

# ASTRONOMY AND ASTROPHYSICS

<b>Graduate Program Head</b>	Abe Falcone
<b>Program Code</b>	ASTRO
<b>Campus(es)</b>	University Park (Ph.D., M.S.)
<b>Degrees Conferred</b>	Doctor of Philosophy (Ph.D.) Master of Science (M.S.) Dual-Title Ph.D. in Astronomy and Astrophysics and Astrobiology
<b>The Graduate Faculty</b>	View ( <a href="https://secure.gradsch.psu.edu/gpms/?searchType=fac&amp;prog=ASTRO">https://secure.gradsch.psu.edu/gpms/?searchType=fac&amp;prog=ASTRO</a> )

The graduate program in Astronomy and Astrophysics prepares students for careers in astronomy, space science and education. Graduate instruction and research opportunities are available in theoretical, observational, and instrumental astronomy and astrophysics. Currently active areas of theoretical research include high-energy astrophysics (including theory of neutron stars, black holes, and gamma ray bursts), relativity and cosmology, stellar dynamics and planet formation, and computational methodology. Observational areas include spectroscopic and photometric observations of high-redshift quasars, galaxies and the intergalactic medium; gamma-ray bursts; X-ray and visible light studies of quasars, starburst and other active galaxies; visible light studies of nearby galaxies and their stellar populations; infrared study of brown dwarfs and protoplanetary disks; spectroscopy and modeling of binary, magnetically active, pre- and post-main sequence stars; spectroscopic searches for planetary systems. Instrumental areas include: development of X-ray telescopes and detectors; and high-precision visible and near-infrared light spectrographs. Department faculty members participate in several university cross-disciplinary organizations: Astrobiology Research Center, Center for Astrostatistics, Center for Exoplanets and Habitable Worlds, and the Institute for Gravitation and the Cosmos.

The department played a seminal role in and leads many science investigations using two NASA-launched satellites, the Chandra X-ray Observatory and the Swift panchromatic gamma-ray burst mission, and the innovative 9-meter Hobby-Eberly Telescope located at the McDonald Observatory in Texas. Faculty and students also observe with other space-based observatories (GALEX, Hubble Space Telescope, Spitzer Space Telescope, XMM-Newton) and ground-based telescopes (Gemini and other national facilities, Magellan, Keck, South Africa Large Telescope, Very Large Telescopes). Physics faculty members closely associated with the Department are involved in particle and gravitational wave observations using the Auger, AMANDA, Ice Cube, and LIGO instruments. The Department has extensive computing facilities, and research is also conducted with university and national supercomputing resources.

Graduate students also have ample opportunity to acquire experience in undergraduate teaching and public outreach.

## Admission Requirements

Applicants apply for admission to the program via the J. Jeffrey and Ann Marie Fox Graduate School application for admission (<https://gradschool.psu.edu/admissions/how-to-apply/>). Requirements listed here are in addition to Graduate Council policies listed under GCAC-300

Admissions Policies (<https://gradschool.psu.edu/graduate-education-policies/>).

Normally, students admitted to the program are required to have a bachelor's degree in physics and/or astronomy with a grade-point average of at least 3.0 in their junior/senior courses in physics, astronomy, math, and related subjects. GRE scores are not accepted.

The language of instruction at Penn State is English. English proficiency test scores (TOEFL/IELTS) may be required for international applicants. See GCAC-305 Admission Requirements for International Students (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-300/gcac-305-admission-requirements-international-students/>) for more information.

Applicants to the Astronomy and Astrophysics program normally have a minimum TOEFL score of 590 on the paper-based test, or a total score of 96 with a 23 on the speaking section for the Internet-based test (iBT).

## Degree Requirements

### Master of Science (M.S.)

Requirements listed here are in addition to Graduate Council policies listed under GCAC-600 Research Degree Policies. (<https://gradschool.psu.edu/graduate-education-policies/>)

The Master of Science degree requires completion of the Ph.D. course requirements with 3.00 grade point average, passage of the qualifying exam, and submission of an acceptable scholarly paper, completed while enrolled in ASTRO 596.

Code	Title	Credits
<b>Required Courses</b>		
<i>10 3-credit courses, including: <sup>1</sup></i>		
ASTRO 501	Fundamental Astronomy	3
ASTRO 502	Fundamental Astrophysics	3
at least 4 additional ASTRO 500-level courses		12
4 additional 3-credit courses <sup>2</sup>		12
<i>In addition, the following courses are required:</i>		
ASTRO 590	Colloquium	1
ASTRO 602	Supervised Experience in College Teaching <sup>3</sup>	1
<b>Culminating Experience</b>		
ASTRO 596	Individual Studies <sup>4</sup>	3
<b>Total Credits</b>		<b>35</b>

<sup>1</sup> No more than 6 credits of ASTRO 596 may be counted toward the ten 3-credit course requirement. If units of ASTRO 596 are used, they must be in addition to those used for the Culminating Experience.

<sup>2</sup> The remaining courses may be chosen from 500-level offerings in any of the following fields: Astronomy & Astrophysics, Physics, Statistics, Mathematics, Applied Mathematics, Biology, Chemistry, Astrobiology, Geosciences, Meteorology, Materials Science and Engineering, Computer Science, or one of the Engineering or Information Science and Technology disciplines. One 400-level class may be substituted for a course that is not one of the ASTRO 500-level courses.

<sup>3</sup> Credits for ASTRO 602 cannot be counted towards the ten 3-credit course requirement.

<sup>4</sup> M.S. students must submit an acceptable scholarly paper, completed while enrolled in ASTRO 596.

## Doctor of Philosophy (Ph.D.)

Requirements listed here are in addition to Graduate Council policies listed under GCAC-600 Research Degree Policies. (<https://gradschool.psu.edu/graduate-education-policies/>)

A minimum of 37 credits is required for the Ph.D., including:

Code	Title	Credits
<b>Required Courses</b>		
<i>A GPA of 3.2 in the following ten 3-credit courses is required:</i> <sup>1</sup>		
ASTRO 501	Fundamental Astronomy	3
ASTRO 502	Fundamental Astrophysics	3
at least 4 additional ASTRO 500-level courses		12
4 additional 3-credit courses <sup>2</sup>		12
<i>In addition, the following courses are required:</i>		
ASTRO 589	Seminar in Current Astronomical Research	3
ASTRO 590	Colloquium	1
ASTRO 596	Individual Studies <sup>3</sup>	3
ASTRO 602	Supervised Experience in College Teaching <sup>4</sup>	1
<b>Total Credits</b>		<b>38</b>

<sup>1</sup> No more than 6 credits of ASTRO 596 may be counted toward the ten 3-credit course requirement. If units of ASTRO 596 are used, they must be in addition to those listed below. If units of ASTRO 596 are used, the GPA computed for the GPA > 3.2 requirement will exclude the units of ASTRO 596.

<sup>2</sup> The remaining courses may be chosen from 500-level offerings in any of the following fields: Astronomy & Astrophysics, Physics, Statistics, Mathematics, Applied Mathematics, Biology, Chemistry, Astrobiology, Geosciences, Meteorology, Materials Science and Engineering, Computer Science, or one of the Engineering or Information Science and Technology disciplines. One 400-level class may be substituted for a course that is not one of the ASTRO 500-level courses.

<sup>3</sup> For directed research in the second year.

<sup>4</sup> Credits for ASTRO 602 cannot be counted towards the ten 3-credit course requirement.

The qualifying examination is a written examination covering any area of astronomy. Students who fail the examination may make a second attempt. At the Comprehensive Examination, the student presents a significant body of original research conducted at Penn State. This Examination tests the student's mastery of the chosen field of research. The student prepares an extended written report and oral presentation, and answers questions on the research and closely related areas. Graduation requires the completion of a dissertation of original research and a final oral examination (the dissertation defense). To earn the Ph.D. degree, doctoral candidates must write a dissertation that is accepted by the Ph.D. committee, the head of the graduate program, and the Graduate School.

## Dual-Titles

### Dual-Title Ph.D. in Astronomy and Astrophysics and Astrobiology

Requirements listed here are in addition to requirements listed in GCAC-208 Dual-Title Graduate Degree Programs (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-200/gcac-208-dual-titles/>).

## Admissions Requirements

Students must apply and be admitted to the graduate program in Astronomy and Astrophysics and The Graduate School before they can apply for admission to the dual-title degree program. After admission to their primary program, students must apply for admission to and meet the admissions requirements of the Astrobiology dual-title program. Refer to the Admission Requirements section of the Astrobiology Bulletin page (<http://bulletins.psu.edu/graduate/programs/majors/astrobiology/>). Doctoral students must be admitted into the dual-title degree program in Astrobiology no later than the end of the fourth semester (not counting summer semesters) of entry into the graduate major program.

## Degree Requirements

To qualify for the dual-title degree, students must satisfy the degree requirements for the Ph.D. in Astronomy and Astrophysics, listed on the Degree Requirements tab. In addition, students must complete the degree requirements for the dual-title in Astrobiology, listed on the Astrobiology Bulletin page (<http://bulletins.psu.edu/graduate/programs/majors/astrobiology/>).

The Qualifying Examination in the major area alone will satisfy the Qualifying Exam requirement for the dual-title program.

In addition to the general Graduate Council requirements for Ph.D. committees (<http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/phd-dissertation-committee-formation/>), the Ph.D. committee of an Astronomy and Astrophysics and Astrobiology dual-title Ph.D. student must include at least one member of the Astrobiology Graduate Faculty. Faculty members who hold appointments in both programs' Graduate Faculty may serve in a combined role. If the chair of the Ph.D. committee is not also a member of the Graduate Faculty in Astrobiology, the member of the committee representing Astrobiology must be appointed as co-chair. The Astrobiology representative on the student's Ph.D. committee will develop questions for and participate in the evaluation of the comprehensive examination.

Students in the dual-title program are required to write and orally defend a dissertation on a topic that is approved in advance by their Ph.D. committee and reflects their original research and education in Astronomy and Astrophysics and Astrobiology. Upon completion of the doctoral dissertation, the candidate must pass a final oral examination (the dissertation defense) to earn the Ph.D. degree. The dissertation must be accepted by the Ph.D. committee, the head of the graduate program, and the Graduate School.

## Minor

A graduate minor is available in any approved graduate major or dual-title program. The default requirements for a graduate minor are stated in Graduate Council policy GCAC-218 Minors (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-200/gcac-218-minors/>).

## Student Aid

Graduate assistantships available to students in this program and other forms of student aid are described in the Tuition & Funding (<https://gradschool.psu.edu/funding/>) section of the J. Jeffrey and Ann Marie Fox Graduate School's website. Students on graduate assistantships must adhere to the course load limits (<https://gradschool.psu.edu/graduate-education-policies/gsad/gsad-900/gsad-901-graduate-assistants/>) set by the Fox Graduate School.

Graduate Teaching Assistantships, externally funded graduate Research Assistantships, and/or University fellowships are typically provided to

student admitted and continuing in good standing. Many students also apply for externally funded fellowships.

## Courses

Graduate courses carry numbers from 500 to 699 and 800 to 899. Advanced undergraduate courses numbered between 400 and 499 may be used to meet some graduate degree requirements when taken by graduate students. Courses below the 400 level may not. A graduate student may register for or audit these courses in order to make up deficiencies or to fill in gaps in previous education but not to meet requirements for an advanced degree.

Astronomy and Astrophysics (ASTRO) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/astro/>)

## Learning Outcomes

### Master of Science (M.S.)

1. **KNOW:** Graduates will demonstrate command of basic observational astronomy and astrophysics, including observing techniques, methods of data analysis, and common theoretical frameworks and techniques.
2. **APPLY/CREATE:** Graduates will apply physics and mathematics knowledge to standard problems in astrophysics, as well as application of statistical principles to data analysis.
3. **COMMUNICATE:** Graduates will clearly and cogently describe the background and motivation of their work, describe their methodology, and present and defend their arguments and conclusions in oral presentations, written papers and reports.
4. **THINK:** Graduates will apply analytical and critical thinking to evaluate research findings reported in scientific journal articles.
5. **PROFESSIONAL PRACTICE:** Graduates will demonstrate working knowledge of the standards for ethical conduct in research through their professional behavior and work.

### Doctor of Philosophy (Ph.D.)

1. **KNOW:** Graduates will demonstrate a breadth of knowledge in astronomy and astrophysics, including observing techniques, methods of data analysis, and common theoretical frameworks and techniques. Graduates will demonstrate depth of knowledge in their subfield, including knowledge of the major techniques and comprehension of the major problems.
2. **APPLY/CREATE:** Graduates will apply physics and mathematics knowledge to standard problems in astrophysics and statistical principles to data analysis. Graduates will create original research in theoretical astrophysics, observational astronomy, or laboratory astrophysics (including but not limited to, instrumentation development). This research entails identifying and evaluating the status of outstanding questions, developing strategies to answer them, and formulating hypotheses and testing them through one or more of the following means: calculations or simulations, model development, analysis of existing data, acquisition and analysis of new data, and design and/or construction of new instruments or methodology.
3. **COMMUNICATE:** Graduates will clearly and cogently describe the background and motivation of their research, describe their research methodology, and present and defend their arguments and conclusions in oral presentations, written papers, and reports. Graduates will synthesize their findings and describe how their work

advances major issues in the field and its implications for future research to address open questions.

4. **THINK:** Graduates will apply analytical and critical thinking to evaluate earlier studies that motivate their dissertation work and relevant contemporaneous studies.
5. **PROFESSIONAL PRACTICE:** Graduates will demonstrate working knowledge of the standards for ethical conduct in research through their professional behavior and work. Graduates will put such ethical conduct into practice during their PhD dissertation research and throughout any associated activity.

## Contact

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