

Astronomy and Astrophysics

Department Website: <http://astro.uchicago.edu>

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.

Program of Study

The Department of Astronomy and Astrophysics offers several courses that satisfy the general education requirement in the physical sciences. The six courses numbered in the 12000s present many options for choosing coherent two- or three-quarter sequences across a range of foundational topics, from the grand principles governing the universe and understanding its beginning, to the formation and evolution of stars and galaxies, and the search for habitable extrasolar planets. The courses include labs for engaging in astronomical inquiry through classical experiments, opportunities for telescope observing, and data analysis. Quantitative analysis will be an important part of these courses; however, any tools needed beyond pre-calculus algebra will be taught as needed.

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

Minor in Astronomy and Astrophysics

Non-science majors may pursue extended exploration of astronomical phenomena to complete the minor in Astronomy and Astrophysics. Students are allowed flexibility in selecting five courses to compose a rigorous program of study according to individual interest, with the requirement that their selection include at least two courses numbered in the 12000s and at least one in the 18000s. It is possible for a student pursuing the minor to substitute ASTR 29700 Participation in Research for one course numbered in the 18000s, if the student is able to make a suitable arrangement with a faculty member who agrees to supervise this effort.

There are no physics or math prerequisites for the minor. Students must meet with the academic affairs administrator before the end of Spring Quarter of their third year to declare their intention to complete the minor and fill out the College's Consent to Complete a Minor (http://college.uchicago.edu/sites/college.uchicago.edu/files/Consent_Minor_Program.pdf) form. Courses taken to satisfy the general education requirement in the physical sciences may not be counted towards the minor.

Courses counted toward the minor must be taken for quality grades (no P/F grading).

Sample Program for the Minor

ASTR 12700	Stars	100
ASTR 12710	Galaxies	100
ASTR 12720	Exoplanets	100
ASTR 18100	The Milky Way	100
ASTR 18200	The Origin and Evolution of the Universe	100
Total Units		500

Students who satisfy their general education requirement in the physical sciences in Astronomy and Astrophysics may pursue the minor through completing the remaining courses numbered in the 12000s and at least one in the 18000s.

Sample Program

(when general education requirement in the physical sciences is taken in Astronomy and Astrophysics)

ASTR 12600	Matter, Energy, Space, and Time	100
ASTR 12620	The Big Bang	100
ASTR 12700	Stars	100
ASTR 12610	Black Holes	100
ASTR 18200	The Origin and Evolution of the Universe	100
Total Units		500

Study Abroad Program

Every Spring Quarter a three-course Astronomy program is offered in Paris, composed from the courses numbered in the 12000s that are offered on campus. This sequence is designed for non-science majors but may also be of interest to science majors who want to supplement their work in physics and chemistry with a quarter devoted to the cosmos.

The Astronomy program in Paris satisfies the general education requirement in the physical sciences. Students who have already completed their general education requirement in the physical sciences may count the three courses taken in

Paris toward the five required to satisfy the minor in Astronomy and Astrophysics. For details, see the Study Abroad (<https://study-abroad.uchicago.edu>) page for Paris: Astronomy (<http://study-abroad.uchicago.edu/programs/paris-astronomy>).

Specialization in Astrophysics

The program leading to a BA in physics with a specialization in astrophysics is a variant of the BA in physics. The degree is in physics, with the designation "with specialization in astrophysics" included on the final transcript. Candidates are required to complete all requirements for the BA degree in physics, plus three courses in astrophysics (selected from ASTR 23900 The Physics of Galaxies, ASTR 24100 The Physics of Stars, ASTR 24300 Cosmological Physics, ASTR 25400 Radiation Processes in Astrophysics, ASTR 28200 Current Topics in Astrophysics), or two courses in astrophysics plus a senior thesis project in physics (PHYS 29100-29200-29300 Bachelor's Thesis) on a topic in astrophysics. If the latter option is chosen, the thesis topic must be approved by the program chair. (This thesis may simultaneously fulfill part of the requirements for honors in physics.) A grade of at least C- must be obtained in each course.

For details on the specialization in astrophysics, see the Physics section of this catalog.

Astronomy and Astrophysics Courses

ASTR 12600. Matter, Energy, Space, and Time. 100 Units.

This course is a comprehensive survey of how the physical world works, and how matter, energy, space, and time evolved from the beginning to the present. We will explore current theories of the evolution of the Universe and see how these four concepts give us remarkable insight into how our world came to be. Beginning with a brief survey of the historical development of mathematics, physics, and astronomy, we then focus on the modern theory of the physical universe, space and time in relativity, the quantum theory of matter and energy, and the evolution of cosmic structure and composition. The lab component for the class will be aimed at understanding some of the tools astronomers and physicists have used to make the observations that led to our picture of the Universe. Although quantitative analysis will be an important part of the course, students will not be expected to employ mathematics beyond algebra. (L)

Instructor(s): S. Meyer Terms Offered: Autumn

Note(s): Approved Sequences Warning! PHSC 12600 can only be combined as follows to form an approved PHSC sequence: PHSC 12600-12610, PHSC 12600-12620, PHSC 12600-12700, or PHSC 12600-12710.

Equivalent Course(s): PHSC 12600

ASTR 12610. Black Holes. 100 Units.

Black holes are the most exotic, extreme and paradoxical systems in the universe. They are the densest concentrations of energy, yet they convert all matter that falls in to a pure vacuum with extreme space-time curvature; they radiate more power than anything else, even though most of their radiation may not even be made of light; they are mathematically the most perfectly understood of any physical structure, but their enigmatic behavior is still the subject of a disagreement, even among experts, that highlights our ignorance of how quantum physics relates to gravity. This course will survey the physics of space and time, the nature of black holes, their effects on surrounding matter and light, the astrophysical contexts in which they are observed, and their importance in such frontier areas of research as quantum gravity and gravitational waves. Quantitative analysis will be an important part of the course, but mathematics beyond algebra will not be required. (L)

Instructor(s): C. Hogan Terms Offered: Winter

Prerequisite(s): PHSC 12600 or PHSC 12700. Prerequisites are required when the course is to be taken as part of an approved sequence to satisfy the PHSC general education requirement. If the course is to be taken as an elective, the prerequisite is recommended but not required.

Note(s): Approved Sequences Warning! PHSC 12610 can only be combined as follows to form an approved PHSC sequence: PHSC 12600-12610 or PHSC 12700-12610.

Equivalent Course(s): PHSC 12610

ASTR 12620. The Big Bang. 100 Units.

How old is the universe? How big is it? What is it made of? Why is there a universe? Will it last forever? Are there other universes? These questions have been asked for millennia. The answers involve our modern theory for the origin of the universe, The Big Bang, a model that can account for much of what we observe. It provides a framework for understanding the last 14 billion years over which our Universe expanded, cooled, and evolved from the simple, formless fog of the primordial soup, into a universe of galaxies, stars, planets, people, poodles, protozoa, pond scum, and politicians. The course will explore the history of scientific cosmology and the evidence for the Big Bang model, its consequences for the earliest moments after the Big Bang, and its predictions for the eventual fate of the Universe. Quantitative analysis will be an important part of the course, but prior experience with mathematics beyond algebra will not be required. (L)

Instructor(s): M. Turner Terms Offered: Spring

Prerequisite(s): PHSC 12600 must be taken before PHSC 12620 to form an approved sequence that will satisfy the PHSC general education requirement. If the course is to be taken as an elective, the prerequisite is recommended but not required.

Note(s): Approved Sequences Warning! PHSC 12620 can only be combined as follows to form an approved PHSC sequence: PHSC 12600-12620.

Equivalent Course(s): PHSC 12620

ASTR 12700. Stars. 100 Units.

Elements such as carbon and oxygen are created in fusion reactions at high temperatures and pressures in the deep interiors of stars, conditions that naturally arise in stars like the Sun. This course will outline the physical principles at work and the history of the development of key ideas: how nuclear physics and the theory of stellar interiors account for how stars shine, why they live for such long times, and how the heavy elements in their cores are dispersed to seed a new generation of stars. Gravity assembles stars out of more diffuse material, a process that includes the formation of planetary systems. The course shows how, taken together, these physical processes naturally lead to the ingredients necessary for the emergence of life. The course features quantitative analysis of data; any tools needed beyond pre-calculus algebra will be taught as part of the course. (L)

Instructor(s): D. Fabrycky Terms Offered: Autumn

Note(s): Approved Sequences Warning! PHSC 12700 can only be combined as follows to form an approved PHSC sequence: PHSC 12700-12710, PHSC 12700-12720 or PHSC 12700-12610.

Equivalent Course(s): PHSC 12700

ASTR 12710. Galaxies. 100 Units.

Galaxies have been called "island universes," places where stars are concentrated, where they are born, and where they die. These collections of stars, gas, and dust form much of the visible structures in the Universe. Using extensive modern observational data from a wide range of telescopes, we will trace the modern understanding of the formation and evolution of galaxies and the stars in them. Galaxies will then be used as markers of yet larger-scale structures, in order to examine the influence of gravity over cosmic time. Our explorations will highlight the profound discovery that most of the mass in galaxies (and the Universe as a whole) is in fact an exotic form of matter—dark matter—that we cannot directly see. Observationally oriented labs will allow students to directly experience how some of the modern understanding of galaxies has arisen. Quantitative analysis will be an important part of the course in both laboratory work and lectures, but mathematics beyond algebra and some geometric understanding will not be required. (L)

Instructor(s): M. Gladders Terms Offered: Winter

Prerequisite(s): PHSC 12600 or PHSC 12700 must be taken before PHSC 12710 to form an approved sequence that will satisfy the PHSC general education requirement. If the course is to be taken as an elective, the prerequisite is recommended but not required.

Note(s): Approved Sequences Warning! PHSC 12710 can only be combined as follows to form an approved PHSC sequence: PHSC 12600-12710, PHSC 12700-12710 or PHSC 12710-12720.

Equivalent Course(s): PHSC 12710

ASTR 12720. Exoplanets. 100 Units.

The past two decades have witnessed the discovery of planets in orbit around other stars and the characterization of extra-Solar (exo-) planetary systems. We are now able to place our Solar System into the context of other worlds and a surprising conclusion that most planetary systems look nothing like our own. A challenging next step is to find planets as small as the Earth in orbit around stars like the Sun. The architecture of planetary systems reflects the formation of the parent star and its protoplanetary disk, and how these have changed with time. This course will review the techniques for discovery of planets around other stars, what we have learned so far about exoplanetary systems, and the driving questions for the future, including the quest for habitable environments elsewhere. Although quantitative analysis will be an important part of the course, students will not be expected to employ mathematics beyond algebra. (L)

Instructor(s): L. Rogers Terms Offered: Spring

Prerequisite(s): PHSC 10800, PHSC 10100, PHSC 12700 or PHSC 12710 must be taken before PHSC 12720 to form an approved sequence that will satisfy the PHSC general education requirement. If PHSC 12720 is to be taken as an elective, the prerequisite is recommended but not required.

Note(s): Approved Sequences Warning! PHSC 12720 can only be combined as follows to form an approved PHSC sequence: PHSC 12700-12720, PHSC 12710-12720, PHSC 10800-12720 or PHSC 10100-12720.

Equivalent Course(s): PHSC 12720

ASTR 18100. The Milky Way. 100 Units.

Within a largely empty universe, we live in a vast stellar "island" that we call the Milky Way. As we survey the stellar and interstellar components of the Milky Way—the distribution and motions of stars and interstellar gas, and how these dynamic, ever-changing components interact with each other during their life cycles inside the Milky Way—we will follow the path of ancient astronomers, wonder at their mistakes and prejudices, and form our own understanding.

Instructor(s): N. Gnedin Terms Offered: Autumn

Prerequisite(s): Any two-course 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.

Equivalent Course(s): PHSC 18100

ASTR 18200. The Origin and Evolution of the Universe. 100 Units.

This course provides a comprehensive introduction to modern cosmology for students wishing to delve deeper into the subject than PHSC 12620 (which is not a prerequisite) but at a similar mathematical level. It will discuss how the fundamental laws of physics allow us to understand the origin, evolution, and large-scale structure of the universe. After a brief review of the history of cosmology, the course will cover the expansion of the universe, Newtonian cosmology, Einstein's Special and General Relativity, black holes, dark matter, dark energy, the Cosmic Microwave Background radiation, Big Bang nucleosynthesis, the early universe, primordial inflation, the origin and evolution of large-scale structure in the universe, and cosmic surveys that are probing inflation and cosmic acceleration.

Instructor(s): Josh Frieman Terms Offered: Winter

Prerequisite(s): Any two-course 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.

Equivalent Course(s): PHSC 18200

ASTR 18300. Searching Between the Stars. 100 Units.

With the advent of modern observational techniques (e.g., radio, 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.

Instructor(s): D. Harper Terms Offered: TBD

Prerequisite(s): Any two-course 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.

Equivalent Course(s): PHSC 18300

ASTR 18400. Origins: From the Big Bang to Human Consciousness. 100 Units.

In this course we will look at the approaches to, data for, and theories of the big transitions in the evolution of the physical universe and the living world.

Instructor(s): Wendy Freedman and Neil Shubin Terms Offered: Spring

Prerequisite(s): Any two-course 10000-level general education sequence in the Physical or Biological Sciences, or instructor consent. Not intended for STEM majors.

Note(s): This course will be cross-listed with BIOS. A fuller course description and complete cross-listing information will be available shortly.

ASTR 18800. Philosophical Problems in Cosmology. 100 Units.

In this course, we will undertake a comparison of the philosophical underpinnings of the Aristotelian and Copernican cosmologies, including a comparison of mechanistic and teleological approaches to the natural world. The epistemological foundations of the scientific method, in particular as applied to cosmology (from Galileo to the modern context) will be examined, as will positivist vs. realistic outlooks on cosmology. (For example, what does science say—or not say—about the inside of a black hole, or the space beyond the Hubble horizon?) We will ponder questions such as: *Do the epistemological foundations of science require us to be able to repeat relevant experiments? If so, does this disqualify cosmology as a science? If not, why? Might our universe be part of a computer simulation? What information could possibly convince us that this is true or false?*

Instructor(s): Dan Hooper Terms Offered: Spring

Prerequisite(s): Any two-course 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.

Equivalent Course(s): PHSC 18800

ASTR 21200. Observational Techniques. 100 Units.

This course will prepare students in methods that will be used in their independent research by introducing observation and analysis techniques in a field of astrophysics chosen by the instructor. Students will learn basics of astronomical instrumentation and will apply that knowledge in a practical context (for example, using an on-campus telescope or telescopes controlled robotically from campus). The process of data reduction and calibration will be illustrated, leading to the extraction of scientifically meaningful results.

Instructor(s): Doyal A. Harper Terms Offered: Spring

Prerequisite(s): PHYS 15400 or by consent of instructor.

ASTR 21300. Origin and Evolution of the Solar System. 100 Units.

This course will explore the formation and evolution of the Solar System, from the collapse of the natal molecular cloud core to the orbital restructuring of the planets. Topics to be covered include: structure and evolution of the solar nebula, dust dynamics in the solar nebula and the formation of planetesimals, accretion of the terrestrial planets, giant planet formation and migration, and meteorites and the historical record of the Solar System they preserve. (L)

Instructor(s): F. Ciesla Terms Offered: Winter

Prerequisite(s): At least one year of physics or chemistry and an understanding of multivariate calculus.

Note(s): This course is offered in alternate years.

Equivalent Course(s): GEOS 32000, GEOS 22000

ASTR 23900. The Physics of Galaxies. 100 Units.

This course will provide a comprehensive introduction to galaxies and the interstellar medium and will examine the physical processes involved in their structure and evolution. Topics will include the stellar content of galaxies and the dynamics of stars within galaxies, the physical state of the interstellar medium, central supermassive black holes and power generation in active galactic nuclei, what can be learned about the distribution of mass from gravitational lensing, and processes that shape the relative distributions of dark matter and baryonic matter.

Instructor(s): Hsiao-Wen Chen Terms Offered: Autumn

Prerequisite(s): PHYS 15400

ASTR 24100. The Physics of Stars. 100 Units.

This course develops the physical theory of the internal structure of stars and how their structure changes with time. The material illustrates how to build model stars based on these physical principles and covers observational constraints on these models, such as the neutrino flux from the core of the Sun. Topics include supernovae and the end states of stars—white dwarfs, neutron stars, and black holes.

Instructor(s): Robert Rosner Terms Offered: Winter

Prerequisite(s): PHYS 15400. PHYS 19700 recommended.

ASTR 24200. The Physics of Galaxies and the Universe. 100 Units.

Physical laws are applied in the study of the structures and evolution of galaxies, quasars, clusters of galaxies, and the universe at large.

Instructor(s): Staff Terms Offered: TBD. Not offered in 2017-18

Prerequisite(s): Students taking the Specialization in Astrophysics who have completed ASTR 24100 may substitute ASTR 23900, ASTR 24300, ASTR 25400 or ASTR 28200 to complete their minimum two-course requirement.

ASTR 24300. Cosmological Physics. 100 Units.

This course will provide a comprehensive introduction to the principal topics in cosmology, including theoretical and observational foundations. Key topics will include the expansion of the Universe, dark matter and energy, cosmic microwave background, hot Big Bang, and the origin and evolution of structure.

Instructor(s): Wayne Hu Terms Offered: Spring

Prerequisite(s): PHYS 15400

ASTR 25400. Radiation Processes in Astrophysics. 100 Units.

Most of what we know about the Universe comes from detection of electromagnetic radiation emitted by individual sources or by diffuse media. #Once we understand the processes by which the radiation was created and the processes by which the radiation is scattered or modified as it passes through matter, we can address the physical nature of the sources. #The physics of radiation processes includes electricity and magnetism; quantum mechanics and atomic and nuclear structure; statistical mechanics; and special relativity.

Instructor(s): Damiano Caprioli Terms Offered: Autumn

Prerequisite(s): PHYS 15400. PHYS 19700 recommended.

ASTR 25800. Astrophysics of Exoplanets. 100 Units.

Extrasolar planets, a.k.a. exoplanets, are planets orbiting other stars. First definitively detected in the mid 1990s, the planet count has rapidly expanded and their physical characterization has sharpened with improved observational techniques.

Theoretical studies of planetary formation and evolution are now attempting to understand this statistical sample. The field also aspires to address questions about life in the universe. This course emphasizes hands-on activities, like working with real astronomical data to find and characterize exoplanets. Topics are the radial velocity, transit, and other discovery and characterization techniques; statistical distributions of known planets; comparisons among planet structure and planetary system types; formation in a protoplanetary disk and subsequent dynamical evolution; the goal of finding life on an exoplanet; colonization of exoplanets; and the Fermi paradox.

Instructor(s): Dan Fabrycky Terms Offered: TBD

Prerequisite(s): PHYS 15400, or consent of instructor. Recommended for third- and fourth-year students majoring in Physics or the Geophysical Sciences, or students who have completed two quarters of Calculus.

ASTR 28200. Current Topics in Astrophysics. 100 Units.

This advanced course presents the forefront research and interests of a member of the Astronomy & Astrophysics faculty, with instructors and topics changing annually.

Instructor(s): Erik Shirokoff Terms Offered: Winter

Prerequisite(s): PHYS 15400. Recommended for third- and fourth-year students majoring in Physics or the Geophysical Sciences, or students who have completed two quarters of Calculus.

ASTR 29700. Participation in Research. 100 Units.

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.

Instructor(s): R. Kron Terms Offered: Autumn, Spring, Winter

Prerequisite(s): Third- or fourth-year standing and consent of instructor and departmental counselor.

Note(s): Students must arrange with instructor in advance of the start of the term. Students are required to submit the College Reading and Research Course Form. Available for either quality grades or for P/F grading. Students may register for this course for as many quarters as they wish; they need not work with the same faculty member each time.



Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

Times was used instead of Trajan.

Times was used instead of Palatino.

The editor may contact Leepfrog for a draft with the correct fonts in place.