

ASTRONOMY (DIV III)

Chair: Professor KAREN KWITTER

Professors: K. KWITTER, J. PASACHOFF. Observatory Supervisor/Senior Lecturer: S. SOUZA.

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 Astrophysics major (administered jointly with the Physics Department) and the Astronomy major 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 home page can be found at astronomy.williams.edu

ASTROPHYSICS MAJOR

The Astrophysics major is designed for students who want a rigorous introduction to the field, including 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. 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

Three 400-level astronomy courses
or Two 400-level astronomy courses *and* one of the following:
Astronomy 211T 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

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

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.

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. 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. 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.

STUDY AWAY

You can find general study-away guidelines for Astronomy/Astrophysics [here](#).

ASPH 493(F) 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.

Class Format: independent study

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Prerequisites: permission of department

Distributional Requirements: Division 3

Fall 2016

HON Section: 01 TBA Instructor: Karen Kwitter

ASPH 494(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.

Class Format: independent study

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Prerequisites: permission of department

Distributional Requirements: Division 3

Spring 2017

HON Section: 01 TBA Instructor: Karen Kwitter

ASPH 497(F) Independent Study: Astrophysics

Astrophysics independent study.

Class Format: independent study

may not be taken on a pass/fail basis; not available for the fifth course option

Distributional Requirements: Division 3

Fall 2016

IND Section: 01 TBA Instructor: Karen Kwitter

ASPH 498(S) Independent Study: Astrophysics

Astrophysics independent study.

Class Format: independent study

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Distributional Requirements: Division 3

Spring 2017

IND Section: 01 TBA Instructor: Karen Kwitter

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

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? What about the recently discovered "chirp" from gravitational radiation resulting from two giant black holes merging? 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 how they end their existence, will provide answers to these questions and more. The course gives special attention to the exciting discoveries of the past few years. Topics include modern astronomical instruments such as the Hubble Space Telescope, the Chandra X-ray Observatory, the Kepler, K2 and TESS missions to discover planets around other stars, the latest huge telescopes and some results from them; how astronomers interpret the light received from distant celestial

objects; the Sun as a typical star (and how its future will affect ours); and our modern understanding of how stars work and how they change with time. We will also discuss how pulsars and black holes result from the evolution of normal, massive stars and how supermassive black holes lurk at the center of galaxies and quasars. We will discuss the discovery of planets around stars other than the Sun. 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 102 (solar system) and 104 (galaxies and cosmology), and students who have taken those courses are welcome.

Observing sessions will include use of the 24-inch telescope and other telescopes for nighttime observations of stars, star clusters, planets and their moons, nebulae, and galaxies, as well as use of other telescopes for daytime observations of the Sun.

Class Format: lecture (three hours per week), observing sessions (scattered throughout the semester), afternoon labs (five times per semester), and a planetarium demonstration

Requirements/Evaluation: evaluation will be based on two hour tests, a final exam, an observing portfolio, and lab reports

Extra Info: not available for the fifth course option

Prerequisites: none

Enrollment Limit: 48

Expected Class Size: 24

Dept. Notes: non-major course

Distributional Requirements: Division 3

Fall 2016

LEC Section: 01 TR 09:55 AM 11:10 AM Instructor: Jay Pasachoff

LAB Section: 02 T 01:00 PM 02:30 PM Instructor: Steven Souza

LAB Section: 03 T 02:30 PM 04:00 PM Instructor: Steven Souza

LAB Section: 04 W 01:00 PM 02:30 PM Instructor: Steven Souza

LAB Section: 05 W 02:30 PM 04:00 PM Instructor: Steven Souza

ASTR 102 Our Solar System and Others

What makes Earth different from all the other planets? What has NASA's Curiosity on Mars found about Mars's past running water and suitability for life? How has knowledge about Pluto been transformed by NASA's 2015 flyby and the associated ground-based studies with which Williams College faculty and students participate? Will asteroids or comets collide with the Earth again? What is a solar eclipse like? 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, 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. 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.

Observing sessions will include use of the 24-inch telescope and other telescopes for nighttime observations of stars, star clusters, planets and their moons, nebulae, and galaxies, as well as use of other telescopes for daytime observations of the Sun.

Class Format: lecture (three hours per week), observing sessions (scattered throughout the semester), afternoon labs (five times per semester), and a planetarium demonstration

Requirements/Evaluation: evaluation will be based on two hour tests, a final exam, an observing portfolio, and laboratory reports

Extra Info: not available for the fifth course option

Prerequisites: none

Enrollment Limit: 48

Expected Class Size: 24

Dept. Notes: non-major course

Distributional Requirements: Division 3

Not Offered Academic Year 2017

LEC Instructor: Marek Demianski

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 has opened a whole different way of observing the Universe from the traditional use of light and other forms of electromagnetic radiation. 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 are giving clues into how the Universe's currently observed structure arose. 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? 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.

Observing sessions will include use of the 24-inch telescope and other telescopes for nighttime observations of stars, star clusters, planets and their moons, nebulae, and galaxies, as well as daytime observations of the Sun.

Observing sessions will include use of the 24-inch telescope and other telescopes for observations of stars, star clusters, planets and their moons, nebulae, and galaxies, as well as daytime observations of the Sun.

Class Format: lecture (three hours per week), observing sessions (scattered throughout the semester), afternoon labs (five times per semester), and a planetarium demonstration

Requirements/Evaluation: evaluation will be based on two hour tests, a final exam, lab reports, and an observing portfolio

Extra Info: not available for the fifth course option

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

Enrollment Limit: 48

Expected Class Size: 24

Dept. Notes: non-major course

Distributional Requirements: Division 3

Spring 2017

LEC Section: 01 TR 09:55 AM 11:10 AM Instructor: Jay Pasachoff

LAB Section: 02 T 01:00 PM 02:30 PM Instructor: Steven Souza

LAB Section: 03 T 02:30 PM 04:00 PM Instructor: Steven Souza

LAB Section: 04 W 01:00 PM 02:30 PM Instructor: Steven Souza

LAB Section: 05 W 02:30 PM 04:00 PM Instructor: Steven Souza

ASTR 111(F) Introduction to Astrophysics (Q)

How do stars work? This course answers that question from start to finish! In this course we undertake a survey of some of the main ideas in modern astrophysics, with an emphasis on the observed properties and evolution of stars; 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 radiation laws and stellar spectra, astronomical instrumentation, physical characteristics of the Sun and other stars, star formation and evolution, nucleosynthesis, white dwarfs and planetary nebulae, pulsars and neutron stars, supernovae, relativity, and black holes (including a discussion of the first reported detection of gravitational waves, generated during the merging of two massive stellar black holes from more than a billion light-years away). Observing sessions include use of the 24-inch and other telescopes for observations of stars, nebulae, planets and galaxies, as well as daytime observations of the Sun.

Class Format: lecture/discussion, observing sessions, and five labs per semester

Requirements/Evaluation: evaluation will be based on weekly problem sets, two hour tests, a final exam, lab reports, and an observing portfolio

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

Enrollment Limit: 28

Expected Class Size: 20

Distributional Requirements: Division 3, Quantitative/Formal Reasoning

Fall 2016

LEC Section: 01 TR 11:20 AM 12:35 PM Instructor: Karen Kwitter

LAB Section: 02 M 01:00 PM 04:00 PM Instructor: Steven Souza

LAB Section: 03 R 01:00 PM 03:40 PM Instructor: Steven Souza

ASTR 207T(F) Extraterrestrial Life in the Galaxy: A Sure Thing, or a Snowball's Chance? (W)

A focused investigation of the possibility of life arising elsewhere in our Galaxy, and the chances of our detecting it. In this course, pairs of students will explore the astronomical and biochemical requirements for the development of Earth-like life. We will consider the conditions on other planets within our solar system as well as on newly-discovered planets circling other stars. We will also analyze the famous "Drake Equation," which calculates the expected number of extraterrestrial civilizations, and attempt to evaluate its components. Finally, we will examine current efforts to detect signals from intelligent alien civilizations and contemplate humanity's reactions to a positive detection.

Class Format: tutorial

Requirements/Evaluation: evaluation will be based on the student's papers, responses to the partner's papers, and evidence of growth in understanding over the semester; as well as improvement in speaking and writing

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Prerequisites: ASTR 111 or BIOL 101-102, CHEM 101-102, or GEOS 101 or equivalent science preparation; instructor's permission required

Enrollment Preferences: if overenrolled, preference given to students who have had ASTR 111

Enrollment Limit: 10

Expected Class Size: 10

Distributional Requirements: Division 3, Writing Intensive

Fall 2016

TUT Section: T1 TBA Instructor: Karen Kwitter

ASTR 211T(F) Astronomical Observing and Data Analysis (Q)

This course will introduce techniques for obtaining and analyzing astronomical data. We begin by learning about practical observation planning and move on to discussion of CCD detectors, signal statistics, digital data reduction, and image processing. We will make use of data we obtain with our 24-inch telescope, as well as data from other optical ground-based observatories and archives. We then go on to learn about non-optical observatories, both space-based (e.g., Chandra X-Ray Observatory, Spitzer Space Telescope) and ground-based (e.g., Atacama Large Millimeter Array), and work with some of their data.

Class Format: tutorial plus computer lab work and observing

Requirements/Evaluation: evaluation will be based on tutorial presentations and weekly problem sets, an hour exam and observing projects

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

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

Enrollment Limit: 10

Expected Class Size: 6

Distributional Requirements: Division 3, Quantitative/Formal Reasoning

Not Offered Academic Year 2017

TUT Instructor: Karen Kwitter

ASTR 217T Planets and Moons (W)

Crosslistings: GEOS 217/ASTR 217

Secondary Crosslisting

We live in a solar system full of wonders. Each planet and each moon is strange: different from our Earth, and different from each other. The recent flood of images and data from Mars constantly reveals new marvels—the rest of the solar system is even stranger. The U.S. put men on the moon; there are robots on Mars; and the Soviet Union landed several times on Venus. The other worlds are known only from flybys and remote images, but it's amazing how much those can teach us. By focusing on recent research, we will examine how the solar system works and delve into its mysteries. Topics may include the possible Late Heavy Bombardment of the moon, runaway greenhouse on Venus, water on Mars, hidden oceans on Europa, and the methane weather cycle on Titan.

Class Format: tutorial

Requirements/Evaluation: six 1500-word papers, discussion & critical analysis; strong focus on polished writing & argument, & papers will be thoroughly edited by the professor for style, grammar & syntax

Extra Info: students will improve writing by integrating into successive papers the editorial comments they receive, & also by editing the writing of their tutorial partners

may not be taken on a pass/fail basis; not available for the fifth course option

Prerequisites: any GEOS course, or permission of instructor

Enrollment Preferences: sophomores

Enrollment Limit: 10

Expected Class Size: 10

Distributional Requirements: Division 3, Writing Intensive

Not Offered Academic Year 2017

TUT Instructor: Ronadh Cox

ASTR 221 Compact Stellar Remnants: White Dwarfs, Neutron Stars, and Black Holes (Q)

Crosslistings: ASTR 221/ASTR 421

Primary Crosslisting

As stars end their varied lives they each end up as a dense, compact remnant. In this course we will study the final stages of stellar evolution and concentrate on the basic properties of the three possible remnant states: white dwarf, neutron star and black hole. We will study radio and X-ray pulsars, which represent observed manifestations of some compact objects. In addition, we will discuss the observations confirming the existence of black holes. Finally, we will explore the extreme conditions existing near neutron stars and black holes and discuss their astrophysical consequences.

Class Format: lecture/discussion

Requirements/Evaluation: evaluation will be based on classroom participation, homework assignments, a midterm exam and final exam.

Prerequisites: if taken under ASTR 221: PHYS 151 or co-requisite of PHYS 142, and MATH 150 or 151; if taken under ASTR 421: Physics 201 & permission of instructor

Enrollment Preferences: if overenrolled, preference will be given to Astronomy and Astrophysics majors

Enrollment Limit: 19

Expected Class Size: 10

Distributional Requirements: Division 3, Quantitative/Formal Reasoning

Not Offered Academic Year 2017

ASTR 330(S) The Nature of the Universe

This course is a journey through space and time from the first 10 seconds to the ultimate fate of the Universe billions of years in 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 giant black holes, relativity, galaxies and quasars, and formation of the large-scale structure of the Universe. We will explore current ideas about the future of the Universe, in particular the acceleration of the Universe's expansion, and its implications for the end of time.

Class Format: lecture/discussion, three hours per week

Requirements/Evaluation: evaluation will be based on two hour tests, a small observing portfolio, occasional quizzes, and a final exam

Extra Info: not available for the fifth course option

Prerequisites: none; 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

Enrollment Limit: 48

Expected Class Size: 20

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

Distributional Requirements: Division 3

Spring 2017

LEC Section: 01 MR 01:10 PM 02:25 PM Instructor:Karen Kwitter

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

Crosslistings: ASTR 336/HSCI 336

Primary Crosslisting

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 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 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 also consider a range of dramas that are based on scientific themes, such as Tom Stoppard's *Arcadia* and Michael Frayn's *Copenhagen*.

Class Format: seminar

Requirements/Evaluation: evaluation will be based on biweekly 5-page papers, participation in discussions, and a 15-page final paper

Prerequisites: none

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

Enrollment Limit: 12

Expected Class Size: 12

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

Distributional Notes: meets Division 3 requirement if registration is under ASTR; meets Division 2 requirement if registration is under HSCI

Distributional Requirements: Division 3, Writing Intensive

Other Attributes: SCST Elective Courses

Not Offered Academic Year 2017

SEM Instructor:Jay Pasachoff

ASTR 340 Great Astronomers and Their Original Publications (W)

Crosslistings: ASTR 340/HSCI 340/LEAD 340

Primary Crosslisting

In the 2014-15 academic year of the study of the book, honoring the new library and the expansion of the Chapin Library of Rare Books, we study many of the greatest names in the history of astronomy, consider their biographies, assess their leadership roles in advancing science, and examine and handle their first-edition books and other publications. Our study includes the original books published as follows: 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 stars and of the Moon, 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); William Herschel and Caroline Herschel (1781, 1798). In more recent centuries, the original works are articles: 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 (pulsar discovery, 1968); 21st-century: Wendy Freedman (Universe's expansion rate, 2000s). We will also read biographies and recent novels dealing with some of the above astronomers. With the collaboration of the librarians, we will meet regularly in the Chapin Library of Rare Books and also have a session at the library of the Clark Art Institute to see its rare books of astronomical interest.

Class Format: seminar

Requirements/Evaluation: class participation, two 5-page intermediate papers, and a final 15-page paper

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

Enrollment Limit: 15

Distribution Notes: meets Division 3 requirement if registration is under ASTR; meets Division 2 requirement if registration is under HSCI or LEAD

Distributional Requirements: Division 3, Writing Intensive

Other Attributes: SCST Related Courses

Not Offered Academic Year 2017

SEM Instructor: Jay Pasachoff

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

The matter between the stars—the interstellar medium—manifests itself in many interesting and unexpected ways, and, as the detritus of stars, its properties and behavior hold clues to the history and future evolution of both stars and the galaxies that contain them. Stars are accompanied by diffuse matter all through their lifetimes, from their birthplaces in dense molecular clouds, to the stellar winds they eject with varying ferocity 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. The existence of life on Earth is eloquent evidence of this chemical enrichment. In this course we will study the interstellar medium in its various forms. We will learn about many of the physical mechanisms that produce the radiation we observe from diffuse matter, 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. 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 the equipment on our observing deck.

Class Format: tutorial, plus computer lab work and observing projects

Requirements/Evaluation: evaluation will be based on tutorial presentations and weekly problem sets, an hour exam and observing projects

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Prerequisites: PHYS 201 or permission of instructor

Enrollment Limit: 10

Expected Class Size: 6

Distributional Requirements: Division 3, Quantitative/Formal Reasoning

Not Offered Academic Year 2017

TUT Instructor: Karen Kwitter

ASTR 410 Compact Stellar Remnants: White Dwarfs, Neutron Stars and Black Holes

A star is a very interesting, very complicated physical object. Properties of stars and their evolutionary paths depend on an intricate interplay of different physical phenomena with gravity, nuclear interactions, radiation processes and even quantum and relativistic effects playing important roles. Using basic physics we will construct simple models of stars and discuss their evolution, concentrating on the key physical processes that play the dominant role at different evolutionary stages. We will discuss late stages of stellar evolution and concentrate on the basic properties of three possible remnants: white dwarfs, neutron stars and black holes. Radio and X-ray pulsars, supernovae including Type Ia and Gamma Ray Bursts will be discussed as well as observational confirmation of existence of black holes. We will explore extreme conditions existing near neutron stars and black holes and discuss their astrophysical consequences.

Class Format: lecture/discussion, three hours per week

Requirements/Evaluation: evaluation will be based on classroom participation, homework assignments, a midterm exam and a final exam

Prerequisites: PHYS 201

Enrollment Limit: 19

Expected Class Size: 12

Distributional Requirements: Division 3

Not Offered Academic Year 2017

LEC Instructor: Marek Demianski

ASTR 412T(S) Solar Physics (W)

We study all aspects of the Sun, our nearest star. We evaluate scientific result from the total solar eclipse of August 21, 2017, the first eclipse whose totality crosses the U.S. from coast to coast since 1918 and the first to be entirely within the US since the nation's founding. In addition to discussing what has been learned about the solar atmosphere from eclipse and related space 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 new GOES16/UVSI (Solar Ultraviolet Imager) run by an alumnus as well as additional Total Solar Irradiance

measurements from ACRIMSAT and SORCE. As a special timely treat, we will discuss the role of solar observations in confirming Einstein's General Theory of Relativity with the bending of light at the 1919 and 1922 total solar eclipses as well as gravitational redshift measurements in solar spectral lines, extending our discussion to the recent "chirp" of gravitational radiation reported in 2016 from LIGO. We also discuss our data analysis of recent transits of Mercury across the face of the Sun (most recently in May 2016) and 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 and from Saturn with NASA's Cassini spacecraft.

Class Format: tutorial; students will meet weekly with the professor in groups of two or three to discuss readings and make presentations, often in PowerPoint or Keynote format

Requirements/Evaluation: evaluation will be based on four 5-page papers, discussions, and presentations; students will be expected to improve their writing throughout the course, with the aid of careful editing by and comments from the professor

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Prerequisites: Astronomy 111 or a 200-level Physics course

Enrollment Limit: 12

Expected Class Size: 6

Distributional Requirements: Division 3, Writing Intensive

Spring 2017

TUT Section: T1 TBA Instructor: Jay Pasachoff

ASTR 420 Observational Cosmology: Observing and Modeling the Universe (Q)

Recent astronomical observations have revealed that the universe contains large amounts of dark matter (most probably consisting of undetected yet very-weakly-interacting particles) and dark energy (a strange kind of uniformly-distributed energy that creates negative pressure causing accelerated expansion of the universe), while ordinary radiating matter (stars, galaxies and clouds of gas) is only a minor addition. In this course we will discuss the most important observations that lead us to these conclusions. We will start by studying and classifying galaxies. Eighty-five years ago Hubble discovered that the universe is expanding and almost 30 years later Gamow proposed the Big Bang model of the evolution of the universe. We will discuss observational data that support the Big Bang model, concentrating on the microwave background radiation and its properties, along with the process of primordial nucleosynthesis. Recent observational data indicate that at a very early stage of evolution the universe passed through a phase of very rapid exponential expansion called "inflation." We will develop and discuss the Standard Cosmological Model that describes the evolution of the universe from the Big Bang to its present state. In particular we will discuss the early phases of radiation-dominated evolution and the late process of structure formation. Finally we will concentrate on the observations indicating that the universe is now dominated by dark matter and dark energy.

Class Format: lecture/discussion

Requirements/Evaluation: evaluation will be based on classroom participation, homework assignments, a midterm exam and a final exam

Prerequisites: PHYS 201 or permission of instructor

Enrollment Preferences: if overenrolled, preference will be given to Astronomy and Astrophysics majors

Enrollment Limit: 19

Expected Class Size: 12

Distributional Requirements: Division 3, Quantitative/Formal Reasoning

Not Offered Academic Year 2017

LEC Instructor: Marek Demianski

ASTR 421 Compact Stellar Remnants: White Dwarfs, Neutron Stars, and Black Holes (Q)

Crosslistings: ASTR 221/ASTR 421

Secondary Crosslisting

As stars end their varied lives they each end up as a dense, compact remnant. In this course we will study the final stages of stellar evolution and concentrate on the basic properties of the three possible remnant states: white dwarf, neutron star and black hole. We will study radio and X-ray pulsars, which represent observed manifestations of some compact objects. In addition, we will discuss the observations confirming the existence of black holes. Finally, we will explore the extreme conditions existing near neutron stars and black holes and discuss their astrophysical consequences.

Class Format: lecture/discussion

Requirements/Evaluation: evaluation will be based on classroom participation, homework assignments, a midterm exam and final exam.

Prerequisites: if taken under ASTR 221: PHYS 151 or co-requisite of PHYS 142, and MATH 150 or 151; if taken under ASTR 421: Physics 201 & permission of instructor

Enrollment Preferences: if overenrolled, preference will be given to Astronomy and Astrophysics majors

Enrollment Limit: 19

Expected Class Size: 10

Distributional Requirements: Division 3, Quantitative/Formal Reasoning

Not Offered Academic Year 2017

LEC Instructor: Marek Demianski

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.

Class Format: independent study

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Prerequisites: permission of department

Distributional Requirements: Division 3

Fall 2016

HON Section: 01 TBA Instructor: Karen Kwitter

ASTR 494(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.

Class Format: independent study

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Prerequisites: permission of department

Distributional Requirements: Division 3

Spring 2017

HON Section: 01 TBA Instructor: Karen Kwitter

ASTR 497(F) Independent Study: Astronomy

Astronomy independent study.

Class Format: independent study

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Distributional Requirements: Division 3

Fall 2016

IND Section: 01 TBA Instructor: Karen Kwitter

ASTR 498(S) Independent Study: Astronomy

Astronomy independent study.

Class Format: independent study

Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option

Distributional Requirements: Division 3

Spring 2017

IND Section: 01 TBA Instructor: Karen Kwitter

ASTR 499(F,S) Physics and Astronomy Colloquium

Crosslistings: PHYS 499/ASTR 499

Secondary Crosslisting

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

Extra Info: registration not necessary to attend

Prerequisites: none

Enrollment Limit: none

Distributional Requirements: Non-divisional

Fall 2016

LEC Section: 01 F 02:35 PM 03:50 PM Instructor: David Tucker-Smith

Spring 2017

LEC Section: 01 F 02:35 PM 03:50 PM Instructor: David Tucker-Smith