

For first-year graduate students and adventurous seniors, a set of basic courses covering broad areas in applied physics is available, supplemented by a set of more specialized courses often closely related to a specific research effort.

#### *Areas of Research and Physical Facilities*

Research in applied physics covers a broad spectrum of activities, ranging from nanostructured materials, solid state devices, and photonics to biophysics and plasma physics. There is research in progress in single-molecule biophysics, synthetic biology, microfluidics, nanostructure fabrication and application in photonics and electronics, ultrahigh-speed fiber optic devices and communications systems, compound semiconductor materials and device physics, spin-dependent transport, photovoltaics, chemical vapor deposition processes, and fluid dynamics. The research program is centered in the Thomas J. Watson, Sr., Laboratories of Applied Physics. This 40,000-square-foot building contains research laboratories including a central micro/nano fabrication facility as well as offices, conference rooms, and a classroom, nestled around an attractive courtyard.

86

## **ASTROPHYSICS**

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The astronomical observatories at Palomar and Mauna Kea, and the Owens Valley Radio Observatory, the Chajnantor Observatory, and the Caltech Submillimeter Observatory, together constitute a unique and unprecedented concentration of ground-based facilities in astronomy.

Access to satellite-based infrared observations is provided by Caltech's Infrared Processing and Analysis Center (IPAC) and the Spitzer Science Center (SSC). For example, IPAC currently supports a number of NASA missions: 2MASS, an all-sky survey at 2 microns, and the Infrared Space Observatory (a mission of the European Space Agency). The SSC is conducting the science operations of the Spitzer Space Telescope—one of the great space observatories. The GALEX mission, a space UV survey of the sky, is also used by Caltech.

The Division of Physics, Mathematics and Astronomy also conducts work in theoretical astrophysics, laboratory astrophysics, gravitational-wave physics, and infrared and submillimeter astronomy, as well as studies of the cosmic microwave background (CMBR). The radio astronomy group works in close collaboration with the optical astronomers in Pasadena. There is close cooperation between these groups and the students and astronomers interested in planetary physics and space science. Caltech is also among the leaders in the development of the National Virtual Observatory.

As a result of the cooperation possible over a broad range of astronomy and theoretical astrophysics, unsurpassed opportunities exist at Caltech for advanced study and research. Courses of study depend upon a broad and thorough preparation in physics, mathematics, and other relevant subjects; the faculty offers advanced instruction in astronomy, astrophysics, solar physics, planetary physics, and astronomical instrumentation and techniques.

#### *Areas of Research*

Both observational and theoretical astrophysics are actively pursued. Topics of current interest in optical and infrared astronomy include observational cosmology; spectroscopic and spectrophotometric studies of quasars and galaxies; studies of the dynamics and composition of galaxies and clusters, nebulae, and interstellar matter; planet and star formation; statistical studies pertinent to cosmology, the structure of the galaxy; globular clusters; gamma-ray bursts; neutron stars; digital sky surveys; the physics of solar phenomena; and many others.

Research in planetary and solar system astronomy is pursued in cooperation with groups in the Division of Geological and Planetary Sciences.

The research in radio astronomy covers cosmology, via observations of the microwave background radiation, and the physical properties of galactic and extragalactic radio sources, including quasars, pulsars, radio galaxies, stellar envelopes, and the planets. The properties of the interstellar medium in our own and other nearby galaxies are investigated in spectroscopic studies of various atomic and molecular spectral lines.

Theoretical astrophysics is pursued not only in the astrophysics department, but in physics and geology as well, and at Caltech includes work on supernovae, pulsars, stellar structure and evolution, stellar and planetary atmospheres, interstellar and intergalactic matter, the physics of radio sources, nucleosynthesis, relativity, and cosmology.

#### *Physical Facilities*

The Rockefeller Boards provided, in 1928, for the construction by the Institute of an astronomical observatory on Palomar Mountain, equipped with a 200-inch reflecting telescope, 48-inch Samuel Oschin and 18-inch Schmidt wide-angle telescopes, and other auxiliary instruments, together with an astrophysical laboratory on the Institute campus. The 48-inch Samuel Oschin Telescope has made possible complete surveys of the northern sky. It is now equipped with a major new digital camera, which will lead to a new generation of sky surveys. The Palomar telescopes have modern instrumentation and detectors designed for both optical and infrared wavelengths. The 200-inch Hale Telescope has been used to make many historical, fundamental discoveries ever since

87

its commissioning in 1948, and through the present day. It is now also used for pioneering advances in adaptive optics.

A multipurpose solar equatorial telescope at an observing station at Big Bear Lake is now run jointly with the New Jersey Institute of Technology. The unique atmospheric conditions in this area make possible investigations of the fine structure of the solar atmosphere. Emphasis is on high-resolution spectroscopy, magnetography, and cinematography. A major effort is the study of solar oscillations.

The Owens Valley Radio Observatory is in a radio-quiet location 400 km north of Pasadena, near Big Pine, California. Its facilities include a 40-meter telescope, a six-element millimeter-wave synthesis interferometer array, a five-element interferometer for solar studies, and a 5.5-meter telescope dedicated to observations of polarized radio emission from the galaxy. The high-precision 10-meter telescopes of the millimeter array are used at wavelengths of 1.3 to 4 mm to map the distribution of interstellar gas and dust in star-forming regions of our own and other galaxies. The array also enables detailed studies of the sun, planetary atmospheres, and the envelopes around evolved stars. These telescopes, which are equipped with very sensitive cryogenically cooled receivers and sophisticated signal-processing and data-recording systems, give Caltech staff and students the widest range of observing opportunities available at any university-related radio observatory in the world.

The Caltech 10-meter Submillimeter Observatory, located on Mauna Kea, Hawaii, was completed in 1986 for the study of the chemistry and physics of planets and cool regions of the interstellar medium.

The Chajnantor Observatory is situated at an altitude of 5,080 m in the Chilean Andes. It is the site of the Cosmic Background Imager, which is used for cosmic microwave background studies, and will also be the site of the QU Imaging Experiment (QUIET) and the Clover experiment, both of which aim at very high sensitivity polarized microwave background studies.

The Keck Foundation funded the construction of two 10-meter optical-infrared telescopes, operated jointly with the University of California as part of an interferometer. Each Keck Telescope has four times the power of the Palomar 200-inch. They can be combined as an interferometer of unprecedented power. These are the two largest optical-infrared telescopes in the world, equipped with adaptive optics and state-of-the-art optical and infrared instrumentation, and they have made numerous fundamental advances in astronomy and cosmology.

## BIOCHEMISTRY AND MOLECULAR BIOPHYSICS

Biochemistry and molecular biophysics has been established as an interdisciplinary program, at the interface of biology, chemistry, and physics, that seeks to understand the chemistry of life. Thus, biochemists and molecular biophysicists study the atomic structure and folding of biopolymers; their interactions with each other and with small molecules; and the roles of particular biopolymers and biopolymer assemblies in cellular physiology. The basic building block of life is the cell; the intellectual focus of modern biochemistry and molecular biophysics is to understand how individual parts interact to give cells their wide spectrum of functions. In particular, biochemistry and molecular biophysics addresses the principles through which the individual components of cells combine in an orderly self-association to produce their form, their function, and their dynamic behavior.

### *Areas of Research*

General areas of research represented within the option include signal transduction, cell cycle, DNA and RNA structure and metabolism, control of gene transcription during development, electron transport proteins and bioenergetics, biological catalysis, macromolecular structure, membrane proteins, and biotechnology and biomolecular engineering. More specific examples of biological phenomena currently under study include the transduction of signals received by cell surface receptors into an appropriate response, as in chemotaxis or transmission of signals across synapses in the nervous system; the replication of DNA; the biochemical networks that control initiation and termination of cell division; the controlled transcription of DNA sequences in the genome into RNA and the processing of this RNA into mRNA and the subsequent translation into protein; the molecular mechanisms controlling the differentiation of precursor cells into specialized cells such as neurons, lymphocytes, and muscle cells; the mechanisms by which synaptic transmission in the brain is regulated during thinking and the formation of memories; the processes, driven by fundamental principles of chemical bonding and molecular energetics, by which a given linear sequence of amino acids folds into a specific three-dimensional structure in the appropriate cellular environment; how electrons move within a cell to accomplish the many redox reactions necessary for life; how light is harvested by photopigments and is perceived in vision; the function of integral membrane proteins in energy and signal transduction processes; and the mechanisms by which enzymes both efficiently and specifically catalyze biochemical interconversions. This fundamental understanding of the molecular basis of biological processes provides a powerful base for the development of applications in