Department of Astronomy and Astrophysics

Chair

- Angela V. Olinto

Professors

- John E. Carlstrom
- Fausto Cattaneo
- Scott Dodelson
- Wendy L. Freedman
- Joshua A. Frieman
- Nickolay Y. Gnedin
- Doyal A. Harper, Jr.
- Craig J. Hogan
- Wayne Hu
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- Alexei M. Khokhlov
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- Andrey V. Kravtsov
- Richard G. Kron
- Stephan S. Meyer
- Angela V. Olinto
- Paolo Privitera
- Robert Rosner
- Michael S. Turner

Associate Professors

- Jacob L. Bean
- Hsiao-Wen Chen
- Michael D. Gladders
- Daniel E. Holz
- Dan Hooper

Assistant Professors

- Bradford A. Benson
- Damiano Caprioli
- Clarence L. Chang
- Daniel Fabrycky
- Leslie Rogers
- Erik Shirokoff

Emeritus Faculty

- Kyle M. Cudworth
- Roger H. Hildebrand
- Lewis M. Hobbs
- Edward J. Kibblewhite
- Arieh Königl
- Donald Q. Lamb, Jr.
- Richard H. Miller
- Takeshi Oka
- Patrick E. Palmer
- Eugene N. Parker
- Noel M. Swerdlow

- James W. Truran, Jr.
- Peter O. Vandervoort
- Donald G. York

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 space telescopes (Hubble, Kepler, Chandra, Fermi, and others) and are actively developing new space missions and observational programs for EUSO, JWST, TESS, and SOFIA. 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 now under construction in the Chilean Andes with first light expected early in the next decade.

Admission

Students seeking admission for graduate study leading to Ph.D. degree in Astronomy and Astrophysics typically enter with an undergraduate degree in Physics or another Physical Science. The following materials should be submitted using the Online Application (https://apply-psd.uchicago.edu/apply) system.

- 3 letters of recommendation
- A personal statement
- GRE and Physics GREs
- TOEFL for International Students
- Application fee (Application Fee Waiver (https://physical-sciences.uchicago.edu/page/application-information/#Application%20Fee%20Waiver))

The Degree of Doctor of Philosophy

During the first and second academic years, students complete six Core courses in addition to electives. The Core courses are ASTR 30100, ASTR 30300, ASTR 30400, ASTR 31100, and ASTR 30600. Additionally, students are expected to complete pre-candidacy research projects that will be presented as part of their candidacy exams.

Year 1: Students take one Core course, ASTR 49900, and 1-2 electives per quarter. Students who actively begin research with a faculty member will enroll in ASTR 37100 as one of their electives. First-year students also serve as teaching assistants in the undergraduate Physical Sciences courses for at least two quarters.

Year 2: Students take one Core course, ASTR 49900, and 1-2 electives per quarter, one of which is expected to be ASTR 37100.

ASTR 30100	Stars	100
ASTR 30300	Interstellar Matter	100
ASTR 30400	Galaxies	100
ASTR 31000	Cosmology I	100
ASTR 31100	High Energy Astrophysics	100
ASTR 30600	Detection of Radiation	100
ASTR 49900	Graduate Research Seminar	100
ASTR 37100	Precandidacy Research: Astron	Var
ASTR 49400	Post-Candidacy Research	Var

A selected list of course descriptions can be seen here.

Candidacy

Second-year students take the first part of the candidacy exam in the Autumn Quarter, and the second part in the Spring Quarter. Advancement to candidacy is made when a student has successfully passed the candidacy exams and established a Thesis Committee. After candidacy is established, students enroll in ASTR 49400 and may also take electives of advanced coursework. Students who advance to candidacy must arrange a first meeting of their committee as soon as it is appointed. Thereafter, at minimum, the candidate should meet with the committee once per year.

Departmental Talks and Events

First-year students are required to attend a regular program of Faculty Research Seminars (FRS) to acquaint themselves with the broad range of faculty research in the department. Attendance at the weekly Astronomy Colloquia is required of all graduate students. There are also numerous informal talks and events presenting current topics and emerging research that bring together students, faculty, scientists and post-docs as an intellectual community. Students may present their own work in- progress at some of these events.

Advising/Mentoring

The Assistant Chair for Academic Affairs is the *de facto* advisor to incoming graduate students; however, students are encouraged to seek out potential research supervisors or mentors as early as possible in their program. It is in the student's interest to become widely acquainted with the faculty before the point of choosing a Thesis Advisor and potential committee members. This can be accomplished through formal and informal mechanisms, such as meeting with faculty outside of class and engaging with them at departmental talks and events. Once a student and faculty member agree to the Thesis Advisor relationship, they may recommend committee members to the Assistant Chair for Academic Affairs for appointment to the Thesis Committee. The committee is to be established by the Autumn Quarter of the third year.

Dissertation Requirements

The Ph.D. thesis consists of a paper that must be submitted to a research journal of high quality and must be judged by the full Thesis Committee to be suitable for publication in such a journal. In the case of a **single-author paper**, the thesis is the manuscript submitted for publication, plus any supplementary appendices augmenting the presentation that might not be appropriate in a published paper. In the case of a **multiple-author paper** or papers (which also must fulfill the requirement of submission for publication), the thesis must be an extended version, written solely by the student and describing in detail his or her contributions to the published work. In both cases, the student's Thesis Committee should approve the planned work at least three quarters before the Final Examination. Both types of theses (single-author paper or extended single-author version of the multiple-author paper) must be submitted in the required University-standard format. Information on formatting requirements and deadlines are available from The University of Chicago Dissertation Office (http://www.lib.uchicago.edu/e/phd).

Final Examination

The Final Examination, or oral defense, marks the candidate's professional entry into scholarship. The thesis forms the basis of the examination. It is a public event at which the candidate will present his or her research to the Thesis Committee, engage in dialogue and debate with the committee, and receive constructive criticism from the committee. A draft copy of the thesis must be submitted to the full Thesis Committee for review two weeks before the Final Examination. After the thesis is approved, the Thesis Advisor will notify the student that it may be submitted to the Dissertation Office. During the first week of the quarter in which a student anticipates the Final Examination, s/he obtains permission to apply for graduation from the administrator in the Department of Astronomy and Astrophysics.

Contacts

For general information about application procedures, please contact the Student Affairs Administrator, Laticia Rebeles, at 773-702-9808. Additional information is available on the Department of Astronomy and Astrophysics (http://astro.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): F. Cattaneo Terms Offered: Autumn
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

ASTR 30300. Interstellar Matter. 100 Units.
Interstellar medium, collision-less systems, distribution of stars in the solar neighborhood, stellar kinematics/dynamics, observations of galactic large-scale structure, theory of galactic structure and evolution.
Instructor(s): H. Chen Terms Offered: Winter
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

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): A. Kravtsov Terms Offered: Spring
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

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): J. Carlstrom Terms Offered: Spring
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

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): S. Dodelson Terms Offered: Autumn
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

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): D. Caprioli Terms Offered: Winter
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

ASTR 31300. Extragalactic Studies. 100 Units.
When, where, and how stars formed in galaxies is central to understanding many other aspects of large stellar systems: baryons streaming into dark-matter haloes, large-scale outflows, patterns in chemical abundances, and how all these processes have changed with time. This class will look at what is known empirically about star formation in nearby galaxies across a wide range of conditions, identifying those that are most significant for building up the mass in stars and most significant energetically for the local interstellar medium. The range of conditions includes strong dynamical interactions on large scales, and high-density regions and regions exposed to intense radiation on small scales. Our approach will study prototype galaxies from relevant classes (e.g. starburst, ultra-luminous infrared emitters, ultraviolet-luminous, etc.), exploring what is known about the recent history of star formation in these systems from multi-wavelength data.
Terms Offered: TBD. Not offered in 2017-18
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

ASTR 31500. Dynamics of Fluids. 100 Units.
Principles of hydrodynamics and hydromagnetics. Equilibrium and stability of fluid systems in astrophysics. Waves. Shocks. Turbulence.
Terms Offered: TBD. Not offered in 2017-18
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

ASTR 31600. Dynamics Particles. 100 Units.
Dynamics of collision-less plasmas and stellar systems. Stochastic processes and kinetic equations. Dynamics of galaxies and star clusters. Astrophysical plasmas.
Terms Offered: TBD. Not offered in 2017-18
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

ASTR 32000. Relativistic Astrophysics. 100 Units.
Special and General relativity and the experimental tests, with applications to astrophysical problems such as super-massive stars, black holes, relativistic star clusters, and gravitational radiation.
Instructor(s): Staff Terms Offered: Spring
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

ASTR 32100. Cosmology II. 100 Units.
Study of physical cosmology with emphasis on the standard big-bang model and its observational and experimental tests.
Terms Offered: TBD. Not offered in 2017-18
Prerequisite(s): Open to advanced undergraduates who have taken Cosmology I by consent of instructor.

ASTR 33000. Computational Physics and Astrophysics. 100 Units.
Basic computational methods useful for astrophysics, supplemented by specific examples drawn primarily from astrophysics. Starting with basics (e.g., precision, errors and error analysis) and basic computational methods (differentiation, integration/quadrature, Monte Carlo, numerical linear algebra), and then discussing solution of problems posed in terms of ordinary and partial differential equations.
Instructor(s): A. Kravtsov Terms Offered: Autumn
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

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.
Terms Offered: TBD. Not offered in 2017-18
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

ASTR 37100. Precandidacy Research: Astron. Var 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): R. Kron Terms Offered: Autumn,Spring,Summer,Winter

ASTR 40600. Gravitational Lensing. 100 Units.
Theory of bending of light by gravitational potentials followed by astrophysical and cosmological applications including; microlensing, planetary searches, strong lensing, and weak lensing.
Instructor(s): Staff Terms Offered: TBD

ASTR 40800. The Perturbed Universe. 100 Units.
This seminar course will cover inflation as the source of structure in the universe and its observational signatures. Topics will include relativistic perturbation theory, canonical and general single field inflationary models, primordial non-Gaussianity, and gravitational waves.
Instructor(s): W. Hu Terms Offered: Winter

ASTR 41800. Introduction to Intergalatic Medium Studies. 100 Units.
As an introduction to intergalactic medium studies, the course will begin with a historical overview of absorption-line studies and proceed with in-depth discussion of on-going research topics. These include the reionization epoch, chemical enrichment of the universe, and association between luminous matter traced by galaxies and gaseous clouds probed by absorption-line observations.
Instructor(s): Staff Terms Offered: TBD. Not offered 2017-18
Note(s): H. Chen

ASTR 43200. High Energy Cosmic Particles. 100 Units.
This graduate level course will focus on high energy particle astrophysics from basic facts to recent discoveries in the study of cosmic rays, gamma-rays, and neutrinos. The course will introduce the main concepts of proposed mechanisms for generating these particles, the past and current detections techniques and observatories, and recent observations. Some particle physics and cosmology will be covered including models of dark matter particles and the effect of cosmic backgrounds on high energy cosmic particles.
Instructor(s): Staff Terms Offered: TBD. Not offered in 2017-18

ASTR 44800. Cosmic Microwave Background. 100 Units.
The first half of the course will be lectures with the goal of establishing a common denominator, and the second half will be research. The course requires a final project to be presented in class. Prerequisites are graduate-level cosmology and general relativity.
Instructor(s): W. Hu Terms Offered: TBD

ASTR 45000. Extreme Optics. 100 Units.
Frontiers in optics will be a review of the state of the art in optics as it applies to astronomy. Topics to be covered will include single dish optics, adaptive optics, building large telescopes and coronography, interferometers using multiple telescopes, lasers for guide stars and wavelength control, LIGO and LISA.
Instructor(s): Staff Terms Offered: TBD. Not offered 2017-18

ASTR 45400. Image Processing (Analysis) 100 Units.
Many key results in current research rely on the inner workings of codes that operate on pixels. Examples are measuring the weak lensing shear field, measuring precise light curves for supernovae in the presence of contaminating light from a host galaxy, high-precision relative photometry (e.g. to detect transits), reliable morphological star/galaxy classification to faint flux limits, reliable color measurements (e.g. for photometric redshifts), crowded-field photometry, and detection of diffuse light to very low surface brightness levels. This course will explore some of the ideas that have been developed to address these and other problems of interest, illustrated by CCD detectors. The format of the class will be first to consider what goes into the pixels (e.g. ingredients of the point-spread function), followed by the techniques for unwinding the instrumental effects, concluding with what extracted parameters are optimal for some particular application (what comes out of the pixels).
Instructor(s): Staff Terms Offered: TBD. Not offered in 2017-18

ASTR 45500. Machine Learning in Astronomy. 100 Units.
This one quarter elective is an applications-based course that will cover major Machine Learning topics applied to astronomy datasets. Topics will include image classification, clustering, and anomaly detection. This course is intended for graduate students and senior undergraduates who have some experience programming in Python.
Instructor(s): Camille Avestruz Terms Offered: Spring. Spring Quarter 2017

ASTR 45600. Superconducting Detectors for Astronomy & Particle Astrophys. 100 Units.
This course will cover the physics and application of superconducting detectors and devices for use in astronomical and particle-astrophysics instruments. Technologies include Transition Edge Sensors, SQUID multiplexers, Kinetic Inductance Detectors and other similar implementations of applied superconductivity. The class will focus on applications of these technologies aimed at addressing topics of interest to fundamental physics and astronomy including Dark Matter searches, studies of the Cosmic Microwave Background, and sub-mm astronomy.
Instructor(s): Clarence Chang Terms Offered: Winter
Prerequisite(s): Open to advanced undergraduates by consent of instructor.

ASTR 45800. Exoplanets. 100 Units.
The study of exoplanets, planets associated with stars other than the Sun, has become one of the most exciting and rapidly evolving areas of modern astronomy. This new course will address general questions concerning the detection and characterization of exoplanets and of what we have already learned about the origin and properties of exoplanetary systems and of how they compare with those of the Solar System. This discussion will be placed in the context of models of planet formation in protoplanetary disks, their structure and composition, and their dynamical interactions with the natal disk, the parent star, and other planets. The course will make use of seminal papers on these topics and will encourage active participation by the students.
Instructor(s): Staff Terms Offered: TBD. Not offered in 2017-18

ASTR 45900. What Makes a Planet Habitable? 100 Units.
This course explores the factors that determine how habitable planets form and evolve. We will discuss a range of topics, from the accretion and loss of atmospheres and oceans, to the long-term carbon cycle, climate dynamics, and the conditions that sustain liquid water on a planet's surface over timescales relevant to the origin and evolution of life. Students will be responsible for reading and discussing papers in peer-reviewed journals each meeting and for periodically preparing presentations and leading the discussion.
Instructor(s): E. Kite Terms Offered: Spring
Equivalent Course(s): GEOS 22060,GEOS 32060

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

ASTR 49900. Graduate Research Seminar. 100 Units.
The instructor chooses a topic for the seminar and assigns papers that develop the topic from the earliest times to the most recent results. Students each present papers during the course, as assigned, and lead a discussion. The purpose is to give students practice in analyzing the literature and in presenting to their peers, as well to assure breadth in the topics covered during their time at Chicago.
Instructor(s): Staff Terms Offered: Autumn,Spring,Winter
Prerequisite(s): E. Shirokoff, P. Privitera, B. Benson

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