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; galactic structure and dynamics of stellar systems; high-energy astrophysics and cosmology; star and planet formation; and spectroscopy.

Admission to the University

Uniform minimum requirements for admission

The following minimum requirements apply to all programs and will be verified by the Graduate Division:

1. A bachelor's degree or recognized equivalent from an accredited institution;
2. A minimum grade-point average of B or better (3.0);
3. If the applicant comes from a country or political entity (e.g. Quebec) where English is not the official language, adequate proficiency in English to do graduate work, as evidenced by a TOEFL score of at least 570 on the paper-and-pencil test, 230 on the computer-based test, 90 on the iBT test, or an IELTS Band score of at least 7 (note that individual programs may set higher levels for any of these); and
4. Enough undergraduate training to do graduate work in the given field.

Applicants who already hold a graduate degree

The Graduate Council views academic degrees as evidence of broad research training, not as vocational training certificates; therefore, applicants who already have academic graduate degrees should be able to take up new subject matter on a serious level without undertaking a graduate program, unless the fields are completely dissimilar.

Programs may consider students for an additional academic master's or professional master's degree if the additional degree is in a distinctly different field.

Applicants admitted to a doctoral program that requires a master's degree to be earned at Berkeley as a prerequisite (even though the applicant already has a master's degree from another institution in the same or a closely allied field of study) will be permitted to undertake the second master's degree, despite the overlap in field.

The Graduate Division will admit students for a second doctoral degree only if they meet the following guidelines:

1. Applicants with doctoral degrees may be admitted for an additional doctoral degree only if that degree program is in a general area of knowledge distinctly different from the field in which they earned their original degree. For example, a physics PhD could be admitted to a doctoral degree program in music or history; however, a student with a doctoral degree in mathematics would not be permitted to add a PhD in statistics.
2. Applicants who hold the PhD degree may be admitted to a professional doctorate or professional master's degree program if there is no duplication of training involved.

Applicants may only apply to one single degree program or one concurrent degree program per admission cycle.

Any applicant who was previously registered at Berkeley as a graduate student, no matter how briefly, must apply for readmission, not admission, even if the new application is to a different program.

Required documents for admissions applications

1. **Transcripts:** Upload unofficial transcripts with the application for the departmental initial review. Official transcripts of all college-level work will be required **if admitted**. Official transcripts must be in sealed envelopes as issued by the school(s) you have attended. Request a current transcript from every post-secondary school that you have attended, including community colleges, summer sessions, and extension programs.
   If you have attended Berkeley, upload unofficial transcript with the application for the departmental initial review. Official transcript with evidence of degree conferral ***will not*** be required if admitted.
2. **Letters of recommendation:** Applicants can request online letters of recommendation through the online application system. Hard copies of recommendation letters must be sent directly to the program, not the Graduate Division.
3. **Evidence of English language proficiency:** All applicants from countries in which the official language is not English are required to submit official evidence of English language proficiency. This requirement applies to applicants from Bangladesh, Burma, Nepal, India, Pakistan, Latin America, the Middle East, the People's Republic of China, Taiwan, Japan, Korea, Southeast Asia, and most European countries. However, applicants who, at the time of application, have already completed at least one year of full-time academic course work with grades of B or better at a U.S. university may submit an official transcript from the U.S. university to fulfill this requirement. The following courses will not fulfill this requirement: 1) courses in English as a Second Language, 2) courses conducted in a language other than English, 3) courses that will be completed after the application is submitted, and 4) courses of a non-academic nature. If applicants have previously been denied admission to Berkeley on the basis of their English language proficiency, they must submit new test scores that meet the current minimum from one of the standardized tests.

Admission to the Program

In addition to the application, transcripts of undergraduate work, and letters of recommendation, applicants must submit scores of the General and Physics Graduate Record Examinations (GRE), and, if applicable, the Test of English as a Foreign Language (TOEFL).

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

Normative Time Requirements

Total Normative Time

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.

Time to Advancement

Curriculum

ASTRON 290A	Introduction to Current Research [1]	1
ASTRON 290B	Introduction to Current Research [1]	1

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
ASTRON C202	Astrophysical Fluid Dynamics
ASTRON 203	Astrophysical Techniques
ASTRON 204	Numerical Techniques in Astronomy
ASTRON 216	Interstellar Matter
ASTRON 218	Stellar Dynamics and Galactic Structure
ASTRON C228	Extragalactic Astronomy and Cosmology
ASTRON C249	Solar System Astrophysics
ASTRON 252	Stellar Structure and Evolution
ASTRON C254	High Energy Astrophysics
ASTRON 267	Course Not Available

[1] The 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.)

Preliminary Exams

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.

Students entering with a Master's Degree or its equivalent may have the preliminary examination requirement waived subject to the discretion of the Chair.

Qualifying Exams

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.

Thesis

The thesis is an original piece of research carried out by the candidate under the supervision of a thesis adviser and two other faculty members (one of whom must be from another discipline). For information regarding guidelines, please see the Graduate Division's website (http://www.grad.berkeley.edu/policies/forms.shtml) .

Required Professional Development

Teaching

All candidates for the PhD in Astrophysics must acquire two semesters of teaching experience during their graduate career, whether or not compensated. 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.

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.

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

Astrophysics

ASTRON 201 Radiation Processes in Astronomy 4 Units
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
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
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.

Instructors: Backer, Basri, Blitz, Graham, Marcy, Welch

ASTRON 204 Numerical Techniques in Astronomy 3 Units
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
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: Bower, Chiang, Kasen, Quataert

Also listed as: PHYSICS C207

ASTRON 216 Interstellar Matter 3 Units
A survey of the observational data and theoretical ideas on the interstellar medium, with emphasis on the inferred physical conditions.
Rules & Requirements

Prerequisites: 201

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, Heiles, Glassgold, Graham

ASTRON 218 Stellar Dynamics and Galactic Structure 3 Units
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
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: Davis, Holzapfel, Lee, Ma, Seljak, White

Also listed as: PHYSICS C228

ASTRON C249 Solar System Astrophysics 3 Units
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
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. Course may be repeated for credit when topic changes.

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
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.

Instructors: Filippenko, Marcy

Formerly known as: C252 and Physics C252

ASTRON C254 High Energy Astrophysics 3 Units
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

Also listed as: PHYSICS C254

ASTRON 255 Computational Methods in Theoretical Astrophysics 3 Units
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 C285 Theoretical Astrophysics Seminar 1 Unit
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 1 Unit
Survey of research currently being performed in the Department or the University.
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 290B Introduction to Current Research 1 Unit
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
Rules & Requirements

Repeat rules: Course may be repeated for credit. Course may be repeated for credit when topic changes.

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

Also listed as: PHYSICS C290C

ASTRON 292 Seminar 1 - 2 Units
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. Course may be repeated for credit when topic changes.

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
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 when topic changes.

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
Tutorial for groups of two or three students.
Rules & Requirements

Repeat rules: Course may be repeated for credit. Course may be repeated for credit when topic changes.

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
Rules & Requirements

Repeat rules: Course may be repeated for credit. Course may be repeated for credit when topic changes.

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
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 a maximum of 4 units.Course may be repeated for a maximum 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 375 Instruction Techniques in General Astronomy 2 - 6 Units
Discussion and practice of teaching techniques as applied to astronomy. Open to graduate students who are presently teaching assistants or associates. Two units for course plus one section; three units for two discussion sections.
Rules & Requirements

Prerequisites: Consent of instructor

Hours & Format

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

Additional Details

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

Grading: Offered for satisfactory/unsatisfactory grade only.

Formerly known as: Astronomy 300

ASTRON 602 Individual Study for Doctoral Students 1 - 8 Units
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. Course may be repeated for credit when topic changes.

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.