.

Nolle, A. Wilson

Professor. B.A., Southwest Texas State Univ., 1938; M.A., Texas, 1939; Ph.D., M.I.T., 1947. Viscoelastic phenomena; fluid oscillations; musical instrument physics; underwater acoustics.

Shih, C. Ken

Assistant Professor. B.S. National Tsing-Hua University, 1977; M.S., University of Oregon, 1981; Ph.D., Stanford, 1988. Compound semiconductors.

Smoluchowski, Roman

Professor of Astronomy and Physics. M.A., Warsaw (Poland), 1933; Ph.D., Groningen (Holland), 1935. Solid-state physics applied to astrophysical problems.

Swift, Jack B.

Professor. B.S., Arkansas, 1963; M.S., Illinois, 1965; Ph.D., 1968. Theoretical studies of liquid crystals; phase transitions; nonlinear dynamics; pattern formation.

Thompson, James C.

Professor. B.A., Texas Christian, 1952; M.A., Rice Inst., 1954; Ph.D., 1956. Disordered systems; optical properties of surfaces and interfaces; photoemission.

Postdoctoral Research Staff

Bylander, M.

Ph.D., Washington, 1980. Theoretical solid state physics.

Fink, R.L.

Ph.D., University of Illinois, 1987. Experimental condensed matter physics.

Kulkarni, A.D.

Ph.D., Texas, 1984. Theoretical solid state physics.

Lee, S.

Ph.D., University of Illinois, 1986. Theoretical condensed matter physics.

Mulholland, G.

Ph.D., Rice, 1989. Experimental solid state physics.

Riffe, D.M.

Ph.D., Cornell University, 1989. Surface and interface spectroscopy.

Smith W. F.

Ph.D., Harvard University, 1989. Experimental condensed matter physics.

Tang, M.

Ph.D., University of Wisconsin, 1989. High temperature superconductors, electron spectroscopy.

Villagran, J.C.

Ph.D., Texas, 1987. Experimental condensed matter physics.

Some Recent Publications

"Direct Writing of 10 nm Features with the Scanning Tunneling Microscope", E.E. Ehrichs, S. Yoon and A.L. de Lozanne, *Applied Phys. Lett.* **53**, 2287 (1988).

"Measurements of the Superconducting Gap of La-Sr-Cu-O With a Scanning Tunneling Microscope", S. Pan, K.W. Ng, A.L. de Lozanne, J.M. Tarascon and L.H. Greene, *Phys. Rev. B* **35**, 7220 (1987).

"As-deposited Superconducting Y-Ba-Cu-O Thin Films on Si, Al_2O_3 and SrTiO_3 Substrates", R.M. Silver, A.B. Berezin, M. Wendman and A.L. de Lozanne, *Appl. Phys. Lett.* **52**, 2174 (1988).

"Properties of *In-Situ* Superconducting Thin Films of Y-Ba-Cu-O on Si, Al_2O_3 , and SrTiO_3 Substrates", R.M. Silver, A.B. Berezin, E. Ogawa and A.L. de Lozanne, Proceedings, Applied Superconductivity Conference, August 1984, San Francisco, CA. *IEEE Trans. Magn.* **MAG-25**, 2516 (1989).

"Lattice Dynamics of High- T_c Superconductors: Optical Modes of the Thallium-Based Compounds", A.D. Kulkarni, F.W. de Wette, J. Prade, U. Schröder and W. Kress, *Phys. Rev. B* **41**, 6409 (1990).

"Lattice Specific Heat of $\text{YBa}_2\text{Cu}_3\text{O}_2$ ", F.W. de Wette, A.D. Kulkarni, J. Prade, U. Schröder and W. Kress, *Phys. Rev. B* **42**, 6707 (1990).

"Relaxation and Dynamics of the (001) Surfaces of Crystals with Perovskite Structure", U. Schröder, J. Prade, F.W. de Wette, A.D. Kulkarni and W. Kress, *Superlattices and Microstructures* **7**, 247 (1990).

"Femtosecond Laser Melting of Graphite", D.H. Reitze, X. Wang, H. Ahn and M.C. Downer, *Phys. Rev. B* **40**, Rapid Communications (1989).

"Two-Photon Spectroscopy of Silicon Using Femtosecond Pulses at Above Gap Frequencies", D.H. Reitze, T.R. Zhang, W.M. Wood and M.C. Downer, *J. Opt. Soc. Am. B* (1990).

"Generation of Synchronized Ultraviolet and Red Femtosecond Pulses by Intracavity Frequency Doubling", G. Focht and M.C. Downer, *IEEE J. Quant. Electron.* **24**, 431 (1988).

"A New Contribution to Spin-Forbidden Rare Earth Optical Transition Intensities: Analysis of All Trivalent Lanthanides", G.W. Burdick, M.D. Downer and D.K. Sardar, *J. Chem. Phys.* **91**, 1511 (1989).

"Interaction of Super-Intense Lightfields with Atoms and Surfaces", M.C. Downer, W.C. Banyai, W.M. Wood, D.C. Anacker and J.L. Erskine, *Proc. SPIE* **1209** (1990).

"Surface Vibrations on Clean and Hydrogen-Saturated $\text{W}(100)$ ", J.L. Erskine, J.P. Woods, A.D. Kulkarni and F.W. de Wette, *J. of Electron Spect. and Related Phenom.* **44**, 27 (1987).



Professor Kleinman

"Bulk Plasmon Enhanced Photoemission from $\text{Nb}(100)$ ", B.-S. Fang, C.A. Ballentine and J.L. Erskine, *Phys. Rev. B* **38**, 4299 (1988).

"Thickness and Temperature Dependent Spin Anisotropy of Ultra-thin Epitaxial Fe Films on $\text{Ag}(100)$ ", J. Araya-Pochet, C.A. Ballentine and J.L. Erskine, *Phys. Rev. B* **38**, 7846 (1988) *Rapid Communication*.

"Hydrogen Adsorption at $\text{Nb}(100)$: Photoemission Evidence of Two-State Exchange Involving Subsurface States", B.-S. Fang, C.A. Ballentine and J.L. Erskine, *Surface Science Letters* **204**, L713 (1988).

"Generation of Ultrasonic Replica Wave Packets", A. Kost and J.D. Gavenda, *Phys. Rev. B* **32**, 1887 (1985).

"Continuously Variable Signal Delays with Ultrasound", A. Kost and J.D. Gavenda, *Ultrasonics, Ferroelectrics, and Frequency Control* **33**, 679 (1986).

"Determination of a Natural Band Offset: The Case of HgTe and CdTe ", C.K. Shih and W.E. Spicer, *Phys. Rev. Lett.* **58**, 2594 (1987).

"Direct Inelastic Scattering of N_2 from $\text{Ag}(111)$. II. Orientation", G.O. Sitz, A.C. Kummel, J.C. Tully and R.N. Zare, *J. Chem. Phys.* **89**, 2572 (1988).

"Stability of CO_2 -Clathrate in Comets", R. Smoluchowski, *EOS* **66**, 945 (1986).

"Clathrate Hydrates in Cometary Nuclei and Porosity", R. Smoluchowski, *M.N.R.S.* **235**, 343 (1988).

"Properties of Mantles of Cometary Nuclei", R. Smoluchowski, *Astron. J.* **97**, 241 (1989).

"Photoemission from Ag into Liquid NH_3 ", G.T. Bennett, R.B. Coffman and J. C. Thompson, *J. Chem. Phys.* **87**, 7242 (1987).

"Attenuated Total Reflection at a Metal-Salt Interface", J.C. Villagran, U. Even and J.C. Thompson, *Solid State Ionics* **27**, 67 (1988).

"Theory of Superconducting Wire Networks and Josephson Junction Arrays in Magnetic Fields", Q. Niu and F. Nori, *Phys. Rev. B* **39**, 2146 (1989).

"Towards a Quantum Pump for Electric Charges", Q. Niu, *Phys. Rev. Lett.* **64**, 1812 (1990).

"Ground-State Degeneracy of the Fractional Quantum Hall States in the Presence of a Random Potential and on High-Genus Riemann Surfaces", X.G. Wen and Q. Niu, *Phys. Rev. B* **41**, 9377 (1990).

"Wannier-Stark Ladders for a Split Bloch Band", Q. Niu, *Phys. Rev. B* **40**, 3625 (1989).

"Quantum Corrections to Hamiltonian Dynamics", Q. Niu and J.H. Jensen, submitted to *Phys. Rev. A*, 1989.



Ming Tang in Professor Erskine's lab

HIGH ENERGY PHYSICS

High energy physics endeavors to understand the constituents of matter and the forces which act between them. In most cases, high energy experiments are performed at an accelerator, where beams of high energy particles are available. Therefore, progress in this field depends both on advances in accelerator design and on improvements in particle detection techniques. Physicists at UT Austin are active both in accelerator physics and in high energy experimentation.

The main high energy activity at the present time is an experiment at the Alternating Gradient Synchrotron accelerator at the Brookhaven National Laboratory in New York. The experiment is a search with extremely high sensitivity for rare or forbidden decays of the neutral long-lived kaon, K_L . An example would be the decay $K_L \rightarrow \mu e$, which is forbidden in the Standard Model of particle interactions because it violates separate lepton number conservation. Such decays, if observed, would represent an important discovery and would be the first indication of physics outside the Standard Model.

The Superconducting Super Collider (SSC), under construction near Waxahatchie, Texas, will be the largest and highest energy accelerator ever built. Its purpose is to collide protons which have been accelerated to an energy of 20 TeV (20×10^{12} electron volts) against protons of the same energy traveling in the opposite direction, achieving a center of mass energy of 40 TeV. The SSC will open a new realm of phenomena for study, including the mechanism of electroweak symmetry breaking. It will also present new challenges to experimenters because of the enormous complexity of the interactions and the high rate at which they will be occurring.

The detectors for SSC experiments will be massive devices, involving hundreds of physicists in their design and construction, costing hundreds of millions of dollars, and requiring roughly 8 years for their completion. Physicists from UT Austin are engaged in the early phase of this project at the present time.

Three members of the Physics Department faculty are accelerator physicists who are jointly members of the SSC Accelerator Division (see Plasma Physics section). This provides graduate students an opportunity to work at the forefront of accelerator physics at the SSC, under the supervision of UT faculty. The Director of the SSC, Roy Schwitters, is also a Professor of Physics at UT, presently on leave.

The High Energy Physics and Accelerator Physics programs at UT Austin are new and growing rapidly. Funding is provided by DOE, the State of Texas, and the SSC Laboratory. Total funding was about \$300,000 for 1989-1990.



Professor Ritchie describing wire chambers in experiment at Brookhaven National Laboratory

Faculty

Hoffmann, Gerald W.

Professor. B.A., Occidental, 1966; Ph.D., California (Los Angeles), 1971. Experimental medium and high energy physics and chemistry.

Lang, Karol

Assistant Professor. M.S., Warsaw University, (Warsaw Poland), 1979; Ph.D., University of Rochester, 1985. Experimental high energy physics; rare decays.

Riley, Peter J.

Professor. B.A.Sc., British Columbia (Canada), 1956; M.A.Sc., 1958; Ph.D., Alberta (Canada), 1962. Experimental medium energy physics, with emphasis on nucleon-nucleon and few nucleon interactions.

Ritchie, Jack L.

Assistant Professor. B.S.Hon., Texas, 1977; M.A., University of Rochester, 1979; Ph.D., 1983. Experimental high energy physics; rare decays.

Schwitters, Roy F.

Sid W. Richardson Foundation Regents Professor. S.B., M.I.T., 1966; Ph.D., 1971. High energy physics; large-scale detectors.

Postdoctoral Research Staff

Johnston, K.

Ph.D., University of Houston, 1991. Particle physics, particle detector design.

McDonough, J.

Ph.D., Temple University, 1987. Experimental high energy physics.

Yamashita, A.

Ph.D., Univ. of Tsukuba, Japan, 1988. High energy particle physics.

Some Recent Publications

"Relativistic Effects in Forward Angle Proton-Nucleus Elastic Scattering", L. Ray, G.W. Hoffmann, M. L. Barlett and N. Ottenstein, *Phys. Rev. C* **37**, 224 (1988).

"The Proton-Nucleus Spin Response at Large Excitations", R. Fergerson, J. McGill, C. Glashauser, K. Jones, S. Nanda, S. Tsu-hsun, M. Barlett, G. Hoffmann, J. Marshall and J. McClelland, *Phys. Rev. C* **38**, 2193 (1988).

"Inclusive and Exclusive Quasielastic $p + {}^2\text{H}$ Spin Observables at 647 and 800 MeV", M.L. Barlett, G.W. Hoffmann, L. Ray, G. Pauletta, K. H. McNaughton, J.F. Amann, K.W. Jones, J. McClelland, M.W. McNaughton, R. Fergerson and D. Lopiano, *Phys. Rev. C* **40**, 2697 (1989).

"Spin Correlation Parameter $A_{nn}(\theta^*)$ for n-p Elastic Scattering at 790 MeV", S. Nath, G. Glass, J.C. Hiebert, J.A. Holt, R.A. Kenefick, L.C. Northcliffe, D.P. Grosnick, D. Lopiano, Y. Ohashi, T. Shima, H.M. Spinka, R. Stanek, T.S. Bhatia, J.J. Jarmer, P.J. Riley, S. Sen, J.A. Faucett, G. Kyle, R.H. Jeppeson and G.E. Tripard, *Phys. Rev. D* **39**, 3520 (1989).

"Spin Dependence of $pp \rightarrow \eta p \pi^+$ from 492 to 796 MeV", R.L. Shypit, D.V. Bugg, A.H. Sanjari, D.M. Lee, M.W. McNaughton, R.R. Silbar, C.L. Hollas, K.H. McNaughton, P. Riley and C.A. Davis, *Phys. Rev. C* **40**, 2203 (1989).

"Evidence Against Broad Dibaryons", R.L. Shypit, D.B. Bugg, D.M. Lee, M.W. McNaughton, R.R. Silbar, N.M. Stewart, A.S. Clough, C.L. Hollas, K.H. McNaughton, P. Riley and C.A. Davis, *Phys. Rev. Lett.* **60**, 901 (1988).

"Search for Neutral Heavy Leptons from Neutrino N Scattering", K. Lang with S.R. Mishra, P. Auchincloss, R. Blair, et al., *Phys. Rev. Lett.* **59**, 1397 (1987).

"Measurement of the Difference in $R = \sigma_L/\sigma_T$ and $\sigma(A)/\sigma(D)$ in Deep Inelastic e-D, e-Fe and e-Au Scattering", K. Lang with S. Dasu, P. de Barbaro, A. Bodek, et al., *Phys. Rev. Lett.* **60**, 2591 (1988).

"Precision Measurement of $R = \sigma_L/\sigma_T$ and F_2 in Deep Inelastic Electron Scattering", K. Lang with S. Dasu, P. de Barbaro, A. Bodek, et al., *Phys. Rev. Lett.* **61**, 1061 (1988).

"Bose-Einstein Correlations in e⁺e⁻ Collisions", R.F. Schwitters with I. Juricic, G. Goldhaber, G. Gidal, et al., *Phys. Rev. D, Part. Fields*, **39**, No. 1, 1-20 (1989).

"Dijet Angular Distributions from pp Collisions at $\sqrt{s} = 1.8$ TeV", R. F. Schwitters with F. Abe, D. Amidei, G. Apollinari, et al., *Phys. Rev. Lett.*, **62**, No. 26, 3020 (June 26, 1989).

"Measurement of W-Boson Production in 1.8 TeV pp Collisions", R.F. Schwitters with F. Abe, D. Amidei, G. Apollinari, et al., *Phys. Rev. Lett.*, **62**, No. 9, 1005 (Feb. 27, 1989).

"New Experimental Limits on $K_L \rightarrow \mu e$ and $K_L \rightarrow ee$ Branching Ratios", J.L. Ritchie, with C. Mathiazhagan, et al., *Phys. Rev. Lett.* **63**, 2181 (1989).

"Measurement of the Branching Ratio for the Decay $K_L \rightarrow \mu\mu$ ", J.L. Ritchie, with C. Mathiazhagan, et al., *Phys. Rev. Lett.* **63**, 2185 (1989).

"Rare Kaon Decays", J.L. Ritchie, *From Action to Answers*, Proceedings of the 1989 Theoretical Advanced Study Institute in Elementary Particle Physics; World Scientific, 1990, 711.

MEDIUM ENERGY AND NUCLEAR PHYSICS

Experiments are done at the Los Alamos National Laboratory's Clinton P. Anderson Meson Physics Facility (LAMPF), The Canadian National Meson Facility (TRIUMF), and Brookhaven National Laboratory's Alternating Gradient Synchrotron Facility (AGS). The experimental program includes the elastic and inelastic scattering of 300-800 MeV protons and neutrons from nuclei; elastic, inelastic, and charge-exchange scattering of 100-300 MeV pions from nuclei; fundamental nucleon-nucleon experiments; and rare decay searches.

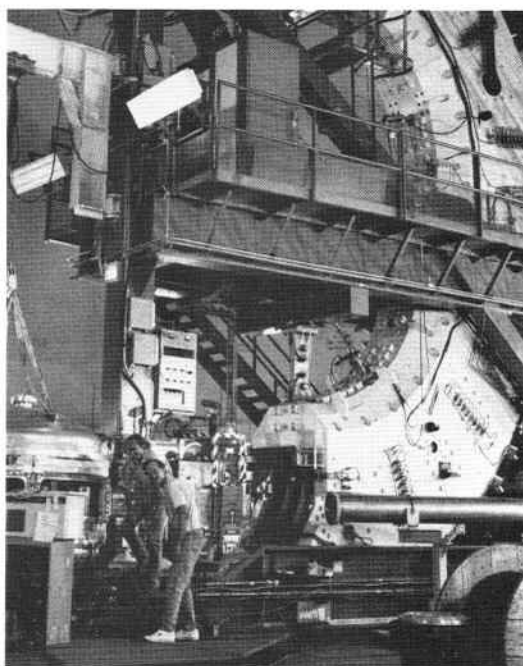
The proton-nucleus and pion-nucleus experiments provide data which test reaction and structure models. For the first time, experiments are being done using polarized nuclear targets; the measurement of spin-observables is a large part of the present experimental program. The nucleon-nucleon program seeks a complete empirical determination of the nucleon-nucleon scattering amplitudes at medium energies; this program presently is focused on providing quality $n + p$ elastic and inelastic data.

Theoretical work which complements the experimental program focuses upon the development of fundamental, microscopic models which describe hadron scattering and reactions. Successful solutions to the complicated nuclear many-body problem are being explored through use of the many-body Schroedinger equation and through relativistic approaches based on the random-phase-approximation. The method is currently being used to calculate the nuclear response from 0 to 400 MeV excitation for inelastic scattering and charge-exchange reactions.

Work in low energy nuclear reaction theory is aimed at finding a unified approach which describes different types of reactions (i.e., direct, incomplete fusion, and fusion). The direct reaction approach to fusion and the breakup-fusion approach to incomplete fusion are being explored.

Currently, 15 graduate students and several undergraduate students are involved in research in medium energy/nuclear physics.

The research is supported by contracts/grants from the United States Department of Energy and The Robert A. Welch Foundation. Total support is in excess of \$750,000 for 1990-91.



Students and faculty at Los Alamos

Faculty

Coker, W. Rory

Professor. B.S., Georgia, 1961; M.S., 1964; Ph.D., 1966. Nuclear reaction theory; medium energy nuclear reactions and scattering.

Hoffman, Gerald W.

Professor. B.A., Occidental, 1966; Ph.D., Univ. of California (Los Angeles), 1971. Experimental medium/high energy physics and chemistry.

Hudspeth, Emmett L.

Professor Emeritus. B.A., Rice Institute, 1937; M.A., 1938; Ph.D., 1940. Nuclear Structure, neutron and triton induced reactions, medical physics.

Ivash, Eugene V.

Professor. B.S., Michigan, 1945; M.S., 1946; Ph.D., 1952. Theoretical nuclear physics, particularly direct reactions and quantum mechanics.

Moore, C. Fred

Professor. B.S., Notre Dame, 1959; M.S., Louisville, 1961; Ph.D., Florida State, 1964. Experimental medium energy meson-nucleus physics and chemistry

Riley, Peter J.

Professor. B.A.Sc., British Columbia (Canada), 1956; M.A.Sc., 1958; Ph.D., Alberta (Canada), 1962. Experimental medium energy physics, with emphasis on nucleon-nucleon and few nucleon interactions.

Udagawa, Takeshi

Professor. B.S., Tokyo (Japan), 1957; M.S., Tokyo University of Education (Japan), 1959; Ph.D., 1962. Theoretical nuclear physics. Nuclear reactions with emphasis on direct reaction methods; light- and heavy-ion reactions.

Zaidi, S.A.A. (Amir)

Associate Professor. B.S., Punjab (Pakistan), 1956; Diplom., Heidelberg (Germany), 1960; Ph.D., 1964. Experimental and theoretical studies of nuclear structure and reaction mechanisms; elementary particle physics.

Postdoctoral Research Staff

Knobles, D.

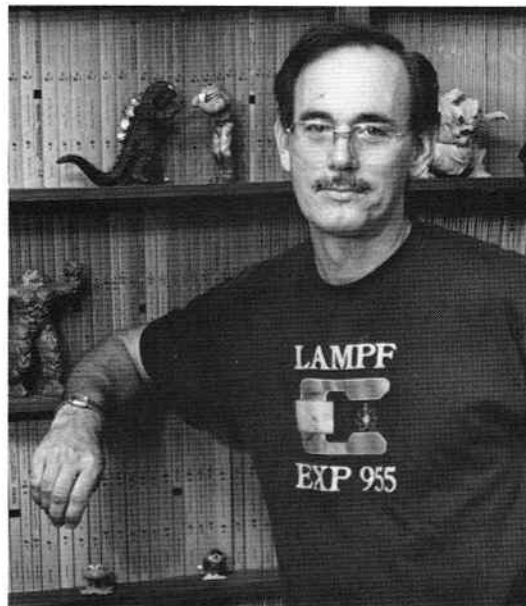
Ph.D., Texas, 1989. Nuclear theory.

Ray, L.

Ph.D., Texas, 1977. Nuclear reaction theory.

Some Recent Publications

"Relativistic Impulse Approximation Description of Polarized Proton Elastic Scattering from Polarized ^{13}C ", L. Ray, G.W. Hoffmann, M.L. Barlett, J.D. Lumpe, B.C. Clark, S. Hama and R.L. Mercer, *Phys. Rev. C* **37**, 1169 (1988).



Professor Hoffmann

"Large Angle $p + {}^{40}\text{Ca}$ Elastic Scattering at 497.5 MeV", G.W. Hoffmann, M. L. Barlett, G. Pauletta, L. Ray, J.F. Amann, K. Jones, J. B. McClelland, R. W. Fergerson, M.M. Gazzaly, B. C. Clark and R. L. Mercer, *Phys. Rev. C* **37**, 1307 (1988).

"Dirac Coupled Channels Calculation for $p + {}^{40}\text{Ca}$ Inelastic Scattering Using the Relativistic Impulse Approximation", S. Shim. B. C. Clark, S. Hama, E. D. Cooper, R. L. Mercer, L. Ray and G. W. Hoffmann, *Phys. Rev. C* **38**, 1968 (1988).

"Evidence for Narrow Structure in the Analyzing Power of the ${}^3\text{He} (p,d)X$ Reaction", L. Santi, M. Barlett, D. Ciskowski, R. Garfagnini, M.M. Gazzaly, G. W. Hoffmann, K. W. Jones, M. A. Nasser, G. Pauletta, C. Smith, N. Tanaka and R. Whitney, *Phys. Rev. C* **38**, 2466 (1988).

"Dynamic Polarization of ${}^{19}\text{F}$ in a Fluorinated Alcohol", D. Hill, T. Kasprzyk, J. J. Jarmer, S. Penttila, M. Krumpolz, G.W. Hoffmann and M. Purcell, *Nuclear Instruments and Methods in Physics Research* **A277**, 319 (1989).

"Breakup-Fusion Analysis of Single-Nucleon Stripping to Bound and Unbound Orbits," T. Udagawa, Y.J. Lee and T. Tamura, *Phys. Rev. C* **39**, 47 (1989).

"Random-Phase-Approximation Calculations of Nuclear Response in the Continuum", T. Udagawa and B.T. Kim, *Phys. Rev. C* **40**, 2271 (1989).

"Continuum Random-Phase-Approximation Study of Direct Decay of Giant Monopole Resonances in ${}^{90}\text{Zr}$ and ${}^{208}\text{Pb}$ ", T. Udagawa and B.T. Kim, *Phys. Lett. B* **230**, 6 (1989).

"Simultaneous Analyses of Elastic Scattering and Fusion Cross Sections for the ${}^{32}\text{S} + {}^{58,64}\text{Ni}$ Systems at Energies Near the Coulomb Barrier", T. Udagawa, T. Tamura and B.T. Kim, *Phys. Rev. C* **39**, 1840 (1989).

" ^{12}C (p+, p+p) ^{11}B Reaction Near Giant Dipole Region", S.H. Yoo, A. Williams, S. Mordechai, C.F. Moore, D.L. Morris, S.J. Seestrom-Morris, J. Jones, S. Sterbenz, D. Dehnhard, D. S. Oakley and A. Fazely, *Phys. Rev. Lett.* **63**, 738 (1989).

"Pion Double Charge Exchange Above the $\Delta(1232)$ Resonance", A.L. Williams, L. Agnew, L.G. Atencio, H.W. Baer, M. Burlein, G.R. Bureson, K.S. Dhuga, H.T. Fortune, G.W. Kyle, J.A. McGill, C.F. Moore, C.L. Morris, S. Mordechai, J. M. O'Donnell, M.W. Rawoll, S. Schilling, J.D. Silk and J.D. Zumbro, *Phys. Lett. B* **216**, 11 (1989).

"Pion Double Charge Exchange to the Double Dipole Resonance", S. Mordechai, N. Auerbach, M. Burlein, H. T. Fortune, S. J. Greene, C. F. Moore, C. L. Morris, J. M. O'Donnell, M. W. Rawool, J.D. Silk, L. Watson, S.H. Yoo and J.D. Zumbro, *Phys. Rev. Lett.* **61**, 531 (1988).

"Pion Inelastic Scattering to the Low-Lying Broad 2^+ in ^{20}Ne ", M. Burlein, H. T. Fortune, W. M. Amos, T. L. Ekenberg, A. Kotwal, P. H. Kutt, J. M. O'Donnell, B. Boyer, A. Fuentes, K. Johnson, C. F. Moore, S. H. Yoo, S. Mordechai, C. L. Morris, J. D. Zumbro, D. L. Watson and K. S. Dhuga, *Phys. Rev. C* **40**, 785 (1989).

"Neutron-Proton Analyzing Power Measurements from 375 to 775 MeV", C.R. Newsom, C.L. Hollas, R.D. Ransome, P.J. Riley, B.E. Bonner, J.G. Boissevain, J.J. Jarmer, M.W. McNaughton, J.E. Simmons, T.S. Bhatia, G. Glass, J.C. Hiebert, L.C. Northcliffe and W.B. Tippens, *Phys. Rev. C* **39**, 965 (1989).



Student working on TEXT diagnostic equipment

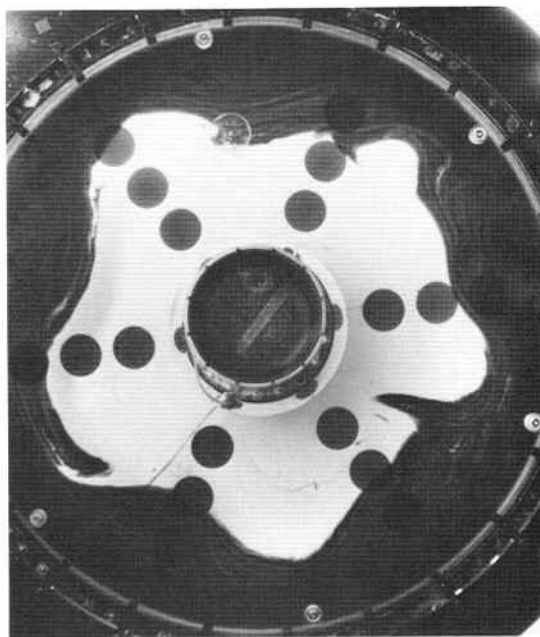
NONLINEAR DYNAMICS

The Center for Nonlinear Dynamics includes five faculty, six postdoctoral associates, and 12 graduate students. Most of the members of the Center are in condensed matter physics, but the subject is inherently interdisciplinary and the members of the Center also interact closely with researchers in mathematics, chemistry, and engineering. Problems of current interest include crack propagation in amorphous materials, the formation of spatial patterns in chemical reaction-diffusion systems, characterization of chaos in diverse dynamical systems, turbulence, vortices and waves in planetary-type flows, growth of fractal metallic clusters, and the formation of river networks by water.

Nonlinear systems exhibit a wide variety of complex dynamical phenomena, including *chaos*, which is irregular, inherently unpredictable behavior in systems whose equations of motion are deterministic. Often the governing equations for the nonlinear problems of interest are known, or at least realistic models can be constructed, but analytical solutions are not possible. Thus laboratory experiments and numerical simulations play an important role in gaining insight into nonlinear phenomena. For the past decade the Center for Nonlinear Dynamics has pioneered in studies of chaos. Experiments at the Center have demonstrated that chaotic fluid flows and chemical reactions can be characterized in phase space by *strange attractors*, as conjectured two decades ago.

Much of the progress in nonlinear dynamics is achieved through close interaction of theory, numerical simulations, and experiments. A recent example was a study of the formation of stable coherent vortices in a turbulent shear flow. Like many of the studies in the Center, the work focused on a simple model system with high symmetry, but the results have relevance to complex natural phenomena. In this case the experiment was motivated by the problem of the Great Red Spot of Jupiter. How could such a large storm persist for centuries without being torn apart by the strong background turbulent shear flow? Experiments and simulations at the Center demonstrated that, for a wide range of conditions, a single robust coherent vortex spontaneously forms and this vortex has properties similar to that of Jupiter's Great Red Spot. Other related experiments in planetary flows are examining a novel approach to the understanding of transport of pollutants in planetary type flows: theorems from Hamiltonian dynamics are being used as a basis for explaining barriers to transport.

Some studies of dynamics focus on the behavior in the neighborhood of transitions from one dynamical regime to another. What are the asymptotic laws that describe the behavior near a transition point? Are the laws in some sense universal, that is, do they describe a wide class of systems? One problem currently being studied theoretically and experimentally is the formation of rapidly propagating cracks in brittle materials like glass or plexiglas. The fracture surface exhibits a well-defined sequence of patterns: the surface is initially smooth, then small irregularities with a characteristic wavelength appear, and then the surface becomes quite



Laboratory simulation of the polar vortex that is the containment vessel for the ozone hole.

rough. Experiments indicate that this sequence occurs for a wide range of conditions in many brittle materials, but no theory yet exists.

Chemical reaction-diffusion systems can spontaneously form spatial patterns that persist as long as the system is refreshed with chemicals. Chemical patterns have been studied theoretically since the 1950s as a possible explanation for morphogenesis, but until recently controlled experiments have been lacking. The rotating spiral pattern on the cover of this brochure is an example of a pattern obtained in a well-controlled experiment at the Center, where experiments and theoretical analysis have shown that there is a transition from simple rotation (characterized by a single frequency) to compound rotation (characterized by two frequencies). This research is now investigating selection rules for reaction-diffusion patterns.

The Center sponsors a weekly seminar and an annual international conference, Dynamics Days, held in January. Research at the Center is supported by grants from the Department of Energy, NASA, Office of Naval Research, The Robert A. Welch Foundation, British Petroleum Venture Research, and IBM. Total support in 1989-90 was about \$600,000.

Faculty

Marder, Michael P.

Assistant Professor. A.B. Cornell, 1982; Ph.D. Univ. of California (Santa Barbara), 1986. Theoretical investigations of pattern formation, phase transitions, and nonlinear dynamics, especially the dynamics of fracture.

McCormick, William D.

Professor. B.S., California Institute of Technology, 1953; Ph.D., Duke, 1959. Nonlinear dynamics; waves and complex dynamics in chemical reaction-diffusion systems; experimental condensed matter physics.

Swift, Jack B.

Professor. B.S., Arkansas, 1963; Ph.D., Illinois, 1968. Theoretical studies of liquid crystals; phase transitions; nonlinear dynamics; pattern formation.

Swinney, Harry L.

Sid W. Richardson Foundation Regents Professor. B.S., Rhodes College, 1961; Ph.D., Johns Hopkins, 1968. Nonlinear dynamics; instabilities and pattern formation; chaos; phase transitions.

Tuckerman, Laurette S.

Assistant Professor of Mathematics. B.S., Princeton, 1976; Ph.D., M.I.T., 1984. Instabilities in fluid dynamics and reaction-diffusion systems; bifurcation theory; numerical analysis; computational fluid dynamics.

Postdoctoral Research Staff

Arneodo, A.

Visiting Professor from the Université de Bordeaux, 1989-90. Dynamical systems theory.

Fineberg, J.

Ph.D. Weizmann Institute, 1988. Experimental nonlinear dynamics; hydrodynamics.

Noszticzius, Z.

Visiting Scientist, 1991-92. Professor, Technical University of Budapest. Chemical dynamics.

Ouyang, Q.

Ph.D., Université de Bordeaux, 1989. Pattern formation.

Solomon, T.

Ph.D., University of Pennsylvania, 1990. Experimental nonlinear dynamics.

Vigil, D.

Ph.D., University of Michigan, 1990. Chemical dynamics and patterns.

Some Recent Publications

"Spiral Wave Dynamics in a Simple Model of Excitable Media: The Transition from Simple to Compound Rotation", D. Barkley, M. Kness and L.S. Tuckerman, *Phys. Rev. A* **42**, 2485 (1990).

"Scaling Properties of Multifractal Functions at an Attractor-Repeller Transition", M.G. Cosenza and J.B. Swift, *Phys. Rev. A* **41**, 6615 (1990).

"The Energy of a Steady State Crack in a Strip", X. Liu and M. Marder, *J. Mech. Phys. Solids*, (1991) in press.

"Periodic to Quasiperiodic Transition of Chemical Spiral Rotation", G. Skinner and H.L. Swinney, *Physica D* **48**, 1 (1991).

"Convective vs. Absolute Instability in Flow Between Counter-Rotating Cylinders", R. Tagg, W.S. Edwards and H.L. Swinney, *Phys. Rev. A* **42**, 831 (1990).

"Spatiotemporal Patterns in a One-Dimensional Open Reaction-Diffusion System", W.Y. Tam and H.L. Swinney, *Physica D* **46**, 10 (1990).

"Bifurcation Analysis of the Eckhaus Instability", L.S. Tuckerman and D. Barkley, *Physica D* **46**, 57 (1990).

"Bifurcation to Spatially Induced Chaos in a Reaction-Diffusion System", J.A. Vastano, T. Russo and H.L. Swinney, *Physica D* **46**, 23 (1990).

"Traveling Waves in Axisymmetric Convection: The Role of Sidewall Conductivity", D. Barkley and L.S. Tuckerman, *Physica D* **37**, 288 (1989).

"Symmetry Breaking in a Chemical Pinwheel", N. Kreisberg, W.D. McCormick and H.L. Swinney, *J. Chem. Phys.* **91**, 6532 (1989).

"Onset of Secondary Flow in the Modulated Taylor-Couette System", X. Wu and J.B. Swift, *Phys. Rev. A* **40**, 7197 (1989).

"Finite-Size Effects on the $f(a)$ Spectrum of the Period-Doubling Attractor", M.G. Cosenza, W.D. McCormick and J.B. Swift, *Phys. Rev. A* **39**, 2734 (1989).

"Information and Entropy in Strange Attractor", A.M. Fraser, *IEEE Transactions on Information Theory* **35**, 245 (1989).

"Symmetry Breaking in a Chemical Pinwheel", N. Kreisberg, W.D. McCormick and H.L. Swinney, *J. Chem. Phys.* **91**, 6532 (1989).

"The Characterization of an Experimental Strange Attractor by Periodic Orbits", D.P. Lathrop and E.J. Kostelich, *Phys. Rev. A* **40**, 4028 (1989).

"Crystals With a Twist", M. Marder, *Phys. Rev. A* **40**, 4824 (1989).

"Laboratory Model of a Planetary Eastward Jet", J. Sommeria, S.D. Meyers and H.L. Swinney, *Nature* **337**, 58 (1989).

"Phase Separation in a T-J Model", M. Marder, N. Papanicolaou and G. Psaltakis, *Phys. Rev. B* **41**, 6920 (1990).

"Rayleigh-Benard Convection with Time-Dependent Boundary Conditions", J.B. Swift and P.C. Hohenberg, *Phys. Rev. A* **39**, 4132 (1989).

"Nonlinear Standing Waves in Couette-Taylor Flow", R. Tagg, W.S. Edwards, H.L. Swinney and P.S. Marcus, *Phys. Rev. A* **39**, 3734 (1989).

"Onset of Secondary Flow in the Modulated Taylor-Couette System", X. Wu and J.B. Swift, *Phys. Rev. A* **40**, 7197 (1989).

"Self-Similarity of Diffusion-Limited Aggregates and Electrodeposition Clusters", F. Argoul, A. Arneodo, G. Grasseau and H.L. Swinney, *Phys. Rev. Lett.* **61**, 2558 (1988).

"The Ballast Resistor: An Experimental Study of a Spatial Pattern Forming System", N. Bujanos, J. Pearson, W.D. McCormick and W. Horsthemke, *Phys. Lett. A* **127**, 138 (1988).

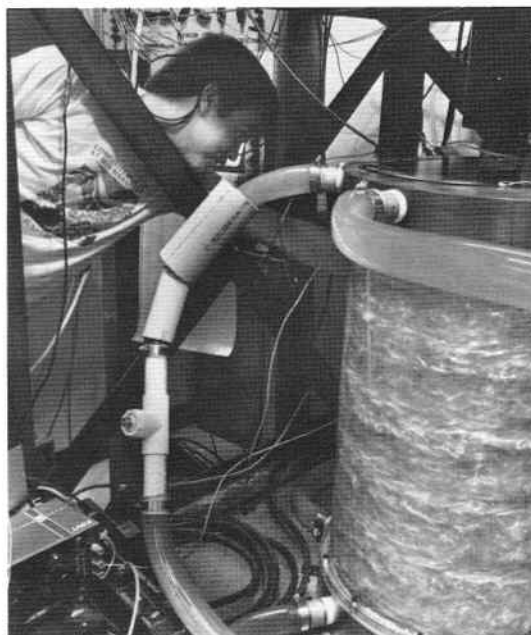
"Noise Reduction in Dynamical Systems", E.J. Kostelich and J.A. Yorke, *Phys. Rev. A* **38**, 1649 (1988).

"Primary Instabilities and Bicriticality in Flow Between Counter-Rotating Cylinders", W.F. Langford, M. Golubitsky, R. Tagg, E. Kostelich and H.L. Swinney, *Phys. Fluids* **31**, 776 (1988).

"A Laboratory Simulation of Jupiter's Great Red Spot", J. Sommeria, S.D. Meyers and H.L. Swinney, *Nature* **331**, 689 (1988).

"Global Bifurcation to Traveling Waves in Axisymmetric Convection", L.S. Tuckerman and D. Barkley, *Phys. Rev. Lett.* **61**, 408 (1988).

"Information Transport in Spatiotemporal Systems", J.A. Vastano and H.L. Swinney, *Phys. Rev. Lett.* **60**, 1773 (1988).



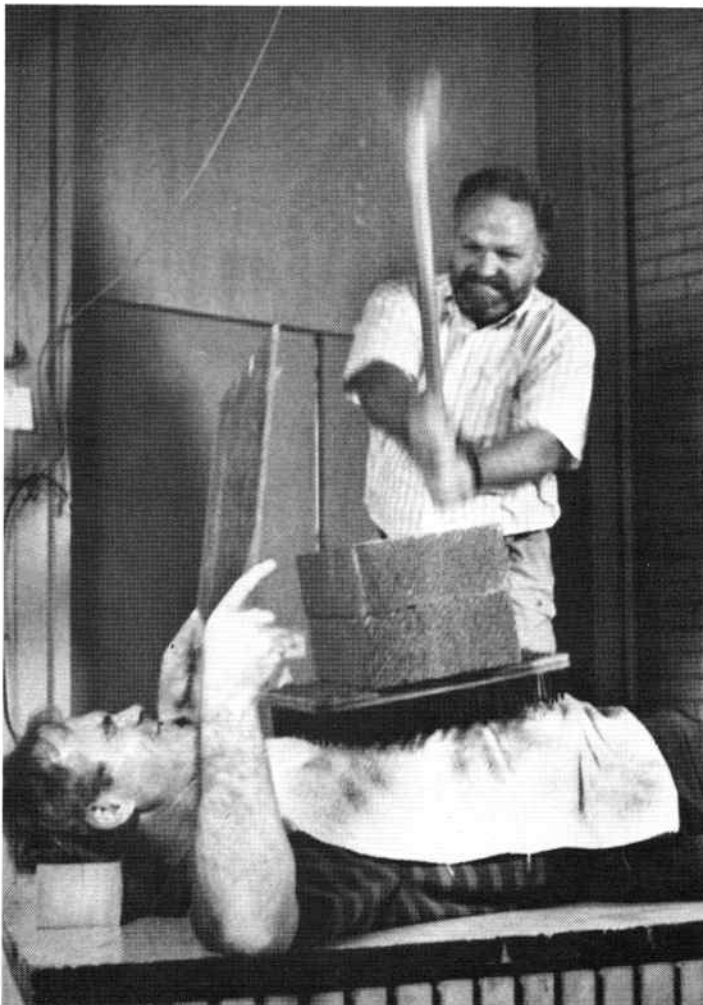
Experiment studying turbulence in a Couette flow reactor

PHYSICS EDUCATION

Physics Department faculty have an interest in science curriculum and research in science education. They have supervised graduate level work in physics education. Projects in physics education may be used to satisfy the research requirements of either the M.A. in Physics for persons admitted to the graduate program in physics, or the M.S. in Science Education for persons admitted to the graduate program in science education.

Past projects include introductory laboratory course development, design of physics education programs for geologists, summer institutes for high school physics teachers, and curriculum development for college theoretical physics.

Members of the Physics faculty are available to supervise Ph.D. research projects related to physics or physical science education undertaken by graduate students in the science education program. Information regarding the science education program can be obtained from the Science Education Center, Education Building 340.



Faculty

Gavenda, J. David

Professor of Physics and Education. B.S., Texas, 1954; M.A., 1956; Ph.D., Brown, 1959. Physics education at the elementary, secondary, and college levels; computer-based education.

Turner, Jack S.

Associate Professor. B.S., Duke, 1964; Ph.D., Indiana, 1969. Computer-based education.

Some Recent Publications

"The Differential Effects of Ausubelian Advance Organizers on the Learning of Students Characterized as Formal-Operational and Concrete-Operational in the Piagetian Paradigm", Sharmila R. Mahajan, Ph.D. dissertation supervised by J. D. Gavenda (1983).

"Evaluation of Computer-Assisted Metric Instruction in a Ninth-Grade Physical Science Program", Kaywin F. Carter, Ph.D. dissertation supervised by J. D. Gavenda (1980).

Professor Turner demonstrating inertia at a Physics Circus

PLASMA PHYSICS

At The University of Texas at Austin, research and teaching of plasma physics are coordinated by two centers: the Institute for Fusion Studies, a theory center, and the Fusion Research Center, an experimental center administering a Tokamak Facility.

The theory of plasma behavior, especially regarding magnetic plasma confinement, is primarily studied in the *Institute for Fusion Studies*. Supported jointly by the Department of Energy and the State of Texas, the Institute is the preeminent national institution for theoretical plasma physics. Its mandate is to train students and conduct research on fundamental physics issues, as well as the more practical questions arising in the evaluation of magnetic fusion concepts. Topics under investigation include fundamental plasma physics; confined plasma equilibrium, stability, and transport; plasma turbulence; astrophysical and space plasmas; numerical plasma simulation; chaotic behavior of magnetic fields and charged-particle orbits; coherent nonlinear fluid motions; and related topics in plasma nonlinear dynamics.



Professor Wootton working on TEXT upgrade

Currently, the Institute has a staff of approximately 25 Ph.D. scientists (including faculty members, full-time researchers, and postdoctoral fellows) and approximately 20 doctoral students, in addition to computer programmers and administrative personnel. It sponsors a vigorous visitor program, with five to ten visiting scientists typically in residence as well as numerous research collaborations with laboratories and universities in the U.S. and other countries. The Institute's role as a center for national and international information exchange is further enhanced by frequent courses, conferences, and workshops. It is the principal site in the U.S. for the exchange activities of the United States-Japan Joint Institute for Fusion Theory.

Experimental research into plasma behavior is carried out by the *Fusion Research Center*. The experiments are performed on TEXT, the Texas Experimental Tokamak, which is currently supported by the Department of Energy, the State of Texas, and the Texas Atomic Energy Research Foundation. There is a permanent technical staff of approximately 15 physicists, 5 engineers and 15 technicians, augmented by approximately 5 visiting physicists. Currently 20 graduate students are working on TEXT towards their higher degrees.

The experiments performed fall into two main categories: those performed by the Fusion Research Center and those performed by visitors using the machine as a national users facility. Many groups, both national and international, send physicists to assist in the TEXT program. Topics under investigation include the study of plasma particle and energy transport, plasma turbulence, plasma behavior in chaotic magnetic fields, and radio frequency heating. A major upgrade of the machine will be completed in 1991.

In addition, the Plasma Theory group supports research in accelerator physics. Faculty at the University along with adjunct faculty from the SSC laboratories are working on problems in advanced accelerator design using concepts such as wake field acceleration or other collective effects. Recent studies of beam stability and the effects of the nonlinearities, have yielded new insights for machine design but also new tests of basic notions about chaos in these systems.

Plasma physics research is supported by contracts and grants from the U.S. Department of Energy, the State of Texas, the National Science Foundation and the Texas Atomic Energy Research Foundation. Total funding for 1989-90 was about \$11 million.

Faculty

Baldwin, David E.

Professor. B.S., M.I.T., 1958; Ph.D., 1962. Kinetic theory, electron cyclotron wave heating, stability theory.

Bengtson, Roger D.

Professor. B.S., Nebraska, 1962; M.S., Virginia Polytechnic Institute, 1964; Ph.D., Maryland, 1968. Experimental plasma physics, plasma spectroscopy.

Berk, Herbert L.

Professor. B.S., New York University, 1960; M.A., Princeton, 1962; Ph.D., 1964. Plasma confinement theory.

Drummond, William E.

Texas Atomic Energy Research Foundation Professor. B.S., Stanford, 1951; Ph.D., 1958. Nonlinear plasma theory, collective accelerators.

Gentle, Ken W.

Professor. B.S., M.I.T., 1962; Ph.D., 1966. Plasma confinement and heating.

Hazeltine, Richard D.

Professor. A.B., Harvard College, 1964; M.S., University of Michigan, 1966; Ph.D., 1968. Plasma physics.

Horton, Jr., C. Wendell

Professor. B.S., Texas, 1963; M.S. Univ. of California (San Diego), 1965; Ph.D., 1967. Microinstabilities, nonlinear theory.

Morrison, Philip J.

Associate Professor. B.S., Univ. of California (San Diego), 1972; M.S., 1974; Ph.D., 1979. Basic nonlinear plasma dynamics, tokamak modelling.

Oakes, M.E.L. (Mel)

Professor. B.S., Louisiana State, 1958; Ph.D., Florida State, 1964. Plasma heating.

Tajima, Toshiki

Professor. B.S., Tokyo, 1971; M.S., 1973; Ph.D., Univ. of California (Irvine), 1975. Computational physics, basic and astrophysical plasma theory.

Taylor, J. Bryan

Fondren Foundation Centennial Professor. B.Sc., Birmingham Univ., Birmingham, England, 1950; Ph.D., 1955; Fellow Royal Society 1970; Maxwell Medal 1971; Max Born Medal 1979; APS Award for Excellence 1986; Chief

Physicist, U.K. Atomic Energy Authority 1981-1989; The Fondren Foundation Centennial Chair in Plasma Theory, The University of Texas at Austin 1989. Fundamental and applied plasma theory.

Wootton, Alan J.

Professor. B.Sc., Royal Holloway College, London University, 1969; Ph.D., Royal Holloway College, London University, 1973. Plasma physics.

Adjunct Faculty

Chao, Alexander W.

Ph.D., State Univ. of New York (Stony Brook), 1974.

Edwards, Donald A.

Ph.D., Cornell, 1961.

Syphers, Michael J.

Ph.D., Univ. of Illinois (Chicago), 1987.

Postdoctoral Research Staff

Aydemir, A.

Ph.D., Columbia, 1980. Magnetohydrodynamic simulation.

Bravenec, R.

Ph.D., California (Berkeley), 1982. Transport.

Edmonds, P.

Ph.D., University College, London, 1963. Diagnostic and experimental design.

Kotschenreuther, M.

Ph.D., Princeton, 1983. Magnetic stochasticity.

McCool, S.

Ph.D., Texas, 1978. Plasma physics.

Macmahon, A.

Ph.D., Univ. of California (Berkeley), 1965. Computer software.

Mahajan, S.

Ph.D., Maryland, 1973. Alfvén waves.

Miner, W.
Ph.D., Texas, 1978. Tokamak transport, computational plasma physics.

Newberger, B.
Ph.D., Princeton, 1976. Numerical simulation.

Patterson, D.
Ph.D., Washington, 1971. Computer software.

Phillips, P.
Ph.D., Texas, 1971. Laser scattering.

Richards, B.
Ph.D., MIT, 1981. Microwave scattering, hard x-rays.

Ritz, Ch.P.
Ph.D., University of Fribourg, 1982. Fluctuations and Transport.

Ross, D.
Ph.D., Harvard, 1964. Alfvén waves, microinstabilities, transport.

Rowan, W.
Ph.D., Texas, 1975. Plasma spectroscopy.

Sing, D.
Ph.D., University of Wisconsin, 1986. Plasma physics.

Sloan, M.
Ph.D., Texas, 1968. Applied plasma physics.

Thompson, J.
Ph.D., Texas, 1969. Applied plasma physics.

Tsui, H.
Ph.D., University of Manchester, 1983. Edge turbulence.

Uglum, J.
Ph.D., M.I.T., 1965. Beam plasma interaction.

Valanju, P.
Ph.D., Texas, 1980. Alfvén waves.

Van Dam, J.
Ph.D., Univ. of California (Los Angeles), 1979. Stability theory in tokamaks, ballooning modes, Alfvén waves and alpha particles.

Ware, A.
Ph.D., Imperial College (London), 1949. Transport.

Wiley, J.
Ph.D., Texas, 1974. Plasma transport and computational plasma physics.

Wong, V.
Ph.D., Oxford, 1965. Instabilities.

Some Recent Publications

"Toroidal Studies of Sawtooth Oscillations in Tokamaks", A.Y. Aydemir, J.C. Wiley and D.W. Ross, *Phys. Fluids B* **1**, 774 (1989).

"Drift Pumping of Tandem Mirror Thermal Barriers, D.E. Baldwin, J.A. Byers, Y.-J. Chen and T.B. Kaiser, *Proc. 11th Inter. Conf. on Plasma Physics and Controlled Fusion Research*, IAEA, Kyoto (1986).

"Theory of Hot Particle Stability", H.L. Berk, H.V. Wong and K.T. Tsang, *Phys. Fluids* **30**, 2681 (1987).

"Hamiltonian Four-Field Model for Nonlinear Tokamak Dynamics", R.D. Hazeltine, C.T. Hsu and P.J. Morrison, *Phys. Fluids* **30** (10), 3204 (1987).

"Drift Wave Vortices and Anomalous Transport", W. Horton, *Phys. Fluids B* **1** (3), 524 (1989).

"Exact and Almost Exact Solutions to the Vlasov-Maxwell System", Swadesh M. Mahajan, *Phys. Fluids B* **1** (1), 43 (1989).

"Relaxation and Reconnection in Plasmas", J. B. Taylor, *Rev. Mod. Phys.* **58**, 741 (1986).

"Free-Energy Expressions for Vlasov Equilibria", P.J. Morrison and D. Pfirsch, *Phys. Rev. A* **40**, 3898 (1989).

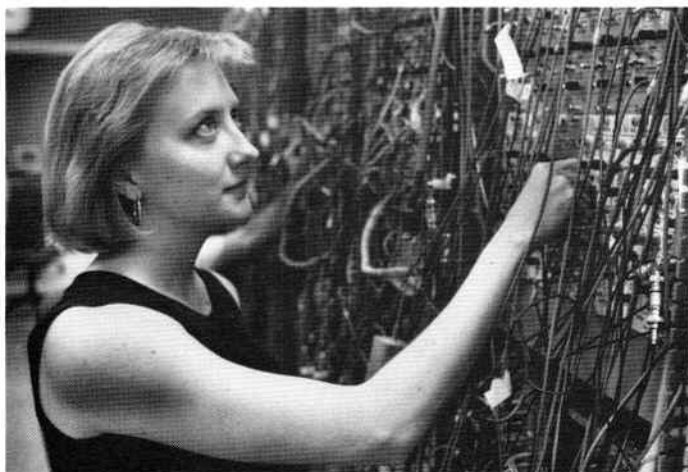
"Diffusive Processes in Cross-Field Flow of Plasma Beams", B. Newberger and H. Rostoker, *J. Appl. Phys.* **65**, 1874 (89).

"Low Frequency Plasma-Waveguide Cutoff", Saad E. Eways and M.E.L. Oakes, *Phys. Fluids* **28**, 444 (1985).

"Energy Buildup in Coronal Magnetic Flux Tubes", R.S. Steinolfson and T. Tajima, *The Astrophysical Journal*, **322**, 503 (1987).

"Plasma Current Sustained by Fusion Charged Particles in a Field Reversed Configuration", H.L. Berk, H. Momota, and T. Tajima, *Phys. Fluids* **30**, 3548 (1987).

"Energetic Particle Stabilization of Ballooning Modes in a Finite Aspect Ratio Tokamak", H. Naitou, J.W. Van Dam and D.C. Barnes, *Nuclear Fusion* **27**, 765 (1987).



Student working on TEXT data input.

"Electron Fokker-Planck Equation for Collisions with Ions in a Magnetized Plasma", A. A. Ware, *Phys. Rev. Lett.* **62**, 1 (1989).

"Turbulence, Transport, and q Measurements in TEXT", by members of the Fusion Research Center and Collaborators, *Proceedings of the Twelfth International Conference on Plasma Physics and Controlled Nuclear Fusion Research*, Nice, France, 1988 (International Atomic Energy Agency, Vienna, Austria, 1989) IAEA-CN-50/A-5-3-2, (1989).

"Temperature Fluctuations and Transport in the Edge Plasma of TEXT", H. Lin, R.D. Bengtson and Ch.P. Ritz, *Physics Fluids B1*, 2027 (1989).

"Magnetic Fluctuation Associated with Density Fluctuations in the Tokamak Edge", Y.J. Kim, K.W. Gentle, Ch.P. Ritz, T.L. Rhodes and R.D. Bengtson, *Nuclear Fusion* **29**, 1, 99 (1989).



Student in Lab

RELATIVITY, COSMOLOGY, QUANTUM GRAVITATION, AND RELATIVISTIC ASTROPHYSICS

The General Theory of Relativity is the theory of gravitation developed by Einstein. It is a theory of interest to the analyst because of its mathematical elegance. It is of direct astrophysical interest because gravity is the dominant force involved in the structure of galaxies, clusters, and the universe. It is essential to understanding such phenomena as black holes and neutron stars. It is of interest to the field theorist because of its coordinate invariance, which makes straight-forward quantum theory impossible and makes a complete theory of quantum gravity both elusive and interesting.

Areas of current research activity include tests of classical cosmology; experimental tests of theories of gravity; quantum gravity and supergravity; exact solutions of Einstein's equations; path integral formulation of quantum mechanics, including stochastic processes on fibre bundles and wave scattering problems; foundations of quantum theory; measurement theory and the fundamentals of quantum interpretation; statistical physics; gravitational processes and particle production in curved spaces; the inverse problem in mechanics; astrophysical interactions of black holes and accretion-disc phenomena; stellar structure; tests of elementary particle theory using cosmological constraints; tests of cosmology via constraints from nucleosynthesis; large-scale numerical calculations in quantum gravity and in general relativistic hydrodynamics in 1, 2, and 3 dimensions, including collapse to black holes; nucleosynthesis in inhomogeneous cosmology; and numerical studies of quantum gravity.

Currently, about 25 graduate students are involved in Ph.D. research in relativity, cosmology, quantum gravity, and relativistic astrophysics.

The research is supported by NSF, the State of Texas, NATO, and private gifts. Total support was in excess of \$600,000 for 1989-90. Typically about six to ten Research Scientists are also supported by these contracts/grants.



Professor Matzner

Faculty

DeWitt, Bryce S.

Professor. B.S., Harvard, 1943; M.A., 1947; Ph.D., 1950. Dirac Medal, 1987. Quantum gravity, supermanifolds, relativistic astrophysics.

DeWitt-Morette, Cecile M.

Professor. Licence es Sciences, Caen (France), 1943; Doctorat d'Etat, Paris (France), 1947. General relativity, mathematical physics, Feynman path integrals.

Matzner, Richard A.

Professor. B.S., Notre Dame, 1963; Ph.D., Maryland, 1967. General relativity and cosmology, kinetic theory, black hole physics and gravitational radiation.

Shepley, Larry C.

Associate Professor. B.A., Swarthmore College, 1961; M.A., Princeton, 1963; Ph.D., 1965. Cosmology, interaction of matter with gravitation.

Wheeler, John A.

Ashbel Smith and Jane and Roland Blumberg Professor Emeritus. Ph.D., Johns Hopkins, 1933. Relativistic astrophysics and quantum cosmology; particle physics.

Postdoctoral Research Staff

Anninos, P.

Ph.D., Drexel, 1989. Relativistic cosmology.

Duval, M.

Ph.D., SISSA, 1987. Numerical relativity.

Myers, E.

Ph.D., Yale, 1984. Numerical investigations within quantum gravity.

Stark, R.

Ph.D., Oxford, 1980. Computational General Relativity.

Some Recent Publications

"The Casimir Effect in Field Theory", B. DeWitt, in *Physics in the Making - Essays in Honor of H.G.B. Casimir*, A. Sarelmijn and M. J. Sparnaay, eds., North-Holland, Amsterdam, 9B, 247 (1989).

"Nonlinear Sigma Models in 4 Dimensions as Toy Models for Quantum Gravity", B. DeWitt, in *Geometrical and Algebraic Aspects of Nonlinear Field Theory*, S. De Filippo, M. Marinaro, G. Marmo and G. Vilasi, eds., Elsevier Science Publishers B.V., North-Holland, 1989.

"The Uses and Implications of Curved-Spacetime Propagators: A Personal View", B. DeWitt, Dirac Medal Lecture, International Center for Theoretical Physics, Trieste, 11 (1988).

"Obstruction to Pin Structures and the Sign of the Metric", C. DeWitt-Morette, in *IX International Congress on*

Mathematical Physics (Swansea) 1988, B. Simon, A. Turman and I.M. Davies, eds., Adam Hilger, Bristol, 294 (1989).

"Quantum Mechanics in Curved Spacetimes: Stochastic Processes on Frame Bundles", C. DeWitt-Morette, in *Quantum Mechanics in Curved Space-Time*, J. Audretsch and V. de Sabbata, eds., Plenum Press, Erice, 1989.

"Path Integral Solutions of Wave Equations with Dissipation", C. DeWitt-Morette and S.K. Foong, *Phys. Rev. Lett.* **62**, 2201 (1989).

"Interaction of $U(1)$ Cosmic Strings: Numerical Intercommutation", R.A. Matzner, *Computers in Physics*, **2**, No. 5, Sept./Oct. 1988, p. 51.

"Behavior of Chaotic Inflation in Anisotropic Cosmologies with Nonminimal Coupling", R.A. Matzner, T. Futamase and T. Rothman, *Phys. Rev.* **D39**, No. 2, 15 January 1989, p. 405.

"Effect of Small-Scale Baryon Inhomogeneity on Cosmic Nucleosynthesis", R.A. Matzner and H. Kurki-Suonio, *Phys. Rev.* **D39**, No. 4, 15 February 1989, p. 1046.

"Nonlinear Solutions for Initial Data in the Vacuum Einstein Equations in Plane Symmetry", R.A. Matzner, J. Centrella and P. Anninos, *Phys. Rev.* **D39**, No. 8, 15 April 1989, p. 2155.

"Peeling $U(1)$ Gauge Cosmic Strings", P. Laguna and R.A. Matzner, *Phys. Rev. Lett.* **62**, 1948 (1989).

"Computer Simulation of Time-Dependent, Spherically Symmetric Spacetimes Containing Radiating Fluids: Formalism and Code Tests", A. Mezzacappa and R.A. Matzner, *Astrophys. J.* **343**, 15 August 1989, p. 853.

"Recent Developments in Cosmology", D.J. McCracken and R.A. Matzner, in *Proceedings of the VIIIth Italian Conf. on General Relativity*, Cerdonio, Cianci, Francaviglia, and Toller, eds. World Scientific, Singapore, (1989).

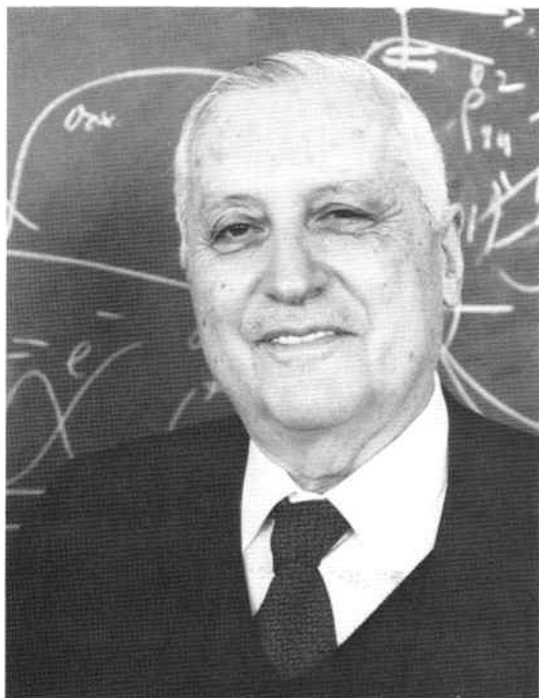
"Interaction of Cosmic Strings", R.A. Matzner, Motion Picture Video, National Center for Supercomputing Applications, University of Illinois, Urbana-Champaign, 1988.

STATISTICAL MECHANICS

Research focuses on the effects of nonlinearity and nonequilibrium structures in complex physical, chemical, and social systems. Two broad areas of research are pursued. One area concerns the dynamical evolution of nonlinear physical and chemical systems which exhibit broken symmetries and are subject to influences from the environment. The other area concerns the dynamical origins of irreversible behavior observed in nonlinear physical and biological systems which evolve in time.

A major topic of research on the macroscopic level concerns the properties of "dissipative structures" and bifurcation phenomena in nonlinear chemical systems and mechanisms for the transition to chaos in chemically reacting systems. These studies include chemical pattern formation and bifurcation sequences to chaos in the Belousov-Zhabotinskii and other reactions, and the effect of nonlinearity and dynamic fields in creating a transition to chaos in chemically reacting systems. Quantum optics systems present many analogs to nonlinear phenomena observed in chemical systems. Phase transitions and bifurcation sequences in quantum optics systems are studied using macroscopic and stochastic theory. The theory of nonlinear chemical systems may also be applied to human populations and social systems and is being used to study economic processes and traffic flow.

Response of nonlinear systems to external influences such as simple external fields and external noise is another major area of research, especially as concerns the dynamics of biological systems on the intra- and intermolecular levels. Stochastic theory is used to study the effect of memory induced by hydrodynamics on the microscopic level. Mechanisms by which external noise may induce phase transitions in nonlinear systems and stabilize otherwise unstable systems are other topics of study.



Nobel Laureate Ilya Prigogine

A fundamental topic of research on the microscopic level concerns the origin of macroscopic irreversibility in unstable reversible nonlinear dynamical systems, and a related topic concerns the effect of external fields in creating chaos and irreversible behavior. A major application involves nonlinear intramolecular dynamics of molecules. Studies of coherent energy propagation (solitons) and chaos in nonlinear quantum and classical dynamics systems are underway. Theoretical and numerical studies of homogeneous nucleation of the liquid state from supersaturated vapor are also currently underway.

Faculty, students, and staff from the Center for Nonlinear Dynamics work closely with the faculty, students, and staff in Statistical Mechanics.

Currently about 15 graduate students are conducting Ph.D. research in statistical mechanics and complex systems. The research is supported by contracts/grants from NSF, DOE, the State of Texas, and The Robert A. Welch Foundation. The total research budget was in excess of \$400,000 for 1989-90.

Faculty

Prigogine, Ilya

Ashbel Smith Professor, Regental Professor of Physics, and Professor of Chemical Engineering. M.A., Brussels (Belgium), 1939; Ph.D., 1941. Nobel Laureate (Chemistry), 1977. Numerous honorary degrees; membership in fifteen national academies, including U.S. and Belgium. Theoretical physics and chemistry, and studies of nonequilibrium processes.

Reichl, Linda E.

Professor. B.S., Denver, 1964; M.S., 1967, Ph.D., 1969. Quantum chaos, transport theory, nonlinear dynamics, nonequilibrium statistical physics, stochastic theory.

Schieve, William C.

Professor. B.S., Reed College, 1951; M.S., Lehigh, 1957; Ph.D., 1959. Nonequilibrium statistical mechanics, quantum optics, stochastic processes, nucleation theory.

Turner, Jack S.

Associate Professor. B.S., Duke, 1964; Ph.D., Indiana, 1969. Nonequilibrium statistical and thermal physics; nonlinear dynamics; physics of self-organizing systems; computational physics.

Adjunct Faculty

Brock, J.R.

Professor of Chemical Engineering. B.E., Rice Institute, 1952; B.S., 1953; M.S., Wisconsin, 1954; Ph.D., 1959. Colloid physics and chemistry, rarefied gas dynamics, statistical mechanics and thermodynamics.

Koschmieder, E.L.

Associate Professor of Meteorology. B.S., Frankfurt, 1952; M.S., Berlin, 1955; Dr rer.nat., Bonn, 1963. Hydrodynamic instabilities and geophysical fluid dynamics.

Schechter, R.S.

Professor of Chemical Engineering and Petroleum Engineering. B.S., Texas A&M, 1950; Ph.D., Minnesota, 1956. Hydrodynamic stability and surface phenomena.

Postdoctoral Research Staff

Chen, Ping

Ph.D., Texas, 1987. Nonlinear dynamics.

Petrovsky, T.Y.

Ph.D., Science University of Tokyo, 1979. Nonlinear dynamics and kinetic theory.

Hasagawa, H.

Ph.D., Tokyo Metropolitan University, 1986. Decrease of finite size effects through twisted boundary conditions.

Some Recent Publications

"Traffic Dynamics Through Human Interaction: Reflections on Some Complex Problems", R. Herman, in *Proceedings of the International Symposium on Evolutionary Dynamics and Nonlinear Dynamics*, (Oxford University Press, 1991).

"Stochastic Manifestation of Chaos", L.E. Reichl, Zhong-Ying Chen and M. Millonas, *Phys. Rev. A* **41**, 1874 (1990).

"Effect of a Static Field on the Stochastic Layer of Microwave Driven Hydrogen", S. Cocke and L.E. Reichl, *Phys. Rev.* **41**, 3733 (1990).

"Exploring Complexity", I. Prigogine and G. Nicolis, (W.H. Freeman and Co., New York, 1989).

"Between Time and Eternity", I. Prigogine and I. Stengers, (Shamballa, Boston, 1990).

"Thermodynamics of Matter Creation in Cosmology", J. G  h  nien, E. Gunzig, P. Nardonne and I. Prigogine, *Proc. Natl. Acad. Sci., USA* **85**, 7428 (1988).

"Chaos and Quantum Fluctuation in the Squeezed Double Well Potential", L. Carlson and W.C. Schieve, *Phys. Rev. A* **40**, 1127 (1989).

"Homoclinic Chaos in the rf SQUID", A. Bulsara, E.W. Jacobs and W.C. Schieve, *Phys. Rev. A* **37**, 3541 (1988).

"Empirical and Theoretical Evidence of Economic Chaos", Ping Chen, *System Dynamics Review* **4**, 81 (1988).

"Turing Instabilities with Nearly Equal Diffusion Coefficients", J.E. Pearson and W. Horsthemke, *J. Chem. Phys.* **90**, 3 (1989).

"Understanding Complex Chemical Dynamics: Computer Simulation and Beyond", J.S. Turner and D.M. Lindberg, in Supercomputing '89, *Proceedings of the Fourth International Conference on Supercomputing*, L.P. Kartashev and S.I. Kartashev, Eds. (International Supercomputing Institute, Inc., St. Petersburg, Florida, 1989, p. 371).

"Chaos in the Showalter—Noyes—Bar-Eli Model of the Belousov-Zhabotinskii Reaction", D.M. Lindberg, J.S. Turner and D. Barkley, *J. Chem. Phys.* **92**, 3238 (1990).

THEORETICAL PARTICLE PHYSICS

A broad program of research in theoretical physics is being pursued that ranges from elementary particle phenomenology to superstring theory, from quantum cosmology to nonlinear quantum mechanics and from experimental data analysis to mathematical physics.

The study of the origin, multiplicity, interaction, and, where appropriate, decay of elementary particles serves to bring out the underlying pattern and the architecture of the physical world. The vast empirical data acquired by scientists all over the world are the primary material on which this research is based. Recent discoveries in the physics of ultra high energies have been the stimulus for new theoretical models to explain these discoveries and their consequences.

All presently available experimental data on particle physics can be described by the standard model. This gauge theory of the electroweak and strong forces among subnuclear particles has been extended in several different ways. These expanded versions of the standard model include multiple Higgs doublets, technicolor, composite models, and supersymmetry. The observable consequences of such extensions are being studied. New phenomena ranging from neutrino oscillations, productions and subsequent decay of new heavy particles to violation of time reversal are being explored. The gravitational force that so far was treated separately can, by way of the superstring theory, be included in a simple description with the other forces.

The implications for astrophysics and cosmology from these new ideas like the nature of the dark matter and the evolution of structures are being addressed. The search for a quantum theory of gravity and, in particular, the study of possible fluctuations in the topology of space time that may have profound effects on the observed constants of nature and especially the cosmological constant are being pursued. Some of these recent developments in theoretical physics required new mathematical tools which are also being developed.

The program in particle physics at The University of Texas at Austin takes place in two research centers, the Center for Particle Theory directed by Professor Duane Dicus, and the Theory Group directed by Professor Steven Weinberg. Funding for this research is provided by the Department of Energy, the National Science Foundation, and the Welch Foundation.

Faculty

Bohm, Arno

Professor. Cand., Phys., Technische Universität Berlin, 1960; Dipl. Phys. Freie Universität Berlin, 1962; Dr. rer. nat., Universität Marburg, 1966. Particle phenomena in terms of algebraic and group-theoretical methods; mathematics of quantum physics.

Candelas, Philip

Professor. B.S. Christ's College, Cambridge, 1973; D. Phil., Oxford, 1977. Supersymmetry and string theory.

Chiu, Charles B.

Professor. B.S., Seattle Pacific College, 1961; Ph.D., California (Berkeley), 1965. Theories of particle interactions, particle collision phenomena and composite models of quarks and leptons.



Nobel Laureate Steven Weinberg

Dicus, Duane A.

Professor. B.S., Washington, 1961; M.S., Washington, 1962; Ph.D., California (Los Angeles), 1968. Field theory of strong, weak and electromagnetic interactions; astrophysical implications of the weak force.

Fischler, Willy

Professor. Licence Physics, Universite Libre Bruxelles, 1972; Ph.D., 1976. Field Theory, supersymmetry, string theory, quantum cosmology, statistical mechanics.

Gleeson, Austin M.

Professor. B.S., Drexel Institute of Technology, 1960; M.S., Pennsylvania, 1963; Ph.D., 1965. Field theory of strong interactions and the physics of superdense matter.

Kaplunovsky, Vadim

Assistant Professor. B.S., Hebrew University in Jerusalem, 1978; Ph.D., Tel Aviv University, 1983. Field Theory, supersymmetry and string theory.

Ne'eman, Yuval

Professor. B.Sc., Israel Institute of Technology, 1945; Mech. Eng. Dip., 1946; D.I.C., Imperial College, London, 1962; Ph.D., London University 1962. Israel Prize, 1969; Einstein Medal (Washington) 1969; Wigner Medal, 1982. Foreign Associate, U.S. National Academy of Sciences; Honorary Member, American Acad. of Arts and Sciences; Honorary Life Member, N.Y. Acad. of Sciences. Fellow, American Physical Society; Fellow, The Inst. of Physics (UK). Elementary particle physics, quantum field theory.

Polchinski, Joseph G.

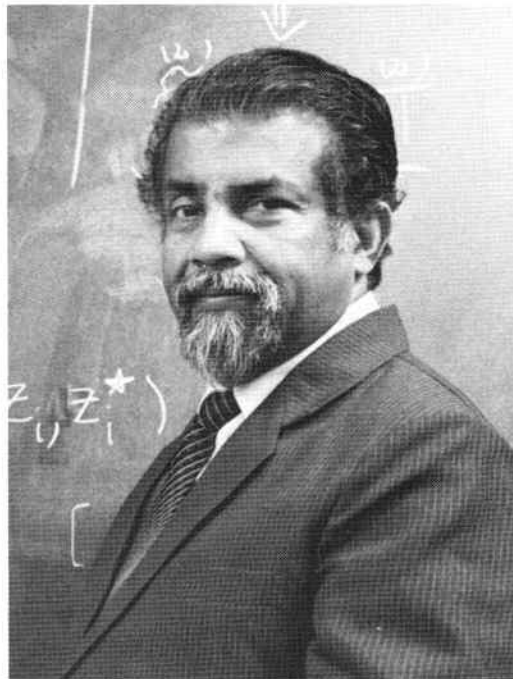
Professor. B.A., California Inst. of Technology, 1975; Ph.D., California (Berkeley), 1980. Supersymmetries, field theory, string theory, quantum gravity.

Sudarshan, E.C.G. (George)

Professor. B.Sc. (Hons.), Madras (India), 1951; M.A., 1952; Ph.D., Rochester, 1958; D.Sc. Honoris Causa, Wisconsin, 1969; D.Sc. Honoris Causa, University of Delhi, 1963. Padma Bhushan (Order of the Lotus), decoration by President of India, 1976. D.Sc. (Eng) Honoris Causa, Chalmers University, 1984. Elementary particle physics, quantum optics, quantum field theory, gauge field theories, fibre bundles, classical mechanics, foundations of physics.

Weinberg, Steven

Regental Professor and Jack S. Josey-Welch Foundation Chair in Science. A.B., Cornell, 1954; Ph.D., Princeton, 1957; D.Sc. Hon., Knox College, 1978; D.Sc. Hon., University of Chicago, 1978; D.Sc. Hon., University of Rochester, 1978; D.Sc. Hon., Yale, 1979; D.Sc. Hon., City University of New York, 1980; D.Sc. Hon., Clark University, 1982; D.Sc. Hon., Dartmouth College, 1984; D.Sc. Hon., Columbia University, 1990; Heineman Prize, 1977; Oppenheimer Prize, 1975; Cresson Medal, Franklin Institute, 1979; Nobel Prize (Physics), 1979; James Madison Medal, Princeton, 1991; Member, National Academy of Sciences, Royal Society of London, American Philosophical Society, American Academy of Arts and Sciences, International Astronomical Union. Particle physics, unification of fundamental interactions, cosmology, astrophysics, supersymmetry and supergravity.



Professor Sudarshan

Postdoctoral Research Staff**Brustein, R.**

Ph.D., Tel-Aviv University, 1988. Quantum gravity.

Dixon, J.A.

D. Phil, Cambridge University, England, 1975. Anomalies, supersymmetries, supergravity.

Gaite, J.

Ph.D., Univ. de Salamanca, 1989.

Giudice, G. F.

D. Phil., International School for Advanced Studies, Italy, 1988.

Karatas, D.

Ph.D., Illinois Institute of Technology, 1989. Experimental tests of supersymmetry and the standard model.

Paban, S.

Ph.D. University of Barcelona, 1988. CP - Violation.

Ordonez, C.

Ph.D. University of Texas, 1986. String theory.

Xu, R.-M.

Ph.D., Brandeis University, 1989. String theory.

Yang, Z.

Ph.D., Brandeis University, 1989. Conformal field theory.

Some Recent Publications

"Higgs Boson Production from Heavy Quark Fusion", D. A. Dicus and S. Willenbrock, *Phys. Rev.* **D39**, 751 (1989).

"On the Spectrum of $J^P = 2^+$ Particles", S. K. Bose and E. C. G. Sudarshan, *Phys. Rev. Lett.* **62**, 1445 (1989).

"Implications of Relativistic Gas-Dynamics for Neutrino-Neutrino Cross Section", D. A. Dicus, S. Nussinov, P. B. Pal and V. Teplitz, *Phys. Lett.* **B218**, 84 (1989).

"BRST Transformations for an Affine Model of Gravity with Local GL(4,R) Symmetry", C. Y. Lee and Y. Ne'eman, *Physics Letters B* (in press).

"Precision Tests of Quantum Mechanics", S. Weinberg, *Phys. Rev. Lett.* **62**, 485 (1989).

"Larger Higgs-Exchange Terms in the Neutron Electric Dipole Moment", S. Weinberg, *Phys. Rev. Lett.* **63**, 2333 (1981).

"Dilaton Tadpoles, String Condensates and Scale Invariance", W. Fischler and L. Susskind, *Phys. Lett.* **B171**, 383 (1986).

"A Two-Dimensional Model of Quantum Gravity", J. Polchinski, *Nucl. Phys.* **B324**, 123 (1989).

"Quantum Mechanics of the Googolplexus", W. Fischler, I. Klebanov, J. Polchinski and L. Susskind, *Nucl. Phys.* **B327**, 157 (1989).

"One Loop Threshold Effects in String Unification", V. Kaplunovsky, *Nucl. Phys.* **B307**, 145 (1988).

"Yukawa Couplings Between (2,1) forms", P. Candelas, *Nucl. Phys.* **B298**, 458 (1988).

"Why Do Quarks Behave Like Bare Dirac Particles?", S. Weinberg, *Phys. Rev. Lett.* **65** (3), 1181 (1990).

"Mended Symmetries", S. Weinberg, *Phys. Rev. Lett.* **65**, 1177 (1990).

"Unitary Constraints on CP Nonconservation in Higgs-boson Exchange", S. Weinberg, *Phys. Rev.* **D42**, 860 (1990).

"Quantum Nucleation of False Vacuum Bubbles", W. Fischler with D. Morgan and J. Polchinski, *Phys. Rev.* **D40**, (8) 2638 (1990).

"Gamow Vectors and Decaying States", A. Bohm, M. Gadella and G. B. Mainland, *Am. J. Phys.* **57**, 12 (1989).

"Renormalization of Gauge-Affine Gravity", Y. Ne'eman and C.Y. Lee, *Phys. Lett.* **B242**, 59 (1990).

"Algorithms for the Polynomial Zeros of Degree 2 of the $3j$ and $6j$ Coefficients", C. Chiu and K.S. Rao, *Journal of Physics A: Math and Gen.* **22**, 3779 (1989).

"Intermittency in Branching Models", C. Chiu and R.C. Hwa, *Phys. Lett. B* **236**, 446 (1990).

"New Connections Between String Theories", J. Polchinski with J. Dai and R. Leigh, *Mod. Phys. Lett.* **A4**, 2073 (1989).

"Baryon Number Violation at High Temperature in the Standard Model", J. Polchinski with M. Dine, O. Lechtenfeld, B. Sakita and W. Fischler, *Nucl. Phys.* **B342**, 381 (1990).

DEPARTMENTAL COLLOQUIA AND SEMINARS

A Department of Physics Colloquium is held every Wednesday during the academic year. This series presents lectures of general interest which help keep the faculty, students and research staff abreast of recent developments in all fields of physics. The colloquium is organized as a graduate course for the benefit of those who choose to enroll in it.

In addition, all of the research/teaching areas of the department sponsor a weekly seminar program. Speakers from other universities and laboratories give talks for the specialist, presenting the latest developments in research.

The Emmett L. Hudspeth Centennial Lectureship is an annual public lecture dedicated to exposition of new discoveries in microscopic physics. This lecture series was endowed by former students of Prof. Emmett Hudspeth to honor him for his contribution to their careers. Recent lectures have been given by Leon Lederman on particle physics, W. Panofsky on large accelerators, and Norman Ramsey on time reversal invariance.

The F.A. Matsen Endowed Regents Lectureship is another annual public lecture focussing on recent developments in fundamental physics. This lecture series was endowed by Prof. Matsen, his colleagues, and friends at his retirement. In 1989, Prof. Andrei Linde of the Lebedev Physical Institute in Moscow gave a talk titled, "The Self-Reproducing University." This lecture series is shared with the Department of Chemistry.

ONGOING COLLABORATIONS

The Department of Physics has many collaborations with other departments and research units at The University of Texas at Austin. These collaborations allow students special opportunities to organize programs of study which are interdisciplinary or require special facilities or support.

Several faculty from the Departments of Astronomy, Chemistry, Electrical and Computer Engineering, Mathematics, and Mechanical Engineering serve as members of the Graduate Studies Committee in Physics. In this way they can supervise the dissertation research of graduate students in Physics. Many other faculty from these departments serve on the supervising committees of doctoral dissertations and master's theses.

In addition, several of the research units at The University of Texas at Austin provide special opportunities for research for graduate students in Physics.

Applied Research Laboratories:

Dedicated to classified and unclassified work in acoustics, electromagnetic wave propagation, and systems analysis. Primarily supported by funds from the Department of Defense.

Institute for Geophysics:

Conducts research in all areas of geophysics with special emphasis on seismic interpretation and ocean geophysics.

Science Education Center:

Coordinates support programs in curriculum development and research in science teaching.



Graduate student tutoring in elementary science

ADMISSION

Admission to the graduate program in Physics requires approval from both the Graduate School of The University of Texas at Austin and the Department of Physics.

The Graduate School has five basic requirements for admission:

1. A bachelor's degree from an accredited institution in the United States or proof of equivalent training at a foreign institution.
2. A satisfactory grade-point average in upper-division (junior- and senior-level) work and in any graduate work already completed. A "B" average satisfies this requirement.
3. A score of at least 1100 on the Graduate Record Examination General Test. Applicants may write to the Educational Testing Service, Rosedale Rd., Princeton, NJ, 08541, for information concerning test administration dates and fees. The GRE Subject Physics test is not required (unless the student is seeking financial aid).
4. Adequate subject preparation for the proposed graduate major. For graduate work in physics, it is assumed that the student has an undergraduate background that includes mechanics at the level of Symon's text, *Mechanics*; electricity and magnetism at the level of Cook, *The Theory of the Electromagnetic Field*; thermodynamics at the level of Kittel and Kroemer, *Thermal Physics*; atomic physics at the level of Morrison, Estle, and Lane, *Quantum States of Atoms, Molecules, and Solids*; and quantum mechanics at the level of Park, *Introduction to Quantum Theory*.

5. Acceptance by the Committee on Graduate Studies of the proposed major area. When all materials required for admission have been received by the Office of Admissions and Records, each file is reviewed by the Graduate School and forwarded to the Graduate Studies Sub-Committee in the Physics Department, where a recommendation is made to grant or deny admission. The Graduate School screens each file once again and submits the recommended action to the Office of Admissions and Records. The latter then issues formal notification of this decision by letter to each applicant.

In addition, the Office of Admissions and Records requires of foreign citizens:

6. Official copy of the TOEFL (Test of English as a Foreign Language) score, minimum score: 550. This test is administered internationally five times a year. For information, write to:

TOEFL
Box 899
Princeton, New Jersey 08540

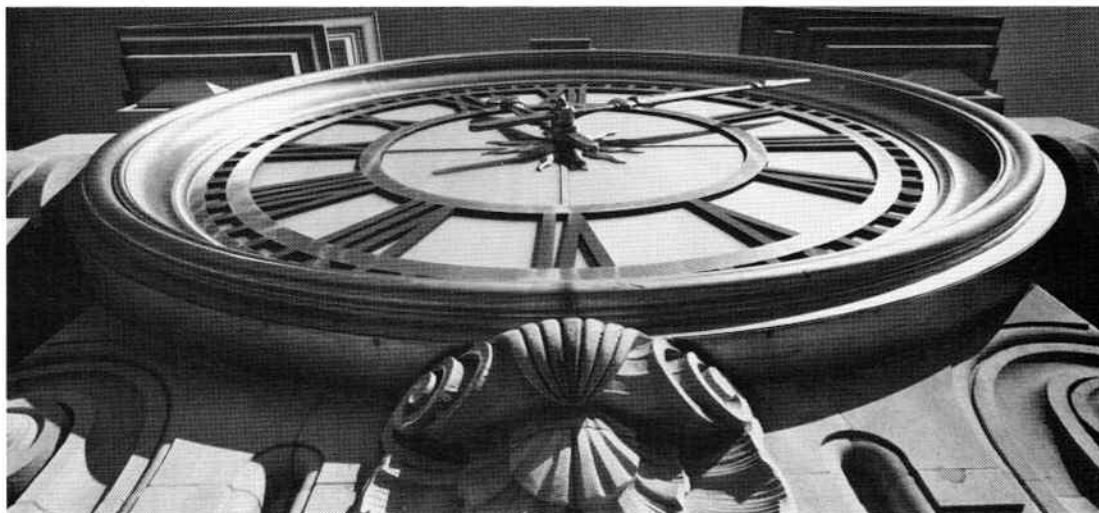
The Department of Physics will review the graduate student application file. It may use additional criteria for admission such as a higher GRE score. Each file is reviewed individually.

Deadlines

Students are urged to file their applications as early as possible. All materials required for Admissions and Records by March 1 for the fall and summer semesters, and by October 1 for the spring semester. Foreign students must file their applications, complete with required documentation, by April 1 for summer and fall and October 1 for spring. For information on admission to the Graduate School, write to the address below for the Graduate Admissions Bulletin. This bulletin contains the necessary application forms.

Director of Admissions and Records
Main Building 7
The University of Texas at Austin
Austin, Texas 78712

For further information regarding admission policy, please consult the *Graduate Catalog*.

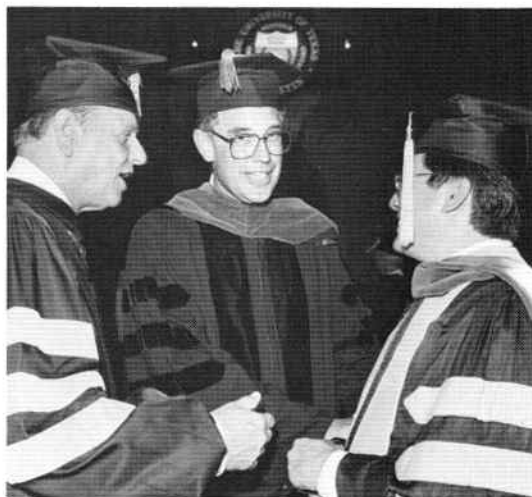


The University of Texas Tower Clock

DEGREE REQUIREMENTS

The requirements for an M.A. degree (an M.S. degree is not awarded in physics) include 30 hours of courses with a B(3.0) average, of which at least six hours are outside the major program. Each candidate is required to write a thesis under the direction of a supervising instructor and a committee appointed by the Dean. All requirements must be completed within one six-year period. The M.A. is not required for the Ph.D. qualifying process.

A student must satisfy four requirements prior to admission to candidacy for the Ph.D. degree in physics: score at least 700 on the GRE Advanced Physics Exam by the end of the first year of graduate study; show evidence of exposure to modern methods of experimental physics by having taken a senior lab course, previous participation in an experimental program or by taking the experimental course (380N); satisfy the core course requirements and the oral exam requirement discussed below.



Commencement

During the first two years of graduate study, the student must take four core courses: Classical Mechanics (385K), Statistical Mechanics (385L), Classical Electrodynamics (387K) and Quantum Mechanics (389K). An average grade of B+ must be achieved in these courses and a grade of at least B- made in each course. The grade made in the experimental physics course (380N) may be substituted for the grade received in one of the core courses in computing the average. A well-prepared student may choose to satisfy the core course requirement by passing the final exams in some of these courses rather than registering for the course.

Within 27 months of entering the graduate physics program, students must take an oral qualifying examination. The examination consists of an oral presentation before a committee of four physics faculty members, of whom one is a member of the Graduate Studies Sub-Committee. The presentation is open to all interested parties. It is followed by a closed question period restricted to the four member faculty committee. The questions during this session are to be directed towards clarifying the presentation, and determining whether the student has a solid grasp of the basic material needed for research in the specialty. The student passes the exam by obtaining a positive vote from at least three of the four faculty members.

Each program of work for the Ph.D. degree must list at least four advanced physics courses (a list of suitable courses is maintained by the Graduate Studies Sub-Committee). The program must also include two advanced courses outside the student's area of specialization and at least one course outside the department. All completed course work included in the degree program presented to the Graduate School at the time of application for candidacy must have been taken within the previous six years (exclusive of maximum of three years of military service). Progress of all doctoral candidates is subject to review by the Dean if not completed within three years from the date of admission to candidacy. A dissertation is required of every candidate, followed by a final oral examination covering the dissertation and the general field of the dissertation.

For further information, please consult the *Graduate Catalog*.

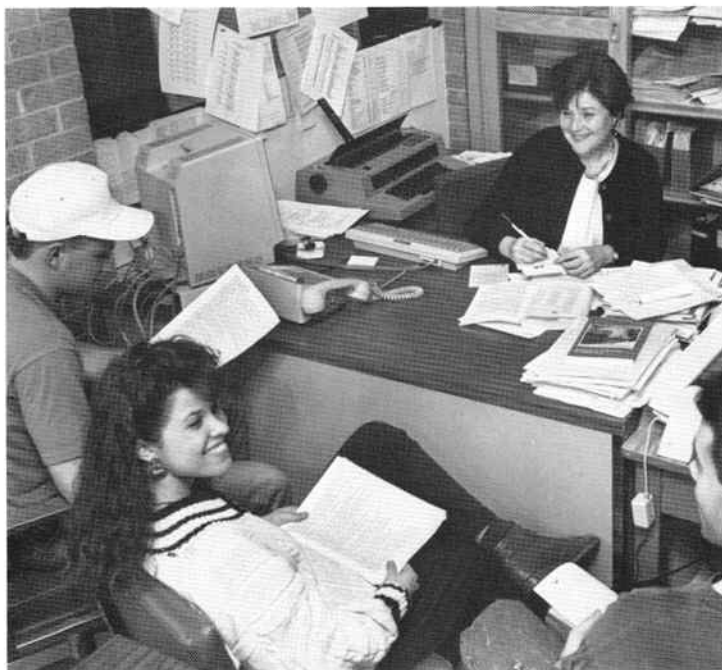
FINANCIAL ASSISTANCE

The most common form of financial assistance for new graduate students is the *Teaching Assistantship* (T.A.). A Teaching Assistantship is a part-time (usually 20 hours per week) job. Duties include teaching laboratories, grading lab manuals/papers, and coaching students enrolled in undergraduate physics courses. All T.A.'s are required to register for nine semester hours of coursework each long semester and maintain at least a B average. Appointments are usually for the nine-month academic year, although a few summer appointments are also available. Stipends vary, usually beginning near \$904/month. Social Security and federal income tax are deducted from this amount. All T.A.'s who have a 20-hour per week appointment are subject to Texas resident tuition rates. All T.A.'s must take a special course in teaching methods, Phy 398T, during their first two semesters.

Another source of income available to beginning graduate students is the *Graduate Assistantship* (or Grader). Duties include grading papers for undergraduate physics courses and coaching of students from several undergraduate classes. Stipends usually begin at \$600 per month for a 20-hour per week appointment. Graders are subject to the same deductions as T.A.'s.

The number of T.A. and Grader positions available each semester is limited; of the approximately 60 T.A. appointments, about 25 are for new, first-year students; of the approximately 20 Grader appointments, about 10 are for new, first-year students. T.A. and Grader jobs for all students are awarded on a competitive basis. In this competition the following are considered by the Graduate Studies Sub-Committee in Physics: (1) undergraduate institution and grade point average, (2) GRE aptitude test scores, (3) GRE advanced physics scores, (4) letters of recommendation, and (5) specific field of interest and research goals of the student. It is therefore very important that the financial aid application package of each student be complete. Particular care should be given

to a detailed statement by the student of his or her research interests and his or her intended field of specialization. All applications for financial aid are reviewed carefully.



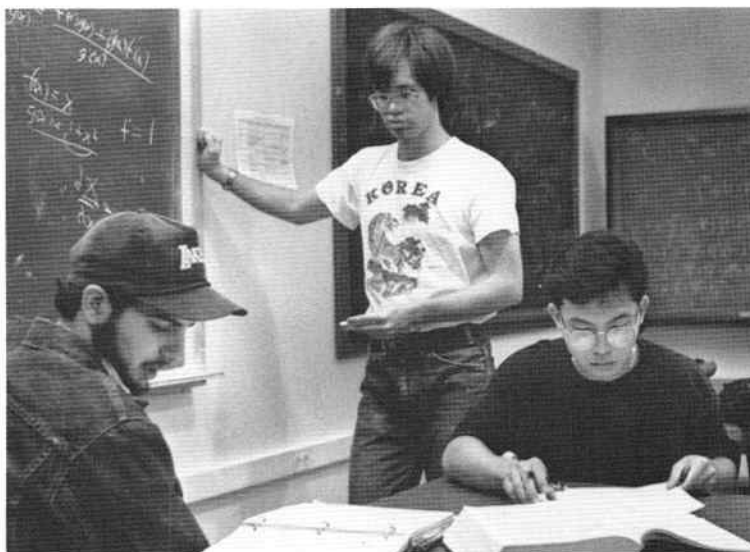
Graduate Coordinator working with students

Application can be made by submitting:

1. Application for Financial Aid form.
2. Three letters of recommendation.
3. Transcripts of all college-level work.
4. Official copy of the GRE Aptitude and Advanced Physics scores.
5. Statement of research interests.

The application form, reference forms, and personal statement form are available from and should be returned to:

Graduate Coordinator
Department of Physics
The University of Texas at Austin
Austin, Texas 78712-1081
Telephone: (512) 471-1664



Graduate student coaching undergrads

Please note that the application for financial aid is separate from and in addition to the application for admission to the Graduate School. The Graduate School processes the admission applications and the Physics Department processes the financial aid applications. Deadline for applying for financial aid is February 1 for the following academic year. Also note that each admission application is processed at the time it is received by the Graduate School, but all financial aid applications are held until February 1 when the financial award competition begins. The student should expect to hear from the Admissions Office within 30 to 60 days after the admission application has been received. A first round of financial aid offers is made by the Physics Department by March 15 and, if necessary, a second round of offers is made around April 15. Financial aid offers are made to about 20% of those recommended for admission. Most T.A. and Grader appointments are for the nine-month academic year; few new appointments are available for the spring semester. Approximately ten T.A. and five Grader appointments are made for the summer session.

The **Preemptive University Fellowship** is used by the Physics Department to attract truly exceptional new graduate students. Usually the Department couples the Preemptive University Fellowship with a T.A. or a **Research Assistantship** (see below) offer to provide the student with a total income of about \$1000/month. No duties are associated with the fellowship portion of the award. In its review of financial aid applications, the Department identifies students qualified for this fellowship and forwards nominations to the Graduate School. Because of the stringent standards set by the Graduate School for this award, only about five nominations can be made each year.

The Department of Physics also offers the John A. Wheeler Fellowship, the Richard N. Lane Fellowship in Classical Physics, and the Arthur Lockenvitz Memorial Endowed Scholarship in Experimental Physics. These programs provide supplemental support for outstanding students. Interested students should write to the Chairman of the Department of Physics.

Another source of income available to more advanced students is the **Assistant Instructorship (A.I.)**. A.I.'s are auxiliary members of the teaching staff and are employed to meet instructional needs at the undergraduate level, primarily in the lower-division areas. A.I.'s must hold a Master's degree or have attained an equivalent level of achievement in graduate study and professional accomplishment. An A.I. must have had at least one semester of service as a T.A., or equivalent. Typically, ten A.I. appointments are made each year. Beginning salaries are \$922/month for 20

hour/week appointments for nine months. Approximately ten A.I. 40 hour/week appointments are made for the summer session. Social Security and federal tax are deducted from A.I. salaries.

A popular source of income available to second-year and more advanced graduate students is the **Graduate Research Assistantship** (G.R.A.). There is a fairly large number of these jobs, awarded by the research groups in the Physics Department who receive federal, state, or private funding for research. Stipends vary according to the classification of the student and are comparable to T.A. salaries. G.R.A.'s are subject to the same deductions and tuition rates as T.A.'s. In some cases G.R.A.'s are awarded to new students who show exceptional promise and who have already decided on an area of specialization. To be considered, the student should contact faculty in their intended area of specialization.

Usually two or three continuing **University Fellowships** are awarded to graduate students in physics every year. These are awarded to students who are already engaged in graduate research in physics. Stipends are comparable to T.A. salaries, but no specific duties are required of Fellows.

Recipients of most fellowships (including NSF Fellows) are allowed to supplement the stipend. Part-time T.A., Grader, and G.R.A. positions are often available for this purpose.

Nonresidents/foreign citizens employed by The University of Texas at Austin as T.A.'s, A.I.'s, and G.R.A.'s for 20 hours or more per week are eligible for resident tuition. Most recipients of University administered fellowships also qualify for resident tuition.

Loans and other forms of financial aid are available to students on the basis of financial needs. For information concerning the various loan programs available at Texas, please write to:

Student Financial Aid Office
The University of Texas at Austin
U.T. Station Box 7758
Austin, Texas 78712



Students in South Mall

COURSE OFFERINGS

Courses in physics are designated by numbers, or by numbers with a capital letter affixed, which indicate both rank and credit value in semester hours. Course numbers 201 through 299 indicate a value of two semester hours; 301 through 399, a value of three semester hours, etc. The two digits on the right indicate the rank of the course: 01 through 19 indicate the course is of lower-division rank; 20 through 79 indicate an upper-division rank; 80 through 99 indicate graduate courses.

Courses

Upper-Division Courses: the following courses are typical junior- and senior-level courses required or recommended for a bachelor's degree in physics at Texas.

336K Classical Dynamics I.

336L Fluid Mechanics.

338K Electronic Techniques.

352K Classical Electrodynamics.

353 Modern Physics I: Introduction to Quantum Phenomena.

373 Modern Physics II: Quantum Mechanics.

362K Modern Physics III: Applications of Quantum Mechanics.

362L Modern Physics IV: Subatomic Physics.

364E Modern Physics for Engineers.

369 Thermodynamics and Statistical Mechanics.

433 Optics

474 Advanced Laboratory I.

375P Introductory Plasma Physics.

375R Introduction to Relativity.

375S Introductory Solid-State Physics.

Graduate Courses: The following courses are generally offered during each academic year.

380L Plasma Physics: Introduction. Particle drifts, equations for plasmas, magnetohydrodynamics, waves and instabilities in the two-fluid model, Vlasov equation, Landau damping, controlled thermonuclear research, plasma diagnostic.

380M Plasma Physics. Stability Theory, Plasma containment, stability theory in fluid models, derivation of Vlasov and Fokker-Planck equations, the dielectric tensor, velocity space and gradient instabilities, Nyquist diagrams.

380N Experimental Physics. Participation in current departmental experimental research in order to provide exposure to experimental techniques used in modern-day physics research.

381M Methods of Mathematical Physics. Theory of analytic functions; linear algebra and vector spaces; orthogonal functions; ordinary differential equations.

381N Methods of Mathematical Physics II. Advanced mathematical method used in theoretical physics. Topics vary.

382M Fluid Mechanics. Flow of ideal and viscous fluids; introduction to turbulence; boundary layers; sound and shock waves.

385K Classical Mechanics. Classical and relativistic Hamiltonian mechanics; Hamilton-Jacobi theory; Lagrangian mechanics for continuous media; symmetry principles and conservation laws.

385L Statistical Mechanics. Equilibrium statistical mechanics; introduction to nonequilibrium concepts; ensembles; classical and quantum gases; statistical physics of solids.

385S Seminar in Statistical Physics. Current topics.

385T Special Topics in Physics. Current topics.

387K Electromagnetic Theory I. Maxwell's equations; plane waves; wave guides; diffraction; multipole radiation.

387L Electromagnetic Theory II. Magnetohydrodynamics and plasmas; relativity; collisions of charge particles; radiation from moving charges; radiation damping.

387M Relativity Theory I. Tensor calculus; Riemannian geometry; geometry of Minkowski spacetime; special relativity theory; general relativity theory; gravitation field equations; weak field approximations; Schwarzschild solution.

387N Relativity Theory II. Advanced topics in general relativity.

288M Graduate Colloquium. Outside speakers and Department members on current physics research topics.

389K Quantum Mechanics I. Operator formalism; Schrodinger equation and Heisenberg formulation; orbital angular momentum; one- and two-electron systems, approximate techniques including perturbation theory; scattering theory.

389L Quantum Mechanics II. Angular momentum; group theory; time-dependent perturbation theory; formal theory of scattering; semiclassical theory of radiation; introduction to second quantization; Dirac Equation.

389M Relativistic Quantum Mechanics. Dirac and Klein-Gordon equations; second quantization; S-matrix; Feynman diagrams; renormalization.

389P Group Theory of Atoms, Molecules, and Solids. Abstract group theory and its application to quantum mechanics of atomic, molecular, and solid-state physics.

690 Graduate Research. May not count toward a master's degree. This course will vary in credit according to the work performed, its value being indicated by the course numbers 190, 290, 390, 690.

391M Nonlinear Plasma Theory. Quasilinear theory, weak turbulence, large amplitude waves, plasma radiation, shock waves, shock structure, computer techniques.

391N Plasma Confinement. Current topics.

391S Seminar in Plasma Physics. Current topics.

391T Special Topics in Plasma. Current topics.

392K Solid-State Physics. Lattice vibrations and thermal properties of solids; band theory of solids; transport properties of metals and semiconductors; optical properties; magnetic properties; magnetic relaxation; superconductivity.

392L Solid-State Physics. Elementary excitations: phonons, electrons, spinwaves; interactions: phonon-phonon, electron-electron, electron-phonon, theory of metals and semi-conductors; transport theory; optical properties.

392S Seminar in Condensed Matter Physics. Current topics.

392T Special Topics in Condensed Matter Physics. Current topics.

393S Seminar in Relativity. Current topics.

393T Special Topics in Relativity. Current topics.

194S Seminar in Theoretical Physics. Current topics.

394T Special topics in Theoretical Physics.

395 Spectroscopy. Spectra of atoms and diatomic molecules; quantum electronics; experimental technique.

395L Plasma Spectroscopy. Ionization-recombination and excitation-deexcitation balances for thermodynamic and nonthermodynamic equilibria; line and continuous radiation; broadening mechanisms of line radiation; applications to plasma diagnostics.

395S Seminar in Atomic and Molecular Physics. Current topics.



Current-journal reading room

395T Special Topics in Atomic and Molecular Physics.

396K Quantum Field Theory. Development of the subject matter of Physics 389M using canonical field theory. Second quantization of the Klein-Gordon, Dirac, and electromagnetic fields; in- and out-fields; S-matrix reduction formulae; Wick's theorem; Feynman rules.

396S Seminar in Particle Physics. Current topics.

396T Special Topics in Particle Physics.

397K Survey of Nuclear Physics. Systematics of stable nuclei; nuclear structure; decay of the nucleus; cross sections and reaction mechanisms; the elementary particles.

397S Seminar in Nuclear Physics. Current topics.

397T Special Topics in Nuclear Physics.

698A,B Thesis

398T Supervised Teaching for Graduate Students in Physics. Required for teaching assistants.

399,699,999 Dissertation.

TUITION, FEES AND EXPENSES

The major expense items one can expect to encounter during an academic semester at The University of Texas at Austin are outlined in the following table.

TUITION AND FEES 1990-91 (for nine hours)

Amounts include hospital and medical services, building-use fee, student union, student services. Estimated cost of books is \$450 per semester.

Tuition and Required Fees

Texas Residents	\$ 353.00
Nonresident and foreign students	1289.00

Optional Fees

Intercollegiate Athletics	\$ 52.00
Locker and Shower	8.00
Parking permit (student)	22.00
Motorcycle parking permit	9.00

The Student Financial Aid Office has issued an estimate of living costs for a nine-month period at The University of Texas at Austin. These figures represent a nine-hour course load each semester, but individual living arrangements vary from student to student, making estimates for an average student difficult to predict.

HOUSING

In recent years, overbuilding in the Austin area has made it fairly easy for students to find inexpensive housing near campus or along one of the free U.T. shuttle bus lines. University-owned housing is available for both unmarried and married students. During the nine-month academic year in 1990-91, room and board costs range from \$2632 to \$4650. University apartments for student families range in cost from \$241 to \$398 per month. Private housing, including co-ops, apartments, duplexes, and houses, is also available. For further information about meal plans, rents and application deadlines, students should write the following address:

Division of Housing and Food Service
The University of Texas at Austin
P.O. Box 7666
Austin, Texas 78712



Cafeteria in student union

Austin boasts two of the largest and most active student cooperative housing associations in the United States. In cooperatives, residents pay a monthly fee covering food, rent and utilities and must contribute several hours per week of labor toward housework, cooking and organizational duties. Students interested in cooperative living should write the following addresses for more information:

Inter-Cooperative Council
510 West 23rd St.
Austin, Texas 78705

College Houses Co-Operatives
2000 Pearl St.
Austin, Texas 78705

Students may also make use of the Off-Campus Housing Office in Kinsolving Dormitory for help finding suitable living arrangements. However, this service is only available to students who can visit the office in person as no assistance can be rendered by mail. There are also several privately run apartment locator services which will help renters find a suitable house or apartment.

LIVING IN AUSTIN

Austin, the state capital, is located on the Colorado River in the Central Texas area. It has a population of nearly 400,000 and is the location of 120 state and 62 federal agencies. Although the State of Texas is usually considered Austin's major employer, in recent years several computer and electronics companies have opened facilities in the Central Texas area. Companies such as Tracor, IBM, Motorola, Texas Instruments, Microelectronics and Computer Technology Corporation (MCC) and Advanced Micro Devices provide jobs for a growing technical and professional workforce.

Austin is an educational center as well. In addition to The University of Texas at Austin, there are four colleges in Austin, including the Austin Community College and Huston-Tillotson College, as well as two seminaries and several business colleges. Additional schools are located within commuting distance at Georgetown, San Marcos and Seguin.



Town Lake gazebo and Austin skyline

Central Texas is well-known for its lakes and parks. A series of seven dams on the Colorado River have created the Highland Lakes, which provide Austin with some of the best opportunities for water sports in the Southwest. These lakes stretch across 150 miles and are ideal for sailing, fishing, swimming and water skiing. Two lakes in this series, Lake Austin and Town Lake, are within the city limits. Town Lake flows through the heart of downtown and is the scene of the annual Austin Aqua Festival, a two-week-long celebration of Texan cultural diversity featuring live music, water sports and ethnic foods. Lake Austin is a favorite swimming and picnic spot located only fifteen minutes by car from downtown.

Austin has 7,000 acres of parks, including public golf courses, tennis courts and over 20 swimming pools. Austinites are

particularly proud of Barton Springs, a section of Barton Creek which is inundated daily by 27 million gallons of clear, 68°F spring water. Austin's weather is predominantly sunny and warm, with summery days numbering about 300 per year. Days with minimum temperatures dropping below 32°F number less than 30, while the average number of days with maximum temperature above 95°F is about 50. About 10 days per year have maximum temperatures in excess of 100°F. On average, it rains about 32 inches per year.

Such weather makes Central Texas ideal for camping, horseback riding and other outdoor activities. The University of Texas Division of Recreational Sports sponsors a wide variety of recreational and sporting activities and also maintains extensive athletic facilities available for all faculty, staff and students. Some of these facilities include locker rooms, steam rooms, sports equipment, swimming pools, basketball courts, 11 handball courts, 14 squash courts, 14 racquetball courts and 40 tennis courts. The University also boasts 26 sports clubs that sponsor instructional, competitive or purely recreational activities, ranging from team sports like soccer to more "exotic" individual activities such as bronc riding and yoga. The Recreational Sports program also sponsors weekend and week-long camping and canoeing trips to various state parks across Texas.

University life offers a variety of cultural and recreational activities. Art, historical and other exhibits appear at various places on campus, including the Harry Ransom Humanities Research Center, The University Art Museum and the Texas Memorial Museum. The Drama and Music Departments and various student theater groups present plays and recitals throughout the year; world-famous groups and individual artists perform regularly at The University of Texas Frank Erwin Center and the Performing Arts Center. The Texas Student Union and other campus organizations sponsor films that are shown at campus theaters nearly every evening of the week. Each semester, the Union offers classes in over 40 different areas, including cookery, foreign languages, auto mechanics, jewelry-making, pottery, chess, bridge and backgammon.

