ASTRONOMY & ASTROPHYSICS (Div III)

Chair: Professor Jay Pasachoff

- Marek Demianski, Visiting Professor of Astronomy
- Kevin Flaherty, Lecturer in Astronomy and Observatory Supervisor; affiliated with: Physics Department
- Anne Jaskot, Assistant Professor of Astronomy and Associate of the Hopkins Observatory; affiliated with: Physics Department; on leave Fall 2021
- Jay M. Pasachoff, Chair and Field Memorial Professor of Astronomy, Director of the Hopkins Observatory

How long will the Sun shine? How do we discover Earth-like planets among the many exoplanets circling other stars? How did the universe begin and how has it evolved over its 13.8-billion-year history? How do we detect not only light but also gravitational waves from afar? Astronomy is the science that asks and tries to answer questions like these. We have come a long way toward understanding what makes the sky appear as it does and how the Universe behaves. The Astronomy Department offers courses for anyone who is interested in learning about the Universe, and who would like to be able to follow new astronomical discoveries as they are made. All courses in Astronomy satisfy the Division III requirement. The Astronomy major and the Astrophysics major (administered jointly with the Physics Department) are described below.

The beginning astronomy courses are offered on two levels. Astronomy 101, 102, 104, and 330-range courses are intended primarily for non-science majors and have no prerequisite. Astronomy 111 is designed for students with some exposure to physics. It has a prerequisite of one year of high school physics or permission of the instructor, and a co-requisite of Mathematics 140 or equivalent background in calculus.

Most of the astronomy courses take advantage of our observational and computational facilities including a 24-inch computer-controlled telescope with sensitive electronic detectors, and our own computer network for image processing and data analysis. The Astronomy Department site can be found at astronomy.williams.edu.

ASTRONOMY MAJOR

The Astronomy major is designed for students with an interest in learning about many aspects of modern astronomy, but who do not choose to take the most advanced physics and math courses of the astrophysics major. It is also appropriate as a second major for students concentrating in another field; in particular, combining an Astronomy major with a related major like Geoscience or Computer Science has been a fruitful path for some of our students. The Astronomy major emphasizes understanding the observed properties of the physical systems that comprise the known Universe, from the Sun and solar system, to the evolution of stars and star clusters, to the Milky Way Galaxy, to external galaxies and clusters of galaxies. Because some knowledge of physics and calculus is necessary to understand many astronomical phenomena, the Astronomy major requires the first two semesters each of the physics and calculus that are also required of Physics majors and Astrophysics majors.

There are several possible routes through the Astronomy major, depending on preparation and interest. Students considering a major in Astronomy should consult with members of the department early and often. A first-year student, if unsure about choosing between Astronomy and Astrophysics, may wish to take not only Astronomy 111 but also Physics 131, 141, or 151 and Mathematics 140 (if necessary) in the fall. Students who might place out of physics courses should read the section on placement under Physics.

Major Requirements for Astronomy

Astronomy 111 Introduction to Astrophysics OR Astronomy 101 Stars: From Suns to Black Holes and either Astronomy 102 The Solar System—Our Planetary Home OR Astronomy 104 The Milky Way Galaxy and the Universe Beyond

Two 200-level Astronomy courses (or additional 400-level Astronomy courses as substitutes)

Two 400-level Astronomy courses

Physics 131 Particles and Waves OR Physics 141 Particles and Waves—Enriched OR equivalent placement

Physics 142 Foundations of Modern Physics or Physics 151 Seminar on Modern Physics

Mathematics 140 Calculus II

Mathematics 150 Multivariable Calculus OR Mathematics 151 Multivariable Calculus OR equivalent placement

The total number of courses required for the Astronomy major is nine. A typical path through the major will begin with Physics 141, which is suitable for students with one year of high school physics and a background in calculus. However, students without high school physics may begin with Physics 131, and students entering with Advanced Placement in physics and/or math may obtain credit toward the major for the equivalent of Physics 142 and/or Mathematics 150 or 151 taken elsewhere. There are some aspects of astronomy that are closely related to chemistry or geosciences. In recognition of this, certain advanced courses in those departments can be accepted for credit toward the Astronomy major.

THE DEGREE WITH HONORS IN ASTRONOMY

The honors degree in Astronomy will be awarded on the basis of a senior thesis presenting the results of an original observational, experimental, or theoretical investigation carried out by the student under the direction of a faculty member in Astronomy. There are no specific grade requirements (other than College-wide requirements for remaining in good academic standing) for entry into the thesis research program; however, a student wishing to do a thesis should have demonstrated both ability and motivation for independent work in previous courses and in any earlier research involvement. Students doing theses will normally choose a topic and an advisor early in the second semester of their junior year and usually begin their thesis work during the summer. During the senior year, those students whose proposals have been approved will elect two courses and a winter study project in addition to the minimum requirements for the major. Preparation for the thesis will occupy at least one course (Astronomy 493) and the winter study project (Astronomy 031). At the end of the winter study period, the department will decide, in consultation with each student, whether to admit that student to honors candidacy. Both a written thesis and an oral presentation to faculty and fellow students are required. The degree with honors will be awarded to those who meet these requirements with distinction. The degree with highest honors will be awarded to those who fulfill the requirements with unusually high distinction.

The department will be flexible with regard to the number and timing of courses devoted to thesis research within the general guidelines of two courses and a winter study project over and above the minimum major requirements and the written and oral presentations, especially in cases of students with advanced standing and/or summer research experience. Students considering unusual requests are urged to consult with potential advisors or the department chair as early as possible.

ASTROPHYSICS MAJOR

The Astrophysics major is designed for students who want a rigorous introduction to the field, and includes not only those who plan graduate study in astronomy, astrophysics, or a closely related area, but also those interested in a wide variety of careers. Astrophysics alumni are not only astronomers but also computer scientists, geologists, teachers, doctors, lawyers, business school professors, and so on. In recent years, many astrophysics majors have had a second major in fields as wide ranging as mathematics, computer science, geosciences, economics, English, and art history. This major emphasizes the description of the Universe and its constituents in terms of physical processes. Potential Astrophysics majors should consult early with members of the Astronomy and Physics Departments to determine their most appropriate route through the major. An essential ingredient in such students' undergraduate training is experience in physics and mathematics. Therefore, the major normally will begin in the first year a student is at Williams with Physics 131, 141, or 151 and Mathematics 140 or 150 or 151 in the fall. Physics 141 is recommended for students with one year of high school physics and a background in calculus. Students with very good background placing them out of Physics 142 and out of Mathematics 140 may choose to take Physics 201 and Mathematics 150 or 151 instead. Astronomy 111 will often be taken in the fall of the sophomore year; however, many students take it in the fall of their first year at Williams, along with physics and math. Students who might place out of physics courses should read the section on placement under Physics; those who place out of Physics 131 or 141 into Physics 142 or 151 should particularly consider taking Astronomy 111 in the fall of their first year.

In addition to the major courses described below, other courses in geosciences, mathematics, and computer science may also be appropriate.

Major Requirements for Astrophysics

Astronomy 111 Introduction to Astrophysics OR Astronomy 101 Stars: From Suns to Black Holes and either Astronomy 102 The Solar System—Our Planetary Home OR Astronomy 104 The Milky Way Galaxy and the Universe Beyond

Physics 131 Particles and Waves OR Physics 141 Particles and Waves—Enriched OR equivalent placement

Physics 142 Foundations of Modern Physics OR Physics 151 Seminar on Modern Physics

Physics 201 Electricity and Magnetism

Physics 202 Waves and Optics

Physics/Mathematics 210 Mathematical Methods for Scientists

Physics 301 Introductory Quantum Physics

Mathematics 150 Multivariable Calculus OR Mathematics 151 Multivariable Calculus

Three 400-level astronomy courses OR two 400-level astronomy courses and one of the following:

Astronomy 211 Astronomical Observing and Data Analysis

Physics 302 Statistical Physics

Physics 402T Applications of Quantum Mechanics

Physics 405T Electromagnetic Theory

Physics 411T Classical Mechanics;

Physics 418 Gravity

The total number of courses required for the Astrophysics major, an interdisciplinary major, is eleven. Students entering with Advanced Placement in physics and/or mathematics may obtain credit toward the major for the equivalent of Physics 141 and/or Mathematics 140 and/or 150 or 151 taken elsewhere, but at least 8 courses in astronomy, physics, and mathematics must be taken at Williams. There are some aspects of astrophysics that are closely related to chemistry or geosciences. In recognition of this relation, certain advanced courses in those departments can be accepted for credit toward the Astrophysics major on a two-for-one basis. It is not possible to double major in Astrophysics and Physics.

THE DEGREE WITH HONORS IN ASTROPHYSICS

The honors degree in Astrophysics will be awarded on the basis of a senior thesis presenting the results of an original observational, experimental, or theoretical investigation carried out by the student under the direction of a faculty member in Astronomy or Physics. There are no specific grade requirements (other than College-wide requirements for remaining in good academic standing) for entry into the thesis research program; however, a student wishing to do a thesis should have demonstrated both ability and motivation for independent work in previous courses and in any earlier research involvement. Students doing theses will normally choose a topic and an advisor early in the second semester of their junior year and usually begin their thesis work during the summer. During the senior year, those students whose proposals have been approved will elect two courses and a winter study project in addition to the minimum requirements for the major. Preparation for the thesis will occupy at least one course (Astrophysics 493) and the winter study project (Astrophysics 031). At the end of the winter study period, the departments will decide, in consultation with each student, whether to admit that student to honors candidacy. Both a written thesis and an oral presentation to faculty and fellow students are required. The degree with honors will be awarded to those who meet these requirements with distinction. The degree with highest honors will be awarded to those who fulfill the requirements with unusually high distinction.

The departments will be flexible with regard to the number and timing of courses devoted to thesis research within the general guidelines of two courses and a winter study project over and above the minimum major requirements and the written and oral presentations, especially in cases of students with advanced standing and/or summer research experience. Students considering unusual requests are urged to consult with potential advisors or the department chairs as early as possible.

STUDY ABROAD

FAQ

Students MUST contact departments/programs BEFORE assuming study away credit will be granted toward the major or concentration.

Can your department or program typically pre-approve courses for major/concentration credit?

Yes, in some cases, if appropriate course information is available in advance (e.g. syllabi and/or course descriptions), though students should be sure to contact the department.

What criteria will typically be used/required to determine whether a student may receive major/concentration credit for a course taken while on study away?

Course title and description, and complete syllabus including readings/assignments.

Does your department/program place restrictions on the number of major/concentration credits that a student might earn through study away?

No.

Does your department/program place restrictions on the types of courses that can be awarded credit towards your major?

No.

Are there specific major requirements that cannot be fulfilled while on study away?

No.

Are there specific major requirements in your department/program that students should be particularly aware of when weighing study away options? (Some examples might include a required course that is always taught in one semester, laboratory requirements.)

Yes. PHYS 301, a required course for the Astrophysics major, is only taught in the fall, and is difficult to replicate abroad, especially regarding the lab component.

Give examples in which students thought or assumed that courses taken away would count toward the major or concentration and then learned they wouldn’t:

None to date.

ASTR 101 (F) Stars: From Suns to Black Holes

For the new era of "multimessenger astronomy" (not only light and its like but also particles from space and gravitational waves): What makes a star shine? For how long will the Sun keep shining and what will happen to it then? What are black holes and how can they form? How and what have we found out about the recently gravitational radiation resulting from two giant black holes merging and, with additional signals in the spectrum, from the merger of two neutron stars? What do we learn about the Sun from total solar eclipses? Astronomy 101, a non-major, general introduction to the part of contemporary astronomy that includes how stars form and die, will provide answers to these questions. We pay special attention to recent exciting discoveries, including regular briefings and current emails plus bonus coverage of NASA's Mars2020 to Mars with the participation of Williams alumni/ae. Topics include discoveries with the Hubble Space Telescope, missions to discover planets around other stars, the latest huge telescopes and some results; how astronomers interpret the light received from distant celestial objects; and the Sun as a typical star. We discuss how pulsars and black holes result from the evolution of massive stars and how supermassive black holes lurk in galaxies/quasars. We discuss the discovery of thousands of "exoplanets" around stars other than the Sun, validating our choice of topics. We regularly discuss the latest news briefs and developments in astronomy and relate them to the topics covered in the course. This course is independent of and on the same level as Astr 102 (solar system)/104 (galaxies/cosmology); students who have taken those courses are welcome. Observing sessions will include remote use of the telescopes for nighttime observations and daytime observations of the Sun, mainly remotely but with on-campus possibilities. There will be five laboratories, available both in afternoon sessions on campus or remotely.

Class Format: lecture (two sessions per week), observing sessions (scattered throughout the semester), afternoon labs (five times per semester), and a planetarium demonstration, available both in place and remotely. Planetarium and Roof-Observatory TAs will be available for consultation, in addition to the instructors, throughout the semester. This course is also available asynchronously.

Requirements/Evaluation: two hour tests, a final exam, an observing portfolio, and lab reports

Prerequisites: none

Enrollment Limit: 30

Enrollment Preferences: first enrolled

Expected Class Size: 20

Grading: yes pass/fail option,   no fifth course option

Unit Notes: non-major course

Distributions: (D3)

Fall 2021

LEC Section: 01   TR 9:55 am - 11:10 am   Jay M. Pasachoff, Kevin Flaherty

LAB Section: 02   T 1:00 pm - 2:30 pm   Kevin Flaherty

LAB Section: 03   T 2:30 pm - 4:00 pm   Kevin Flaherty

LAB Section: 04   W 1:00 pm - 2:30 pm   Kevin Flaherty

LAB Section: 05   W 2:30 pm - 4:00 pm   Kevin Flaherty

ASTR 102 (S) Our Solar System and Others

What makes Earth different from all the other planets? What have NASA's Curiosity and Perseverance on Mars (with their alumni/ae participation!) found about that planet's past running water and suitability for life? How has knowledge about Pluto and Arrokoth beyond it been transformed by NASA's flybys and the associated ground-based studies with which Williams College faculty and students participated? Will asteroids or comets collide with the Earth again? What is a solar eclipse like and how do we prepare for the April 8, 2024, totality? What do we learn from the rare transits of Mercury and of Venus that Williams faculty and students have studied? Astronomy 102, a non-major, general introduction to the part of contemporary astronomy that comprises the study of the solar system, will provide answers to these questions and more. We will cover the historical development of humanity's understanding of the solar system, examining contributions by Aristotle, Ptolemy, Copernicus, Galileo, Kepler, Newton, Einstein, and others. We will discuss the discovery of over 4000 exoplanets around stars other than the Sun. The course gives special attention to exciting discoveries of the past few years by space probes and by the Hubble Space Telescope and the Kepler/K2/TESS missions, as well as plans and hopes for NASA's James Webb Space Telescope (at this deadline scheduled for launch in December 2021). We regularly discuss the latest news briefs and developments in astronomy and relate them to the topics covered in the course. This course is independent of, and on the same level as Astronomy 101 (stars and stellar evolution) and 104 (galaxies and cosmology), and students who have taken those courses are welcome.

Class Format: lecture (three hours per week), observing sessions (scattered throughout the semester), afternoon labs (five times per semester), and a planetarium demonstration. A planetarium demonstration will also take place, available both in place and remotely. Planetarium and Roof-Observing TAs will be available for consultation, in addition to the instructors, throughout the semester. This course is also available asynchronously.

Requirements/Evaluation: two hour tests, a final exam, an observing portfolio, and lab reports

Prerequisites: none

Enrollment Limit: 48

Enrollment Preferences: first enrolled

Expected Class Size: 30

Grading: yes pass/fail option, no fifth course option

Unit Notes: non-major course

Distributions: (D3)

Spring 2022

LEC Section: 01 TR 9:55 am - 11:10 am Jay M. Pasachoff, Kevin Flaherty

LAB Section: 02 T 1:00 pm - 2:30 pm Kevin Flaherty

LAB Section: 03 T 2:30 pm - 4:00 pm Kevin Flaherty

LAB Section: 04 W 1:00 pm - 2:30 pm Kevin Flaherty

LAB Section: 05 W 2:30 pm - 4:00 pm Kevin Flaherty

ASTR 104 (S) The Milky Way Galaxy and the Universe Beyond

It has been less than a century since the Sun was discovered not to be at the center of the Milky Way Galaxy, and the Milky Way Galaxy was determined to be only one of countless "island universes" in space. A host of technological advances is enabling us to understand even more clearly our place in the universe and how the universe began. For example, the recently discovered "chirp" from gravitational radiation (reported in 2016) resulting from two giant black holes merging, and the "chirp" from two neutron stars merging, also producing light, radio and x-ray radiation, has opened a whole different way of observing the Universe from the traditional use of light and other forms of electromagnetic radiation. We are now therefore in the new era of multimessenger astronomy. Further, the Hubble Space Telescope and the Chandra X-ray Observatory bring exceptionally clear images over a wider range of the spectrum; their images are aiding astronomers to better understand the past and future of the Universe, and new infrared images are expected with the launch of the James Webb Space Telescope. Observations with those and other new telescopes on the ground and in space help to confirm and enlarge our understanding of the Big Bang. In addition, study of the early Universe (most recently from the Planck spacecraft) and large-scale mapping programs such as the Sloan Digital Sky Survey, the European Space Agency's Gaia, and the Dark Energy Survey. Astronomy 104, a non-major, general introduction to part of contemporary astronomy comprising the study of galaxies and the Universe, explores the answers to questions like: What is the Milky Way?; Why are quasars so luminous?; Is the Universe made largely of "dark matter" and "dark energy"?; What determines the ultimate fate of the Universe? How have studies of Cepheid variables and distant supernovae with the Hubble Space Telescope determine that the Universe is 13.8 billion years old and indicated that the Universe's expansion is accelerating? How significant is the current discrepancy between the age and expansion rate of the Universe as measured from supernova observations as opposed to measurements from the cosmic background radiation? We regularly discuss the latest news briefs and developments in astronomy and relate them to the topics covered in the course. This course is independent of, and on the same level as Astronomy 101 and 102, and students who have taken those courses are welcome.

Class Format: lecture (two sessions per week), observing sessions (scattered throughout the semester), afternoon labs (five times per semester), and a planetarium demonstration, available both in place and remotely. Planetarium and Roof-Observatory TAs will be available for consultation, in addition to the instructors, throughout the semester. This course is also available asynchronously. Current astronomical discoveries will be discussed at the beginning of each class and by email throughout the semester.

Requirements/Evaluation: two hour tests, a final exam, lab reports, and an observing portfolio

Prerequisites: none; not open to students who have taken or are taking ASTR 330

Enrollment Limit: 25

Expected Class Size: 15

Grading: yes pass/fail option, no fifth course option

Unit Notes: non-major course

Distributions: (D3)

Not offered current academic year

ASTR 107 (F) Astrobiology

Cross-listings: GEOS 107 ASTR 107

Secondary Cross-listing

Astrobiology is the study of the origin, evolution, and distribution of life in the universe. As such it is an inherently interdisciplinary field, incorporating all of the basic natural sciences: biology, chemistry, physics, astronomy, and the earth sciences, as well as aspects of philosophy, sociology, and engineering. Questions we will seek answers to in this class include: How, why, when, and where did life evolve on Earth, and what does that tell us about how it might evolve elsewhere? What are the chances that there is life on other planets and moons in our solar system, and why? Are there habitable planets elsewhere in the universe, and will we ever truly know if any of them contain life? We will approach these questions using a combination of lectures, activities, labs, homework assignments, and visits from some of the country's leading Astrobiology researchers. Examples of lab and homework activities include exploring our definition of life by making observations about living and non-living systems, examining evidence for ancient habitable environments in rocks, and modeling chemical fingerprinting tools used by Mars rovers. Assessment will be based on participation, quizzes, labs and homework assignments, and a final group project where students will present a mock NASA mission proposal. This course requires no previous experience in the sciences. This course is in the Sediments and Life group for the Geosciences major.

Class Format: Lectures will be partially flipped with student responsible for watching videos before class; class time will be split between short lectures, small group activities, and class discussions. Lab groups will meet in person every other week and have group project work on alternate weeks that may be done virtually or in person.

Requirements/Evaluation: Assessment will be based on participation, quizzes, labs and homework assignments, and a final group project where students will present a mock NASA mission proposal.

Prerequisites: none

Enrollment Limit: 46

Enrollment Preferences: first year and second year students, Geosciences majors

Expected Class Size: 46

Grading: yes pass/fail option, yes fifth course option

Unit Notes: This course counts towards the GEOS Group B Electives - Sediments and Life

Distributions: (D3)

This course is cross-listed and the prefixes carry the following divisional credit:

GEOS 107 (D3) ASTR 107 (D3)

Attributes: GEOS Group B Electives - Sediments + Life

Fall 2021

LEC Section: 01 TR 9:55 am - 11:10 am Phoebe A. Cohen

LAB Section: 02 T 1:00 pm - 3:00 pm Phoebe A. Cohen

LAB Section: 03 R 1:00 pm - 3:00 pm Phoebe A. Cohen

ASTR 111 (F) Introduction to Astrophysics (QFR)

The science of astronomy spans vast scales of space and time, from individual atoms to entire galaxies and from the universe's beginning to the future fate of our Sun. In this course, we will survey some of the main ideas in modern astrophysics, with an emphasis on the physics of stars and galaxies. ASTR 111 is the first course in the Astrophysics and Astronomy major sequences. It is also appropriate for students planning to major in one of the other sciences or mathematics and for others who would like a quantitative introduction that emphasizes the relationship of contemporary physics to astronomy. Topics include gravity and orbits, radiation laws and stellar spectra, physical characteristics of the Sun and other stars, star formation and evolution, black holes, galaxies, the expanding universe, and the Big Bang. Students will also use telescopes remotely to observe stars, nebulae, planets, and galaxies and to make daytime observations of the Sun.

Class Format: The class has 6 afternoon labs. Nighttime observing sessions will occur throughout the semester.

Requirements/Evaluation: weekly problem sets, two hour-long tests, a final exam, lab reports, and an observing portfolio

Prerequisites: a year of high school Physics, concurrent college Physics, or permission of instructor, and MATH 140 or equivalent

Enrollment Limit: 28

Enrollment Preferences: potential Astronomy majors

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: The course requires regular problem sets and quantitative assignments. The course will emphasize how physical equations explain the observed properties of the universe.

Fall 2021

LEC Section: 01 TR 11:20 am - 12:35 pm Marek Demianski, Kevin Flaherty

LAB Section: 02 M 1:00 pm - 4:00 pm Kevin Flaherty

LAB Section: 03 R 1:00 pm - 4:00 pm Kevin Flaherty

ASTR 211 (S) Astronomical Observing and Data Analysis (QFR)

How do astronomers make scientific measurements for objects that are light-years away from Earth? This course will introduce the basics of telescopes and observations and will give students hands-on training in the techniques astronomers use to obtain, process, and analyze scientific data. We will discuss observation planning, CCD detectors, signal statistics, image processing, and photometric and spectroscopic observations. We will begin by focusing on ground-based optical observations and will move on to non-optical observations, both electromagnetic (e.g., radio waves, X-rays) and non-electromagnetic (e.g., gravitational waves, neutrinos). Throughout the course, students will use computational techniques to work with real astronomical data, taken with our 24" telescope and from data archives.

Class Format: discussion, computer lab work, and observing

Requirements/Evaluation: weekly problem sets, lab work, and observing projects

Prerequisites: MATH 150 or 151; prior experience with Unix and computer programming is helpful, but not required

Enrollment Limit: 14

Enrollment Preferences: Astronomy or Astrophysics majors

Expected Class Size: 8

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: The course requires regular problem sets. Labs require computer programming and statistical and graphical analyses of data.

Spring 2022

LEC Section: 01 MR 1:10 pm - 2:25 pm Anne Jaskot, Kevin Flaherty

LAB Section: 02 W 1:10 pm - 3:50 pm Kevin Flaherty

ASTR 217 (S) Planets and Moons

Cross-listings: ASTR 217 GEOS 217

Secondary Cross-listing

This course examines the history and geology of the solar system. No two planets are exactly alike, and as we acquire more data and higher-resolution images, our sense of wonder grows. However, we can't hike around and hammer rocks on Venus or Titan, so we have to infer composition, form, texture and process from remotely-captured images and sparse chemical and spectral data. We will consider the origin of the solar system, the formation and evolution of planetary bodies, and the role of impacts, volcanism, tectonics and geomorphology in shaping them. We will summarize basic geological concepts of stratigraphy, structure and chronology and show how they can be applied off-world. We will review solar system exploration, and will include planetary data in lab exercises. This course is in the Solid Earth group for the Geosciences major.

Requirements/Evaluation: Periodic short quizzes, reading journal, lab exercises, class participation

Prerequisites: any 100-level GEOS or any 100-level ASTR course, or permission of instructor

Enrollment Limit: 20

Enrollment Preferences: Geosciences majors, Astronomy/Astrophysics majors, and sophomores

Expected Class Size: 12

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3)

This course is cross-listed and the prefixes carry the following divisional credit:

ASTR 217 (D3) GEOS 217 (D3)

Attributes: GEOS Group C Electives - Solid Earth

Not offered current academic year

ASTR 240 (F) Great Astronomers and Their Original Publications (WS)

Cross-listings: STS 240 ASTR 240 HSCI 240 LEAD 240

Primary Cross-listing

In this course we will study some of the greatest figures in astronomy and consider their leadership in advancing progress in the field. We will consider their lives and works, especially as represented by original copies of their books and other publications. These great astronomers include: 16th century, Nicolaus Copernicus (heliocentric universe); Tycho Brahe (best pre-telescopic observations); 17th century, Galileo (discoveries with his first astronomical telescope, 1610; sunspots, 1613; *Dialogo*, 1632); Johannes Kepler (laws of planetary motion, 1609, 1619); Johannes Hevelius and Elisabeth Hevelius (atlases of the Moon and of stars, 1647, and 1687); Isaac Newton (laws of universal gravitation and of motion, 1687); 18th century, Edmond Halley (*Miscellanea curiosa*, eclipse maps, 1715, 1724); John Flamsteed and Margaret Flamsteed (*Atlas Coelestis*, 1729); and William Herschel and Caroline Herschel (1781, 1798). Also, from more recent times in which original works are often articles rather than books: 20th century, Albert Einstein (special relativity, 1905; general relativity, 1916); Marie Curie (radioactivity); Cecilia Payne-Gaposchkin (hydrogen dominating stars, 1929), Edwin Hubble (Hubble's law, 1929); Vera Rubin (dark matter, 1970s); Jocelyn Bell Burnell (pulsar discovery, 1968); and 21st century: Wendy Freedman (Universe's expansion rate, 2000s). First editions will be available in Williams's Chapin Library of rare books, and facsimiles or digital copies will be provided for remote learning. We will also consider how such original materials are collected and preserved, and look at examples from the wider world of rarities, such as a leaf from the *Gutenberg Bible* (c. 1450) and a Shakespeare *First Folio* (1623, with a discussion of astronomical references in Shakespeare's plays). We evaluate a trove of books and papers about historic transits of Venus. We discuss matters of fraud and authenticity, especially the case of a purported *Sidereus Nuncius*, shown to be a modern construction. The course will be taught in collaboration between an astronomer and a rare books librarian, with remote lectures by experts from around the world.

Class Format: Meeting on campus in the Chapin Library classroom (Sawyer 452) or remotely; students who are not on campus can visit the original books at a later time/year.

Requirements/Evaluation: class participation, two 5-page intermediate papers, and a final 15-page paper; student choice of additional readings from a provided reading list

Prerequisites: none

Enrollment Limit: 12

Enrollment Preferences: if overenrolled, preference by written paragraph of explanation of why student wants to take the course

Expected Class Size: 12

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (WS)

This course is cross-listed and the prefixes carry the following divisional credit:

STS 240 (D2) ASTR 240 (D3) HSCI 240 (D3) LEAD 240 (D3)

Writing Skills Notes: Comments on submitted papers will aid in writing skills

Attributes: LEAD Facets or Domains of Leadership

Not offered current academic year

ASTR 317 (S) Current topics in Planetary Geology (WS)

Cross-listings: GEOS 317 ASTR 317

Secondary Cross-listing

We will look in detail at geological processes on rocky and icy bodies of the Solar System. Each week will have a specific theme, and students will read a series of scientific articles on that topic. The readings will form the basis for writing and discussion. Areas to be investigated may include ice ages on Mars, the origin of Earth's moon, tectonics on Venus, chaos terrain on Europa, geysers on Enceladus, cryovolcanism on Triton, methane lakes on Titan, the viability of mining in the Asteroid Belt, and the prospects for life on other worlds. This course is in the Solid Earth group for the Geosciences major.

Class Format: Students meet with the professor weekly, in pairs, with one student writing each week and the other critiquing; and both engaging in detailed discussion of the readings.

Requirements/Evaluation: Evaluation is based on written papers, critiques, and discussion.

Prerequisites: GEOS/ASTR 217 (Planets and Moons); OR any two courses at 200-level or higher in Geosciences and/or Astronomy; OR permission of instructor

Enrollment Limit: 10

Enrollment Preferences: Geosciences and Astronomy majors and prospective majors

Expected Class Size: 6

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (WS)

This course is cross-listed and the prefixes carry the following divisional credit:

GEOS 317 (D3) ASTR 317 (D3)

Writing Skills Notes: This tutorial-style course focuses on writing, with 6 papers (5-7 pages) written bi-weekly throughout the semester, and partner critiques in alternate weeks.

Attributes: GEOS Group C Electives - Solid Earth

Not offered current academic year

ASTR 330 (S) The Nature of the Universe

This course is a journey through space and time from the first fractions of a second after the Big Bang to the ultimate fate of the Universe billions of years into the future. Topics include the Big Bang and its remnant cosmic background radiation, cosmic inflation, conditions during the first three minutes, creation of the elements, stellar and galactic black holes, relativity, the detection of gravitational waves, galaxies and quasars, dark matter, and the formation of the large-scale structure of the Universe. We will explore current ideas about the fate of our Universe, including the acceleration of its expansion, and its implications for the end of time. Finally, we will consider the fantastic but serious theoretical proposal that ours is but one of countless universes existing within a *multiverse*.

Class Format: This is a remote course. Synchronous lectures and break-out discussions will take place during the scheduled class time. These lectures may be recorded for the benefit of students in substantially different time zones; these students will then schedule a separate small-group discussion time in consultation with the professor. Remote observing sessions will occur throughout the semester.

Requirements/Evaluation: two midterm exams, a small observing portfolio, occasional quizzes, and a final exam

Prerequisites: none

Enrollment Limit: 48

Enrollment Preferences: open only to juniors and seniors; closed to students who have taken or are taking ASTR 104, and closed to ASTR, ASPH, and PHYS majors; preference given to seniors

Expected Class Size: 25

Grading: yes pass/fail option, no fifth course option

Unit Notes: non-major course; course in the 33X sequence are meant as general education courses for students in all majors

Distributions: (D3)

Not offered current academic year

ASTR 336 (S) Science, Pseudoscience, and the Two Cultures

Cross-listings: LEAD 336 ASTR 336 HSCI 336

Primary Cross-listing

A famous dichotomy between the sciences and the humanities, and public understanding of them, was laid down by C. P. Snow and has been widely discussed, with ignorance of the second law of thermodynamics compared with ignorance of Shakespeare. In this seminar, we will consider several aspects of science and scientific culture, including how scientific thinking challenges the claims of pseudoscience. We will consider C. P. Snow and his critics as well as the ideas about the Copernican Revolution and other paradigms invented by Thomas Kuhn. We will discuss the recent "Science Wars" over the validity of scientific ideas. We will consider the fundamental originators of modern science, including Tycho, Kepler, Galileo, and Newton, viewing their original works in the Chapin Library of rare books and comparing their interests in science with what we now call pseudoscience, like alchemy. We will review the history and psychology of astrology and other pseudosciences. Building on the work of Martin Gardner in *Fads and Fallacies in the Name of Science*, and using such recent journals as *The Skeptical Inquirer* and *The Scientific Review of Alternative Medicine*, we consider from a scientific point of view what is now called complementary or alternative medicine, including both older versions such as chiropractic and newer nonscientific practices. We will discuss the current global-climate-change deniers and their effects on policy. We discuss vaccination policy. We consider such topics as GM (genetically modified) foods, the safety and regulation of dietary supplements, and the validity of government and other recommendations relevant to the roles of dietary salt, sugar, and fat in health. We consider the search for extraterrestrial intelligence (SETI) and reports of UFO's and aliens. We consider the possible effects that superstitious beliefs have on the general public's cooperation in vaccination programs and other consequences of superstition. We will discuss conspiracy theories such as those about the Kennedy assassination, in view of the 2017 release of many documents from the time and the recent book by Alexandra Zapruder, the granddaughter of the person whose on-the-spot movie documented the fatal shot. We also consider a range of dramas that are based on scientific themes, such as Tom Stoppard's *Arcadia* and Michael Frayn's *Copenhagen*.

Requirements/Evaluation: biweekly 5-page papers, participation in discussions, and a 15-page final paper

Prerequisites: none

Enrollment Limit: 12

Enrollment Preferences: juniors and seniors and to those with backgrounds in science, history of science, or philosophy

Expected Class Size: 12

Grading: yes pass/fail option, yes fifth course option

Unit Notes: non-major course; does not count toward ASPH, ASTR or PHYS major

Distributions: (D3)

This course is cross-listed and the prefixes carry the following divisional credit:

LEAD 336 (D3) ASTR 336 (D3) HSCI 336 (D2)

Not offered current academic year

ASTR 402 (S) Between the Stars: The Interstellar Medium (QFR)

The matter between the stars--the interstellar medium--tells the story of the past and future evolution of galaxies and the stars within them. Stars are accompanied by diffuse matter all through their lifetimes, from their birthplaces in dense molecular clouds, to the stellar winds they eject as they evolve, to their final fates as they shed their outer layers, whether as planetary nebulae or dazzling supernovae. As these processes go on, they enrich the interstellar medium with the products of the stars' nuclear fusion. Interpreting the emission from this interstellar gas is one of astronomers' most powerful tools to measure the physical conditions, motions, and composition of our own galaxy and others. In this course we will study the interstellar medium in its various forms, from cold, dense, star-forming molecular clouds to X-ray-emitting bubbles formed by supernovae. We will learn about the physical mechanisms that produce the radiation we observe, including radiative ionization and recombination, collisional excitation of "forbidden" lines, collisional ionization, and synchrotron radiation. Applying our understanding of these processes, we will analyze the physical conditions and chemical compositions of a variety of nebulae. Finally, we will discuss the evolution of interstellar material in galaxies across cosmic time. This course is observing-intensive. Throughout the semester students will work in small groups to design, carry out, analyze, and critique their own observations of the interstellar medium using remote observations and archival data.

Class Format: Tutorial meetings will be scheduled with the professor. Meetings may be held in-person, subject to classroom availability, or remotely. Students will also complete observing projects by controlling telescopes remotely and analyzing observations in astronomical databases.

Requirements/Evaluation: weekly problem sets, 10-page final paper, and observing projects

Prerequisites: ASTR 111 and PHYS 201 or permission of instructor

Enrollment Limit: 10

Enrollment Preferences: juniors and seniors

Expected Class Size: 6

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: In this course, students will derive quantitative physical formulas, use these equations to calculate and compare physical properties, and generate and analyze graphical representations of data. They will also make and analyze measurements of astronomical data through observing projects.

Not offered current academic year

ASTR 404 (S) Unsolved Problems in Galaxy Evolution

In this tutorial, we will learn about galaxies and their evolution by focusing on some of the key mysteries astronomers are trying to solve. Questions may include: How do galaxies turn their gas supply into stars? Is there a universal initial mass function for star formation? What is the origin of multiple stellar populations in globular clusters? Why do some galaxies cease star formation? Which galaxies reionized the universe? We will discuss the nature of each unsolved problem, debate the theories proposed to answer it, and consider how future progress might be made.

Requirements/Evaluation: student's papers, responses to the partner's papers, and problem sets

Prerequisites: ASTR 111 and PHYS 142 or 151 or permission of instructor

Enrollment Limit: 10

Enrollment Preferences: Juniors and Seniors

Expected Class Size: 6

Grading: no pass/fail option, no fifth course option

Distributions: (D3)

Spring 2022

TUT Section: T1 TBA Anne Jaskot

ASTR 412 (F) Heliophysics

Cross-listings: ASTR 412 PHYS 412

Primary Cross-listing

We study all aspects of the Sun, our nearest star. In addition to discussing our observations of recent eclipses and what has been learned about the solar atmosphere from eclipse research, we discuss the solar interior (including the Nobel-prize-winning solar neutrino experiment and helioseismology), the photosphere, the chromosphere, the corona, and the solar wind. We discuss the Sun as an example of stars in general. We discuss both theoretical aspects and observational techniques, including work at recent total solar eclipses. We discuss results from current spacecraft, including the Solar and Heliospheric Observatory (SOHO), the Solar Dynamics Observatory, the Sun Watcher (SWAP), and Hinode (Sunrise), and the newer GOES/UVSI (Solar Ultraviolet Imager) run by an alumnus as well as additional Total Solar Irradiance measurements from spacecraft. We will discuss the role of solar observations in confirming Einstein's General Theory of Relativity with the bending of light at the 1919, 1922, and 2017 total solar eclipses as well as gravitational redshift measurements in solar spectral lines, extending our discussion to the recent "chirp" of gravitational radiation reported from several colliding black holes and neutron stars observed with the Laser Interferometer Gravitational-wave Observatory (LIGO). We also discuss transits of Mercury across the face of the Sun, most recently on November 11, 2019. We highlight the 2004 and 2012 transits of Venus across the face of the Sun as observed from Earth, the first such transits of Venus since 1882, as well as our work in observing transits of Venus from Jupiter with the Hubble Space Telescope. We discuss plans for observing future total solar eclipses, including those of December 4, 2021, near or over Antarctica; October 23, 2023, in northwestern Australia; and April 8, 2024, over Mexico and a U.S. path from Texas to northern New England.

Requirements/Evaluation: biweekly tutorial presentations; biweekly response to colleagues' presentations

Prerequisites: ASTR 111 or a 200-level Physics course; or permission of the instructor

Enrollment Limit: 10

Expected Class Size: 10

Grading: no pass/fail option, no fifth course option

Distributions: (D3)

This course is cross-listed and the prefixes carry the following divisional credit:

ASTR 412 (D3) PHYS 412 (D3)

Fall 2021

TUT Section: T1 TBA Jay M. Pasachoff

ASTR 493 (F) Senior Research: Astronomy

An original experimental or theoretical investigation is carried out under the direction of a faculty member in Astronomy, as discussed under the heading of the degree with honors in Astronomy above. This is part of a full-year thesis (493-494).

Prerequisites: permission of department

Grading: no pass/fail option, no fifth course option

Distributions: (D3)

Fall 2021

HON Section: 01 TBA Jay M. Pasachoff

ASTR 494 (F)(S) Senior Research: Astronomy

An original experimental or theoretical investigation is carried out under the direction of a faculty member in Astronomy, as discussed under the heading of the degree with honors in Astronomy above. This is part of a full-year thesis (493-494).

Prerequisites: permission of department

Grading: no pass/fail option, no fifth course option

Distributions: (D3)

Fall 2021

HON Section: 01 TBA Jay M. Pasachoff

Spring 2022

HON Section: 01 TBA Jay M. Pasachoff

ASTR 495 (F) Senior Research: Astrophysics

Cross-listings: PHYS 495 ASTR 495

Primary Cross-listing

An original experimental or theoretical investigation is carried out under the direction of a faculty member in Astronomy or Physics, as discussed under the heading of the degree with honors in Astrophysics above.

Prerequisites: permission of department

Grading: no pass/fail option, no fifth course option

Distributions: (D3)

This course is cross-listed and the prefixes carry the following divisional credit:

PHYS 495 (D3) ASTR 495 (D3)

Fall 2021

HON Section: 01 TBA Jay M. Pasachoff

ASTR 496 (F)(S) Senior Research: Astrophysics

An original experimental or theoretical investigation is carried out under the direction of a faculty member in Astronomy or Physics, as discussed under the heading of the degree with honors in Astrophysics above.

Prerequisites: permission of department

Grading: no pass/fail option, no fifth course option

Distributions: (D3)

Fall 2021

HON Section: 01 TBA Jay M. Pasachoff

Spring 2022

HON Section: 01 TBA Jay M. Pasachoff

ASTR 497 (F) Independent Study: Astronomy or Astrophysics

Astronomy independent study.

Grading: no pass/fail option, no fifth course option

Distributions: (D3)

Fall 2021

IND Section: 01 TBA Jay M. Pasachoff

ASTR 498 (S) Independent Study: Astronomy or Astrophysics (QFR)

Astronomy/Astrophysics independent study, directed by one of the Astronomy faculty: Pasachoff/Jaskot/Flaherty

Requirements/Evaluation: Regular work with the instructor; submitted presentations and papers as agreed upon

Prerequisites: suitable Astronomy/Astrophysics/Physics/Math-Stats-Geosciences/Chemistry courses

Enrollment Limit: 10

Enrollment Preferences: research topic

Expected Class Size: 5

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: Substantial quantitative and formal reasoning are involved

Spring 2022

IND Section: 01 TBA Jay M. Pasachoff

ASTR 499 (F)(S) Physics and Astronomy Colloquium

Cross-listings: PHYS 499 ASTR 499

Secondary Cross-listing

Physicists and Astronomers from around the country come to explain their research. Students of Physics and Astronomy at any level are welcome. Registration is not necessary to attend. A non-credit course.

Class Format: colloquium

Requirements/Evaluation: not a for-credit course

Prerequisites: none

Enrollment Limit: none

Enrollment Preferences: none

Grading: non-graded

Unit Notes: registration not necessary to attend

Distributions: No divisional credit

This course is cross-listed and the prefixes carry the following divisional credit:

PHYS 499 No divisional credit ASTR 499 No divisional credit

Fall 2021

LEC Section: 01 F 2:30 pm - 4:00 pm Frederick W. Strauch

Spring 2022

LEC Section: 01 F 2:30 pm - 4:00 pm Frederick W. Strauch

Winter Study ---

ASTR 13 (W) Meteorology inside and outside of total eclipses

We will discuss and use the meteorology station (temperature/pressure/wind) purchased jointly by the Astronomy Department and the Environmental Analysis Lab. Its first use was to measure the meteorological effects of the abrupt darkening of the solar radiation by a factor of a million during the 2017 total solar eclipse that swept across the United States, and we look forward to using it similarly during the October 2023 annular and April 2024 total eclipses in the U.S. In the meantime, we can set it up on campus and assess it and other local meteorological methods using both real-world weather events in addition to a variety of student-designed experimental weather scenarios. The instructor, Prof. Marcos Peñaloza-Murillo, is a Venezuelan atmospheric scientist who spent a Fulbright year and another academic year in the Astronomy Department at Williams from his home location in Mérida, Venezuela.

Requirements/Evaluation: Short paper and final project or presentation

Prerequisites: none

Enrollment Limit: 10

Enrollment Preferences: A paragraph to express interest could be used

Grading: pass/fail only

Unit Notes: Marcos Peñaloza-Murillo, an atmospheric-physics professor emeritus from Venezuela, spent a Fulbright year and an additional year at Williams working with faculty and students on the response of Earth's atmosphere to the darkening caused by solar eclipses.

Materials/Lab Fee: none

Winter 2022

LEC Section: 01 Cancelled

ASTR 16 (W) An Infinity of Worlds: Planets and the Search for Life

Less than a generation ago, we wondered, as we had for millions of years before, whether there were any other planets at all. Now, we are privileged to be in the first generation of humans to know that many of the points of light dusting our night sky are host to orbiting worlds, some of which may be like our Earth. In this course, we will explore the techniques that are being used to discover these new worlds. We will make our own contributions to this great age of discovery, by using NASA spacecraft data to search for new planets. This course, aimed at non-majors, will deal with the science of planet hunting, the astounding diversity of planets known to exist, the emerging science of astrobiology, and the enduring question of "are we alone?" through works of science fiction and cutting-edge research.

Requirements/Evaluation: 10-page paper

Prerequisites: none

Enrollment Limit: 20

Enrollment Preferences: If overenrolled, preference will be given to first-years and sophomores

Grading: pass/fail only

Unit Notes: Rob Wittenmyer '98 is Professor of astrophysics at the University of Southern Queensland in Australia. He is a veteran planet hunter with more than 85 published planet discoveries and is the Chief Investigator of the Minerva-Australis observatory which is NASA's key Southern ground support for the Transiting Exoplanet Survey Satellite.

Materials/Lab Fee: none

Winter 2022

LEC Section: 01 MWF 10:00 am - 12:50 pm Rob Wittenmyer

LEC Section: 02 MWF 1:00 pm - 3:50 pm Rob Wittenmyer

ASTR 31 (W) Senior Research: Astronomy

To be taken by students registered for Astronomy 493, 494.

Grading: pass/fail only

Winter 2022

HON Section: 01 TBA Jay M. Pasachoff

ASTR 32 (W) Senior Research: Astrophysics

To be taken by students registered for Astrophysics 495, 496.

Class Format: independent study

Grading: pass/fail only

Winter 2022

HON Section: 01 TBA Jay M. Pasachoff

ASTR 99 (W) Independent Study: Astronomy or Astrophysics

Open to upperclass students. Students interested in doing an independent project (99) during Winter Study must make prior arrangements with a faculty sponsor. The student and professor then complete the independent study proposal form available online. The deadline is typically in late September. Proposals are reviewed by the pertinent department and the Winter Study Committee. Students will be notified if their proposal is approved prior to the Winter Study registration period.

Grading: pass/fail only

Winter 2022

IND Section: 01 TBA Jay M. Pasachoff