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 Graduate School application for admission (http://gradschool.psu.edu/prospective-students/how-to-apply/). Requirements listed here are in addition to Graduate Council policies listed under GCAC-300 Admissions Policies (http://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 (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-305-admission-requirements-international-students/) for more information.

Applicants to the Astronomy and Astrophysics program must 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. (http://gradschool.psu.edu/graduate-education-policies/)

The Master of Science degree requires completion of the Ph.D. course requirements (except the 3 credits of ASTRO 589) with 3.00 grade point average, passage of the qualifying exam, and submission of an acceptable scholarly paper, completed while enrolled in ASTRO 596.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTRO 501</td>
<td>Fundamental Astronomy</td>
<td>3</td>
</tr>
<tr>
<td>ASTRO 502</td>
<td>Fundamental Astrophysics</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>at least 4 additional ASTRO 500-level courses</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>4 additional 3-credit courses</td>
<td>12</td>
</tr>
</tbody>
</table>

In addition, the following courses are required:

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<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTRO 590</td>
<td>Colloquium</td>
<td>1</td>
</tr>
<tr>
<td>ASTRO 602</td>
<td>Supervised Experience in College Teaching</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Individual Studies</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Credits 34

1. 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. A GPA of 3.2 in the ten 3-credit courses is required.

2. Credits for ASTRO 602 cannot be counted towards the minimum credits required for the degree.

3. 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. (http://gradschool.psu.edu/graduate-education-policies/gcac-600/). A minimum of 37 credits is required for the Ph.D., including:

<table>
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<tr>
<td>ASTRO 501</td>
<td>Fundamental Astronomy</td>
<td>3</td>
</tr>
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<tr>
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</table>

*In addition, the following courses are required:*

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<tr>
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<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTRO 589</td>
<td>Seminar in Current Astronomical Research</td>
<td>3</td>
</tr>
<tr>
<td>ASTRO 590</td>
<td>Colloquium</td>
<td>1</td>
</tr>
<tr>
<td>ASTRO 596</td>
<td>Individual Studies</td>
<td>3</td>
</tr>
<tr>
<td>ASTRO 602</td>
<td>Supervised Experience in College Teaching</td>
<td>3</td>
</tr>
</tbody>
</table>

**Total Credits** 37

1. 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. A GPA of 3.2 in the ten 3-credit courses is required.

2. For directed research in the second year.

3. Credits for ASTRO 602 cannot be counted towards the minimum credits required for the degree.

The qualifying examination is an oral 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 (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-208/). The default requirements for a graduate minor are stated in Graduate Council policies listed under GCAC-600 Research Degree Policies (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/gcac-600-research-degree-policies/), depending on the type of degree the student is pursuing:

- GCAC-611 Minor - Research Doctorate (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-611-minor-research-doctorate/)
- GCAC-641 Minor - Research Master’s (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-641-minor-research-masters/)
- GCAC-709 Minor - Professional Doctorate (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-709-professional-doctoral-minor/)

**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
Student Aid
Graduate assistantships available to students in this program and other forms of student aid are described in the Tuition & Funding (http://gradschool.psu.edu/graduate-funding/) section of The Graduate School's website. Students on graduate assistantships must adhere to the course load limits (http://gradschool.psu.edu/graduate-education-policies/gsad/gsad-900/gsad-901-graduate-assistants/) set by The 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/Think/Apply: Graduates will have demonstrated command of basic observational astronomy and astrophysics, including observing techniques, methods of data analysis, and common theoretical frameworks and techniques. This will include the ability to apply physics and mathematics knowledge to standard problems in astrophysics, as well as application of statistical principles to data analysis.
2. Communicate: Graduates will be able to 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.
3. Ethical Professional Conduct: 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/Think: Graduates will have demonstrated command of basic observational astronomy and astrophysics, including observing techniques, methods of data analysis, and common theoretical frameworks and techniques. This will include the ability to apply physics and mathematics knowledge to standard problems in astrophysics, as well as application of statistical principles to data analysis.
2. Apply/Think/Create: Graduates will be able to carry out original research in theoretical astrophysics, observational astronomy, or laboratory astrophysics (including but not limited to instrumentation development). This 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.
3. Communicate: Graduates will be able to 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, and, where applicable, proposals.
4. Ethical Professional Conduct: Graduates will demonstrate working knowledge of the standards for ethical conduct in research through their professional behavior and work.

Contact
Campus University Park
Graduate Program Head Rebekah Ilene Dawson
Director of Graduate Studies (DGS) Randy Lee McEntaffer
or Professor-in-Charge (PIC)
Program Contact Amanda Igyarto
Program Website View (https://science.psu.edu/astro/)