ASTROPHYSICAL AND PLANETARY SCIENCES

The Department of Astrophysical and Planetary Sciences is one of the few programs that combines both astrophysics and planetary science, providing a unified view of space sciences, the solar system and comparative planetology, stellar and galactic astronomy, and cosmology. Students are given hands-on experience with telescopes, optics, instrumentation, and computer-image processing and modeling.

For further information concerning undergraduate studies, contact the undergraduate program assistant.

Course code for this program is ASTR.

Bachelor's Degree

- Astronomy - Bachelor of Arts (BA) (catalog.colorado.edu/undergraduate/colleges-schools/arts-sciences/programs-study/astrophysical-planetary-sciences/astronomy-bachelor-arts-ba)

Minor

- Astronomy - Minor (catalog.colorado.edu/undergraduate/colleges-schools/arts-sciences/programs-study/astrophysical-planetary-sciences/astronomy-minor)

Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Armitage, Philip J.
Professor; PhD, University of Cambridge (England)

Ayres, Thomas R. (https://experts.colorado.edu/display/fisid_100090)
Research Professor; PhD, University of Colorado Boulder

Baker, Daniel N. (https://experts.colorado.edu/display/fisid_103264)
Distinguished Professor; PhD, University of Iowa

Bally, John (https://experts.colorado.edu/display/fisid_105710)
Professor; PhD, University of Massachusetts at Amherst

Barth, Charles A.
Professor Emeritus

Begelman, Mitchell C. (https://experts.colorado.edu/display/fisid_100446)
Professor; PhD, University of Cambridge (England)

Berta-thompson, Zachory (https://www.colorado.edu/aps/zachory-berta-thompson)
Assistant Professor; PhD, Harvard University

Brain, David A. (https://experts.colorado.edu/display/fisid_149098)
Associate Professor; PhD, University of Colorado Boulder

Brown, Benjamin P. (https://experts.colorado.edu/display/fisid_153758)
Assistant Professor; PhD, University of Colorado Boulder

Burns, Jack O. (https://experts.colorado.edu/display/fisid_124317)
Professor; PhD, Indiana University Bloomington

Cash, Webster C. Jr. (https://experts.colorado.edu/display/fisid_101759)
Professor; PhD, University of California, Berkeley

Comerford, Julia M. (https://experts.colorado.edu/display/fisid_151471)
Associate Professor; PhD, University of California, Berkeley

Conti, Peter S.
Professor Emeritus

Cranmer, Steven (https://experts.colorado.edu/display/fisid_155051)
Associate Professor; PhD, University of Delaware

Danforth, Charles W. (https://experts.colorado.edu/display/fisid_130779)
Instructor

Darling, Jeremiah K. (https://experts.colorado.edu/display/fisid_141767)
Associate Professor; PhD, Cornell University

Dulk, George A.
Professor Emeritus

Duncan, Douglas K. (https://experts.colorado.edu/display/fisid_126824)
Senior Instructor

Ellingson, Erica (https://experts.colorado.edu/display/fisid_100118)
Associate Professor; PhD, University of Arizona

Ergun, Robert E. (https://experts.colorado.edu/display/fisid_115912)
Professor; PhD, University of California, Berkeley

Esposito, Larry Wayne (https://experts.colorado.edu/display/fisid_100502)
Professor; PhD, University of Massachusetts at Amherst

France, Kevin Christopher (https://experts.colorado.edu/display/fisid_145201)
Assistant Professor; PhD, Johns Hopkins University

Glenn, Jason (https://experts.colorado.edu/display/fisid_115556)
Professor; PhD, University of Arizona

Green, James C. (https://experts.colorado.edu/display/fisid_102344)
Professor; PhD, University of California, Berkeley

Halverson, Nils W. (https://experts.colorado.edu/display/fisid_134252)
Professor; PhD, California Institute of Technology

Hamilton, Andrew J.S. (https://experts.colorado.edu/display/fisid_101517)
Professor, Chair; PhD, University of Virginia

Hindman, Bradley W. (https://experts.colorado.edu/display/fisid_103726)
Associate Research Professor, Lecturer; PhD, University of Colorado Boulder

Hornstein, Seth D. (https://experts.colorado.edu/display/fisid_144237)
Senior Instructor; PhD, University of California, Los Angeles

Kowalski, Adam (https://www.colorado.edu/aps/adam-kowalski)
Assistant Professor; PhD, University of Washington

Linsey, Jeffrey
Professor Emeritus

Madigan, Ann-Marie (https://experts.colorado.edu/display/fisid_158298)
Assistant Professor; PhD, Leiden University, The Netherlands
Malville, J. McKim  
Professor Emeritus  

McCray, Richard A.  
Professor Emeritus  

Rast, Mark Peter (https://experts.colorado.edu/display/fisid_142997)  
Associate Professor; PhD, University of Colorado Boulder  

Schneider, Nicholas M. (https://experts.colorado.edu/display/fisid_102620)  
Professor; PhD, University of Arizona  

Shull, J Michael (https://experts.colorado.edu/display/fisid_103350)  
Professor; PhD, Princeton University  

Snow, Theodore P. Jr  
Professor Emeritus  

Speiser, Theodore W.  
Professor Emeritus  

Stocke, John T.  
Professor Emeritus; PhD, University of Arizona  

Thomas, Gary E.  
Professor Emeritus  

Toomre, Juri (https://experts.colorado.edu/display/fisid_100767)  
Professor; PhD, University of Cambridge (England)  

Courses  

ASTR 1000 (3) The Solar System  
Introduction to the night sky, planets, moons and the life in our solar system. Highlights the latest discoveries from space. For non-science majors. Some lectures may be held at Fiske Planetarium. Offers opportunities for nighttime observations at Sommers-Bausch Observatory.  

Equivalent - Duplicate Degree Credit Not Granted: ASTR 1010, but without lab  
ASTR 1010 or ASTR 1030  

Requirements: Restricted to non- Astronomical (ASTR) majors only.  

Additional Information: Arts Sci Core Curr: Natural Science Sequence  
Arts Sci Core Curr: Natural Science Non-Sequence  
Arts Sci Gen Ed: Distribution-Natural Sciences  
MAPS Course: Natural Science  

ASTR 1010 (4) Introductory Astronomy 1  
Introduction to the night sky, planets, moons and the life in our solar system. Highlights the latest discoveries from space. For non-science majors. Some lectures may be held at Fiske Planetarium. Requires nighttime observations at Sommers-Bausch Observatory. Degree credit granted for only one of ASTR 1000 or ASTR 1010.  

Equivalent - Duplicate Degree Credit Not Granted: ASTR 1000, but with additional lab  

Requirements: Restricted to non- Astronomical (ASTR) majors only.  

Additional Information: Arts Sci Core Curr: Natural Science Sequence  
Arts Sci Core Curr: Natural Science Lab  
Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences  
MAPS Course: Natural Science Lab or Lab/Lec  

ASTR 1020 (4) Introductory Astronomy 2  
Non-science majors learn the nature and workings of the Sun, stars, neutron stars, black holes, galaxies, quasars, structure and origins of the universe. Some lectures may be held at Fiske Planetarium. Offers opportunities for nighttime observations at Sommers-Bausch Observatory. Includes recitation. Sequence link ASTR 1010. Credit granted for only one of ASTR 1020, ASTR 1200, and ASTR 1040.  

Requirements: Restricted to non-Astronomy (ASTR) majors only.  

Additional Information: Arts Sci Core Curr: Natural Science Sequence  
Arts Sci Core Curr: Natural Science Non-Sequence  
Arts Sci Gen Ed: Distribution-Natural Sciences  

ASTR 1030 (4) Accelerated Introductory Astronomy 1  
Covers principles of modern astronomy summarizing our present knowledge about the Earth, Sun, moon, planets and origin of life. Requires nighttime observation sessions at Sommers-Bausch Observatory. Required in ASTR major/minor. Like ASTR 1000 and 1010, but taught at a higher intellectual level, including a significant amount of quantitative analysis.  

Equivalent - Duplicate Degree Credit Not Granted: ASTR 1000 or ASTR 1010  

Requirements: Requires prerequisite or corequisite course of MATH 1300 or APPM 1350 or APPM 1340 and APPM 1345 (all minimum grade C).  

Additional Information: GT Pathways: GT-SC1 - Natural Physical Sci:Lec Crse w/ Req Lab  
Arts Sci Core Curr: Natural Science Sequence  
Arts Sci Core Curr: Natural Science Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences  
Arts Sci Gen Ed: Distribution-Natural Sci Lab  

ASTR 1040 (4) Accelerated Introductory Astronomy 2  
Covers principles of modern astronomy summarizing our present knowledge about the Sun, stars, birth and death of stars, neutron stars, black holes, galaxies, quasars, and the organization and origins of the universe. May require nighttime observing sessions at Sommers-Bausch Observatory. Required in ASTR major/minor. Includes a recitation. Taught at a higher intellectual level including a significant amount of quantitative analysis.  

Equivalent - Duplicate Degree Credit Not Granted: ASTR 1020 and ASTR 1200  

Requirements: Requires prerequisite course of ASTR 1010 or ASTR 1030 and MATH 1300 or APPM 1350 or APPM 1340 and APPM 1345 (all minimum grade C).  

Additional Information: GT Pathways: GT-SC2 - Natural Physical Sci:Lec Crse w/o Req Lab  
Arts Sci Core Curr: Natural Science Sequence  
Arts Sci Core Curr: Natural Science Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences  

ASTR 1200 (3) Stars and Galaxies  
Non-science majors are introduced to the nature and workings of the Sun, stars, neutron stars, black holes, interstellar gas, galaxies, quasars, plus structure and origins of the universe. Some lectures may be held at Fiske Planetarium. Offers opportunities to attend nighttime observation sessions at Sommers-Bausch Observatory.  

Equivalent - Duplicate Degree Credit Not Granted: ASTR 1002 and ASTR 1040  

Requirements: Restricted to non- Astronomical (ASTR) majors only.  

Additional Information: Arts Sci Core Curr: Natural Science Non-Sequence  
Arts Sci Gen Ed: Distribution-Natural Sciences  
MAPS Course: Natural Science
ASTR 2000 (3) Ancient Astronomies of the World
Documents the numerous ways in which observational astronomy and cosmology have been features of ancient cultures. Includes naked eye astronomy, archaeoastronomy, ethnoastronomy, concepts of time, calendrics, cosmogony, and cosmology.

Additional Information: Arts Sci Core Curr: Human Diversity
Arts Sci Core Curr: Natural Science Non-Sequence
Arts Sci Gen Ed: Diversity-Global Perspective
Arts Sci Gen Ed: Distribution-Natural Sciences
MAPS Course: Natural Science

ASTR 2010 (3) Modern Cosmology-Origin and Structure of the Universe
Introduces modern cosmology to nonscience majors. Covers the Big Bang; the age, size, and structure of the universe; and the origin of the elements and of stars, galaxies, the solar system, and life.

Additional Information: Arts Sci Core Curr: Natural Science Non-Sequence
Arts Sci Gen Ed: Distribution-Natural Sciences
MAPS Course: Natural Science

ASTR 2020 (3) Space Astronomy and Exploration
Covers physical principles of performing astronomy from space for science and exploration. The basic design of launch vehicles and spacecraft, orbital dynamics, and instruments will be described in the context of specific space missions (e.g. Hubble Telescope, Mars rovers) as well as prospects for future space observatories in orbit and on the Moon.

Additional Information: Arts Sci Core Curr: Natural Science Non-Sequence
Arts Sci Gen Ed: Distribution-Natural Sciences
MAPS Course: Natural Science

ASTR 2030 (3) Black Holes
Black holes are one of the most bizarre phenomena of nature. Students are introduced to the predicted properties of black holes, astronomical evidence for their existence and formation, and modern ideas about space, time, and gravity.

Additional Information: Arts Sci Core Curr: Natural Science Non-Sequence
Arts Sci Gen Ed: Distribution-Natural Sciences
MAPS Course: Natural Science

ASTR 2040 (3) The Search for Life in the Universe
Introduces the scientific basis for the possible existence of life elsewhere in the universe. Includes origin and evolution of life on Earth and the search for evidence of life in our solar system, including Mars and Jupiter’s moon Europa. Discusses the conditions necessary for life and whether they might arise on planets around other stars. Credit only for this course or ASTR 3300.

Equivalent - Duplicate Degree Credit Not Granted: GEOL 2040
Additional Information: Arts Sci Core Curr: Natural Science Non-Sequence
Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 2050 (3) The Sun and Society: Living with an Active Star
Introduces non-science majors to the many ways out Sun influences life and society. Covers how the Sun generates energy, how it evolves over billions of years, how it affects Earth’s climate and biology, how it produces dangerous “space weather”, how we can harness its power and how life in other solar systems would depend on the properties of their Suns.

Grading Basis: Letter Grade
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences
MAPS Course: Natural Science

ASTR 2100 (3) Fundamental Concepts in Astrophysics
Covers topics in modern physics required for upper-level astrophysics and planetary science courses, including quantum mechanics, electromagnetic spectra, atomic and nuclear physics, and thermodynamics, in the context of astrophysics, planetary and space sciences. Also introduces key topics in mathematics to support these topics.

Requisites: Requires prerequisite course of PHYS 1120 or PHYS 1125 and APPM 1360 or MATH 2300 (minimum grade C-).

Grading Basis: Letter Grade

ASTR 2500 (3) Gateway to Space
Introduces the basics of atmosphere and space sciences, space exploration, spacecraft design, rocketry and orbits. Students design, build, and launch a miniature satellite on a high altitude balloon. Explores the current research in space through lectures from industry.

Equivalent - Duplicate Degree Credit Not Granted: ASEN 1400
Requisites: Restricted to Astronomy (ASTR) majors only.

Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 2600 (3) Introduction to Scientific Programming
Introduces principles, methods and tools of scientific programming commonly used in research. Topics include an introduction to programming in Python, data structures, numerical methods for calculus and data manipulation/visualization. Techniques covered are relevant to many technical fields but emphasis is placed on application to problems in astronomy and planetary science. Class time is split between lectures and in-lab tutorials.

Requisites: Requires prerequisite course of MATH 1300 or APPM 1350 and PHYS 1110 or PHYS 1115 (minimum grade C-).

Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 2840 (1-3) Independent Study
Instructor consent required.
Repeatable: Repeatable for up to 6.00 total credit hours.

ASTR 3300 (3) Extraterrestrial Life
Discusses the scientific basis for the possible existence of extraterrestrial life. Includes origin and evolution of life on Earth; possibility of life elsewhere in the solar system, including Mars; and the possibility of life on planets around other stars. Department enforced prerequisite: one-year sequence in a natural science. Credit only for this course or ASTR 2040.

Equivalent - Duplicate Degree Credit Not Granted: GEOL 3300
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 3400 (3) Research Methods in Astronomy
Introduces research methods in astronomy and engages students in an active research project. The research projects will vary and may include astronomical observations, data analysis, scientific programming, theoretical models and statistical inference. As part of their research, students will read scientific papers, attend local seminars and prepare oral and written research proposals and reports. Elective for ASTR majors.

Requisites: Requires prerequisite courses of ASTR 1040 and PHYS 1125 or 1120 (all minimum grade C-). Requires co-requisite or prerequisite of ASTR 2600 (minimum grade C-). Restricted to ASTR majors.

Grading Basis: Letter Grade

Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences
Arts Sci Gen Ed: Distribution-Natural Sci Lab
ASTR 3510 (4) Observations and Instrumentation 1
Lab course in astronomical observation and instrumentation. Hands-on exercises include obtaining and analyzing multi-wavelength data, basic optical design and instrumentation and statistical analysis of data, with emphasis on imaging applications. A significant number of night time observation sessions are required. Elective for APS majors. Elective for APS minors on available basis.

**Requisites:** Requires a prerequisite or corequisite of APPM 1360 or MATH 2300 and ASTR 1020 or ASTR 1040 and PHYS 1120 (all minimum grade C-). Restricted to Astrophysics (ASTR) majors only.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences
Arts Sci Gen Ed: Distribution-Natural Sci Lab

ASTR 3520 (4) Observations and Instrumentation 2
Lab course in observation and instrumentation. Hands-on exercises include obtaining and analyzing multi-wavelength data, optical design and instrumentation, and statistical analysis, with emphasis on spectroscopy. A significant number of night time observation sessions are required. Elective for APS majors. Elective for APS minors on space available basis.

**Requisites:** Requires a prerequisite course of ASTR 3510 (minimum grade C-). Restricted to Astrophysics (ASTR) majors only.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences
Arts Sci Gen Ed: Distribution-Natural Sci Lab

ASTR 3560 (3) Astronomical Instrumentation Laboratory
Teaches students aspects of astronomical instrument design in a hands-on setting. Students will learn elementary principles of geometrical optics, diffraction, light detection, signal conditioning, data acquisition and motion control, and mechanical design. Students will apply these principles working in groups to design and build optical spectrometers.

**Requisites:** Requires prerequisite courses of ASTR 1040 and MATH 2300 or APPM 1360 and PHYS 2170 (minimum grade C-).

**Grading Basis:** Letter Grade

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences
Arts Sci Gen Ed: Distribution-Natural Sci Lab

ASTR 3710 (3) Formation & Dynamics of Planetary Systems
Covers the origin of planetary systems and their dynamical evolution. Topics include the physics and chemistry of planetary formation, orbital mechanics and extrasolar planets. This course and ASTR 3720 and ASTR 3750 may be taken in any order. Elective for APS major and minor.

**Requisites:** Requires prerequisite course of PHYS 1120 and MATH 2300 or APPM 1360 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 3720 (3) Planets and Their Atmospheres
Explores the physics and chemistry of the atmospheres of Mars, Venus, Jupiter, Saturn, and Titan. Examines evolution of the atmospheres of Earth, Venus, and Mars; and the escape of gases from the Galilean satellites, Titan and Mars; the orbital characteristics of moons, planets, and comets. Uses recent results of space exploration. Elective for APS major and minor.

**Equivalent - Duplicate Degree Credit Not Granted:** ATOC 3720

**Requisites:** Requires prerequisite courses of PHYS 1120 and APPM 1360 or MATH 2300 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 3730 (3) Astrophysics 1 - Stellar and Interstellar
Provides a quantitative introduction to the radiative and gravitational physics relevant to stellar and galactic astrophysics, as applied to understanding observations of tars, stellar evolution, stellar remnants and the structure of the Milky Way. Elective for APS major and minor.

**Requisites:** Requires prerequisite courses of PHYS 2130 or PHYS 2170 or ASTR 2100 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 3740 (3) Cosmology and Relativity
Special and general relativity as applied to astrophysics, cosmological models, observational cosmology, experimental relativity and the early universe. Elective for APS major and minor.

**Requisites:** Requires prerequisite courses of PHYS 2130 or PHYS 2170 or ASTR 2100 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 3750 (3) Planets, Moons, and Rings
Approaches the physics of planets, emphasizing their surfaces, satellites, and rings. Topics include formation and evolution of planetary surfaces, history of the terrestrial planets, and dynamics of planetary rings. This course and ASTR 3720 may be taken for credit in any order. Elective for APS major and minor.

**Requisites:** Requires prerequisite courses of PHYS 1120 and APPM 1360 or MATH 2300 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 3760 (3) Solar and Space Physics
Explores the physical processes linking the Sun and planets, emphasizing solar radiative and particulate variability and the response of planetary atmospheres and magnetospheres. Topics include the solar dynamo, solar wind, coronal mass ejections, cosmic ray modulation, magnetospheres, aurora, the space environment, and climate variability. Elective for APS major and minor.

**Requisites:** Requires prerequisite courses of PHYS 2130 or PHYS 2170 or ASTR 2100 (all minimum grade C-).

**Recommended:** Prerequisite PHYS 3310.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 3800 (3) Introduction to Scientific Data Analysis and Computing
Introduces scientific data analysis from a practical perspective. Covers statistical analysis, model fitting, error analysis, theoretical compliance and image analysis with examples from space-based and ground-based astronomy. Elective for APS major. Opened to qualified non-majors with instructor consent.

**Requisites:** Requires prerequisite course of ASTR 2600 or prerequisite or corequisite courses of ASTR 1020 or ASTR 1040 and PHYS 1120 and APPM 1360 or MATH 2300 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

ASTR 3830 (3) Astrophysics 2 - Galactic and Extragalactic
The second semester of a year-long introduction to astrophysical processes. The physical processes developed in ASTR 3730 are applied to topics in extragalactic astronomy, including galaxies, supermassive black holes, galaxy clusters and cosmology. Elective for APS major and minor.

**Requisites:** Requires prerequisite courses of ASTR 3730 and PHYS 2130 or PHYS 2170 and APPM 2350 or MATH 2400 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences
**ASTR 4330 (3) Cosmochemistry**
Investigates chemical and isotopic data to understand the composition of the solar system: emphasis on the physical conditions in various objects, time scales for change, chemical and nuclear processes leading to change, observational constraints, and various models that attempt to describe the chemical state and history of cosmological objects in general and the early solar system in particular. Department enforced prerequisite: upper-division undergraduate standing in physical science and upper-division undergraduate chemistry or physics or math courses.

**Equivalent - Duplicate Degree Credit Not Granted:** ASTR 5330 and GEOL 4330 and GEOL 5330

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**ASTR 4500 (1-3) Special Topics in Astrophysical and Planetary Sciences**
Topics vary each semester.

**Repeatable:** Repeatable for up to 9.00 total credit hours.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**ASTR 4800 (3) Space Science: Practice and Policy**
Exposes students to current controversies in science that illustrate the scientific method and the interplay of observation, theory, and science policy. Students research and debate both sides of the issues, which include strategies and spin-offs of space exploration, funding of science, big vs. small science, and scientific heresy and fraud.

**Recommended:** Prerequisite one year of college level astronomy or physics.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**ASTR 4840 (1-3) Independent Study**
Instructor consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**ASTR 4841 (1-3) Independent Study**

**Repeatable:** Repeatable for up to 7.00 total credit hours.