Astronomy and Astrophysics

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Astrophysics deals with some of the most majestic themes known to science. Among these are the evolution of the universe from the Big Bang to the present day; the origin and evolution of planets, stars, galaxies, and the elements themselves; the unity of basic physical law; and the connection between the subatomic properties of nature and the observed macroscopic universe.

Three sequences of courses present the study of these topics in different scope and depth:

(1) PHSC 11900-12000-12700 is a two- or three-quarter sequence that satisfies the general education requirements in the physical sciences. The first two quarters cover the formation and evolution of stars, the galaxy, and the extragalactic universe; and the third quarter deals with the solar system. NTSC 10100-10200-10300-10400 is a four-quarter sequence that satisfies the general education requirements in physical sciences and biological sciences. NTSC 10200 deals with the evolution of the universe.

(2) For those seeking a more in-depth examination of selected astrophysical topics, astronomy courses numbered in the 18000s are offered, usually to be taken in the sophomore year or later. These courses are intended for students from throughout the College.

(3) For students considering graduate work in astrophysics, the Department of Astronomy and Astrophysics recommends the program leading to a degree of B.A. in Physics with Specialization in Astrophysics. For details, see the Physics section of this catalog. Tutorial and research courses are available in addition to more informal opportunities for work and study in the Department of Astronomy and Astrophysics. Participation in a weekly seminar on current topics in astrophysical research is also recommended.

Faculty

J. Carlstrom, J. Cronin, K. Cudworth, S. Dodelson, J. Frieman, D. Harper, Jr., L. Hobbs, W. Hu, S. Kent, E. Kibblewhite, E. Kolb, A. Königl, A. Kravtsov, R. Kron, D. Lamb, Jr., S. Meyer, T. Oka, A. Olinto, P. Palmer, C. Pryke, R. Rosner, N. Swerdlow, S. Swordy, J. Truran, M. Turner, P. Vandervoort, D. York

Courses: Astronomy and Astrophysics (ASTR)

18100. The Milky Way. (=PHSC 18100) *PQ: Any 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.* In this course we study what is known about our galaxy, the Milky Way. We discuss its size, shape, composition, location among its neighbors, motion, how it evolves, and where we are located within it, with an emphasis on how we know what we claim to know. *Not offered 2003-04; will be offered 2004-05.*

18200. The Origin and Evolution of the Universe. (=PHSC 18200) *PQ: Any 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.* This course discusses how the laws of nature allow us to understand the origin, evolution, and large-scale structure of the universe. After a review of the history of cosmology, we see how discoveries in the twentieth century (the expansion of the universe and the cosmic background radiation) form the basis of the hot Big Bang model. Within the context of the Big Bang, we learn how our universe evolved from the primeval fireball. *L. Hui. Autumn.*

18300. Searching Between the Stars. (=PHSC 18300) *PQ: Any 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.* With the advent of modern observational techniques such as radio and satellite astronomy, it has become possible to study free atoms, molecules, and dust in the vast space between the stars. The observation of interstellar matter provides information on the physical and chemical conditions of space and on the formation and evolution of stars. *D. Harper. Winter.*

18500. The Lives and Deaths of Stars. (=PHSC 18500) *PQ: Any 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.* In this course we study the observed properties of stars and the physics that enables us to understand them. Star formation, stellar evolution, and the deaths of stars are discussed. *This course is offered in alternate years. K. Cudworth. L: C. Pryke. Spring.*

20000. Tutorial in Astronomy and Astrophysics. *PQ: Any 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics. Class limited to six students. May be taken either for a letter grade or for* P/N *or* P/F. Students in this tutorial read topics in astronomy and astrophysics under the supervision of a faculty member. Students meet with the instructor in groups of one to three for approximately two hours per week to discuss readings on mutually agreed-upon topics. *Summer, Autumn, Winter, Spring.*

21300. Origin and Evolution of the Solar System. (=GEOS 21300) *PQ: Consent of instructor. Knowledge of physical chemistry helpful.* Representative topics include abundance and origin of the elements; formation, condensation, and age of the solar system; meteorites and the historical record of the solar system they preserve; comets and asteroids; the planets and their satellites; temperatures and atmospheres of the planets; and the origin of the Earth's lithosphere, hydrosphere, atmosphere, and biosphere. *L. Grossman. Winter. L.*

24100. The Physics of Stars and Stellar Systems. *PQ: PHYS 23400 or consent of instructor*. Building upon a student's previous knowledge of physics, this course introduces the astrophysics of stars and stellar systems with an emphasis on the physical nature of stars. Topics include the tools of astronomy, both observational and theoretical Hertzsprung-Russell diagrams, structure and evolution of stars, binary stars, star clusters, and end states of stars such as white dwarfs, neutron stars, and black holes. *A. Konigl. L: P. Palmer. Autumn.*

24200. The Physics of Galaxies and the Universe. *PQ: ASTR 24100 or consent of instructor*. Physical laws are applied in attempts to understand the structures and evolution of galaxies, quasars, clusters of galaxies, and the universe at large. *S. Dodelson. Winter.*

28000. Current Topics in Astrophysics. *PQ: ASTR 24100 and 24200, or consent of instructor*. An area of current research interest in astrophysics is explored in considerable detail. The topic varies, but some examples include the early universe, high energy astrophysics, magneto-hydrodynamics in astrophysics, observational cosmology, and cosmic microwave background. The topic for 2003-04 is the cosmic microwave background. *W. Hu. Spring.*

29700. Participation in Research. *PQ: Third- or fourth-year standing and consent of instructor and departmental counselor. Available for either* Pass *or letter grading. Students are required to submit the College Reading and Research Course Form. Students may register for this course for as many quarters as they wish; they need not work with the same faculty member each time*. Students are assigned to work in the research group of a member of the faculty. Participation in research may take the form of independent work on a small project or assistance to an advanced graduate student or faculty member in his or her research. *Summer, Autumn, Winter, Spring. L.*

Students with adequate preparation may register for the following graduate-level courses with the consent of the instructor:

30100-30200-30300-30400. Astrophysics I, II, III, IV. *PQ: Consent of instructor and a minimum of one year of physics. (Normally students should have completed or be enrolled concurrently in PHYS 33000-32200 or 34100-34200.)* This course is designed to provide a firm foundation in the principles of astrophysics (e.g., hydrostatic equilibrium of a self-gravitating object, radiative transfer, radiation from a diffuse gas) needed to carry out modern astrophysical research. Many astrophysical topics are discussed, but the emphasis is on elucidating general principles rather than attempting to survey the field. *Weekly seminar on current topics in astrophysical research required. Autumn, Winter, Spring.*

30500. Radiative Processes in Astrophysics. *PQ: Open to concentrators with advanced standing. ASTR 24200 and PHYS 22700, or consent of instructor*. The course deals with the fundamentals of radiative transfer. The basic physics of radiation fields is studied and applied to astrophysical systems. Emission and scattering processes and the theory of radiative transfer are discussed in the context of model stellar atmospheres. Radiation

processes important to astrophysics, such as Bremsstrahlung, cyclotron and synchrotron radiation, Compton scattering, and atomic and molecular transitions are covered, with an emphasis on their observational manifestations (e.g., spectra, polarization properties). *W. Hu. Autumn.*

30600. Radiation Measurements and Instrumentation in Astrophysics. *PQ: Consent of instructor.* Topics discussed include radiation as a random process, optical coherence, and signal analysis in spatial and temporal domains, along with the detection and measurement of radiation with astronomical instruments. *J. Carlstrom. Winter.*

31300. Extragalactic Studies. *PQ: Consent of instructor.* Topics include galaxies and intergalactic space, determination of Hubble's law, and peculiar extragalactic objects such as radio galaxies, Seyfert galaxies, and quasars. *Not offered 2003-04; will be offered 2004-05.*

31500. Dynamics I (Fluids). *PQ: Consent of instructor.* This course examines the principles of hydrodynamics and hydromagnetics. Topics also include equilibrium and stability of fluid systems in astrophysics, waves, shocks, and turbulence. *Not offered 2003-04; will be offered 2004-05.*

31600. Dynamics II (Particles). *PQ: Consent of instructor.* This course examines the dynamics of collisionless plasmas and stellar systems. Stochastic processes and kinetic equations, dynamics of galaxies and star clusters, and astrophysical plasmas are explored. *This course is offered in alternate years. A. Königl. Winter.*

32000. Relativistic Astrophysics. *PQ: Consent of instructor.* This course covers topics in special relativity, as well as the general theory of relativity and its experimental tests, with applications to astrophysical problems such as super-massive stars, black holes, relativistic star clusters, and gravitational radiation. *Not offered 2003-04; will be offered 2004-05.*

32100. Cosmology. *PQ: Consent of instructor.* The standard Big Bang cosmological model, together with its tests and a discussion of nonstandard models, is covered. Topics include the Robertson-Walker metric, the 3K background, Big Bang nucleosynthesis, the determination of the age of the universe, and galaxy formation, as well as other current problems in cosmology. *Not offered 2003-04; will be offered 2004-05.*

34000. Statistical Methods in Astrophysics. *PQ: Consent of instructor.* This course explores the variety of statistical methods used in modern astrophysics. *This course is offered in alternate years. J. Frieman. Spring.*

36100. Interstellar Medium. *PQ: Consent of instructor.* Topics covered include the physics of interstellar gas, emission nebulae, HI regions, interstellar grains and molecules, and cosmic rays and the interstellar magnetic field. *This course is offered in alternate years. D. York. Autumn.*

38300. Astronomy in Antiquity. (=CFSC 35600, HIPS 28000) *PQ: Consent of instructor.* This is an introductory course on the most important astronomy of antiquity, that is, Babylonian observational and mathematical astronomy preserved in cuneiform tablets and Ptolemy's observational and

mathematical astronomy preserved in the *Almagest* and the *Planetary Hypotheses*. *N. Swerdlow. Winter.*

Other courses of interest:

PHSC 11900-12000-12700. Introduction to Astrophysics. *Autumn, Winter, Spring.*

PHYS 29100-29200-29300. Bachelor's Thesis. *PQ: Open to concentrators with fourth-year standing and consent of instructor.* This yearlong sequence is designed to involve the student in current research. The student works on a research project in physics or a closely related field, such as astrophysics, leading to the writing of a bachelor's thesis. The project may be one suggested by the instructor, or one proposed by the student and approved by the instructor. *Autumn, Winter, Spring.*