

# Graduate Program Manual

## 2019-2020

### Department of Astronomy University of Arizona

#### Graduate Program in Astronomy & Astrophysics

##### **Mission of our Graduate Program**

The Graduate Program of the University of Arizona Department of Astronomy and Steward Observatory trains students to become independent scientists with the knowledge and skills to conduct and communicate world-class astronomical research. A Ph.D. in Astronomy and Astrophysics from the University of Arizona signifies a student's excellence in research, which is demonstrated through a significant, original, and scholarly contribution to astrophysical knowledge. We admit graduate students who have met high standards of achievement and shown potential for conducting original research, with the expectation that they will succeed in attaining a doctoral degree in astronomy. The academic program is structured in support of this goal, emphasizing research throughout the graduate career; providing mentoring from

individual advisors and our interactive community of students, postdocs, scientists, and faculty. Students will gain firsthand experience with the tools and facilities that define the state of the art in our field.

## Description of the Ph.D. Program

All members of the Department are responsible for providing a stimulating intellectual environment that supports the growth of the graduate students. The core curriculum provides the broad knowledge base that is an essential foundation for astrophysical research. Through electives and minor offerings, students obtain focused instruction in areas of interest to them. Training in spoken and written scientific communication is an emphasis of our program. Communication skills are sharpened through class work, research activities, seminar series, and teaching opportunities. Students are supported in their development through the relationship with their advisor, frequent meetings with their mentoring committee, peer-to-peer learning, and contact with the wider Department through seminars, talks, and interactions in and out of the workplace. These structures provide training in the activities of a professional scientist, the ethical conduct of research, an introduction into the scientific community, and guidance on future career paths.

The pursuit of a graduate degree is an exercise in high scholarship, and students have significant responsibility for their own intellectual development and educational progress. Students have access to the facilities and research tools of the Observatory, including instrumentation laboratories, supercomputers, and direct access to telescopes for millimeter, IR, and optical wavelengths. With these tools and the support of the Department, students can follow their interests, develop new skills, and assimilate knowledge. We expect our students to approach research in the manner of a scholar, through study, writing, teaching, and listening. They are integral to the health and intellectual life of the Department and participate broadly in its activities, including seminars and discussions, education, and decision-making.

Graduates of this Department will have been trained comprehensively in the conduct of scientific research and prepared to be leaders in the community of professional astronomers. The experience and skills gained in our program will prepare students to be successful as astronomers, and along many other career paths they may choose.

# Graduate Program Guide and Requirements

## Beginning the Graduate Program

Upon arrival, new students should meet with the Graduate Program Advisor, who will help them plan their first year of graduate study. All students should check with the computer support group to open an individual account on the observatory's computer network. Most departmental memos are sent by e-mail, and most students and faculty use the computers for computations, word processing, etc. For office supplies such as pens, pencils, and pads of paper, see Michelle Cournoyer or Amanda Lohmoeller in the Academic Office, room N204. For general advice be sure to ask the other graduate students.

Students normally register for classes by using the UAccess Student on-line computer registration system. Tuition and fees must generally be paid about one week before classes start. Graduate Teaching Assistants (GTAs) and Research Associates (RAs) do not have to pay out-of-state tuition, but you will have to pay Registration Fees (about \$200). All students are encouraged to apply for fellowships and scholarships.

All graduate students who have teaching assistantships must have completed the GTA Training Programs administered by the Graduate College and [Office of Instruction and Assessment](#). Only students who have attended the required two

sessions will receive paychecks from the University. The sessions generally occur during the week before the first day of classes.

After the semester is well underway, it may be a good idea for the new student to assess how much time he/she is spending on various professional activities. We feel that the major, long-term emphasis here is on research, with lesser amounts of time devoted to one's own course work and teaching duties.

For a first-year student taking eight or so credit hours of courses, the situation is somewhat different, and the student might well be spending 50% of his/her work time on course work (both in class and out). That would leave 40% for research and 10% on miscellany such as attending colloquia, journal club, etc. Of course, this is just a rough guide, and exceptions will certainly be the rule here. It is not a requirement for first year graduate students to teach.

About grades in course work: Although one must maintain a 3.0 GPA, the real purpose of any course should be to foster the student's comprehension. Grades per se are secondary, but we realize that there is some correlation between grades and understanding. Certainly, a grade below "B" on a graduate course may indicate serious problems. Please note that all Graduate Teaching and Research Assistants must register for at least six units of graduate credit per semester. These can include Independent Research or Dissertation, when appropriate.

All students have an obligation to teach for a total of two semesters at some point in their graduate careers. The department recommends that students get involved in research as early as possible. As a result, most students choose to postpone their teaching until their third or fourth year. The department is quite flexible on this issue.

Students who wish to hold a research assistantship (RA) during their first semester must notify us by mid-July that they plan to do an RA (or to do research using their NSF, NASA, Steward or Graduate College Fellowship, if they've been offered one).

Students who decided to do an RA their first semester (and who are not on a Fellowship) must tell us by mid-September who their advisor will be for that semester. If for some reason a student does not have an advisor at that point, he or she will be assigned one.

Sometimes a student will be unable to obtain a research assistantship with their first choice of advisor because that person does not have the time or funding resources. (Fellowship students can work with anyone as long as the advisor has the time.) In such cases, we can remind the students that they are encouraged to pursue several different research projects during their graduate careers, and that a faculty member who is initially unavailable may later become a collaborator or supervisor. In addition, there are ample opportunities for research projects as independent study projects (without salary) or with faculty, staff or postdocs who are not their research supervisors.

Research advisors can be chosen from the ranks of [research or teaching faculty at Steward Observatory](#). Members of the faculty of the Lunar and Planetary Laboratory, Planetary Sciences, Physics, Optical Science, and staff members at the National Optical Astronomy Observatory may also serve as student research advisors.

When the student has chosen a research advisor, he/she should check with the Graduate Program Advisor (currently Josh Eisner) to see about selecting two or three more faculty members to serve with the research advisor on the student's mentoring committee. This committee meets every term and guides the student up to the prelim exam. After passing the exam, the student then forms a thesis committee, which may or may not include mentoring committee members. The thesis committee meets every term until completion of the Ph.D. and makes sure the student remains on track through his/her career at Steward.

## Course Requirements

Students are required to complete successfully the 5 "core" courses in astronomy: ISM & Star Formation (Astronomy 515), Stars & Accretion (545), Cosmology (541), Galaxies (540), and Instrumentation & Statistics (518). In addition, students are required to take another eight graded credits of non-core courses. Core courses are taken during the first

two fall semesters. The student can fulfill the non-core requirement by choosing from a wide range of 3 credit elective and 1-2 credit seminars that are typically offered in the spring semesters and coordinated with the core courses offered the previous semester. Students can also satisfy the non-core requirement by taking courses offered by other departments, including Physics, Lunar and Planetary, Biology, Chemistry, Electrical Engineering, and Optical Sciences. Courses below the 500 level are not acceptable for graduate credit.

By the end of the third semester, the student should have completed the core Ph.D. qualification requirement, which consists of five graduate astronomy core courses, with a grade of C or better in each course. The student's overall GPA must remain 3.0 or above to hold either a research or teaching assistantship. A GPA of 3.0 is also a graduation requirement for either a Masters or Ph.D. in Astronomy.

Core courses will always be taken for letter grades by Astronomy students, but may be taken for Pass/Fail credit, with instructor approval, by students from other departments. Electives and seminars may be taken for Pass/Fail credit, subject to the limitation of no more than two Pass/Fail courses per semester and the overall constraint of having taken a sufficient number of credits in letter-graded courses.

By the end of the fifth semester, students should have taken 16 units of graded core courses, 8-9 units of graded elective/seminars, and 20-21 units of Independent Research (Astronomy 900) and/or other elective/seminars for a total of 45 units. By the end of their graduate career, students should have taken an additional 18 units of dissertation credits (Astronomy 920) for a total of 63 units.

## Typical Graduate Plan

Fall Semester	Spring Semester
First or Second Year	
ASTR 515 (4 units): Interstellar Medium & Star Formation	Elective (3 units) and/or Seminar (2)
ASTR 545 (4 units): Stars & Accretion	Elective (3 units) and/or Seminar (2)
ASTR 900 (at least 4 units): Research	ASTR 900 (at least 4 units): Research
Second or First Year	
ASTR 540 (2 units): Structure & Dynamics of Galaxies	

ASTR 541 (3 units): Cosmology	Elective (3 units) and/or Seminar (2)
ASTR 518 (3 units): Instrumentation & Statistics	Elective (3 units) and/or Seminar (2)
ASTR 900 (at least 4 units): Research	ASTR 900 (at least 4 units) Research
Third Year	
ASTR 920: Dissertation	ASTR 920: Dissertation
Fourth Year	
ASTR 920: Dissertation	ASTR 920: Dissertation

## Example Electives and Seminars

ASTR 503. Physics of the Solar System (3 units)

ASTR 513. Data Mining and Machine Learning in Astronomy (2)

ASTR 516. Modern Astronomical Optics (3)

ASTR 520. Seminar on Advanced Extragalactic Astronomy (2)

ASTR 545. Seminar on Star and Planet Formation (2)

ASTR 553. Solar System Dynamics (3)

ASTR 560. Seminar with a Focus on Stellar Evolution from an Observational Perspective (2)

ASTR 569. Introduction to General Relativity (3)

ASTR 582. Seminar on High Energy Astrophysics (2)

ASTR 585. Radio Astronomy (3)

ASTR 588. Astrochemistry (3)

ASTR 589. Topics in Theoretical Astrophysics (3)

ASTR 596B. Methods in Computational Astrophysics (3)

PTYS 558. Plasma Physics with Astrophysical and Solar System Applications (3)

as well as other related courses in Planetary Sciences, Optics, Biology, Chemistry, Physics, Mathematics, Engineering, and Computer Sciences.

## Required Teaching

All students have an obligation to teach for a total of two semesters at some point in their graduate careers. The department recommends that students get involved in research as early as possible. As a result, most students choose to postpone their teaching until their third or fourth year.

All graduate students who have teaching assistantships must have completed the GTA Training Programs administered by the Graduate College and [Office of Instruction and Assessment](#). Only students who have attended the required two sessions will receive paychecks from the University. The sessions generally occur during the week before the first day of classes.

## Graduate Minors

### The Astronomy Minor

Formally, all PhD students in our program select both a major and a minor subject. For most, both are astronomy. However, it is possible for the minor to be in one of the other science or engineering disciplines. The course requirement is set by the minor department, but usually at least three of the required elective courses are graduate courses in the minor department. At least one representative from the minor department should participate on the preliminary and final oral (thesis defense) exams.

The astronomy department allows graduate students whose PhD major is in another department to minor in astronomy. We require that they pass nine units of coursework that the department considers acceptable for this purpose, preferably "core" courses, and that one astronomy faculty member participate in the preliminary and final oral exams.

See the [Graduate Catalogue](#) and the "Handbook for Completing the Steps to Your Degree" for more information. These publications also contain requirements involving the dissertation, as does also the [Manual for Theses and Dissertations](#).

### The Astrobiology Minor

The Department of Astronomy and the Department of Planetary Sciences jointly offer a graduate minor in Astrobiology. This minor is recommended for astronomy or other students with strong interests in astrobiology, exoplanets, planet formation, or planetary sciences. The minor allows students to develop a strong core of understanding in astrobiology, enhancing their specific research in astronomy, biosciences, earth sciences, etc. The minor requires nine credits from among the following courses: Astrochemistry 588A (3 credits), Planetary Astrobiology (3 credits), Key Concepts in Biology (MCB315, 3 credits), and Geoastronomy (3 credits).

# Preliminary Exam

The required preliminary exam consists of two parts: 1) a written, comprehensive examination in late January/early February of the fourth semester after the five core courses have been completed, and 2) an oral examination on the student's research to be taken at the beginning of the fifth semester after the research paper has been completed.

The written exam is authored, administered, and graded by a committee of several faculty members and is given simultaneously to all students in the second-year class. This exam is approximately eight hours long, lasting two days. Four hours are devoted to "closed book" questions, four hours to "open book" questions. During the "open book" exam, the student can use all resources in the building except for other people and, if prohibited, the internet. A folder containing exams from past years is available in the department academic office.

If a student fails the written exam, one more attempt is allowed. The re-take exam, which is administered by members of the prelim exam committee, is typically at the end of the fourth semester. The student chooses the re-take exam format, which is either another "closed book" plus "open book" written exam or an oral exam in the spirit of the written exam. The oral re-take exam is chaired by a member of the Academic Program Committee. If the student fails the re-take exam, he/she will not be allowed to pursue a Ph.D., but may still obtain a Masters degree by completing a short, written thesis, usually a version of her/his research paper, and passing the research oral exam described below.

The student takes an oral exam on her/his research at the beginning of the fifth semester. (This research exam can be taken before the written exam if the student's research paper is completed earlier.) While the goal is for the student to finish a paper that would qualify for submission to a publication like the *Astrophysical Journal*, the bar for passing the oral exam is lower. The student should get as close as possible to a submission-worthy paper before the oral exam (and many do in fact defend submitted or published papers). The outcome of the exam is determined by the quality of this research paper (and the student's understanding of what it still requires to be publication-grade), the student's presentation of the material, and the student's answers to questions on the paper's content and related areas of astronomy. The exam begins with the student's 25-30 minute talk on the research paper, followed by a round of questions. The student then leaves the room while the committee decides whether additional rounds of questions are necessary. The exam must be no longer than three hours. If the student fails the research exam, a second try will generally be allowed up to six months later. If the student fails the research exam again, he/she is dropped from qualification for a Ph.D., although a Masters degree may be awarded at the discretion of the committee.

The chair of the research exam committee should be an astronomy faculty person not associated with the student in research, mentoring, or advising. The chair is also a voting member who asks questions. The chair is empowered to make sure that correct procedures are followed and that the rights of the student are protected. The chair will also be responsible for filing the signed papers reporting the exam's outcome to the Graduate College. The chair has the right in extreme circumstances to report directly to the Chairman of the Department, if she/he feels that an exam was conducted improperly and/or the result was not justified.

The Graduate College requires that the examining committee consist of a minimum of four people, including at least three tenured or tenure-track faculty members. The committee should include no more than two members associated with the student in research. Additional members not associated with the student, including the chair, are approved by the department's graduate advisor after consulting with the student. At least one member should work in a markedly different field than that of the candidate. In rare cases, there may be reason for an additional research collaborator of the student to be appointed to the committee, but then two non-associated committee members must be appointed so that the committee has five people. (Note that, regardless of committee size, two negative votes are sufficient to fail the candidate.)

# Dissertation

## Dissertation Plan and Timeline

By the end of the 5th semester, each student is required to submit a dissertation plan and timeline to the department office, Graduate Advisor, and their dissertation committee. The dissertation plan can be modified and made more detailed as the student's dissertation research continues. The initial plan should include rough outlines of the thesis chapters. For each chapter that is a science research paper, the student should summarize the science question being addressed, why that question is important, why it hasn't already been addressed by others, and how his/her work will lead potentially to a resolution. Later iterations of the dissertation plan, prepared before and revised after dissertation committee meetings, should include detailed outlines and figures for each chapter.

The timeline can also be modified over time based on how the direction and/or scope of the research changes. Graduate students are guaranteed funding for five years. Given that the average time to graduation is 5.5 years, any extension of the dissertation defense date beyond the sixth year of graduate study requires the approval of the Academic Program Committee.

## Final Dissertation Defense

A five-person committee, which may be different from the student's thesis committee, is appointed when the student's dissertation is completed. (The Grad College requires only four, but the faculty agreed to have five members to insure that at least four will be present at the exam in the event of an emergency.) All five should read the thesis at least three weeks in advance -- or some other length of time agreed to by the committee and student -- and forward questions/comments to the student in advance of the exam.

The oral exam consists of a 30-minute talk by the student, to which the "public" are invited. In the private session following, questions are asked by each committee member on the thesis work and associated topics in the subject area.

The possible outcomes are (1) pass with no reservations, (2) pass conditional upon changes made to the dissertation recommended by members of the committee, or (3) fail. In case (2) the committee may grant discretion to the principal advisor to enforce the changes to be made to the thesis recommended by the committee. The members would sign the paperwork certifying completion of a satisfactory thesis, but the advisor would withhold the paperwork until satisfactory changes are made in the opinion of the advisor. All requirements for the degree of Doctor of Philosophy must be completed within 5 years of passing the prelim exam. Should a student not finish within that time period, he or she may be allowed to re-take the prelim with permission of the program, and then proceed to complete other requirements, e.g., the dissertation.

# Committees, Advising and Thesis Plan

## Mentoring, Second-Year, and Thesis Committees

The mission of the mentoring (first-year), second-year, and thesis committees is to guide and provide advice and perspective for graduate students as they pass through the program. The committees should meet at least once a semester and at each meeting hear from students about their progress with classes and research. Members can and should meet with students individually as needed.

During the first year students are assigned a Mentoring Committee by the department that consists of dedicated professionals who not only advise about academics and research but who also assist and advise students with the transition to graduate school. During the second year, students will form their Second-Year Committee, which will include an increased focus on the research that students are doing for their second-year project. After passing the prelims, students will form their Thesis Committee, similar in scope to the Second-Year Committee but which may (or may not) include different members.

These committees are a long-term resource for students but also serve to help students maintain the expected timeline for completion of the Ph.D. It should be recognized that committee members also benefit from this interactive experience, not only in research but also in learning how to become better advisors, colleagues, and educators. The committee provides an additional layer of advocacy and protection alongside the principal advisor.

Members of the committees should provide advice, feedback, and guidance on any topic relevant to reaching this goal, including the following:

- 1) developing and adjusting a plan for successful research projects that result in important publications and build up competitive skills/expertise by the time of graduation;
- 2) developing and maintaining productive and harmonic student-advisor and student-collaborator relations;
- 3) questions related to ethical aspects of the research and collaborations;
- 4) any non-work related problems the student seeks the committee's advice on;
- 5) development of skills, knowledge, and connections that are important for career development.

## **Forming Your Committee:**

Mentoring committees will be assigned to first-year students and will include the research advisor and two other faculty members. Second-Year and Thesis committees shall consist of no less than four faculty members, including the student's principle research advisor, chosen by the student with close consultation with the student's research advisor, and approved by the department Director of Graduate Studies (DGS).

## **Committee meeting format:**

Meetings will consist mostly of time during which students can present details of their current work and seek feedback and/or advice from committee members. Every meeting will include some time where the student leaves the room, and some time where the student's advisor leaves the room.

## **Committee Meeting Frequency Requirement:**

Mentoring Committees for first year students should first meet by the end of the first semester. Second-Year Committees should first meet by the end of the fifth semester. After successful completion of the prelims, Thesis Committees should convene twice a year. The department office will send out reminders regarding committee meetings, and students should inform the office that the committee meeting has taken place. Those who are having difficulties in scheduling committee meetings by the middle of the semester are strongly encouraged to seek help from the DGS and the department office. Students will only be allowed to register for independent study or thesis research credit hours for the subsequent semester when either the committee has met, or permission is granted by the DGS for the postponement of the committee meeting.

## Thesis Plan:

By the end of the fifth semester, students should develop a working outline for their thesis plans. This document contains succinct descriptions of the thesis projects. The thesis plan will likely evolve over the course of graduate study and be updated regularly. Thesis plans should be made available to the thesis mentoring committee before committee meetings, and should be sent to the APC before the annual graduate student review meeting.

# Contact Information

Buell Jannuzi ([buelljannuzi@email.arizona.edu](mailto:buelljannuzi@email.arizona.edu)), Head, Department of Astronomy, Director, Steward Observatory

Xiaohui Fan ([fan@as.arizona.edu](mailto:fan@as.arizona.edu)), Associate Department Head

Dan Marrone ([dmarrone@email.arizona.edu](mailto:dmarrone@email.arizona.edu)), Director of Graduate Studies

Richard Green ([rgreen@email.arizona.edu](mailto:rgreen@email.arizona.edu)) Assistant Professor, Graduate Admissions Chair

Ryan Boyden ([rboyden@email.arizona.edu](mailto:rboyden@email.arizona.edu)) co-Chairs, Graduate Student Council

Katie Chamberlain ([katiechambe@email.arizona.edu](mailto:katiechambe@email.arizona.edu)) co-Chairs, Graduate Student Council

Erin Maier ([erinmaier@email.arizona.edu](mailto:erinmaier@email.arizona.edu)), co-Chairs, Graduate Student Council

Michelle Cournoyer ([michelle@email.arizona.edu](mailto:michelle@email.arizona.edu)), Manager, Academic Affairs, Department office

Amanda Lohmoeller ([morrisa1@email.arizona.edu](mailto:morrisa1@email.arizona.edu)), Administrative Associate, Department Office