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. ASTR UN3997 and ASTR UN3998 cannot be repeated for credit.

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 Introduction 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  
Zoltan Haiman  
Jules P. Halpern  
David J. Helfand  
Kathryn Johnston  
Laura Kay (Barnard)  
Jeremiah P. Ostriker  
Frederik B. S. Paerels  
Joseph Patterson  
Mary E. Putman  
David Schiminovich (Chair)  
Edward A. Spiegel (emeritus)  
Jacqueline van Gorkom  

### Associate Professor

Marcel Agüeros  

### Assistant Professors

David Kipping  
Melissa K. Ness  
Lorenzo Sironi  

### 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. Patterson, van Gorkom (Fall 2019)  
Profs. Kipping, Ness, Johnston (Spring 2020)  

### 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 Introduction 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 Introduction To Electricity, Magnetism, and Optics
- PHYS UN1403  and Introduction to Classical and Quantum Waves

Sequence 2:
PHYS UN1601  Physics, I: Mechanics and Relativity
- PHYS UN1602  and Physics, II: Thermodynamics, Electricity, and Magnetism
- PHYS UN2601  and Physics, III: Classical and Quantum Waves

Sequence 3:
PHYS UN2801  Accelerated Physics I
- PHYS UN2802  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  and Quantum Mechanics II
OR
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 2019
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.
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 2019: ASTR UN1420
Course Number: 001/060274
Times/Location: T Th 10:10am - 11:25am
Instructor: Mary Putman
Points: 3
Enrollment: 53/65

ASTR BC1753 Life in the Universe. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: recommended preparation: a working knowledge of high school algebra.
Introduction to astronomy intended primarily for nonscience majors. Includes the history of astronomy; the apparent motions of the moon, sun, stars, and planets; gravitation and planetary orbits; the physics of the earth and its atmosphere; and the exploration of the solar system. This course is similar to ASTR W1403. You cannot enroll in both courses and receive credit for both.

Fall 2019: ASTR BC1753
Course Number: 001/090972
Times/Location: T Th 2:40pm - 3:55pm
Instructor: Laura Kay
Points: 3
Enrollment: 108/150

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 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 2019: ASTR UN1836
Course Number: 001/060271
Times/Location: M W 1:10pm - 2:25pm
Instructor: Frederik Paerels
Points: 3
Enrollment: 39/40

ASTR UN1903 Astronomy Lab 1. 1 point.
Laboratory for ASTR UN1403. Projects include observations with the department’s 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 2019: ASTR UN1903
Course Number: 001/090238
Times/Location: W 7:00pm - 10:00pm
Instructor: Aaron Tran
Points: 1
Enrollment: 10/14

ASTR UN1904 Astronomy Lab 2. 1 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 2019: ASTR UN1904
Course Number: 001/09066
Times/Location: M 6:00pm - 9:00pm
Instructor: Laura Kay
Points: 1
Enrollment: 8/13

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 2019: ASTR UN2001
Course Number: 001/060259
Times/Location: M W 10:10am - 11:25am
Instructor: Greg Bryan
Points: 3
Enrollment: 34/35
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 2019: ASTR UN3997
Course Number Section/Call Number Times/Location Instructor Points Enrollment
ASTR 3997 001/60268 3 points
1 point
Enrollment

Jules Halpern

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 unforseen 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.

Fall 2019: ASTR GR6001
Course Number Section/Call Number Times/Location Instructor Points Enrollment
ASTR 6001 001/60275 3 points
1 point
Enrollment

Jules Halpern

1/15
ASTR 8003 Astrophysical fluid Dynamics (Lecture). 3 points.
Not offered during 2019-20 academic year.

An introduction to the fundamental concepts of fluid dynamics with
focus on standad applications of the theory to a variety of important
astrophysical situations and objects. A brief introduction to several key
numerical concepts. A brief description of the complications that arise
when a fluid is magnetized.

Fall 2019: ASTR 8003

Spring 2019: ASTR UN1404

ASTR UN1404 Stars, Galaxies and Cosmology (Lecture). 3 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.

Spring 2019: ASTR UN1404

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.

Spring 2019: ASTR UN1453

ASTR UN1610 Theories of the Universe: From Babylon to the Big Bang. 3 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 2019: ASTR UN1610
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.

Spring 2019: ASTR BC1754
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 1754   001/05649   T Th 11:40am - 12:55pm 202 Altschul Hall   Frederik Paerels   3   93/120

ASTR UN1903 Astronomy Lab 1. 1 point.
Laboratory for ASTR UN1403. Projects include observations with the department’s 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 2019: ASTR UN1903
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 1903   001/09238   W 7:00pm - 10:00pm 1402 Pupin Laboratories   Laura Kay, Aaron Tran   1   10/14

Fall 2019: ASTR UN1903
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 1903   001/09066   M 6:00pm - 9:00pm 1402 Pupin Laboratories   Laura Kay, Jorge Cortes   1   8/13
ASTR 1903   002/09067   T 6:00pm - 9:00pm 1402 Pupin Laboratories   Laura Kay, Doyeon Kim   1   12/13
ASTR 1903   003/09068   W 6:00pm - 9:00pm 1332 Pupin Laboratories   Laura Kay, Tianhuan Lu   1   8/13

ASTR UN1904 Astronomy Lab 2. 1 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 2019: ASTR UN1904
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 1904   001/06986   M 6:00pm - 9:00pm 1332 Pupin Laboratories   Laura Kay, Aliya Nur Babul   1   14/14
ASTR 1904   002/07691   T 6:00pm - 9:00pm 1402 Pupin Laboratories   Laura Kay, Tomer Yavetz   1   8/14
ASTR 1904   003/05781   W 6:00pm - 9:00pm 1332 Pupin Laboratories   Laura Kay, Matthew Abruzzo   1   9/14

Fall 2019: ASTR UN1904
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 1904   001/09064   W 7:00pm - 10:00pm 1402 Pupin Laboratories   Laura Kay, Navin Sridhar   1   10/13

ASTR UN2002 Introduction To Astrophysics, II. 3 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 2019: ASTR UN2002
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 2002   001/77422   M W 8:40am - 9:55am 707 Hamilton Hall   Jules Halpern   3   13/25

ASTR UN3102 Planetary Dynamics and Physics of the Solar System. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Spring 2019: ASTR UN3102
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 3102   001/12567   T Th 10:10am - 11:25am 1332 Pupin Laboratories   James Applegate   3   6/20

ASTR UN3103 Galaxies. 3 points.
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

Spring 2019: ASTR UN3103
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 3103   001/69228   T Th 10:10am - 11:25am 1332 Pupin Laboratories   Jacqueline van Gorkom   3   11/20

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 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 2019: ASTR UN3646
Course Number   Section/Call Number   Times/Location   Instructor   Points   Enrollment
ASTR 3646   001/22651   Th 7:00pm - 9:30pm 1402 Pupin Laboratories   David Schiminovich   3   24/25
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.

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<td>Marcel Agueros</td>
<td>3</td>
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ASTR GR6004 Stellar Structure and Evolution. 3 points.
Topics include the physics of stellar structure, stellar atmospheres, radiation transport, nucleosynthesis, stellar evolution, star formation, pulsation, interacting binary stars, white dwarfs, and neutron stars.

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<td>M W 10:10am - 11:25am</td>
<td>Greg Bryan</td>
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</table>
ASTR UN1404 Stars, Galaxies and Cosmology (Lecture). 3 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.

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<td>ASTR 1404</td>
<td>001/21934</td>
<td>T Th 8:40am - 9:55am 963 Ext Schermerhorn Hall</td>
<td>Lorenzo Sironi 3</td>
<td>35/40</td>
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Spring 2019: ASTR UN1404

Fall 2019: ASTR UN1404

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.

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<tr>
<td>ASTR 1453</td>
<td>001/29559</td>
<td>M W 2:40pm - 3:55pm 633 Seeley W. Mudd Building</td>
<td>Kathryn Johnston 3</td>
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</table>

Spring 2019: ASTR UN1453

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.

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<th>Instructor</th>
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<tr>
<td>ASTR 1420</td>
<td>001/60274</td>
<td>T Th 10:10am - 11:25am 313 Fayerweather</td>
<td>Mary Putman 3</td>
<td>53/65</td>
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</tbody>
</table>

Spring 2019: ASTR UN1420

ASTR UN1610 Theories of the Universe: From Babylon to the Big Bang. 3 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.

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<td>ASTR 1610</td>
<td>001/11019</td>
<td>T Th 2:40pm - 3:55pm 329 Pupin Laboratories</td>
<td>Joseph Patterson 3</td>
<td>71/86</td>
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</table>

Spring 2019: ASTR UN1610

ASTR BC1753 Life in the Universe. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

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

Introduction to astronomy intended primarily for nonscience majors. Includes the history of astronomy; the apparent motions of the moon, sun, stars, and planets; gravitation and planetary orbits; the physics of the earth and its atmosphere; and the exploration of the solar system. This course is similar to ASTR W1403. You cannot enroll in both courses and receive credit for both.

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<tr>
<td>ASTR 1753</td>
<td>001/09072</td>
<td>T Th 2:40pm - 3:55pm 202 Altshul Hall</td>
<td>Laura Kay 3</td>
<td>108/150</td>
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</tbody>
</table>

Fall 2019: ASTR BC1753

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 BC1754 and ASTR C1404.

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<tr>
<td>ASTR 1754</td>
<td>001/05649</td>
<td>T Th 11:40am - 12:55pm 202 Altshul Hall</td>
<td>Frederik Paerels 3</td>
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Spring 2019: ASTR BC1754

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<tr>
<td>ASTR 1753</td>
<td>001/09072</td>
<td>T Th 2:40pm - 3:55pm 202 Altshul Hall</td>
<td>Laura Kay 3</td>
<td>108/150</td>
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</tr>
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</table>

Fall 2019: ASTR BC1753
### 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.

<table>
<thead>
<tr>
<th>Fall 2019: ASTR UN1836 Course</th>
<th>Number</th>
<th>Section/Call</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tbody>
<tr>
<td>ASTR 1836 001/60271</td>
<td>M W 1:10pm - 2:25pm</td>
<td>Frederik Paerels</td>
<td>3</td>
<td>39/40</td>
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### ASTR UN1903 Astronomy Lab 1. 1 point.
Laboratory for ASTR UN1403. Projects include observations with the department's telescopes, computer simulation, laboratory experiments in spectroscopy, and the analysis of astronomical data. Lab 1 ASTR UN1903 - goes with ASTR BC1754, ASTR UN1403 or ASTR UN1454.

<table>
<thead>
<tr>
<th>Spring 2019: ASTR UN1903 Course</th>
<th>Number</th>
<th>Section/Call</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<tr>
<td>ASTR 1903 001/09238</td>
<td>W 7:00pm - 10:00pm</td>
<td>Laura Kay</td>
<td>10/14</td>
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<tr>
<td>ASTR 1903 001/09056</td>
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<td>Laura Kay</td>
<td>8/13</td>
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<tr>
<td>ASTR 1903 002/09067</td>
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<td>Laura Kay</td>
<td>12/13</td>
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<tr>
<td>ASTR 1903 003/09068</td>
<td>W 6:00pm - 9:00pm</td>
<td>Tianhuan Lu</td>
<td>8/13</td>
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</table>

### ASTR UN1904 Astronomy Lab 2. 1 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).

<table>
<thead>
<tr>
<th>Spring 2019: ASTR UN1904 Course</th>
<th>Number</th>
<th>Section/Call</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<tr>
<td>ASTR 1904 001/06986</td>
<td>M 6:00pm - 9:00pm</td>
<td>Kyle Babul</td>
<td>14/14</td>
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<td>ASTR 1904 002/07691</td>
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<tr>
<td>ASTR 1904 003/05781</td>
<td>W 6:00pm - 9:00pm</td>
<td>Matthew Abruzzo</td>
<td>9/14</td>
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### 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.

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<thead>
<tr>
<th>Fall 2019: ASTR UN2001 Course</th>
<th>Number</th>
<th>Section/Call</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<tbody>
<tr>
<td>ASTR 2001 001/60259</td>
<td>M W 10:10am - 11:25am</td>
<td>Greg Bryan</td>
<td>3</td>
<td>34/35</td>
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### ASTR UN2002 Introduction To Astrophysics, II. 3 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.

<table>
<thead>
<tr>
<th>Spring 2019: ASTR UN2002 Course</th>
<th>Number</th>
<th>Section/Call</th>
<th>Times/Location</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>ASTR 2002 001/77422</td>
<td>M W 8:40am - 9:55am</td>
<td>Jules Halpern</td>
<td>13/25</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.

<table>
<thead>
<tr>
<th>Fall 2019: ASTR UN2900 Course</th>
<th>Number</th>
<th>Section/Call</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>ASTR 2900 001/60250</td>
<td>F 10:10am - 11:25am</td>
<td>Caleb Scharf</td>
<td>40/40</td>
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### 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


Spring 2019: ASTR UN3102
Course Number: ASTR 3102
Section/Call Number: 001/12567
Times/Location: T Th 1:10pm - 2:25pm
Instructor: Applegate
Points: 3
Enrollment: 6/20

ASTR UN3103 Galaxies. 3 points.
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.

Spring 2019: ASTR UN3103
Course Number: ASTR 3103
Section/Call Number: 001/69228
Times/Location: T Th 10:10am - 11:25am
Instructor: van Gorkom
Points: 3
Enrollment: 11/20

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.

Spring 2019: ASTR UN3105
Course Number: ASTR 3105
Section/Call Number: 001/22651
Times/Location: Th 7:00pm - 9:30pm
Instructor: Schiminovich
Points: 3
Enrollment: 24/25

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?

Fall 2019: ASTR UN3106
Course Number: ASTR 3106
Section/Call Number: 001/60276
Times/Location: T Th 1:10pm - 2:25pm
Instructor: Caleb Scharf
Points: 3
Enrollment: 30/30

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.

ASTR UN3602 Physical Cosmology and Extragalactic Astronomy. 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. 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 2019: ASTR UN3602
Course Number: ASTR 3602
Section/Call Number: 001/24606
Times/Location: Th 10:10am - 11:25am
Instructor: Applegate
Points: 3
Enrollment: 11/20

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 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 2019: ASTR UN3646
Course Number: ASTR 3646
Section/Call Number: 001/22651
Times/Location: Th 7:00pm - 9:30pm
Instructor: David
Points: 3
Enrollment: 24/25
ASTR C3985 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.

Spring 2019: ASTR UN3996
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
ASTR 3996  001/60264  M 2:40pm - 3:55pm  Zoltan Haiman  1  2/10
(1402 Pupin Laboratories)

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.

Spring 2019: ASTR UN3998
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
ASTR 3998  001/16098  Marcel Agueros  3  5/10

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.

Fall 2019: ASTR GR6001

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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 6001</td>
<td>001/60275</td>
<td>M W 2:40pm - 3:55pm</td>
<td>Jules Halpern</td>
<td>3</td>
<td>7/15</td>
</tr>
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<td></td>
<td></td>
<td>1332 Pupin Laboratories</td>
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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.

Of Related Interest

Physics and Astronomy (Barnard)

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>ASTR BC1753</td>
<td>Life in the Universe</td>
</tr>
<tr>
<td>ASTR BC1754</td>
<td>Stars, Galaxies, and Cosmology</td>
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Physics

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<tbody>
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<td>PHYS UN3002</td>
<td>From Quarks To the Cosmos: Applications of Modern Physics</td>
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