# ASTROPHYSICAL AND PLANETARY SCIENCES (ASTR)

## 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
**Requisites:** 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
MAPS Course: Natural Science

**ASTR 1010 (4) Introductory Astronomy: The Solar System w/Lab**
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
**Requisites:** Restricted to non- Astronomy (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: Stars & Galaxies w/Recitation**
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.
**Equivalent - Duplicate Degree Credit Not Granted:** ASTR 1040 or ASTR 1200
**Requisites:** 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
**Requisites:** 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 Physcal 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 Sci Lab
Arts Sci Gen Ed: Distribution-Natural Sciences

**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 or ASTR 1200
**Requisites:** 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 Physicl Sci:Lec Crse w/o Req Lab
Arts Sci Core Curr: Natural Science Sequence
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 1020 or ASTR 1040
**Requisites:** Restricted to non- Astronomy (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, ASEN 1403, ECEN 1400 and GEEN 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.
**Equivalent - Duplicate Degree Credit Not Granted:** PHYS 2600
**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 or PHYS 2600 (minimum grade C-). Restricted to ASTR majors.
**Grading Basis:** Letter Grade
**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab
Arts Sci Gen Ed: Distribution-Natural Sciences

**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 space available basis.
**Requisites:** Requires a prerequisite or corequisite core 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 Sci Lab
Arts Sci Gen Ed: Distribution-Natural Sciences

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

**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 (PHYS 2130 or PHYS 2170 or ASTR 2100) (minimum grade C-).
**Grading Basis:** Letter Grade
**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab Arts Sci Gen Ed: Distribution-Natural Sciences

**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) and prerequisite or corequisite course of ASTR 2100 or MATH 2400 or APPM 2350 (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) and prerequisite or corequisite course of ASTR 2100 or MATH 2400 or APPM 2350 (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 PHYS 2600) and 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 course of ASTR 3730 (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.

**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 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.