Department of Astronomy and Astrophysics

Chair

- John E. Carlstrom

Professors

- Jacob L. Bean
- Bradford A. Benson
- John E. Carlstrom
- Fausto Cattaneo
- Hsiao-Wen Chen
- Scott Dodelson
- Daniel Fabrycky
- Wendy L. Freedman
- Michael D. Gladders
- Nickolay Y. Gnedin
- Daniel E. Holz
- Daniel Hooper
- Wayne Hu
- Eliza Kempton
- Edward W. Kolb
- Andrey V. Kravtsov
- Jeffrey McMahon
- Paolo Privitera
- Robert Rosner
- Abigail G. Vieregg

Associate Professors

- Damiano Caprioli
- Chihway Chang
- Clarence L. Chang
- Alex Drlica-Wagner
- Leslie Rogers
- Irina Zhuravleva

Assistant Professors

- Alex Ji
- Austin Joyce
- Harley Katz
- Gordan Krnjaic
- Jamie Law-Smith
- Diana Powell
- Jessica Zebrowski

Senior Instructional Professor

- Derek Buzasi

Emeritus Faculty

- Kyle M. Cudworth
- Joshua A. Frieman
- Doyal A. Harper, Jr.
- Lewis M. Hobbs
- Craig J. Hogan

- Edward J. Kibblewhite
- Arieh Königl
- Richard G. Kron
- Donald Q. Lamb, Jr.
- Stephan S. Meyer
- Takeshi Oka
- Angela V. Olinto
- Patrick E. Palmer
- Michael S. Turner

Research Faculty

- Thomas Crawford
- Rahul Datta
- Cosmin Deaconu
- Vikram Dwarkadas
- Richard Kessler
- Eric Oberla
- Alexandra Rahlin

Faculty in the Department of Astronomy and Astrophysics work on a wide range of topics at the frontiers of astrophysics: from understanding the beginning of the Universe to the search for habitable extrasolar planets; from the formation and evolution of the earliest galaxies to modeling the most energetic events in the modern Universe; from exploring our own solar system to the largest structures of the Universe. The department participates in major facilities that support the programs of our research groups. Many of these projects take advantage of connections with the neighboring national laboratories, Argonne and Fermilab, for both intellectual and technical resources. Research groups have access to leading telescopes worldwide, including the 6.5-m Magellan Telescopes at Las Campanas, Chile; the Dark Energy Survey at Cerro Tololo Inter-American Observatory in Chile; and the South Pole Telescope, with its ongoing development of powerful new imagers for measuring the Cosmic Microwave Background. Departmental researchers also make use of a number of telescopes (Hubble, Kepler, Chandra, Fermi, and others) and are actively developing new programs for EUSO, POEMMA, JWST, WFIRST, TESS, SOFIA and LSST. Chicago is an active participant in gravitational waves research as a member of LIGO, leading the development of the Holometer at Fermilab, and studying extreme cosmic particles at the Auger Observatory. We are a founding member of the world's largest optical telescope, the 25-meter Giant Magellan Telescope, which is scheduled for completion in Chile in the 2030s.

Program Requirements

The requirements for the Ph.D. degree in Astronomy and Astrophysics are satisfied through the following steps:

- Satisfactory completion of graduate courses in the pre-candidacy period
- Maintainence of full-time scholastic residence of at least 300 units of coursework per quarter, including summer
- Completion of pre-candidacy research projects
- Successful completion of a two-part Candidacy Exam
- Identification of a Thesis Advisor
- Formation of a Thesis Committee
- Thesis research and preparation
- Final Examination

Mentoring

Each student is assigned a faculty mentor to help with navigating graduate school by guiding them to achieve academic and professional goals and supporting their well-being and personal development. In addition, each student is assigned a peer mentor to welcome them and provide support as they begin their graduate school career. Students may also consult with their faculty mentor concerning research, especially during the first year when students are beginning to identify research projects and advisors. Each week there are various talks, seminars, and colloquia highlighting current research by departmental members and visitors that bring together students, faculty, research scientists and post-docs as a vibrant intellectual community. These occasions help facilitate discovery of research areas and projects that may be of interest to students.

Pre-Candidacy Curriculum

During the first and second years of the Ph.D. program (the pre-candidacy period), students complete eight required courses and at least four electives numbered in the 300s or 400s. Sample electives include ASTR 40800

The Perturbed Universe, ASTR 31220 The James Webb Space Telescope at Five Years, and ASTR 46100 Dynamics of Exoplanets. Graduate-level courses offered by departments in the Physical Sciences Division may be taken as electives, subject to approval by the Deputy Chair for Academic Affairs.

Students also enroll in 100 units of ASTR 37100 Precandidacy Research in the Autumn, Winter and Spring Quarters, and 300 units in the Summer Quarter. In this course, students arrange with a faculty member to conduct a short-term independent research project lasting one or more quarters. Research completed in ASTR 37100 is presented in the two-part Candidacy Exam, which is held before the start of the Autumn Quarter as students begin their second and third years in the Ph.D. program.

ASTR 30100	Stars	100
ASTR 35000	Order-of-Magnitude Astrophysics	100
ASTR 31000	Cosmology I	100
ASTR 49910	Graduate Seminar: Colloquium	100
ASTR 30400	Galaxies	100
ASTR 30350	Exoplanets	100
ASTR 31100	High Energy Astrophysics	100
ASTR 30600	Detection of Radiation	100
Electives		400
Precandidacy Research		1200
Total Units		2400

Advancement to Candidacy

Students advance to candidacy after successfully completing part two of the Candidacy Exam, identifying a thesis advisor, and forming a thesis committee. At this point, students enroll in ASTR 49400 Post-Candidacy Research and may continue to take elective courses.

Financial Support

All students admitted to the Ph.D. program are offered full financial support. Generally this takes the form of a teaching assistantship that provides a full tuition scholarship and pays a competitive monthly stipend. Teaching assistants are typically assigned to one of the undergraduate laboratory courses in the general education program. The department requires a minimum of two quarters of teaching, usually completed in the first year of the program, after which students may continue to be supported through teaching assistantships, research assistantships, or fellowship funding.

Grading Policy

All required courses are taken for a quality grade (3.0 on a scale of 4.0). ASTR 37100 Pre-Candidacy Research and ASTR 49400 Post-Candidacy Research are typically taken as P/F, but a letter grade may be requested by the student.

Students are expected to maintain an average grade of B (3.0 on a scale of 4.0) or better. If a student falls below this average, the Deputy Chair for Academic Affairs, in consultation with the student and other faculty, will identify appropriate actions for enhancing academic progress.

Dissertation and Final Examination

The Ph.D. thesis may be a single-author or long-form paper (a collection of multiple-author papers) that is submitted to a research journal of high quality and judged to be suitable for publication by the student's full Thesis Committee. This research is presented to the Thesis Committee in a Final Examination to engage in dialogue and debate. Final examinations are public events attended by the departmental community.

Contacts

For general information about application procedures, please contact the Student Affairs Administrator, Laticia Rebeles, lrebeles@astro.uchicago, (773) 702-9808. Additional information regarding the academic program is available on the Department of Astronomy and Astrophysics (https://astrophysics.uchicago.edu/) website.

Astronomy and Astrophysics Courses

ASTR 30100. Stars. 100 Units.
Introduction to stars (physical and observational), hydrodynamics of self-gravitating fluids, statistical mechanics and equations of state, energy transport, astrophysical nuclear reactions, stellar models, advanced topics. Instructor(s): Harley Katz Terms Offered: Autumn

ASTR 30350. Exoplanets. 100 Units.
Since their initial discovery in the 1990s, thousands of exoplanets have been discovered orbiting other stars. This course will address the detection, dynamics, and statistics of exoplanets, models of exoplanet formation,

composition, structure, and evolution, exoplanet atmospheres and environments, and prospects for exoplanet habitability.
Instructor(s): Diana Powell Terms Offered: Autumn

ASTR 30400. Galaxies. 100 Units.
The observed universe, the universe at high redshift, early universe microwave background radiation, relativistic homogeneous isotropic cosmologies, evolution of structure in the universe, primordial nucleosynthesis.
Instructor(s): Andrey Kravtsov Terms Offered: Spring

ASTR 30600. Detection of Radiation. 100 Units.
Radiation as a random process, optical coherence, and signal analysis in spatial and temporal domains, along with the detection and measurement of radiation with astronomical instruments.
Instructor(s): Clarence Chang Terms Offered: Spring

ASTR 31000. Cosmology I. 100 Units.
This course presents an introduction to the principles of cosmology. The first part introduces homogeneous, relativistic cosmologies and covers the Robertson-Walker metric, dynamics in the presence of matter, radiation, and dark energy, the universe as a function of time and redshifts, and techniques for calculating observable quantities. The next part covers the growth and evolution of structure in the universe including the formation of clusters and voids, correlation functions, and the mass spectrum. The next part covers the physics of the early universe, including inflation, primordial nucleosynthesis, and recombination. The final part covers current topics in cosmology, including analysis of the cosmic microwave background and tests for detecting and measuring dark matter and dark energy.
Instructor(s): Scott Dodelson Terms Offered: Winter

ASTR 31100. High Energy Astrophysics. 100 Units.
This course covers a wide range of phenomena associated with the astrophysics of high energy photons, cosmic rays and neutrinos, including the processes of ionization, bremsstrahlung, synchrotron, pion production, Compton and inverse Compton scattering, as well as cosmic ray acceleration. Specific sources of high energy emission will also be discussed, including active galaxies, pulsars, gamma-ray bursts and supernova remnants.
Instructor(s): Irina Zhuravleva Terms Offered: Winter

ASTR 31220. The James Webb Space Telescope at Five Years. 100 Units.
Launched in December of 2021, the revolutionary James Webb Space Telescope (JWST) has expanded our understanding of the cosmos, both near and far, and is making many important discoveries. This course aims to equip graduate students (and advanced undergraduates) who are interested in observational astrophysics with an understanding of the discovery potential of JWST, to better enable such students to make use of it in their own research. Through the lens of some JWST discoveries, the course will examine technical aspects of the observatory and its instruments, detailing both what JWST can do exceptionally well, and what is still challenging at the edge of discovery with this extraordinary machine. The course will include an examination of the development of JWST proposals, and a look at the complex and centrally important JWST exposure time calculator, good use of which is a central pillar of most successfully JWST proposals.
Instructor(s): Michael Gladders Terms Offered: Spring

ASTR 31400. Creative Machines and Innovative Instrumentation. 100 Units.
An understanding of the techniques, tricks, and traps of building creative machines and innovative instrumentation is essential for a range of fields from the physical sciences to the arts. In this hands-on, practical course, you will design and build functional devices as a means to learn the systematic processes of engineering and fundamentals of design and construction. The kinds of things you will learn may include mechanical design and machining, computer-aided design, rapid prototyping, circuitry, electrical measurement methods, and other techniques for resolving real-world design problems. In collaboration with others, you will complete a mini-project and a final project, which will involve the design and fabrication of a functional scientific instrument. The course will be taught at an introductory level; no previous experience is expected. The iterative nature of the design process will require an appreciable amount of time outside of class for completing projects. The course is open to undergraduates in all majors (subject to the pre-requisites), as well as Master's and Ph.D. students.
Instructor(s): Wakely (Autumn Quarter); Juan Estrada (Winter Quarter); Derek Buzasi (Spring Quarter) Terms Offered: Autumn Spring Winter
Prerequisite(s): PHYS 12200 or PHYS 13200 or PHYS 14200; or CMSC 12100 or CMSC 12200 or CMSC 12300; or consent of instructor.
Equivalent Course(s): PHYS 21400, CMSC 21400, PSMS 31400, ASTR 21400

ASTR 32100. Cosmology II. 100 Units.
Study of physical cosmology with emphasis on the standard big-bang model and its observational and experimental tests.
Instructor(s): Wayne Hu Terms Offered: Autumn

ASTR 34000. Statistical Methods in Astrophysics. 100 Units.
An exploration of the variety of statistical methods used in modern astrophysics. We discuss the frequentist (hypothesis tests, confidence intervals) and Bayesian (explicit priors, model-choosing, parameter estimation) approaches. Other topics include: Markov Chain Monte Carlo and other computational statistics; multi-

dimensional likelihood space; Fischer information matrices; time series analysis. Assignments draw from examples in the astronomical literature.
Instructor(s): Jeffrey McMahon Terms Offered: Winter

ASTR 35000. Order-of-Magnitude Astrophysics. 100 Units.
In physics and astrophysics, an approximate answer is often just as (if not more) useful than an exact answer. Making order-of-magnitude estimates is helpful to develop physical intuition, to verify numerical solutions, and to evaluate whether a research problem is worth pursuing. In this course, students will receive coaching and practice in physics-based reasoning, back-of-the envelope estimation, and thinking on their feet. Students will be encouraged to take a broad perspective, to think critically, and to have fun using physics to understand the universe around them.
Instructor(s): Jamie Law-Smith Terms Offered: Autumn

ASTR 37100. Precandidacy Research. 300.00 Units.
Students arrange with a faculty research supervisor to conduct a short-term independent research project lasting one or more quarters. Research completed in ASTR 37100 is presented as part of the student's candidacy exams.
Instructor(s): Various Terms Offered: Autumn Spring Summer Winter

ASTR 46100. Dynamics of Exoplanets. 100 Units.
Exoplanets are planets that orbit other stars. As most detection methods are indirect, planets' orbital dynamics is key to basic characterization, and it was historically important to confirm their existence. Their surprising orbital properties challenged planet formation and evolution theories, prompting further development of dynamical theories. This course covers orbital mechanics of N-body systems from the short-term, relevant to observations such as transit-timing variations, all the way to billion-year timescales, relevant to the dynamical winnowing of unstable systems. It covers highly eccentric and inclined orbits, scattering and resonant dynamics, planetary orbits in binary star systems, the additional physics of tidal dissipation and orbital migration due to a gas disk, and current research topics.
Instructor(s): Daniel Fabrycky Terms Offered: Winter

ASTR 49400. Post-Candidacy Research. 300.00 Units.
Independent research undertaken towards completion of the dissertation.
Instructor(s): Various Terms Offered: Autumn Spring Summer Winter
Prerequisite(s): Completion of all candidacy requirements.

ASTR 49910. Graduate Seminar: Colloquium. 100 Units.
In this course for first-year Ph.D. students in Astronomy and Astrophysics, students will become acquainted with the research of the weekly colloquium speakers and prepare for active participation in the colloquia.
Instructor(s): Eliza Kempton Terms Offered: Winter

ASTR 49920. Graduate Seminar: Fellowship and Proposal Writing. 100 Units.
In this course for first-year Ph.D. students in Astronomy and Astrophysics, students will identify prospective fellowship or research funding opportunities and learn how to prepare strong applications, with the goal of producing completed examples as final projects.
Instructor(s): Jacob Bean Terms Offered: Spring

ASTR 49930. Graduate Seminar: Candidacy Preparation. 100 Units.
In this course for second-year Ph.D. students in Astronomy and Astrophysics, students will prepare for part two of the candidacy examination through presentations, board work, discussion, and questions.
Instructor(s): Leslie Rogers Terms Offered: Spring