

ASTRONOMY

Departmental Office: 1328 Pupin; 212-854-3278
<http://www.astro.columbia.edu>

Director of Undergraduate Studies:
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Astronomy is, at once, the oldest science and one of the most vibrant fields of modern research. Its goal is to construct testable, quantitative, coherent models of the universe (the UNlty of the dIVERSE) and its contents—galaxies, stars, and planets. The department offers two majors, both of which require a solid grounding in the mathematics and physics necessary for the pursuit of the discipline.

The astrophysics major is designed as preparation for graduate study and consists of a standard physics major sequence; a yearlong introduction to astrophysics (typically taken in the sophomore year, but open to first-years with adequate preparation in calculus and physics); and two required courses covering advanced topics in astronomy. Research, in the form of summer internships and/or term-time independent projects, which can lead to a senior thesis, is strongly encouraged. For a research thesis, students should enroll in the parallel, two-semester sequence *ASTR UN3997-ASTR UN3998 INDEPENDENT RESEARCH*, preferably in their senior year. Students begin the research project in the fall and complete the written thesis in the spring.

The astronomy major provides a basis for further study in the field, but is also designed to be compatible with liberal arts students who pursue other careers and those wishing to combine astronomy with related sciences other than physics, such as chemistry or geology. It requires only two physics courses beyond the introductory sequence and can be completed easily if begun in the sophomore year.

The department offers numerous introductory astronomy courses at the 1000-level that do not have prerequisites. The calculus-based *ASTR UN2001 INTRO TO ASTROPHYSICS I-ASTR UN2002 INTRO TO ASTROPHYSICS II* sequence is recommended for astronomy majors and concentrators and is required for astrophysics majors.

Most 3000-level courses, as well as *ASTR GU4260 MODELING THE UNIVERSE*, are offered every other year. Students should inquire with the director of undergraduate studies if they have specific questions on the course schedule. *ASTR UN3996 Current Research in Astrophysics* is a one-point course offered in the fall, designed to introduce majors to research methods and topics. It requires students to attend the department colloquia and a seminar designed to help students understand the colloquium topic. The 3000-level courses need not be taken in any particular order.

Professors

James Applegate
 Greg Bryan (Chair)
 Zoltan Haiman
 Jules P. Halpern (*emeritus*)
 David J. Helfand
 Kathryn Johnston
 Laura Kay (Barnard)
 Jeremiah P. Ostriker
 Frederik B. S. Paerels
 Joseph Patterson

Mary E. Putman
 David Schiminovich
 Jacqueline van Gorkom (*emeritus*)

Associate Professor

Marcel Agüeros
 David Kipping
 Lorenzo Sironi

Assistant Professors

Melissa K. Ness
 Jane Huang

Adjunct Professor

Michael Allison (GISS)
 Mordecai-Mark MacLow (Hayden Planetarium)
 Rebecca Oppenheimer (Hayden Planetarium)
 Michael Shara (Hayden Planetarium)
 Ruth Angus (Hayden Planetarium)

Senior Lecturer

On Leave

Prof. Patterson, Schiminovich, Zoltan (*Fall 2022*)

Guidelines for all Astronomy Majors, Concentrators, and Interdepartmental Majors

Courses in which the grade of D has been received do not count toward the major or concentration requirements.

Major in Astronomy

The major requirements, to be planned with the director of undergraduate studies, are as follows:

Mathematics

Calculus sequence through MATH UN1202 Calculus IV or MATH UN1208 Honors Mathematics IV

Astronomy

Select one of the following options:

Option 1:

Two 3-point 1000-level astronomy courses
 12 points in astronomy at the 2000-level or above

Option 2:

ASTR UN2001 INTRO TO ASTROPHYSICS I
 - ASTR UN2002 and INTRO TO ASTROPHYSICS II
 9 points in astronomy at the 3000-level or above

Physics

Select one of the following physics sequences:

Sequence 1:

PHYS UN1401 - PHYS UN1402 - PHYS UN1403	INTRO TO MECHANICS # THERMO and INTRO ELEC/MAGNETISM # OPTCS and INTRO-CLASSCL # QUANTUM WAVES
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Sequence 2:

PHYS UN1601 - PHYS UN1602 - PHYS UN2601	PHYSICS I:MECHANICS/RELATIVITY and PHYSICS II: THERMO, ELEC # MAG and PHYSICS III:CLASS/QUANTUM WAVE
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Sequence 3:

PHYS UN2801 - PHYS UN2802	ACCELERATED PHYSICS I and ACCELERATED PHYSICS II
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Additional Physics Courses

Two physics courses at the 3000-level or above

Students contemplating graduate study are advised to include at least two of these physics courses:

PHYS UN3003	MECHANICS
PHYS UN3007	ELECTRICITY-MAGNETISM
PHYS GU4021 - PHYS GU4022	QUANTUM MECHANICS I and QUANTUM MECHANICS II

One of these may be substituted for 3 points of astronomy.

Major in Astrophysics

Students considering an Astrophysics major are encouraged to meet with the director of undergraduate studies. If possible, it is useful to start the physics sequence in the first year.

Mathematics

Calculus sequence through MATH UN1202 Calculus IV or MATH UN1208 Honors Mathematics IV

Astronomy

ASTR UN2001 - ASTR UN2002	INTRO TO ASTROPHYSICS I and INTRO TO ASTROPHYSICS II
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6 points in astronomy at the 3000-level or above

Physics

Select one of the following physics sequences:

Sequence 1:

PHYS UN1401 - PHYS UN1402 - PHYS UN1403	INTRO TO MECHANICS # THERMO and INTRO ELEC/MAGNETISM # OPTCS and INTRO-CLASSCL # QUANTUM WAVES
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Sequence 2:

PHYS UN1601 - PHYS UN1602 - PHYS UN2601	PHYSICS I:MECHANICS/RELATIVITY and PHYSICS II: THERMO, ELEC # MAG and PHYSICS III:CLASS/QUANTUM WAVE
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Sequence 3:

PHYS UN2801 - PHYS UN2802	ACCELERATED PHYSICS I and ACCELERATED PHYSICS II
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Additional Physics Courses

PHYS UN3003	MECHANICS
PHYS UN3007	ELECTRICITY-MAGNETISM
PHYS UN3008	ELECTROMAGNETIC WAVES # OPTICS
PHYS GU4021 - PHYS GU4022	QUANTUM MECHANICS I and QUANTUM MECHANICS II

OR

PHYS BC3006 - PHYS GU4023	QUANTUM PHYSICS and THERMAL # STATISTICAL PHYSICS
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Concentration in Astronomy

An extra 3 points of physics can substitute for 3 points of astronomy, as long as the course submitted is at the equivalent or higher level. The concentration requirements are as follows:

Mathematics

9 points of mathematics

Astronomy

15 points of astronomy, nine of which must be at or above the 2000-level

Physics

9 points of physics

Fall 2023

ASTR UN1403 EARTH, MOON, AND PLANETS. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: recommended preparation: a working knowledge of high school algebra.

Prerequisites: recommended preparation: a working knowledge of high school algebra. The overall architecture of the solar system. Motions of the celestial sphere. Time and the calendar. Major planets, the earth-moon system, minor planets, comets. Life in the solar system and beyond. This course is similar to ASTR BC 1753. You cannot enroll in both courses and receive credit for both

Fall 2023: ASTR UN1403

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1403	001/12449	T Th 1:10pm - 2:25pm 141 Uris Hall	James Applegate	3.00	57/75

ASTR UN1420 Galaxies and Cosmology. 3 points.

CC/GS: Partial Fulfillment of Science Requirement

Galaxies contain stars, gas dust, and (usually) super-massive black holes. They are found throughout the Universe, traveling through space and occasionally crashing into each other. This course will look at how these magnificent systems form and evolve, and what they can tell us about the formation and evolution of the Universe itself. You cannot enroll in ASTR UN1420 in addition to ASTR BC1754 or ASTR UN1404 and receive credit for both.

Fall 2023: ASTR UN1420

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1420	001/12451	M W 10:10am - 11:25am 602 Hamilton Hall	Mary Putman	3	63/80

Spring 2024: ASTR UN1420

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1420	001/12728	T Th 8:40am - 9:55am 702 Hamilton Hall	Kathryn Johnston	3	80/80

ASTR UN1453 ANOTHER EARTH. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement
This course cannot be taken for credit if BC1753 has been taken.

This course will explore the unique properties of Earth, compared to other planets in the Solar System, and the possibility of Earth-like planets around other stars. The basics of the Solar System, gravity, and light will be covered, as well as the geology and atmospheres of the terrestrial planets. The properties of Earth that allowed life to develop and whether life can develop on other planets will be discussed. Finally, the discovery of planets beyond our Solar System and the likelihood of another Earth will be a key component of the course

Fall 2023: ASTR UN1453

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1453	001/12452	T Th 10:10am - 11:25am 601 Fairchild Life Sciences Bldg	David Kipping	3.00	39/60

ASTR UN1836 STARS AND ATOMS. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: recommended preparation: a working knowledge of high school algebra.

Prerequisites: recommended preparation: a working knowledge of high school algebra. What is the origin of the chemical elements? This course addresses this question, starting from understanding atoms, and then going on to look at how atoms make stars and how stars make atoms. The grand finale is a history of the evolution of the chemical elements throughout time, starting from the Big Bang and ending with YOU. You cannot enroll in ASTR UN1836 in addition to ASTR BC1754 or ASTR UN1404 and receive credit for both

Fall 2023: ASTR UN1836

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1836	001/12453	T Th 8:40am - 9:55am 702 Hamilton Hall	Kathryn Johnston	3.00	42/80

Spring 2024: ASTR UN1836

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1836	001/12729	M W 2:40pm - 3:55pm 307 Uris Hall	Marcel Agueros	3.00	54/54

ASTR UN1903 ASTRONOMY LAB I. 1.00 point.

Laboratory for ASTR UN1403. Projects include observations with the departments telescopes, computer simulation, laboratory experiments in spectroscopy, and the analysis of astronomical data. Lab 1 ASTR UN1903 - goes with ASTR BC1753, ASTR UN1403 or ASTR UN1453

Fall 2023: ASTR UN1903

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1903	001/00612	M 6:00pm - 9:00pm 1402 Pupin Laboratories	Laura Kay, James Sullivan	1.00	12/15
ASTR 1903	002/00613	T 7:00pm - 10:00pm 1402 Pupin Laboratories	Laura Kay, Michael Messere	1.00	7/15

Spring 2024: ASTR UN1903

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1903	001/16125	M 6:00pm - 9:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	16/16
ASTR 1903	002/16124	T 7:00pm - 10:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	16/16
ASTR 1903	003/17754	W 6:00pm - 9:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	14/16

ASTR UN1904 ASTRONOMY LAB II. 1.00 point.

Laboratory for ASTR UN1404. Projects include use of telescopes, laboratory experiments in the nature of light, spectroscopy, and the analysis of astronomical data. Lab 2 ASTR UN1904 - goes with ASTR BC1754 or ASTR UN1404 (or ASTR UN1836 or ASTR UN1420)

Fall 2023: ASTR UN1904

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1904	001/00614	W 6:00pm - 9:00pm 1402 Pupin Laboratories	Laura Kay, Max Lee	1.00	13/15

Spring 2024: ASTR UN1904

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1904	001/16126	M 7:00pm - 10:00pm 1332 Pupin Laboratories	Greg Bryan	1.00	10/16

ASTR UN2001 INTRO TO ASTROPHYSICS I. 3.00 points.

Prerequisites: a working knowledge of calculus. Corequisites: a course in calculus-based general physics. First term of a two-term calculus-based introduction to astronomy and astrophysics. Topics include the physics of stellar interiors, stellar atmospheres and spectral classifications, stellar energy generation and nucleosynthesis, supernovae, neutron stars, white dwarfs, and interacting binary stars

Fall 2023: ASTR UN2001

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 2001	001/12456	M W 2:40pm - 3:55pm 333 Uris Hall	Marcel Agueros	3.00	28/40

ASTR UN2900 FRONTIERS OF ASTROPHYSICS. 1.00 point.

Several members of the faculty each offer a brief series of talks providing context for a current research topic in the field and then present results of their ongoing research. Opportunities for future student research collaboration are offered. Grading is Pass/Fail

Fall 2023: ASTR UN2900

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 2900	001/12454	F 10:10am - 11:25am 330 Uris Hall	David Helfand	1.00	51/60
ASTR 2900	AU1/18954	F 10:10am - 11:25am Othr Other	David Helfand	1.00	5/5

ASTR UN3273 HIGH ENERGY ASTROPHYSICS. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics. No previous, \nastronomy background required.

A survey of the most energetic and explosive objects in the Universe and their radiation. Topics include: techniques of X-ray and gamma-ray astronomy; observations of neutron stars (pulsars) and black holes; accretion disks and relativistic jets; supernovae, supernova remnants, gamma-ray bursts, quasars and active galactic nuclei; clusters of galaxies; cosmic rays and neutrinos.

Fall 2023: ASTR UN3273

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3273	001/12458	M W 2:40pm - 3:55pm 825 Seeley W. Mudd Building	Lorenzo Sironi	3.00	16/30
ASTR 3273	AU1/19016	M W 2:40pm - 3:55pm Othr Other	Lorenzo Sironi	3.00	5/5

ASTR UN3602 PHYSICAL COSMOLOGY. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics.

Prerequisites: one year of calculus-based general physics. The standard hot big bang cosmological model and modern observational results that test it. Topics include the Friedmann equations and the expansion of the universe, dark matter, dark energy, inflation, primordial nucleosynthesis, the cosmic microwave background, the formation of large-scale cosmic structures, and modern cosmological observations

Fall 2023: ASTR UN3602

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3602	001/12695	T Th 2:40pm - 3:55pm 307 Uris Hall	Greg Bryan	3.00	30/40
ASTR 3602	AU1/18913	T Th 2:40pm - 3:55pm Othr Other	Greg Bryan	3.00	4/5

ASTR UN3997 INDEPENDENT RESEARCH. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: the instructor's permission. For an independent research project or independent study, a brief description of the proposed project or reading, with the supervising faculty member's endorsement, is required for registration.

Prerequisites: the instructor's permission. For an independent research project or independent study, a brief description of the proposed project or reading, with the supervising faculty member's endorsement, is required for registration. A variety of research projects conducted under the supervision of members of the faculty. Observational, theoretical, and experimental work in galactic and extragalactic astronomy and cosmology. The topic and scope of the work must be arranged with a faculty member in advance; a written paper describing the results of the project is required at its completion (note that a two-term project can be designed such that the grade YC is given after the first term). Senior majors in astronomy or astrophysics wishing to do a senior thesis should make arrangements in May of their junior year and sign up for a total of 6 points over their final two terms. Both a substantial written document and an oral presentation of thesis results are required

Fall 2023: ASTR UN3997

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3997	001/12461		Melissa Ness	3.00	9/15

ASTR GU4260 MODELING THE UNIVERSE. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics.

Prerequisites: one year of calculus-based general physics. The goal of this course is to provide a basic hands-on introduction to the practice and theory of scientific computing with applications in astronomy and astrophysics. The course will include an introduction to programming, as well as a sampling of methods and tools from the field of scientific computing. The course will include a hands-on project in which students use numerical methods to solve a research problem. Students who are interested in participating in research projects are strongly encouraged to take the course in their sophomore or junior year

Fall 2023: ASTR GU4260

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 4260	001/12470	T Th 10:10am - 11:25am 233 Seeley W. Mudd Building	Mordecai-Mark Mac Low	3.00	34/30

ASTR GR6001 RADIATIVE PROCESSES. 3.00 points.

Prerequisites: 3000-level electromagnetic theory and quantum mechanics.

Prerequisites: 3000-level electromagnetic theory and quantum mechanics. Radiation mechanisms and interaction of radiation with matter. Applications of classical and semiclassical radiation theory and atomic physics to astrophysical settings. Radiative transfer, polarization, scattering, line radiation, special relativity, bremsstrahlung, synchrotron radiation, inverse Compton scattering, ionization losses, shocks and particle acceleration, plasma processes, atomic structure and spectroscopic terms, radiative transitions and oscillator strengths, curve of growth, molecular spectra

Fall 2023: ASTR GR6001

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 6001	001/12471	M W 1:10pm - 2:25pm 503 Hamilton Hall	Frederik Paerels	3.00	20/15

Spring 2024

ASTR UN1234 UNIVERSAL TIMEKEEPER. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: high school algebra and latent curiosity are assumed. The goal of the course is to illustrate — and perhaps even inculcate — quantitative and scientific reasoning skills. The subject material employed in this task is the study of atoms and their nuclei which, through a wide variety of physical and chemical techniques, can be used to reconstruct quantitatively the past. Following an introduction to atoms, light, and energy, we will explore topics including the detection of art forgeries, the precise dating of archeological sites, a reconstruction of the development of agriculture and the history of the human diet, the history of past climate (and its implications for the future), the history and age of the Earth, and the history of the Universe. The course has no required text. Readings of relevant articles and use of on-line simulations will be required.

Spring 2024: ASTR UN1234

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1234	AU1/18950	T Th 10:10am - 11:25am Othr Other	David Helfand	3.00	7/7
ASTR 1234	001/12726	T Th 10:10am - 11:25am 303 Uris Hall	David Helfand	3.00	60/65

ASTR UN1420 Galaxies and Cosmology. 3 points.

CC/GS: Partial Fulfillment of Science Requirement

Galaxies contain stars, gas dust, and (usually) super-massive black holes. They are found throughout the Universe, traveling through space and occasionally crashing into each other. This course will look at how these magnificent systems form and evolve, and what they can tell us about the formation and evolution of the Universe itself. You cannot enroll in ASTR UN1420 in addition to ASTR BC1754 or ASTR UN1404 and receive credit for both.

Fall 2023: ASTR UN1420

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1420	001/12451	M W 10:10am - 11:25am 602 Hamilton Hall	Mary Putman	3	63/80

Spring 2024: ASTR UN1420

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1420	001/12728	T Th 8:40am - 9:55am 702 Hamilton Hall	Kathryn Johnston	3	80/80

ASTR BC1753 LIFE IN THE UNIVERSE. 3.00 points.

An introductory course intended primarily for nonscience majors. This interdisciplinary course focuses on the subject of Life in the Universe. We will study historical astronomy, gravitation and planetary orbits, the origin of the chemical elements, the discoveries of extrasolar planets, the origin of life on Earth, the evolution and exploration of the Solar System, global climate change on Venus, Mars and Earth, and the Search for Extraterrestrial Life (SETI). You cannot receive credit for this course and for ASTR UN1403 or ASTR UN1453. Can be paired with the optional Lab class ASTR UN1903

Spring 2024: ASTR BC1753

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1753	001/00347	T Th 2:40pm - 3:55pm 202 Altschul Hall	Nicholas Luber	3.00	132/120

ASTR UN1836 STARS AND ATOMS. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: recommended preparation: a working knowledge of high school algebra.

Prerequisites: recommended preparation: a working knowledge of high school algebra. What is the origin of the chemical elements? This course addresses this question, starting from understanding atoms, and then going on to look at how atoms make stars and how stars make atoms. The grand finale is a history of the evolution of the chemical elements throughout time, starting from the Big Bang and ending with YOU. You cannot enroll in ASTR UN1836 in addition to ASTR BC1754 or ASTR UN1404 and receive credit for both

Fall 2023: ASTR UN1836

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1836	001/12453	T Th 8:40am - 9:55am 702 Hamilton Hall	Kathryn Johnston	3.00	42/80

Spring 2024: ASTR UN1836

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1836	001/12729	M W 2:40pm - 3:55pm 307 Uris Hall	Marcel Agueros	3.00	54/54

ASTR UN1903 ASTRONOMY LAB I. 1.00 point.

Laboratory for ASTR UN1403. Projects include observations with the departments telescopes, computer simulation, laboratory experiments in spectroscopy, and the analysis of astronomical data. Lab 1 ASTR UN1903 - goes with ASTR BC1753, ASTR UN1403 or ASTR UN1453

Fall 2023: ASTR UN1903

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1903	001/00612	M 6:00pm - 9:00pm 1402 Pupin Laboratories	Laura Kay, James Sullivan	1.00	12/15
ASTR 1903	002/00613	T 7:00pm - 10:00pm 1402 Pupin Laboratories	Laura Kay, Michael Messere	1.00	7/15

Spring 2024: ASTR UN1903

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1903	001/16125	M 6:00pm - 9:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	16/16
ASTR 1903	002/16124	T 7:00pm - 10:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	16/16
ASTR 1903	003/17754	W 6:00pm - 9:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	14/16

ASTR UN1904 ASTRONOMY LAB II. 1.00 point.

Laboratory for ASTR UN1404. Projects include use of telescopes, laboratory experiments in the nature of light, spectroscopy, and the analysis of astronomical data. Lab 2 ASTR UN1904 - goes with ASTR BC1754 or ASTR UN1404 (or ASTR UN1836 or ASTR UN1420)

Fall 2023: ASTR UN1904

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1904	001/00614	W 6:00pm - 9:00pm 1402 Pupin Laboratories	Laura Kay, Max Lee	1.00	13/15

Spring 2024: ASTR UN1904

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1904	001/16126	M 7:00pm - 10:00pm 1332 Pupin Laboratories	Greg Bryan	1.00	10/16

ASTR UN2002 INTRO TO ASTROPHYSICS II. 3.00 points.

Prerequisites: a working knowledge of calculus. Corequisites: the second term of a course in calculus-based general physics. Continuation of ASTR UN2001; these two courses constitute a full year of calculus-based introduction to astrophysics. Topics include the structure of our galaxy, the interstellar medium, star clusters, properties of external galaxies, clusters of galaxies, active galactic nuclei, and cosmology

Spring 2024: ASTR UN2002

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 2002	001/12738	M W 10:10am - 11:25am 963 Ext Schermerhorn Hall	Frederik Paerels	3.00	18/40

ASTR UN2910 Introduction to Research Skills in Astrophysics. 1.00 point.

Participation in research is an essential component of a complete undergraduate science education, and is mandatory for those students wishing to go on to the PhD. This course is designed to introduce students to doing astronomy beyond the classroom. It will cover basic topics including but not limited to: coding in astronomy, utilizing international archives, manipulating data, running simulations, reading academic papers, making and giving presentations, academic culture, time management, working in collaborations, and career paths. Students will engage in first-hand research on a specific astronomical topic in order to put their skills to practice; the first year, the selected topic is galactic dynamics and the power of stellar streams to probe the mass distribution and history of the Galaxy. By the end of the course, students should be fully prepared to enter a summer research internship and make the most of their time there. We encourage students considering majoring in Astronomy or Astrophysics who are interested in astrophysical research to take this course. Priority will be given to those interested in majoring in Astrophysics who have no prior research experience. Students should have taken at least one semester of college-level physics and have a knowledge of calculus. No prior experience in python coding is required

Spring 2024: ASTR UN2910

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 2910	001/14870	F 10:00am - 1:00pm 1332 Pupin Laboratories	Kiyari Tavangar	1.00	14/12

ASTR UN3105 EXTRASOLAR PLANETS # ASTROBIOL. 3.00 points.

Prerequisites: One year of calculus-based physics.

The emerging field of extrasolar planets and astrobiology will be covered at a quantitative level, with a major emphasis on astrophysical phenomena and techniques. The subject will be introduced through an investigation of current planetary formation theories and approaches to planet detection, including what we currently know about extrasolar planets and detailed reference to state-of-the-art studies.

An astronomer's view of the origin of life and extreme biology will be developed and applied to questions of cosmo-chemistry, observable life-signatures, habitable zones and other astrophysical constraints on the development of organisms.

Spring 2024: ASTR UN3105

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3105	001/12740	M W 2:40pm - 3:55pm 307 Pupin Laboratories	Jane Huang	3.00	35/35

ASTR UN3646 OBSERVATIONAL ASTRONOMY. 3.00 points.

Prerequisites: one year of general astronomy

Prerequisites: one year of general astronomy Introduction to the basic techniques used in obtaining and analyzing astronomical data. Focus on ground-based methods at optical, infrared, and radio wavelengths. Regular use of the telescope facilities atop the roof of the Pupin Labs and at Harriman Observatory. The radio-astronomy portion consists mostly of computer labs, In research projects, students also work on the analysis of data obtained at National Observatories

Spring 2024: ASTR UN3646

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3646	001/12741	Th 7:00pm - 9:30pm 1402 Pupin Laboratories	David Schiminovich	3.00	28/25

ASTR UN3998 INDEPENDENT RESEARCH. 3.00 points.

Prerequisites: the instructor's permission. For an independent research project or independent study, a brief description of the proposed project or reading, with the supervising faculty member's endorsement, is required for registration.

Prerequisites: the instructors permission. For an independent research project or independent study, a brief description of the proposed project or reading, with the supervising faculty members endorsement, is required for registration. A variety of research projects conducted under the supervision of members of the faculty. Observational, theoretical, and experimental work in galactic and extragalactic astronomy and cosmology. The topic and scope of the work must be arranged with a faculty member in advance; a written paper describing the results of the project is required at its completion (note that a two-term project can be designed such that the grade YC is given after the first term). Senior majors in astronomy or astrophysics wishing to do a senior thesis should make arrangements in May of their junior year and sign up for a total of 6 points over their final two terms. Both a substantial written document and an oral presentation of thesis results are required

Spring 2024: ASTR UN3998

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3998	001/12743		Joseph Patterson	3.00	5/15

ASTR GR6002 PHYSICS OF THE ISM AND IGM. 3.00 points.

A survey of diffuse matter in the universe with emphasis on astrophysical processes and their observational consequences. Topics include radiative transfer, dust, ionization, thermal balance, magnetic fields, hydrodynamics, shocks and star formation in the context of gaseous nebulae and the multi-phase ISM, ICM and IGM

Spring 2024: ASTR GR6002

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 6002	001/12744	T Th 1:10pm - 2:25pm 1332 Pupin Laboratories	David Schiminovich	3.00	13/15

All Courses (including those not offered in academic year 2023-2024)

ASTR UN1234 UNIVERSAL TIMEKEEPER. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: high school algebra and latent curiosity are assumed.

The goal of the course is to illustrate — and perhaps even inculcate — quantitative and scientific reasoning skills. The subject material employed in this task is the study of atoms and their nuclei which, through a wide variety of physical and chemical techniques, can be used to reconstruct quantitatively the past. Following an introduction to atoms, light, and energy, we will explore topics including the detection of art forgeries, the precise dating of archeological sites, a reconstruction of the development of agriculture and the history of the human diet, the history of past climate (and its implications for the future), the history and age of the Earth, and the history of the Universe. The course has no required text. Readings of relevant articles and use of on-line simulations will be required.

Spring 2024: ASTR UN1234

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1234	AU1/18950	T Th 10:10am - 11:25am Othr Other	David Helfand	3.00	7/7
ASTR 1234	001/12726	T Th 10:10am - 11:25am 303 Uris Hall	David Helfand	3.00	60/65

ASTR S1403D Earth, Moon, and Planets. 3 points.

Prerequisites: Recommended preparation: a working knowledge of high school algebra.

May be counted toward the science requirement for most Columbia University undergraduate students. The overall architecture of the solar system. Motions of the celestial sphere. Time and the calendar. Major planets, the earth-moon system, minor planets, comets. Life in the solar system and beyond.

ASTR UN1403 EARTH, MOON, AND PLANETS. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: recommended preparation: a working knowledge of high school algebra.

Prerequisites: recommended preparation: a working knowledge of high school algebra. The overall architecture of the solar system. Motions of the celestial sphere. Time and the calendar. Major planets, the earth-moon system, minor planets, comets. Life in the solar system and beyond. This course is similar to ASTR BC 1753. You cannot enroll in both courses and receive credit for both

Fall 2023: ASTR UN1403

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1403	001/12449	T Th 1:10pm - 2:25pm 141 Uris Hall	James Applegate	3.00	57/75

ASTR UN1404 STARS, GALAXIES # COSMOLOGY. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Distances to, and fundamental properties of, nearby stars; nucleosynthesis and stellar evolution; novae and supernovae; galaxies; the structure of the universe and theories concerning its origin, evolution, and ultimate fate. You can only receive credit for ASTR UN1404 if you have not taken ASTR BC1754, ASTR UN1420 or ASTR UN1836

ASTR UN1453 ANOTHER EARTH. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

This course cannot be taken for credit if BC1753 has been taken.

This course will explore the unique properties of Earth, compared to other planets in the Solar System, and the possibility of Earth-like planets around other stars. The basics of the Solar System, gravity, and light will be covered, as well as the geology and atmospheres of the terrestrial planets. The properties of Earth that allowed life to develop and whether life can develop on other planets will be discussed. Finally, the discovery of planets beyond our Solar System and the likelihood of another Earth will be a key component of the course

Fall 2023: ASTR UN1453

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1453	001/12452	T Th 10:10am - 11:25am 601 Fairchild Life Sciences Bldg	David Kipping	3.00	39/60

ASTR UN1420 Galaxies and Cosmology. 3 points.

CC/GS: Partial Fulfillment of Science Requirement

Galaxies contain stars, gas dust, and (usually) super-massive black holes. They are found throughout the Universe, traveling through space and occasionally crashing into each other. This course will look at how these magnificent systems form and evolve, and what they can tell us about the formation and evolution of the Universe itself. You cannot enroll in ASTR UN1420 in addition to ASTR BC1754 or ASTR UN1404 and receive credit for both.

Fall 2023: ASTR UN1420

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1420	001/12451	M W 10:10am - 11:25am 602 Hamilton Hall	Mary Putman	3	63/80

Spring 2024: ASTR UN1420

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1420	001/12728	T Th 8:40am - 9:55am 702 Hamilton Hall	Kathryn Johnston	3	80/80

ASTR UN1610 THEOR-UNIVERS:BABYLON-BIG BANG. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Milestones in the science of cosmology over the past 6000 years. Skylore and observation in ancient cultures. The twin revolutions of the Greeks: Pythagoras and Ptolemy; and Aristotle, Aquinas, and the Great Chain of Being. The scientific revolution: the impersonal and deterministic world-order of Newton, Laplace, and Kelvin. The erosion of that world-order by mathematics and experiment in the 20th century (relativity, quantum physics, dark matter, and the expanding universe). Today's searches for a new grand order in the Universe, which can cope - or maybe not - with these blows to yesterday's comfortable wisdom

ASTR BC1753 LIFE IN THE UNIVERSE. 3.00 points.

An introductory course intended primarily for non-science majors. This interdisciplinary course focuses on the subject of Life in the Universe. We will study historical astronomy, gravitation and planetary orbits, the origin of the chemical elements, the discoveries of extrasolar planets, the origin of life on Earth, the evolution and exploration of the Solar System, global climate change on Venus, Mars and Earth, and the Search for Extraterrestrial Life (SETI). You cannot receive credit for this course and for ASTR UN1403 or ASTR UN1453. Can be paired with the optional Lab class ASTR UN1903

Spring 2024: ASTR BC1753

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1753	001/00347	T Th 2:40pm - 3:55pm 202 Altschul Hall	Nicholas Luber	3.00	132/120

ASTR BC1754 Stars, Galaxies, and Cosmology. 3 points.

BC: Fulfillment of General Education Requirement: Quantitative and Deductive Reasoning (QUA).

Prerequisites: Recommended preparation: A working knowledge of high school algebra.

Corequisites: Suggested parallel laboratory course: ASTR C 1904y.

Examines the properties of stars, star formation, stellar evolution and nucleosynthesis, the Milky Way and other galaxies, and the cosmological origin and evolution of the universe. Students may not receive credit for both ASTR BC 1754 and ASTR C1404.

ASTR UN1836 STARS AND ATOMS. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: recommended preparation: a working knowledge of high school algebra.

Prerequisites: recommended preparation: a working knowledge of high school algebra. What is the origin of the chemical elements? This course addresses this question, starting from understanding atoms, and then going on to look at how atoms make stars and how stars make atoms. The grand finale is a history of the evolution of the chemical elements throughout time, starting from the Big Bang and ending with YOU. You cannot enroll in ASTR UN1836 in addition to ASTR BC1754 or ASTR UN1404 and receive credit for both

Fall 2023: ASTR UN1836

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1836	001/12453	T Th 8:40am - 9:55am 702 Hamilton Hall	Kathryn Johnston	3.00	42/80

Spring 2024: ASTR UN1836

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1836	001/12729	M W 2:40pm - 3:55pm 307 Uris Hall	Marcel Agueros	3.00	54/54

ASTR UN1903 ASTRONOMY LAB I. 1.00 point.

Laboratory for ASTR UN1403. Projects include observations with the departments telescopes, computer simulation, laboratory experiments in spectroscopy, and the analysis of astronomical data. Lab 1 ASTR UN1903 - goes with ASTR BC1753, ASTR UN1403 or ASTR UN1453

Fall 2023: ASTR UN1903

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1903	001/00612	M 6:00pm - 9:00pm 1402 Pupin Laboratories	Laura Kay, James Sullivan	1.00	12/15
ASTR 1903	002/00613	T 7:00pm - 10:00pm 1402 Pupin Laboratories	Laura Kay, Michael Messere	1.00	7/15

Spring 2024: ASTR UN1903

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1903	001/16125	M 6:00pm - 9:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	16/16
ASTR 1903	002/16124	T 7:00pm - 10:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	16/16
ASTR 1903	003/17754	W 6:00pm - 9:00pm 1402 Pupin Laboratories	Greg Bryan	1.00	14/16

ASTR UN1904 ASTRONOMY LAB II. 1.00 point.

Laboratory for ASTR UN1404. Projects include use of telescopes, laboratory experiments in the nature of light, spectroscopy, and the analysis of astronomical data. Lab 2 ASTR UN1904 - goes with ASTR BC1754 or ASTR UN1404 (or ASTR UN1836 or ASTR UN1420)

Fall 2023: ASTR UN1904

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1904	001/00614	W 6:00pm - 9:00pm 1402 Pupin Laboratories	Laura Kay, Max Lee	1.00	13/15

Spring 2024: ASTR UN1904

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 1904	001/16126	M 7:00pm - 10:00pm 1332 Pupin Laboratories	Greg Bryan	1.00	10/16

ASTR UN2001 INTRO TO ASTROPHYSICS I. 3.00 points.

Prerequisites: a working knowledge of calculus. Corequisites: a course in calculus-based general physics. First term of a two-term calculus-based introduction to astronomy and astrophysics. Topics include the physics of stellar interiors, stellar atmospheres and spectral classifications, stellar energy generation and nucleosynthesis, supernovae, neutron stars, white dwarfs, and interacting binary stars

Fall 2023: ASTR UN2001

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 2001	001/12456	M W 2:40pm - 3:55pm 333 Uris Hall	Marcel Agueros	3.00	28/40

ASTR UN2002 INTRO TO ASTROPHYSICS II. 3.00 points.

Prerequisites: a working knowledge of calculus. Corequisites: the second term of a course in calculus-based general physics. Continuation of ASTR UN2001; these two courses constitute a full year of calculus-based introduction to astrophysics. Topics include the structure of our galaxy, the interstellar medium, star clusters, properties of external galaxies, clusters of galaxies, active galactic nuclei, and cosmology

Spring 2024: ASTR UN2002

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 2002	001/12738	M W 10:10am - 11:25am 963 Ext Schermerhorn Hall	Frederik Paerels	3.00	18/40

ASTR UN2900 FRONTIERS OF ASTROPHYSICS. 1.00 point.

Several members of the faculty each offer a brief series of talks providing context for a current research topic in the field and then present results of their ongoing research. Opportunities for future student research collaboration are offered. Grading is Pass/Fail

Fall 2023: ASTR UN2900

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 2900	001/12454	F 10:10am - 11:25am 330 Uris Hall	David Helfand	1.00	51/60
ASTR 2900	AU1/18954	F 10:10am - 11:25am Othr Other	David Helfand	1.00	5/5

ASTR UN3101 MODERN STELLAR ASTROPHYSICS. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics.

Introductory astronomy is not required, but some exposure to astronomy is preferable. In the first half of the course, we will examine the physics of stellar interiors in detail, leading us to develop models of stellar structure and consider how stars evolve. In the second half of the course, we will discuss special topics, such as pre-main sequence evolution, the late stages of stellar evolution, and supernovae and compact objects.

ASTR UN3102 Planetary Dynamics and Physics of the Solar System. 3 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based Physics.

The physics and astrophysics of planets, comets, asteroids, natural and artificial satellites, and pretty much anything in the Solar System - including the Sun. Detailed study of the Earth's atmosphere and oceans: circulations, climate, and weather. Orbital dynamics. The emerging science of extrasolar planets. The origin, evolution, and eventual fate of planets.

ASTR UN3103 GALAXIES. 3.00 points.

Prerequisites: one year of calculus-based general physics.

Prerequisites: one year of calculus-based general physics. Galaxies fill the universe with structure. They are bound objects that harbor stars, gas, dust and dark matter. This course will discuss the content and structure of galaxies. It will start with the Milky Way, a rotating spiral galaxy, with a particular emphasis on the properties of the interstellar medium. Dwarf galaxies, the building blocks of larger galaxies, will subsequently be discussed, followed by spiral, elliptical and irregular galaxies. The formation and evolution of these different galaxy types will be an important focus of the course, as well as the environment in which the galaxies reside. We will intersperse reviews of current papers on galaxies throughout the semester

ASTR UN3105 EXTRASOLAR PLANETS # ASTROBIOL. 3.00 points.

Prerequisites: One year of calculus-based physics.

The emerging field of extrasolar planets and astrobiology will be covered at a quantitative level, with a major emphasis on astrophysical phenomena and techniques. The subject will be introduced through an investigation of current planetary formation theories and approaches to planet detection, including what we currently know about extrasolar planets and detailed reference to state-of-the-art studies. An astronomer's view of the origin of life and extreme biology will be developed and applied to questions of cosmo-chemistry, observable life-signatures, habitable zones and other astrophysical constraints on the development of organisms.

Spring 2024: ASTR UN3105

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3105	001/12740	M W 2:40pm - 3:55pm 307 Pupin Laboratories	Jane Huang	3.00	35/35

ASTR UN3106 The Science of Space Exploration. 3 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one semester course in introductory astronomy or astrophysics (e.g., ASTR UN1403, ASTR UN1404, ASTR UN1420, ASTR UN1836, ASTR UN2001, ASTR UN2002, ASTR BC1753, ASTR BC1754). Ability in mathematics up to and including calculus is strongly urged. How and why do humans explore space? Why does it require such extraordinary effort? What have we found by exploring our Solar System? We investigate the physics and biological basis of space exploration, and the technologies and science issues that determine what we can accomplish. What has been accomplished in the past, what is being explored now, and what can we expect in the future? How do space scientists explore the Solar System and answer science questions in practice? What do we know about solar systems beyond our own?

ASTR UN3273 HIGH ENERGY ASTROPHYSICS. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics. No previous, \nastronomy background required.

A survey of the most energetic and explosive objects in the Universe and their radiation. Topics include: techniques of X-ray and gamma-ray astronomy; observations of neutron stars (pulsars) and black holes; accretion disks and relativistic jets; supernovae, supernova remnants, gamma-ray bursts, quasars and active galactic nuclei; clusters of galaxies; cosmic rays and neutrinos.

Fall 2023: ASTR UN3273

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3273	001/12458	M W 2:40pm - 3:55pm 825 Seeley W. Mudd Building	Lorenzo Sironi	3.00	16/30
ASTR 3273	AU1/19016	M W 2:40pm - 3:55pm Othr Other	Lorenzo Sironi	3.00	5/5

ASTR UN3602 PHYSICAL COSMOLOGY. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics.

Prerequisites: one year of calculus-based general physics. The standard hot big bang cosmological model and modern observational results that test it. Topics include the Friedmann equations and the expansion of the universe, dark matter, dark energy, inflation, primordial nucleosynthesis, the cosmic microwave background, the formation of large-scale cosmic structures, and modern cosmological observations

Fall 2023: ASTR UN3602

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3602	001/12695	T Th 2:40pm - 3:55pm 307 Uris Hall	Greg Bryan	3.00	30/40
ASTR 3602	AU1/18913	T Th 2:40pm - 3:55pm Othr Other	Greg Bryan	3.00	4/5

ASTR UN3646 OBSERVATIONAL ASTRONOMY. 3.00 points.

Prerequisites: one year of general astronomy

Prerequisites: one year of general astronomy Introduction to the basic techniques used in obtaining and analyzing astronomical data. Focus on ground-based methods at optical, infrared, and radio wavelengths. Regular use of the telescope facilities atop the roof of the Pupin Labs and at Harriman Observatory. The radio-astronomy portion consists mostly of computer labs, In research projects, students also work on the analysis of data obtained at National Observatories

Spring 2024: ASTR UN3646

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3646	001/12741	Th 7:00pm - 9:30pm 1402 Pupin Laboratories	David Schiminovich	3.00	28/25

ASTR UN3985 Statistics and the Universe (Seminar). 3 points.

Prerequisites: First year calculus required, introductory physics or astronomy

Essential statistical methods will be applied in a series of case studies and research projects taken from the latest advances in cosmology, astronomy and physics. Statistics of measurement and detection, fundamentals of hypothesis testing, classifications, data modeling, time-series analysis, correlation and clustering will be explored through hands-on investigation using data from recent experiments and surveys.

ASTR UN3996 Current Research in Astrophysics. 1 point.

Prerequisites: two semesters of astronomy classes and two semesters of physics classes.

The goal of this course is to introduce astronomy and astrophysics majors to the methods and topics of current astronomical research. The course will also help with the development of critical thinking skills. Each week, the topic of the course will be centered on the subject of the Astronomy department colloquium; this may include research on planets, stars, galaxies or cosmology. There will be two required meetings per week: the first will be to discuss papers related to the colloquium (time TBD), and the second will be the colloquium itself (at 4:15 pm each Wednesday). Grading is Pass/Fail.

ASTR UN3997 INDEPENDENT RESEARCH. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: the instructor's permission. For an independent research project or independent study, a brief description of the proposed project or reading, with the supervising faculty member's endorsement, is required for registration.

Prerequisites: the instructor's permission. For an independent research project or independent study, a brief description of the proposed project or reading, with the supervising faculty member's endorsement, is required for registration. A variety of research projects conducted under the supervision of members of the faculty. Observational, theoretical, and experimental work in galactic and extragalactic astronomy and cosmology. The topic and scope of the work must be arranged with a faculty member in advance; a written paper describing the results of the project is required at its completion (note that a two-term project can be designed such that the grade YC is given after the first term). Senior majors in astronomy or astrophysics wishing to do a senior thesis should make arrangements in May of their junior year and sign up for a total of 6 points over their final two terms. Both a substantial written document and an oral presentation of thesis results are required

Fall 2023: ASTR UN3997

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3997	001/12461		Melissa Ness	3.00	9/15

ASTR UN3998 INDEPENDENT RESEARCH. 3.00 points.

Prerequisites: the instructor's permission. For an independent research project or independent study, a brief description of the proposed project or reading, with the supervising faculty member's endorsement, is required for registration.

Prerequisites: the instructors permission. For an independent research project or independent study, a brief description of the proposed project or reading, with the supervising faculty members endorsement, is required for registration. A variety of research projects conducted under the supervision of members of the faculty. Observational, theoretical, and experimental work in galactic and extragalactic astronomy and cosmology. The topic and scope of the work must be arranged with a faculty member in advance; a written paper describing the results of the project is required at its completion (note that a two-term project can be designed such that the grade YC is given after the first term). Senior majors in astronomy or astrophysics wishing to do a senior thesis should make arrangements in May of their junior year and sign up for a total of 6 points over their final two terms. Both a substantial written document and an oral presentation of thesis results are required

Spring 2024: ASTR UN3998

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 3998	001/12743		Joseph Patterson	3.00	5/15

ASTR GU4260 MODELING THE UNIVERSE. 3.00 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics.

Prerequisites: one year of calculus-based general physics. The goal of this course is to provide a basic hands-on introduction to the practice and theory of scientific computing with applications in astronomy and astrophysics. The course will include an introduction to programming, as well as a sampling of methods and tools from the field of scientific computing. The course will include a hands-on project in which students use numerical methods to solve a research problem. Students who are interested in participating in research projects are strongly encouraged to take the course in their sophomore or junior year

Fall 2023: ASTR GU4260

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 4260	001/12470	T Th 10:10am - 11:25am 233 Seeley W. Mudd Building	Mordecai-Mark Mac Low	3.00	34/30

ASTR GU4302 General Relativity, Black Holes, and Cosmology. 3 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics.

Einstein's General Theory of Relativity replaced Newtonian gravity with an elegant theory of curved spacetime. Einstein's theory led to unforeseen and unnerving predictions of singularities and cosmological instabilities. Nearly a century later, these mathematical oddities have been confirmed astrophysically in the existence of black holes, an expanding universe, and a big bang. The course will cover Einstein's General Theory, beginning with special relativity, with an emphasis on black holes and the big bang.

ASTR GU4303 ASTROSTATISTICS. 3.00 points.

Astronomers live in era of "big data". Whilst astronomers of a century ago collected a handful of photographic plates each night, modern astronomers collect thousands of images encoded by millions of pixels in the same time. Both the volume of data and the ever present desire to dig deeper into data sets has led to a growing interest in the use of statistical methods to interpret observations. This class will provide an introduction to the methods commonly used in understanding astronomical data sets, both in terms of theory and application. It is one six classes the department offers every fourth semester

ASTR GR6001 RADIATIVE PROCESSES. 3.00 points.

Prerequisites: 3000-level electromagnetic theory and quantum mechanics.

Prerequisites: 3000-level electromagnetic theory and quantum mechanics. Radiation mechanisms and interaction of radiation with matter. Applications of classical and semiclassical radiation theory and atomic physics to astrophysical settings. Radiative transfer, polarization, scattering, line radiation, special relativity, bremsstrahlung, synchrotron radiation, inverse compton scattering, ionization losses, shocks and particle acceleration, plasma processes, atomic structure and spectroscopic terms, radiative transitions and oscillator strengths, curve of growth, molecular spectra

Fall 2023: ASTR GR6001

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
ASTR 6001	001/12471	M W 1:10pm - 2:25pm 503 Hamilton Hall	Frederik Paerels	3.00	20/15

ASTR GR6003 GALAXIES. 3.00 points.

An introduction to the study of galaxies, from both observational and theoretical perspectives. The course will review our current understanding of the formation and evolution of galaxies through descriptions of: their structure and dynamics; the gas and stellar populations they contain; and what we know about the distribution of dark matter within them.

ASTR GR6005 PHYSICAL COSMOLOGY LEC. 3.00 points.

Of Related Interest

Physics and Astronomy (Barnard)

ASTR BC1753	LIFE IN THE UNIVERSE
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ASTR BC1754	Stars, Galaxies, and Cosmology
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Physics

PHYS UN3002	From Quarks To the Cosmos: Applications of Modern Physics
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