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 Doctoral Degree Requirements (https://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) (https://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.

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 Emeritus; PhD, University of Massachusetts at Amherst

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

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

Blum, Lauren W. (https://experts.colorado.edu/display/fisid_167200/)
Assistant Professor; PhD, University of Colorado Boulder

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

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

Burns, Jack O.
Professor Emeritus, Faculty Fellow; 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/)
Professor; PhD, University of California, Berkeley

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

Curry, Shannon (https://experts.colorado.edu/display/fisid_169552/)
Associate Professor; PhD, University of Michigan

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

Dexter, Jason (https://experts.colorado.edu/display/fisid_164095/)
Assistant Professor; PhD, University of Washington Seattle

Ellingson, Erica (https://experts.colorado.edu/display/fisid_100118/)
Professor Emeritus; 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

Fleming, Brian (https://experts.colorado.edu/display/fisid_154011/)
Assistant Research Professor; PhD, Johns Hopkins University

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

Green, James C. (https://experts.colorado.edu/display/fisid_102344/)
Professor Emeritus; 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

Hayne, Paul (https://experts.colorado.edu/display/fisid_163352/)
Associate Professor; PhD, University of California, Los Angeles

Hindman, Bradley W. (https://experts.colorado.edu/display/fisid_103726/)
Assistant 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

Kazachenko, Maria (https://experts.colorado.edu/display/fisid_160195/)
Associate Professor; PhD, Montana State University

Keller, John M. (https://experts.colorado.edu/display/fisid_163223/)
Senior Instructor; PhD, University of Arizona

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

Linsky, Jeffrey
Professor Emeritus

Madigan, Ann-Marie (https://experts.colorado.edu/display/fisid_158298/)
Associate Professor; PhD, Leiden University (Netherlands)

Malaspina, David M. (https://experts.colorado.edu/display/fisid_148393/)
Assistant Professor; PhD, University of Colorado Boulder

Malville, J. McKim
Professor Emeritus

Nelson, Erica Lynn (https://experts.colorado.edu/display/fisid_166298/)
Assistant Professor; PhD, Yale University

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

Reardon, Kevin Patrick (https://experts.colorado.edu/display/fisid_154925/)
Professor Adjunct

Rosario-Franco, Marialis (https://experts.colorado.edu/display/fisid_172547/)
Assistant Teaching Professor; PhD, University of Texas at Arlington

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

Shull, J Michael
Professor Emeritus; PhD, Princeton University

Snow, Theodore P. Jr
Professor Emeritus

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

Suess, Wren (https://experts.colorado.edu/display/fisid_174290/)
Assistant Professor; PhD, University of California Berkeley

Thomas, Gary E.
Professor Emeritus

Toomre, Juri (https://experts.colorado.edu/display/fisid_100767/)
Professor, Faculty Fellow, Professor Emeritus; 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.
Requisites: Restricted to graduate students only.

ASTR 5540 (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.

ASTR 5560 (3) Radiative Processes in Planetary Atmospheres
Application of radiative transfer theory to problems in planetary atmospheres, with primary emphasis on the Earth's atmosphere; principles of atomic and molecular spectroscopy; infrared band representation; absorption and emission of atmospheric gases; radiation flux and flux divergence computations; radiative transfer and fluid motions; additional applications such as the greenhouse effect, inversion methods and climate models. Department enforced prerequisite or corequisite: ASTR 5110.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 5560
Requisites: Restricted to graduate students only.

ASTR 5700 (3) Stellar Astrophysics
Explores stellar interiors, evolution and atmospheres, with the Sun and its heliosphere being used as the closest and best-studied example of a star. Covers energy generation, transport, principles of stellar structure, stellar rotation, pulsation and evolution to supernova and compact object stages. Includes radiation transport in stellar photospheres, chromospheres, coronas, winds. Department enforced prerequisite: senior level undergraduate physics.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite ASTR 5120.

ASTR 5710 (3) High-Energy Astrophysics
Studies astrophysics of UV, x-ray, gamma-ray and cosmic-ray sources, 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.
Requisites: Restricted to graduate students only.

ASTR 5720 (3) Galaxies
Highlights the classification, structure, content, dynamics, and other observational properties of galaxies, active galaxies, and clusters of galaxies. Discusses Hubble's Law, the cosmic distance scale,and the intergalactic medium. Department enforced prerequisite: senior level undergraduate physics.
Requisites: Restricted to graduate students only.

ASTR 5730 (3) Stellar Atmospheres and Radiative Transfer
Explores stellar atmospheres: basic stellar atmospheres, spectral line formation, interpretation of stellar spectra and model atmospheres. Examines solar physics: the Sun as a star, solar cycle, chromospheric and coronal structure, energy balance, magnetic field and solar wind. Department enforced prerequisites: ASTR 5110 and undergraduate physics.
Requisites: Restricted to graduate students only.

ASTR 5740 (3) Interstellar Astrophysics
Highlights structure, dynamics and ecology of the interstellar medium, stressing the physical mechanisms that govern the thermal, ionization and dynamic state of the gas and dust; observations at all wavelengths; star formation; relation to external galaxies. Department enforced prerequisite: ASTR 5110.
Requisites: Restricted to graduate students only.

ASTR 5760 (3) Astrophysical Instrumentation
Covers the fundamentals underlying the design, construction and use of instrumentation used for astrophysical research ranging from radio-wavelengths to gamma rays. Topics include Fourier transforms and their applications, optical design concepts, incoherent and coherent signal detection, electronics and applications, and signal acquisition and processing. Department enforced prerequisite: senior level undergraduate physics.
Requisites: Restricted to graduate students only.

ASTR 5770 (3) Cosmology
Studies the smooth universe, including Friedmann-Robertson-Walker metric, Friedmann equations, cosmological parameters, inflation, primordial nucleosynthesis, recombination, and cosmic microwave background. Also studies the lumpy universe, including linear growth of fluctuations, power spectra of CMB and galaxies, dark matter, and large scale flows. Covers galaxy formation and intergalactic medium. Department enforced prerequisite: senior level undergraduate physics or instructor consent will be required.
Requisites: Restricted to graduate students only.

ASTR 5780 (3) Mission Design and Development for Space Sciences
Brings science and engineering students together to develop the multidisciplinary skills required to create a successful proposal to develop a NASA-funded small space mission. Goals: 1) develop the proposal science objectives based on scientific community priorities and NASA Announcement of Opportunity. 2) Understand how science requirements lead to the design of instrumentation. 3) Understand practical aspects of mission development.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 5440
Grading Basis: Letter Grade

ASTR 5800 (3) Planetary Surfaces and Interiors
Examines processes operating on the surfaces of solid planets and in their interiors. Emphasizes spacecraft observations, their interpretation, the relationship to similar processes on Earth, the relationship between planetary surfaces and interiors and the integrated geologic histories of the terrestrial planets and satellites.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 5800
Requisites: Restricted to graduate students only.

ASTR 5810 (3) Planetary Atmospheres
Covers the structure, composition, and dynamics of planetary atmospheres. Also includes origin of planetary atmospheres, chemistry and cloud physics, greenhouse effects, climate, and the evolution of planetary atmospheres past and future.
Requisites: Restricted to graduate students only.

ASTR 5820 (3) Origin and Evolution of Planetary Systems
Considers the origin and evolution of planetary systems, including proto-planetary disks, condensation in the solar nebula, composition of meteorites, planetary accretion, comets, asteroids, planetary rings and extrasolar planets. Applies celestial mechanics to the dynamical evolution of solar system bodies.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 5820
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 9.00 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
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

ASTR 6940 (1) Master's Candidate for Degree
Registration intended for students preparing for a thesis defense, final examination, culminating activity, or completion of degree.

ASTR 6950 (1-6) Master's Thesis

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.