ASTROPHYSICAL AND PLANETARY SCIENCES

The curriculum and research in the department emphasizes three major areas: astrophysics, planetary sciences, and solar and space physics.

Those wishing to pursue graduate work in APS leading to candidacy for an advanced degree should carefully read the Master's Degree Requirements (catalog.colorado.edu/graduate/degree-requirements/masters-degree-requirements) and the Doctoral Degree Requirements (catalog.colorado.edu/graduate/degree-requirements/doctoral-degree-requirements).

Course code for this program is ASTR.

Doctoral Degree

- Astrophysical and Planetary Sciences - Doctor of Philosophy (PhD) (catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/astrophysical-planetary-sciences/astrophysical-planetary-sciences-doctor-philosophy-phd)

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

Linsky, 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 5110 (3) Atomic and Molecular Processes
Explores the application of quantum physics and statistical mechanics to problems in astrophysics, space physics and planetary science, with an emphasis on radiative processes and spectroscopy of atoms and molecules.

Requisites: Restricted to graduate students only.

ASTR 5120 (3) Radiative and Dynamical Processes
An introduction to radiative and dynamical processes aimed at graduate students in astrophysics, space physics and planetary science. Covers transport phenomena, the macroscopic treatment of radiation fields, magnetohydrodynamics and dynamical processes associated with planetary orbits and N-body systems.

Requisites: Restricted to graduate students only.

ASTR 5140 (3) Astrophysical and Space Plasmas
Teaches magnetohydrodynamics and a few related areas of plasma physics applied to space and astrophysical systems, including planetary magnetospheres and ionospheres, stars, and interstellar gas in galaxies.

Equivalent - Duplicate Degree Credit Not Granted: PHYS 5141
Requisites: Restricted to Physics (PHYS) or Astronomy (ASTR) graduate students only.

ASTR 5150 (3) Introductory Plasma Physics
Includes basic phenomena of ionized gases, static and dynamic shielding, linear waves, instabilities, particles in fields, collisional phenomena, fluid equations, collisionless Boltzman equations, Landau damping, scattering and absorption of radiation in plasmas, elementary nonlinear processes, WKB wave theory, controlled thermonuclear fusion concepts, astrophysical applications and experimental plasma physics (laboratory).

Equivalent - Duplicate Degree Credit Not Granted: PHYS 5150
Requisites: Restricted to graduate students only.

ASTR 5300 (3) Introduction to Magnetospheres
Introduces solar and stellar winds, and planetary and stellar magnetospheres. Acquaints students with the guiding center theory for particle motion, magnetospheric topology, convection, radiation belts, magnetic storms and substorms, and auroras.

Requisites: Restricted to graduate students only.

ASTR 5330 (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: graduate standing in physical science and graduate chemistry or physics or math courses.

Equivalent - Duplicate Degree Credit Not Granted: ASTR 4330 and GEOL 4330 and GEOL 5330
Requisites: Restricted to graduate students only.

ASTR 5400 (3) Introduction to Fluid Dynamics
Covers equations of fluid motion relevant to planetary atmospheres and oceans and stellar atmospheres; effects of rotation and viscosity; and vorticity dynamics, boundary layers and wave motions. Introduces instability theory, nonlinear equilibration and computational methods in fluid dynamics. Department enforced prerequisite: partial differential equations or equivalent.

Equivalent - Duplicate Degree Credit Not Granted: ATOC 5400 and PHYS 5400
Requisites: Restricted to graduate students only.

ASTR 5410 (3) Fluid Instabilities, Waves, and Turbulence
Involves linear and nonlinear analyses of small-scale waves and instabilities in stratified fluids, with effects of rotation. Studies internal gravity and acoustic waves with terrestrial, planetary and astrophysical applications. Studies thermal and double-diffusive convection, homogeneous and stratified shear flow instabilities. Examines these topics from the onset of small amplitude disturbances to their nonlinear development and equilibration. Department enforced prerequisite: ASTR 5400 or ATOC 5060.

Equivalent - Duplicate Degree Credit Not Granted: ATOC 5410
Requisites: Restricted to graduate students only.

ASTR 5500 (3) Mathematical Methods
Presents an applied mathematics course designed to provide the necessary analytical and numerical background for courses in astrophysics, plasma physics, fluid dynamics, electromagnetism, and radiation transfer. Topics include integration techniques, linear and nonlinear differential equations, WKB and Fourier transform methods, adiabatic invariants, partial differential equations, integral equations, and integrodifferential equations. Draws illustrative examples from the areas of physics listed above.

Equivalent - Duplicate Degree Credit Not Granted: ATOC 5540
Requisites: Restricted to graduate students only.

ASTR 5550 (3) Observations, Data Analysis and Statistics
Introduces multi-wavelength observational techniques, their limitations and effects of various noise sources. Describes basic data handling, error analysis, and statistical tests relevant to modeling. Topics include probability distributions, model-fitting algorithms, confidence intervals, correlations, sampling and convolution. Students derive physical measurements and uncertainties with hands-on analysis of real datasets. Department enforced prerequisite: senior level undergraduate physics or instructor consent will be required.

Requisites: Restricted to graduate students only.
**Requisites:**

- **prerequisite:** ASTR 5110.

**Highlights structure, dynamics and ecology of the interstellar medium, including fundamentals of radiative and particle processes, neutron stars, black holes, pulsars, quasars, supernovas and their remnants; stellar flares; accretion disks; binary x-ray sources; and other cosmic x-ray sources. Department enforced prerequisite: senior level undergraduate physics.

**Grading Basis:** Letter Grade

**Requisites:** Restricted to graduate students only.
ASTR 5830 (3) Topics in Planetary Science
Examines current topics in planetary science, based on recent discoveries, spacecraft observations and other developments. Focuses on a specific topic each time the course is offered, such as Mars, Venus, Galilean satellites, exobiology, comets or extrasolar planets. Department enforced prerequisite: restricted to graduate students in the physical sciences.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 5830 and GEOL 5830
Repeatable: Repeatable for up to 6.00 total credit hours.
Requisites: Restricted to graduate students only.

ASTR 5835 (1) Seminar in Planetary Science
Studies current research on a topic in planetary science. Students and faculty give presentations. Subjects may vary each semester. Department enforced prerequisite: senior level undergraduate physics.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 5835 and GEOL 5835
Repeatable: Repeatable for up to 4.00 total credit hours.
Requisites: Restricted to graduate students only.

ASTR 5920 (1-6) Reading and Research in Astrophysical and Planetary Sciences
Instructor consent required.
Repeatable: Repeatable for up to 6.00 total credit hours.
Requisites: Restricted to graduate students only.

ASTR 6000 (1) Seminar in Astrophysics
Studies current research and research literature on an astrophysical topic. Students and faculty give presentations. Subjects vary each semester. May be repeated for a total of 4 credit hours to meet candidacy requirements.
Repeatable: Repeatable for up to 4.00 total credit hours.
Requisites: Restricted to graduate students only.

ASTR 6050 (3) Space Instrumentation
Provides an overview of the relevant space environment and process, the types of instruments flown on recent mission and the science background of the measurement principles.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 6050 and GEOL 6050
Grading Basis: Letter Grade

ASTR 6610 (3) Earth and Planetary Physics 1
Examines mechanics of deformable materials, with applications to earthquake processes. Introduces seismic wave theory. Other topics include inversion of seismic data for the structure, composition and state of the interior of the Earth.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6610 and PHYS 6610
Requisites: Restricted to graduate students only.

ASTR 6620 (3) Earth and Planetary Physics 2
Covers space and surface geodetic techniques as well as potential theory. Other topics are the definition and geophysical interpretation of the geoid and of surface gravity anomalies; isostasy; post-glacial rebound; and tides and the rotation of the Earth.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6620 and PHYS 6620
Requisites: Restricted to graduate students only.

ASTR 6630 (3) Earth and Planetary Physics 3
Examines the solar system, emphasizing theories of its origin and meteorites. Highlights distribution of radioactive materials, age dating, heat flow through continents and the ocean floor, internal temperature distribution in the Earth, and mantle convection. Also covers the origin of the oceans and atmosphere.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6630 and PHYS 6630
Requisites: Restricted to graduate students only.

ASTR 6650 (1-3) Seminar in Geophysics
Advanced seminar studies in geophysical subjects for graduate students.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6650 and PHYS 6650
Requisites: Restricted to graduate students only.

ASTR 6940 (1) Master's Candidate for Degree
Grading Basis: Pass/Fail

ASTR 6950 (1-6) Master's Thesis
Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

ASTR 7160 (3) Intermediate Plasma Physics
Topics vary yearly but include nonlinear effects such as wave coupling, quasilinear relaxation, particle trapping, nonlinear Landau damping, collisionless shocks, solutions; nonneutral plasmas; kinetic theory of waves in a magnetized plasma; anisotropy; inhomogeneity; radiation-ponderomotive force, parametric instabilities, stimulated scattering; plasma optics; kinetic theory and fluctuation phenomena.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 7160
Recommended: Prerequisite PHYS 5150.

ASTR 7500 (1-3) Special Topics in Astrophysical and Planetary Sciences
Acquaints students with current research in astrophysical and planetary sciences. Topics vary each semester.
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

ASTR 7920 (1-6) Reading and Research in Astrophysical and Planetary Sciences
Instructor consent required.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

ASTR 8990 (1-10) Doctoral Dissertation
All doctoral students must register for not fewer than 30 hours of dissertation credit as part of the requirements for the degree. For a detailed discussion of doctoral dissertation credit, refer to the Graduate School section.
Repeatable: Repeatable for up to 30.00 total credit hours.
Requisites: Restricted to graduate students only.