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 UNIty 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 Introduction 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 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 Aguiers  
David Kipping  
Lorenzo Sironi

**Assistant Professors**

Melissa K. Ness

**Adjunct Professor**

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

**Senior Lecturer**

Caleb Scharf

**On Leave**

Profs. Aguiers, Bryan, Ness, Patterson, Schiminovich (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 Introduction To Astrophysics, I  
- ASTR UN2002 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 Introduction To Mechanics and Thermodynamics  
- PHYS UN1402 and INTRO ELEC/MAGNETISM # OPTCS  
- PHYS UN1403 and Introduction to Classical and Quantum Waves
Sequence 2:

- PHYS UN1601
- PHYS UN1602
- PHYS UN2601

Physics, I: Mechanics and Relativity
and Physics, II: Thermodynamics,
Electricity, and Magnetism
and Physics, III: Classical and Quantum Waves

Sequence 3:

- PHYS UN2801
- PHYS UN2802

Accelerated Physics I
and Accelerated Physics II

Additional Physics Courses

- PHYS UN3003 Mechanics
- PHYS UN3007 Electricity and Magnetism
- PHYS GU4021 Quantum Mechanics I
- PHYS GU4022 Quantum Mechanics II
- PHYS BC3006 Quantum Physics
- PHYS GU4023 and Thermal and Statistical Physics

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

- PHYS UN3003 Mechanics
- PHYS UN3007 Electricity and Magnetism
- PHYS GU4021 Quantum Mechanics I
- PHYS GU4022 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 Introduction To Astrophysics, I
and INTRO TO ASTROPHYSICS II

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

Introduction To Mechanics and
Thermodynamics
and INTRO ELEC/MAGNETISM # OPTCS
and Introduction to Classical and Quantum Waves

**Sequence 2:**

- PHYS UN1601
- PHYS UN1602
- PHYS UN2601

Physics, I: Mechanics and Relativity
and Physics, II: Thermodynamics,
Electricity, and Magnetism
and Physics, III: Classical and Quantum Waves

**Sequence 3:**

- PHYS UN2801
- PHYS UN2802

Accelerated Physics I
and Accelerated Physics II

### Additional Physics Courses

- PHYS UN3003 Mechanics
- PHYS UN3007 Electricity and Magnetism
- PHYS UN3008 Electromagnetic Waves and Optics
- PHYS GU4021 Quantum Mechanics I
- PHYS GU4022 Quantum Mechanics II
- PHYS BC3006 Quantum Physics
- PHYS GU4023 and Thermal and Statistical Physics

### 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 2022

**ASTR UN1234 The Universal Timekeeper: Reconstructing History Atom by Atom. 3 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.

### Fall 2022: ASTR UN1234

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<td>001/13631</td>
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<td>David Helfand</td>
<td>3</td>
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</table>

**ASTR UN1403 Earth, Moon and Planets (Lecture). 3 points.**
CC/GS: Partial Fulfillment of Science Requirement

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.

### Spring 2022: ASTR UN1403

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>ASTR 1403</td>
<td>001/13393</td>
<td>T Th 1:10pm - 2:25pm 702 Hamilton Hall</td>
<td>James Applegate</td>
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### Fall 2022: ASTR UN1403

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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tbody>
<tr>
<td>ASTR 1403</td>
<td>001/1332</td>
<td>T Th 1:10pm - 2:25pm Room TBA</td>
<td>James Applegate</td>
<td>3</td>
<td>71/75</td>
</tr>
</tbody>
</table>
ASTR 1453 Another Earth. 3 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 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 2022: ASTR UN1903

ASTR UN1903 ASTRONOMY LAB I. 1.00 point.
Laboratory for ASTR UN1403. Projects include observations with the department 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

Spring 2022: ASTR UN1903

ASTR 1903 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)

ASTR UN2001 Introduction To Astrophysics, I. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

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 2022: ASTR UN2900

ASTR UN2900 Frontiers of Astrophysics. 1 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 2022: ASTR UN3103

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 and Astrobiology. 3 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.

### Fall 2022: ASTR UN3105

<table>
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<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>ASTR 3105</td>
<td>001/13637</td>
<td>M W 10:10am - 11:25am Room TBA</td>
<td>Caleb Scharf</td>
<td>3</td>
<td>35/35</td>
</tr>
</tbody>
</table>

ASTR UN3997 Independent Research. 3 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.

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 2022: ASTR UN3997

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<th>Enrollment</th>
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<tr>
<td>ASTR 3997</td>
<td>001/13638</td>
<td></td>
<td>Frederik Paerels</td>
<td>3</td>
<td>5/10</td>
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</table>

ASTR GR6003 Galaxies. 3 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.

### Fall 2022: ASTR GR6003

<table>
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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<td>ASTR 6003</td>
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<td>T Th 8:40am - 9:55am Room TBA</td>
<td>Kathryn Johnston</td>
<td>3</td>
<td>5/20</td>
</tr>
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</table>

ASTR GR9001 Graduate Seminar. 3 points.
Not offered during 2022-23 academic year.

### Fall 2022: ASTR GR9001

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>ASTR 9001</td>
<td>001/13640</td>
<td></td>
<td>Mary Putman</td>
<td>3</td>
<td>6/15</td>
</tr>
</tbody>
</table>

Spring 2022

ASTR UN1403 Earth, Moon and Planets (Lecture). 3 points.
CC/GS: Partial Fulfillment of Science Requirement

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.

### Spring 2022: ASTR UN1403

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tbody>
<tr>
<td>ASTR 1403</td>
<td>001/13393</td>
<td>T Th 1:10pm - 2:25pm Room TBA</td>
<td>James Applegate</td>
<td>3</td>
<td>58/75</td>
</tr>
</tbody>
</table>

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

### Spring 2022: ASTR UN1610

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<th>Enrollment</th>
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<tr>
<td>ASTR 1610</td>
<td>001/13398</td>
<td>T Th 2:40pm - 3:55pm Hall 209</td>
<td>Joseph Patterson</td>
<td>3.00</td>
<td>65/80</td>
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</table>

ASTR UN1836 Stars and Atoms. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

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 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.

### Spring 2022: ASTR UN1836

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>ASTR 1836</td>
<td>001/13396</td>
<td>M W 1:10pm - 2:25pm Room 326</td>
<td>Marcel Aguiers</td>
<td>3</td>
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</table>
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

Spring 2022: ASTR UN1903
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>ASTR 1903</td>
<td>001/00072</td>
<td>W 7:00pm - 10:00pm 1402 Pupin Laboratories</td>
<td>Kai Yeung Chow, Laura Kay</td>
<td>1.00</td>
<td>11/12</td>
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<tr>
<td>ASTR 1903</td>
<td>001/000553</td>
<td>M 6:00pm - 9:00pm Room TBA</td>
<td>Laura Kay</td>
<td>1.00</td>
<td>8/8</td>
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<tr>
<td>ASTR 1903</td>
<td>002/000554</td>
<td>T 6:00pm - 9:00pm Room TBA</td>
<td>Laura Kay</td>
<td>1.00</td>
<td>8/8</td>
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Fall 2022: ASTR UN1903
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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<th>Enrollment</th>
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<tr>
<td>ASTR 1904</td>
<td>001/000173</td>
<td>M 6:00pm - 9:00pm 1402 Pupin Laboratories</td>
<td>Laura Kay, Jennifer Mead</td>
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<tr>
<td>ASTR 1904</td>
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<td>T 6:00pm - 9:00pm 1402 Pupin Laboratories</td>
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<td>ASTR 1904</td>
<td>001/000555</td>
<td>W 7:00pm - 10:00pm Room TBA</td>
<td>Laura Kay</td>
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<td>2/8</td>
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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)

Spring 2022: ASTR UN1904
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<th>Course Number</th>
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<th>Times/Location</th>
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<td>ASTR 1904</td>
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<td>T 6:00pm - 9:00pm 1402 Pupin Laboratories</td>
<td>Laura Kay, Ryan Golant</td>
<td>1.00</td>
<td>11/12</td>
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<tr>
<td>ASTR 1904</td>
<td>001/000555</td>
<td>W 7:00pm - 10:00pm Room TBA</td>
<td>Laura Kay</td>
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<td>2/8</td>
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Fall 2022: ASTR UN1904
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<th>Times/Location</th>
<th>Instructor</th>
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<td>Laura Kay, Ryan Golant</td>
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<td>11/12</td>
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<td>W 7:00pm - 10:00pm Room TBA</td>
<td>Laura Kay</td>
<td>1.00</td>
<td>2/8</td>
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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 2022: ASTR UN2002
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
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<td>ASTR 2002</td>
<td>001/13400</td>
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<td>Mary Putman</td>
<td>3.00</td>
<td>33/35</td>
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ASTR UN3273 High Energy Astrophysics. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: one year of calculus-based general physics. No previous astronomy 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.

Spring 2022: ASTR UN3273
<table>
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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
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<tr>
<td>ASTR 3273</td>
<td>001/13402</td>
<td>M W 1:10pm - 2:25pm 425 Pupin Laboratories</td>
<td>Lorenzo Sironi</td>
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<td>16/20</td>
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</tbody>
</table>

ASTR UN3646 Observational Astronomy. 3 points.
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. In research projects, students also work on the analysis of data obtained at National Observatories.

Spring 2022: ASTR UN3646
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<th>Course Number</th>
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<tr>
<td>ASTR 3646</td>
<td>001/13405</td>
<td>Th 7:00pm - 9:30pm 1402 Pupin Laboratories</td>
<td>David Schiminovich</td>
<td>3</td>
<td>34/30</td>
</tr>
</tbody>
</table>

ASTR UN3998 Independent Research. 3 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.
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 2022: ASTR UN3998
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<th>Course Number</th>
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<tr>
<td>ASTR 3998</td>
<td>001/13407</td>
<td></td>
<td>Frederik Paerels</td>
<td>3</td>
<td>4/10</td>
</tr>
</tbody>
</table>
ASTR GU4260 Modeling the Universe. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

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.

Spring 2022: ASTR GU4260
Course Number   Section/Call Number   Times/Location           Instructor    Points    Enrollment
ASTR 4260       001/15330             T Th 2:40pm - 3:55pm    140 Uris Hall  Mordecai-Mark 3 Mac Low  28/30

ASTR GR6002 Physics of The Interstellar Medium and Intergalactic Medium. 3 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 2022: ASTR GR6002
Course Number   Section/Call Number   Times/Location           Instructor    Points    Enrollment
ASTR 6002       001/13410             M W 10:10am - 11:25am  227 Seeley W. Mudd Building  Frederik Paerels 3 15/20

ASTR GR9004 Graduate Research Seminar II. 3 points.

Spring 2022: ASTR GR9004
Course Number   Section/Call Number   Times/Location           Instructor    Points    Enrollment
ASTR 9004       001/13411             Th 4:00pm - 5:15pm      424 Pupin Laboratories  Melissa Ness  3 15/15

All Courses (including those not offered in academic year 2022-2023)

ASTR UN1234 The Universal Timekeeper: Reconstructing History Atom by Atom. 3 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.

Fall 2022: ASTR UN1234
Course Number   Section/Call Number   Times/Location           Instructor    Points    Enrollment
ASTR 1234       001/13631             M W 8:40am - 9:55am      Room TBA  David Helfand  3 29/50

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 (Lecture). 3 points.
CC/GS: Partial Fulfillment of Science Requirement
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.

Spring 2022: ASTR UN1403
Course Number   Section/Call Number   Times/Location           Instructor    Points    Enrollment
ASTR 1403       001/13393             T Th 1:10pm - 2:25pm      702 Hamilton Hall  James Applegate  3 58/75

Fall 2022: ASTR UN1403
Course Number   Section/Call Number   Times/Location           Instructor    Points    Enrollment
ASTR 1403       001/13632             T Th 1:10pm - 2:25pm      Room TBA  James Applegate  3 71/75
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 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 2022: ASTR UN1453

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<th>Course Number</th>
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<td>ASTR 1453</td>
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<td>T Th 10:10am - 11:25am</td>
<td>David Kipping</td>
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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.

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 Being. The scientific revolution: the impersonal and deterministic world-

Spring 2022: ASTR UN1610

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<tr>
<td>ASTR 1610</td>
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<td>T Th 2:40pm - 3:55pm</td>
<td>Joseph Patterson</td>
<td>3.00</td>
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</table>

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

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

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 points.
CC/GS: Partial Fulfillment of Science Requirement

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 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.

Spring 2022: ASTR UN1836

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<td>ASTR 1836</td>
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<td>M W 1:10pm - 2:25pm</td>
<td>Marcel Agueros</td>
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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

Spring 2022: ASTR UN1903

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<th>Course Number</th>
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<td>ASTR 1903</td>
<td>001/00172</td>
<td>W 7:00pm - 10:00pm</td>
<td>Kai Yeung Chow, Laura Kay</td>
<td>1.00</td>
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Fall 2022: ASTR UN1903

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<td>Laura Kay</td>
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<td>ASTR 1903</td>
<td>002/00554</td>
<td>T 6:00pm - 9:00pm</td>
<td>Laura Kay</td>
<td>1.00</td>
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</table>
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)

Spring 2022: ASTR UN1904

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<th>Course Number</th>
<th>Section/Call Number</th>
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<tr>
<td>ASTR 1904</td>
<td>001/00173</td>
<td>M 6:00pm - 9:00pm 1402 Pupin Laboratories</td>
<td>Laura Kay</td>
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<td>ASTR 1904</td>
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<td>T 6:00pm - 9:00pm 1402 Pupin Laboratories</td>
<td>Laura Kay, Jennifer Mead</td>
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Fall 2022: ASTR UN1904

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<td>Laura Kay</td>
<td>1.00</td>
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</table>

ASTR UN2001 Introduction To Astrophysics, I. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

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 2022: ASTR UN2001

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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<tr>
<td>ASTR 2001</td>
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<td>M W 1:10pm - 2:25pm Room TBA</td>
<td>Lorenzo Sironi</td>
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</table>

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 2022: ASTR UN2002

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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<tr>
<td>ASTR 2002</td>
<td>001/13400</td>
<td>T Th 10:10am - 11:25am 415 Schapirio Cepser</td>
<td>Mary Putman</td>
<td>3.00</td>
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</table>

ASTR UN2900 Frontiers of Astrophysics. 1 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 2022: ASTR UN2900

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<th>Course Number</th>
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<tr>
<td>ASTR 2900</td>
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<td>F 10:10am - 11:25am Room TBA</td>
<td>Caleb Scharf</td>
<td>1</td>
<td>32/55</td>
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</table>

ASTR UN3101 Modern Stellar Astrophysics II. 3 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.

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.

Fall 2022: ASTR UN3103

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<th>Course Number</th>
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<tr>
<td>ASTR 3103</td>
<td>001/13636</td>
<td>T Th 10:10am - 11:25am Room TBA</td>
<td>Frederik Paerels</td>
<td>3.00</td>
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ASTR UN3105 Extrasolar Planets and Astrobiology. 3 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.

Fall 2022: ASTR UN3105

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<td>ASTR 3105</td>
<td>001/13637</td>
<td>M W 10:10am - 11:25am Room TBA</td>
<td>Caleb Scharf</td>
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</table>
ASTR UN3106 The Science of Space Exploration. \textit{3 points.}\newline
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. \textit{3 points.}\newline
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: one year of calculus-based general physics. No previous, \text{\`a}stronomia 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.

ASTR UN3602 Physical Cosmology and Extragalactic Astronomy. \textit{3 points.}\newline
CC/GS: Partial Fulfillment of Science Requirement

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.

ASTR UN3646 Observational Astronomy. \textit{3 points.}\newline
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. In research projects, students also work on the analysis of data obtained at National Observatories.

ASTR UN3985 Statistics and the Universe (Seminar). \textit{3 points.}\newline
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. \textit{1 point.}\newline
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. \textit{3 points.}\newline
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.

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.

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<td>Lorenzo Sironi</td>
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ASTR UN3997 Fall 2022:

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Spring 2022:

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<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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</thead>
<tbody>
<tr>
<td>ASTR 3646</td>
<td>001/13405</td>
<td>Th 7:00pm - 9:30pm</td>
<td>David</td>
<td>3</td>
<td>34/30</td>
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<td></td>
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<td>1402 Pupin Laboratories</td>
<td>Schiminovich</td>
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ASTR UN3998 Independent Research. 3 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.
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.

ASTR GU4260 Modeling the Universe. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
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.

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 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 points.
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.

ASTR GR6003 Galaxies. 3 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. 3 points.

Of Related Interest

Physics and Astronomy (Barnard)
ASTR BC1753 LIFE IN THE UNIVERSE
ASTR BC1754 Stars, Galaxies, and Cosmology

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