

# Astrophysics

The Department of Astronomy offers a graduate program aimed at the PhD degree in astrophysics. Entering students need not have majored in astronomy, although some background in astronomy is desirable. A strong background in physics, however, is essential.

Research is a major part of the PhD program, and the department offers opportunities in a wide variety of fields, including theoretical and observational astrophysics; infrared, optical, and radio astronomy; time-domain astronomy; high-energy astrophysics and cosmology; discovery and analysis of exoplanets; star formation and stellar evolution.

The department has established six years as the normative time to degree. Normative time is the elapsed calendar time in years that under normal circumstances will be needed to complete all requirements for the PhD, assuming a student who enters without deficiencies, who is engaged in full-time uninterrupted study, and who is making desirable progress toward the degree.

## Admission to the University

### Applying for Graduate Admission

Thank you for considering UC Berkeley for graduate study! UC Berkeley offers more than 120 graduate programs representing the breadth and depth of interdisciplinary scholarship. The Graduate Division hosts a complete list (<https://grad.berkeley.edu/admissions/choosing-your-program/list/>) of graduate academic programs, departments, degrees offered, and application deadlines can be found on the Graduate Division website.

Prospective students must submit an online application to be considered for admission, in addition to any supplemental materials specific to the program for which they are applying. The online application and steps to take to apply can be found on the Graduate Division website (<https://grad.berkeley.edu/admissions/steps-to-apply/>).

### Admission Requirements

The minimum graduate admission requirements are:

1. A bachelor's degree or recognized equivalent from an accredited institution;
2. A satisfactory scholastic average, usually a minimum grade-point average (GPA) of 3.0 (B) on a 4.0 scale; and
3. Enough undergraduate training to do graduate work in your chosen field.

For a list of requirements to complete your graduate application, please see the Graduate Division's Admissions Requirements page (<https://grad.berkeley.edu/admissions/steps-to-apply/requirements/>). It is also important to check with the program or department of interest, as they may have additional requirements specific to their program of study and degree. Department contact information can be found here (<https://guide.berkeley.edu/graduate/degree-programs/>).

### Where to apply?

Visit the Berkeley Graduate Division application page (<http://grad.berkeley.edu/admissions/apply/>).

## Admission to the Program

In addition to the application, transcripts of undergraduate work and letters of recommendation are required. The GRE is no longer required nor accepted. If applicable, the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS) may be required too.

Detailed information concerning admission, financial aid, and degree requirements may be found on the department's website (<http://astro.berkeley.edu/academics/graduate/>)

If you have further questions on admission to our program, you can send e-mail to [gradinfo@astro.berkeley.edu](mailto:gradinfo@astro.berkeley.edu).

### The requirements for the Astrophysics PhD degree as follows:

1. Required Courses
  - a. ASTRON 290A and 290B (a seminar)
  - b. A total of 6 graduate (or equivalent) courses, 3 of which are from the Astronomy Department
2. Teaching
3. Examinations (Preliminary and Qualifying)
4. Thesis (signed by committee)
5. University Registration

## Curriculum

### Core Courses

- ASTRON 290A Introduction to Current Research [2] <sup>1</sup>
- ASTRON 290B Introduction to Current Research [1] <sup>1</sup>

A total of six graduate or equivalent courses, three of which must be from the Astronomy Department. It is strongly recommended that these be drawn from the following basic courses:

- ASTRON C207 Radiation Processes in Astronomy [4]
- ASTRON C202 Astrophysical Fluid Dynamics [4]
- ASTRON 203 Astrophysical Techniques [3]
- ASTRON 204 Numerical Techniques in Astronomy [3]
- ASTRON C207 Radiation Processes in Astronomy [4]
- ASTRON 218 Stellar Dynamics and Galactic Structure [3]
- ASTRON C228 Extragalactic Astronomy and Cosmology [3]
- ASTRON C249 Solar System Astrophysics [3] \*
- ASTRON 252 Stellar Structure and Evolution [3]
- ASTRON C254 High Energy Astrophysics [3]
- ASTRON 255 Computational Methods in Theoretical Astrophysics [3]
- ASTRON 256 Astronomy Data Science Laboratory [4]

### Recommended Courses

ASTRON 298	Directed Group Study	1-4
MPS 375	Professional Preparation: Supervised Teaching in Math and the Physical Sciences	2

<sup>1</sup> When available, this Introduction to Current Research seminar is required of all students in their first year. This consists of weekly lectures by different faculty members and research staff, and

introduces the student to current research being carried out in the department and nearby labs. (This course is not a preliminary exam topic.)

\* These courses are offered based on interest.

## Teaching

All candidates for the Ph.D. in Astrophysics must acquire two semesters of teaching experience during their graduate career.

It is desirable that this requirement be satisfied early in the graduate career, but it may be delayed for those international students who have not acquired adequate command of English, or other reasons, at the discretion of the Chairperson. The requirement may be waived for transfer students who have acquired similar teaching experience elsewhere.

## Examinations

All candidates must pass two oral examinations administered by the faculty. The preliminary examination should be completed by the end of the second academic year of study and focuses on basic competency in three subfields selected by the student. The qualifying examination should be completed by the end of the fourth academic year of study and is composed of a review of a thesis topic and an examination of a student's competency in his or her research subfield. Students entering with a Master's Degree or its equivalent may have the preliminary examination requirement waived subject to the discretion of the Chair.

## Thesis

The thesis is an original piece of research carried out by the candidate under the supervision of a thesis advisor and two other faculty members (one of whom must be from another discipline). The Graduate Division has published guidelines (<http://www.grad.berkeley.edu/policies/forms.shtml>) for dissertations and theses.

## University Registration

Registration is required of all students making any use of University facilities, including access to faculty. A student is required to be registered, or pay the filing fee, whichever is applicable for the semester in which the degree is conferred. To be eligible for filing fee status the student must have been continuously registered since entering (allowing for one year of approved withdrawal), and registered in the term immediately preceding the one in which the Filing Fee is requested. You must register each semester before the end of the third week of classes.

## Master's Degree

Students are normally not admitted for the master's degree only, but may find it worthwhile to add to their record en route to the PhD. Once these requirements have been fulfilled, the student should see the student affairs officer to obtain an Application for Candidacy for the master's degree.

In order to earn the master's, students are required to pass the preliminary exam and must complete 24 units of upper division and graduate courses, including 12 units of "non-research" (lecture) courses.

## Astrophysics

### ASTRON 201 Radiation Processes in Astronomy 4 Units

Terms offered: Spring 2012, Fall 2011, Fall 2010

An introduction to the basic physics of astronomy and astrophysics at the graduate level. Principles of energy transfer by radiation. Elements of classical and quantum theory of photon emission; bremsstrahlung, cyclotron and synchrotron radiation. Compton scattering, atomic, molecular and nuclear electromagnetic transitions. Collisional excitation of atoms, molecules and nuclei.

#### Rules & Requirements

**Prerequisites:** Physics 105, 110A; 110B concurrently; open to advanced undergraduates with GPA of 3.70

#### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

#### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructors:** Chiang, Quataert

### ASTRON C202 Astrophysical Fluid Dynamics 4 Units

Terms offered: Spring 2025, Fall 2024, Fall 2023, Spring 2023

Principles of gas dynamics, self-gravitating fluids, magnetohydrodynamics and elementary kinetic theory. Aspects of convection, fluid oscillations, linear instabilities, spiral density waves, shock waves, turbulence, accretion disks, stellar winds, and jets.

#### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

#### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructors:** Chiang, Kasen, Ma, Quataert, White

**Also listed as:** PHYSICS C202

## ASTRON 203 Astrophysical Techniques 3 Units

Terms offered: Spring 2021, Spring 2019, Spring 2018  
Introduction to the flow of astronomical signals through telescope optics and into detectors; subsequent calibration, deconvolution of instrumental artifacts, and analysis. A broad wavelength approach is maintained with focus on shared fundamental concepts. Students "adopt a wavelength band" for assignments and presentations. Analysis and simulation of astronomical signals, noise, and errors.

### Rules & Requirements

**Prerequisites:** 201 and 290A; 290B must be taken concurrently

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of laboratory per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructor:** Graham

## ASTRON 204 Numerical Techniques in Astronomy 3 Units

Terms offered: Fall 2011, Spring 2010, Spring 2008  
Methods of data analysis, model fitting, and data display, all oriented towards the detailed analysis of astronomical observation data and/or numerical results from simulations. Specific topics include probability density functions, error propagation, maximum likelihood, least squares, data and function fitting, Fourier transforms, wavelets, principal components analysis, color images. The software language used is the Interactive Data Language (IDL).

### Rules & Requirements

**Prerequisites:** Mathematics 54

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of seminar per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructor:** Heiles

## ASTRON C207 Radiation Processes in Astronomy 4 Units

Terms offered: Spring 2025, Fall 2023, Fall 2022, Fall 2021  
An introduction to the basic physics of astronomy and astrophysics at the graduate level. Principles of energy transfer by radiation. Elements of classical and quantum theory of photon emission; bremsstrahlung, cyclotron and synchrotron radiation. Compton scattering, atomic, molecular and nuclear electromagnetic transitions. Collisional excitation of atoms, molecules and nuclei.

### Rules & Requirements

**Prerequisites:** Physics 105, 110A; 110B concurrently; open to advanced undergraduates with GPA of 3.70

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructors:** Chiang, Kasen, Quataert

**Also listed as:** PHYSICS C207

## ASTRON 218 Stellar Dynamics and Galactic Structure 3 Units

Terms offered: Fall 2023, Fall 2021, Fall 2019  
A basic course. Structure and kinematics of the galaxy; stellar population concepts; dynamics of stellar systems with and without encounters.

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructors:** Blitz, Davis, Graham

## ASTRON C228 Extragalactic Astronomy and Cosmology 3 Units

Terms offered: Spring 2025, Fall 2022, Spring 2021, Fall 2016

A survey of physical cosmology - the study of the origin, evolution, and fate of the universe. Topics include the Friedmann-Robertson-Walker model, thermal history and big bang nucleosynthesis, evidence and nature of dark matter and dark energy, the formation and growth of galaxies and large scale structure, the anisotropy of the cosmic microwave radiation, inflation in the early universe, tests of cosmological models, and current research areas. The course complements the material of Astronomy 218.

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructors:** Holzapfel, Lee, Ma, Seljak, White

**Also listed as:** PHYSICS C228

## ASTRON C249 Solar System Astrophysics 3 Units

Terms offered: Fall 2019, Fall 2018, Fall 2017

The physical foundations of planetary sciences. Topics include planetary interiors and surfaces, planetary atmospheres and magnetospheres, and smaller bodies in our solar system. The physical processes at work are developed in some detail, and an evolutionary picture for our solar system, and each class of objects, is developed. Some discussion of other (potential) planetary systems is also included.

### Rules & Requirements

**Prerequisites:** 149, 169, C160A or consent of instructor

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructors:** Chiang, de Pater

**Also listed as:** EPS C249

## ASTRON 250 Special Topics in Astrophysics 3 Units

Terms offered: Spring 2024, Spring 2022, Fall 2021

Topics will vary from semester to semester. See department for announcements.

### Rules & Requirements

**Prerequisites:** Consent of instructor

**Repeat rules:** Course may be repeated for credit without restriction.

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

## ASTRON 252 Stellar Structure and Evolution 3 Units

Terms offered: Spring 2025, Spring 2022, Spring 2020

Equations of stellar structure, radiative transfer and convection, thermonuclear reactions and stellar energy generations; stellar models, degenerate configurations, evolutionary sequences, supernovae, neutron stars, black holes, nucleosynthesis.

### Rules & Requirements

**Prerequisites:** Physics 110A-110B, 112, 137A-137B

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructor:** Filippenko

## ASTRON C254 High Energy Astrophysics 3 Units

Terms offered: Spring 2025, Spring 2024, Spring 2023, Spring 2022  
Basic physics of high energy radiation processes in an astrophysics environment. Cosmic ray production and propagation. Applications selected from pulsars, x-ray sources, supernovae, interstellar medium, extragalactic radio sources, quasars, and big-bang cosmologies.

### Rules & Requirements

**Prerequisites:** 201 or consent of instructor. 202 recommended

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructors:** Boggs, Quataert

**Formerly known as:** Physics C254, Astronomy C254

**Also listed as:** PHYSICS C254

## ASTRON 255 Computational Methods in Theoretical Astrophysics 3 Units

Terms offered: Spring 2020, Spring 2018, Spring 2016  
A broad in-depth survey of state-of-the-art numerical approaches to astrophysical self-gravitational gas dynamics with application to large scale simulation of coupled non-linear astrophysical flows. Finite-difference approaches for Lagrangian and Eulerian astrophysical hydrodynamics and coupled radiation-hydrodynamics. N-body gravitation techniques including direct N-body, P-M, P3M, and hierarchical Tree. Particle gas dynamics methods such as smooth particle hydrodynamics (SPH), adaptive SPH and unification of SPH, and gravity tree hierarchies (TREE-SPH). Advanced techniques such as higher order Godunov finite difference methods with adaptive mesh refinement (AMR). Applications of these approaches in three broad areas: cosmology, high energy astrophysics, and star formation and the interstellar medium.

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructor:** Klein

## ASTRON 256 Astronomy Data Science Laboratory 4 Units

Terms offered: Fall 2024, Fall 2022, Spring 2021  
This course features 3 data-centric laboratory experiments that draw on a variety of tools used by professional astronomers. PhD students will learn to procure and clean data (drawn from a variety of world-class astronomical facilities), assess the fidelity/quality of data, build and apply models to describe data, learn statistical and computational techniques to analyze data (e.g., Bayesian inference, machine learning, parallel computing), and effectively communicate data and scientific results. There is a heavy emphasis on software development in the Python language, statistical techniques, and high-quality communication (e.g., written reports, oral presentations, and data visualization).

### Rules & Requirements

**Prerequisites:** This class assumes that you have completed introductory astrophysical instruction (at the Astro 7A and 7B level) as well as knowledge of calculus (e.g. similar to Math 53) and linear algebra (e.g., similar to Math 54 or Physics 89). You should have proficiency or fluency in the Python programming language. This class heavily emphasizes software development, and is not the place to learn Python for the first time

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of laboratory per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

**Instructor:** Bloom

## ASTRON C285 Theoretical Astrophysics Seminar 1 Unit

Terms offered: Spring 2025, Fall 2024, Spring 2024, Fall 2023, Fall 2022  
The study of theoretical astrophysics.

### Hours & Format

**Fall and/or spring:** 15 weeks - 1 hour of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

**Instructor:** Quataert

**Also listed as:** PHYSICS C285

## ASTRON 290A Introduction to Current Research 2 Units

Terms offered: Fall 2021, Fall 2020, Fall 2019

Professional Skills and Directed Reading (a.k.a. "how to be a professional astronomer")

### Rules & Requirements

**Prerequisites:** Consent of instructor

### Hours & Format

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

**Instructor:** Lu

## ASTRON 290B Introduction to Current Research 1 Unit

Terms offered: Spring 2020, Spring 2019, Spring 2018

Continuation of 290A. Study of a research topic with an individual staff member.

### Rules & Requirements

**Prerequisites:** Consent of instructor

### Hours & Format

**Fall and/or spring:** 15 weeks - 1 hour of lecture per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

**Instructor:** de Pater

## ASTRON C290C Cosmology 2 Units

Terms offered: Spring 2025, Fall 2024, Spring 2024, Spring 2023

### Rules & Requirements

**Repeat rules:** Course may be repeated for credit without restriction.

### Hours & Format

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

**Instructors:** White, Cohn

**Formerly known as:** Physics C290C, Astronomy C290C

**Also listed as:** PHYSICS C290C

## ASTRON 292 Seminar 1 - 2 Units

Terms offered: Spring 2025, Fall 2024, Spring 2024

In addition to the weekly colloquium, the Department offers seminars in advanced topics, several of which are announced at the beginning of each semester. A maximum of 5 units may be taken per semester with a limitation of 2 in any one section.

### Rules & Requirements

**Repeat rules:** Course may be repeated for credit without restriction.

### Hours & Format

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

## ASTRON C292 Planetary Science Seminar 1 Unit

Terms offered: Spring 2025, Fall 2024, Spring 2024, Fall 2023, Spring 2023

The departments of Astronomy and Earth and Planetary Science offer a joint research seminar in advanced topics in planetary science, featuring speakers drawn from graduate students, postdoctoral researchers, faculty, and visiting scholars. Topics will span planetary interiors; surface morphology; atmospheres; dynamics; planet formation; and astrobiology. Speakers will vary from semester to semester. Meetings will be held once a week for 1 hour each, and the schedule of speakers will be determined on the first day of class. To pass the class, participants will be required to give a 30-minute presentation, either on their own research or on recent results from the literature.

### Rules & Requirements

**Repeat rules:** Course may be repeated for credit without restriction.

### Hours & Format

**Fall and/or spring:** 15 weeks - 1-1 hours of seminar per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

**Also listed as:** EPS C292

## ASTRON 298 Directed Group Study 1 - 4 Units

Terms offered: Fall 2021, Fall 2020, Fall 2019

Tutorial for groups of two or three students.

### Rules & Requirements

**Repeat rules:** Course may be repeated for credit without restriction.

### Hours & Format

**Fall and/or spring:** 15 weeks - 0 hours of independent study per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

## ASTRON 299 Advanced Study and Research 2 - 12 Units

Terms offered: Spring 2025, Fall 2024, Spring 2024

### Rules & Requirements

**Repeat rules:** Course may be repeated for credit without restriction.

### Hours & Format

**Fall and/or spring:** 15 weeks - 2-12 hours of independent study per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate

**Grading:** Letter grade.

## ASTRON 301 Undergraduate Astronomy Instruction 1 - 2 Units

Terms offered: Fall 2004, Fall 2003, Fall 2002

Open to a limited number of highly qualified undergraduate students interested in astronomy teaching at the college level. Students will participate in a seminar on educational methods and engage in tutorial or laboratory teaching under supervision of a faculty member.

### Rules & Requirements

**Prerequisites:** An elementary astronomy course and consent of instructor

**Repeat rules:** Course may be repeated for credit up to a total of 4 units.

### Hours & Format

**Fall and/or spring:** 15 weeks - 1 hour of lecture and 3-6 hours of laboratory per week

### Additional Details

**Subject/Course Level:** Astronomy/Professional course for teachers or prospective teachers

**Grading:** Offered for pass/not pass grade only.

## ASTRON 602 Individual Study for Doctoral Students 1 - 8 Units

Terms offered: Fall 2015, Fall 2014, Fall 2013

Individual study in consultation with the major field adviser, intended to provide an opportunity for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D. (and other doctoral degrees). May not be used for unit or residence requirement for the doctoral degree.

### Rules & Requirements

**Repeat rules:** Course may be repeated for credit without restriction.

### Hours & Format

**Fall and/or spring:** 15 weeks - 1-8 hours of independent study per week

### Additional Details

**Subject/Course Level:** Astronomy/Graduate examination preparation

**Grading:** Offered for satisfactory/unsatisfactory grade only.