ASTRONOMY

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http://astronomy.yale.edu
M.S., M.Phil., Ph.D.

Chair
Priyamvada Natarajan

Director of Graduate Studies
Pieter van Dokkum (203.432.3000, pieter.vandokkum@yale.edu)

Professors Héctor Arce, Charles Bailyn, Charles Baltay (*Physics*), Sarbani Basu, Paolo Coppi, Pierre Demarque (*Emeritus*), Debra Fischer (*Emeritus*), Marla Geha, Larry Gladney (*Physics*), Jeffrey Kenney, Richard Larson (*Emeritus*), Priyamvada Natarajan, C. Megan Urry (*Physics*), William van Altena (*Emeritus*), Frank van den Bosch, Pieter van Dokkum, Robert Zinn

Associate Professors Reina Maruyama (*Physics*), Daisuke Nagai (*Physics*), Nikhil Padmanabhan (*Physics*)

Assistant Professor Earl Bellinger, Laura Newburgh (*Physics*), Chiara Mingarelli (*Physics*), Malena Rice

FIELDS OF STUDY

Fields include observational and theoretical astronomy, solar and stellar astrophysics, exoplanets, the interstellar medium and star formation, galactic astronomy, extragalactic astronomy, radio astronomy, high-energy astrophysics, and cosmology.

SPECIAL REQUIREMENTS FOR THE PH.D. DEGREE

A typical program of study includes twelve courses taken during the first four terms, and must include the core courses listed below:

The Physics of Astrophysics (ASTR 500), Computational Methods in Astrophysics and Geophysics (ASTR 520), Observational Astronomy (ASTR 555), Interstellar Matter and Star Formation (ASTR 560), either Stellar Populations (ASTR 510) or Stellar Astrophysics (ASTR 550), and either Galaxies (ASTR 530) or The Evolving Universe (ASTR 565). ASTR 620 or PHYS 678 may be substituted for ASTR 520 with the permission of the director of graduate studies (DGS).

Students require the permission of the instructor and the DGS to skip a core class if they think that they have sufficient knowledge of the field. Students will be required to demonstrate their knowledge of the field before they are allowed to skip any core class.

Two of the twelve courses must be research credits, each earned by working in close collaboration with a faculty member. Of the two research credits, one must be earned doing a theoretical research project and one doing an experimental research project. The students need to present the results of the project as a written report and will be given an evaluation of their performance.

The choice of the four remaining courses depends on the candidate's interest and background and must be decided in consultation with the DGS and/or the prospective thesis adviser. Advisers may require students to take particular classes and obtain a specified minimum grade in order for a student to work with them for their thesis. Students must take any additional course that their supervisors require even after their fourth term. In addition, all students, regardless of their term of study, have to attend Professional Seminar (ASTR 710 and ASTR 711) every term, unless registered in absentia. Students must also take Responsible Conduct in Research for Physical Scientists (PHYS 590), which discusses ethics and responsible conduct in scientific research and fulfills the requirement stipulated by the National Science Foundation for all students and for all postdoctoral researchers funded by the NSF. Note that ASTR 710, ASTR 711, and PHYS 590 may not be used to fulfill the twelve-course requirement.

Students are encouraged to take graduate courses in physics or related subjects. On an irregular basis, special topic courses and seminars are offered, which provide the opportunity to study some fields in greater depth than is possible in standard courses. To achieve both breadth and depth in their education, students are encouraged to take a few courses beyond their second year of study.

There is no foreign language requirement. A written comprehensive examination, normally taken at the end of the fourth term of graduate work, tests the student's familiarity with the entire field of astronomy and related branches of physics and mathematics. Particular attention will be paid to the student's performance in the field in which the student plans to do research. An oral examination, held a few weeks after the written examination, is based on the student's chosen field of research. Satisfactory performance in these examinations, an acceptable record in course and research work, and an approved dissertation prospectus are required for admission to candidacy for the Ph.D. degree. The dissertation should present the results of an original and thorough investigation, worthy of publication. Most importantly, it should reflect the candidate's capacity for independent research. An oral dissertation defense is required.

Teaching experience is an integral part of graduate education in astronomy. All students are required to serve as teaching fellows for four terms. Both the level of teaching assignments and the scheduling of teaching are variable and partly determined by the needs of the department. Most students will teach in each of their first three terms and complete their fourth teaching assignment sometime after the qualifying exam. Students who require additional support from the graduate school must teach additional terms, if needed, after they have fulfilled the academic teaching requirement.

HONORS REQUIREMENT

Students must earn a grade of Honors in at least three classes by the end of the fourth term of full-time study and have a grade average of High Pass or better.

MASTER'S DEGREES

M.Phil. Upon application, the department will recommend for the award of the M.Phil. degree any student who has completed all the requirements of the Ph.D. degree except the Ph.D. dissertation. These requirements include taking and passing the qualifying exam and submission of the research projects' final written reports (one for each of the two ASTR 580 projects).

M.S. Students who withdraw from the Ph.D. program may be eligible to receive the M.S. degree if they have met the requirements and have not already received the M.Phil. degree. For the M.S., students must successfully complete at least nine courses (not including ASTR 710 and ASTR 711) and at least one research project (ASTR 580). The student should have a grade average of High Pass in the courses and a grade of High Pass or above in the research project.

Program materials are available upon request to the Director of Graduate Studies, Department of Astronomy, Yale University, PO Box 208101, New Haven CT 06520-8101.

COURSES

ASTR 500a, The Physics of Astrophysics Sarbani Basu
Primarily for incoming students in the Ph.D. program in Astronomy. The basic physics and related mathematics needed to take the advanced graduate courses. Topics in mechanics, thermodynamics and statistical mechanics, fluid mechanics, special relativity, and electrodynamics with applications to astrophysical systems are covered. Open to undergraduates with permission of the instructor.

ASTR 518a, Stellar Dynamics Marla Geha
The study of dynamics in astronomy. Stellar dynamics attempts to answer what happens when a large number of particles (stars or galaxies) orbit under the influence of their mutual gravity. This course covers the dynamics of astronomical objects ranging from binary stars to globular clusters to galaxies. Particular emphasis is placed on direct applications to observational data.

ASTR 520a / EPS 538a, Computational Methods in Astrophysics and Geophysics Paolo Coppi
The analytic and numerical/computational tools necessary for effective research in astronomy, geophysics, and related disciplines. Topics include numerical solutions to differential equations, spectral methods, and Monte Carlo simulations. Applications are made to common astrophysical and geophysical problems including fluids and N-body simulations.

ASTR 530b, Galaxies Jeffrey Kenney
The structure and morphology of galaxies, stellar populations, interstellar media, star formation, central black holes, galaxy mergers, and galaxy properties as a function of environment.

ASTR 550b, Stellar Astrophysics Sarbani Basu
An introduction to the physics of stellar atmospheres and interiors. The basic equations of stellar structure, nuclear processes, stellar evolution, white dwarfs, and neutron stars.

ASTR 560b, Interstellar Matter and Star Formation Hector Arce
The composition, extent, temperature, and density structure of the interstellar medium (ISM). Excitation and radiative processes; the properties of dust; the cold and hot ISM in the Milky Way and other galaxies. Dynamics and evolution of the ISM, including interactions between stars and interstellar matter. Physics and chemistry of molecular clouds and the process of star formation.

ASTR 565a, The Evolving Universe Pieter van Dokkum
Overview of cosmic history from the formation of the first star to the present day, focusing on direct observations of the high-redshift universe.

ASTR 575b, Exoplanets Malena Rice
In recent years hundreds of exoplanets have been discovered orbiting around other stars. This course reviews the physics of planetary orbits, current exoplanet detection techniques, recent progress in characterizing exoplanet interiors and atmospheres, and the implications of these findings for our understanding of planet formation and evolution.

ASTR 580a or b, Research Staff
By arrangement with faculty.

ASTR 585a, Radio Astronomy Hector Arce
Introduction to radio astronomy, theory, and techniques. Includes radiation fundamentals, antenna theory, and an introduction to radio interferometry. Discussion of spectral line radio emission and of thermal and nonthermal radio emission mechanisms in the context of galactic and extragalactic astronomical observations.

ASTR 666a / AMTH 666a / EPS 666a / MATH 666a, Classical Statistical Thermodynamics John Wettlaufer
Classical thermodynamics is derived from statistical thermodynamics. Using the multi-particle nature of physical systems, we derive ergodicity, the central limit theorem, and the elemental description of the second law of thermodynamics. We then develop kinetics, the origin of diffusion, transport theory, and reciprocity from the linear thermodynamics of irreversible processes. Topics of focus include Onsager reciprocal relations, the Fokker-Planck and Cahn-Hilliard equations, stability in the sense of Lyapunov, time invariance symmetry and maximum principles. We explore phenomena cross a range of problems in science and engineering. Prerequisites for Yale College students: PHYS 301, PHYS 410, MATH 246 or similar and/or permission of instructor.

ASTR 710a and ASTR 711b, Professional Seminar Staff
A weekly seminar covering science and professional issues in astronomy.