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

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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>ASTR 12700</td>
<td>Stars</td>
<td>100</td>
</tr>
<tr>
<td>ASTR 12710</td>
<td>Galaxies</td>
<td>100</td>
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<tr>
<td>ASTR 12720</td>
<td>Exoplanets</td>
<td>100</td>
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<tr>
<td>ASTR 18100</td>
<td>The Milky Way</td>
<td>100</td>
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<tr>
<td>ASTR 18200</td>
<td>The Origin and Evolution of the Universe</td>
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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)

<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Credits</th>
</tr>
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<tbody>
<tr>
<td>ASTR 12600</td>
<td>Matter, Energy, Space, and Time</td>
<td>100</td>
</tr>
<tr>
<td>ASTR 12620</td>
<td>The Big Bang</td>
<td>100</td>
</tr>
<tr>
<td>ASTR 12700</td>
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<td>ASTR 12610</td>
<td>Black Holes</td>
<td>100</td>
</tr>
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<td>ASTR 18200</td>
<td>The Origin and Evolution of the Universe</td>
<td>100</td>
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Study Abroad Program

Every Spring Quarter a three-course Astronomy program is offered in Paris, composed from the six 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

For students considering graduate work in astrophysics, the Department of Astronomy and Astrophysics recommends the program leading to a degree of BA in physics with a specialization in astrophysics. Students are required to complete all requirements for the BA degree in physics, plus a two-quarter sequence in astrophysics of ASTR 24100 The Physics of Stars and Stellar Systems and ASTR 24200 The Physics of Galaxies and the Universe. Additionally, students complete a third course, either ASTR 28200 Current Topics in Astrophysics or a year-long sequence PHYS 29100 Bachelor's Thesis in physics.
Tutorial and research courses (ASTR 20000 Tutorial in Astronomy and Astrophysics and ASTR 29700 Participation in Research) 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.

For details on the specialization in astrophysics, see the Physics (http://collegecatalog.uchicago.edu/thecollege/physics) section of this catalog.

Astronomy and Astrophysics Courses

**ASTR 12600. Matter, Energy, Space, and Time. 100 Units.**
A comprehensive survey of how the physical world works, and how matter, energy, space, and time evolved from the beginning to the present. A brief survey of the historical development of mathematics, physics, and astronomy leads to a conceptual survey of 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 major theme of this course is the understanding of all nature, from the prosaic to the exotic, using powerful quantitative theory grounded in precise experiments. 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
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 mathematically the most perfectly understood of any physical structure, but their enigmatic behavior is still the subject of a violent disagreement among experts. 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, frontier areas of research such as quantum gravity and gravitational waves, and the importance of space-time physics to everyday needs such as navigation and energy. The modern theory of space and time, as well as black holes, will be placed in historical context, with special attention to the work of Albert Einstein. Quantitative analysis will be an important part of the course, but mathematics beyond algebra will not be required. (L)
Instructor(s): E. Shirokoff 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 requirements. If the course is to be taken as an elective, prerequisite requirements are not required.
Equivalent Course(s): PHSC 12610
**ASTR 12620. The Big Bang. 100 Units.**
The Big Bang model describes the Universe on the largest scales and its evolution from the earliest observationally accessible times through the formation of the complex world we live in today. The key motivating observations include the expansion of the Universe and how it has changed with time; the existence of radiation indicating a hot and dense early phase; the abundance of the light elements; and how matter is organized over a wide range of physical scales. 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): W. Freedman/E. Kolb
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 requirements. If PHSC 12620 is to be taken as an elective, the prerequisite is not required.
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 the 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 form 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, namely elements like carbon, nitrogen, and oxygen, and planets in stable orbits around long-lived stars. 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
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. The study of galaxies reaches back to the Renaissance; Galileo Galilei first pointed a telescope skyward in 1610 and confirmed a then–2,000-year-old Greek conjecture about the nature of our own galaxy—the Milky Way. This course will use extensive modern observational data from a wide range of telescopes to trace the modern picture for 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 explore the influence of gravity over cosmic time. The object of study in this course is galaxies, and the narrative arc traced through that extensive data and understanding will highlight our 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. 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. This course will feature several observationally oriented labs that will allow students to directly experience how some of the modern understanding of galaxies has arisen. (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 requirements. If PHSC 12710 is to be taken as an elective, the prerequisite is not required.

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): J. Bean

Terms Offered: Spring

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

Equivalent Course(s): PHSC 12720
ASTR 18100. The Milky Way. 100 Units.
The Sun and its planetary system is part of a larger hierarchical structure, a flattened disk of stars called the Milky Way that provides an environment for the birth of new stars, seeded by the deaths of other stars. The Milky Way is thus a dynamic system in several senses of the word. This course will survey the stellar and interstellar components of the Milky Way, the distribution in space and motions of the stars and the interstellar gas, how these components interact with each other, and how the whole system evolves.
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 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 (i.e., 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.
Instructor(s): M. Turner 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 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 18500. The Lives and Deaths of Stars. 100 Units.
In this course we study the observed properties of stars and the physics that enable us to understand them. Star formation, stellar evolution, and the deaths of stars are discussed.
Terms Offered: Not Offered 2016-2017
Prerequisite(s): Any two-course 1000-level general education sequence in chemistry, geophysical sciences, physical sciences or physics
Equivalent Course(s): PHSC 18500
ASTR 20000. Tutorial in Astronomy and Astrophysics. 100 Units.
Students in this tutorial read topics in astronomy and astrophysics under the supervision of a faculty member. Instructors meet with one to three students for approximately two hours each week to discuss readings on topics they choose together.
Instructor(s): R. Kron Terms Offered: Autumn, Winter, Spring
Prerequisite(s): Any 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.
Note(s): Students must arrange with instructor in advance of the start of the term. Class limited to six students. Available for either quality grades or for P/F grading.

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 24100. The Physics of Stars and Stellar Systems. 100 Units.
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 (e.g., white dwarfs, neutron stars, black holes). (L)
Instructor(s): A. Königl Terms Offered: Autumn
Prerequisite(s): PHYS 23400 or consent of instructor.

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): H. Chen Terms Offered: Winter
Prerequisite(s): ASTR 24100 or consent of instructor.

ASTR 28200. Current Topics in Astrophysics. 100 Units.
This course explores in considerable detail an area of current research interest in astrophysics. The topic varies, but recent examples include the early universe, high-energy astrophysics, magneto-hydrodynamics in astrophysics, and observational cosmology.
Instructor(s): D. Fabrycky Terms Offered: Spring
Prerequisite(s): ASTR 24100 and 24200, or consent of instructor.
Note(s): Recommended for third- and fourth-year students majoring in Physics or the Geophysical Sciences, or students who have completed two quarters of Calculus.
Equivalent Course(s): ASTR 38200
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, Winter, Spring

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.