

## **Astrophysics Ph.D. Requirements**

### **Department Of Physics And Astronomy**

Completion of the Astrophysics Ph.D. requires (1) completion of 72 credit hours of coursework with satisfactory grades in each course and an overall average of B (3.00) or higher; (2) successfully passing a Qualifying Examination administered by a committee of the Graduate Faculty; and (3) writing and defending the dissertation. The dissertation is to be an original, publishable contribution to the scientific literature in the student's field of specialization, and must be defended in a public forum. The following paragraphs provide details. The Astrophysics PhD program is administered by the Director of Graduate Studies (DGS) in Astrophysics and the Graduate Program Committee (GPC) in Astrophysics. The DGS in Astrophysics, with the consent and approval of the GPC in Astrophysics, has the authority to approve exceptions to departmental rules in rare circumstances.

### **1. Course Requirements**

The Graduate School requires a total of 72 hours of credit (formal course work plus registered research hours) prior to receiving the Ph.D. Within this 72 credit hours, the Department of Physics and Astronomy requires 28 hours of formal course work<sup>1</sup> including:

- Five core courses covering the foundations of astrophysics, as detailed below, totaling 16 credit hours.
- Additional graduate-level courses to make a total of 12 credit hours in any subject relevant to the student's overall program of graduate study and research.
- A minimum of two semesters of Teaching Practicum (ASTR 8002) to be taken before the qualifying examination. This is a zero credit course.
- Four semesters of Astrophysics Seminars (ASTR 8003) to be taken before the qualifying examination. This is a zero credit course.

A student must earn a grade of B or higher in each course counted towards these 28 hours. A student must earn a satisfactory grade ("S") in ASTR 8002 and 8003.

Core courses provide the basic foundation for research. There are three ways to satisfy each core course requirement: take and pass the course with a grade of B or higher; take and pass an alternate written exam on the material covered by that particular course; or transfer the credit from a similar approved course that was taken at a different institution. A student who receives a B- or lower grade in any core course has a second chance to meet the course requirement either by retaking the course a single time or by taking and passing the corresponding alternate written exam. Note that exceptionally well-prepared incoming students may take and pass one or more of the alternate written exams to place out of the corresponding core course(s). A failure to pass the exam before the respective course is taken is not going to count against the two chances to satisfy the course requirement. Students who, due to a repeated low course grade or failure on the alternate written exam, fail to satisfy any one of the core course requirements may be dropped from the Ph.D. program at the discretion of the GPC in Astrophysics. Students who receive a B-

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<sup>1</sup> The Graduate School requires only 24 credit hours of formal coursework. The Departmental requirement is higher because of the number and breadth of core courses required to properly prepare for a career in astronomy. Additional coursework may be recommended by a student's advisor.

or lower in more than one core course may also be dropped from the Ph.D. program at the discretion of the GPC in Astrophysics.

### **1a. Transfer Credit**

Students who have taken graduate courses elsewhere may petition the GPC in Astrophysics to have those courses evaluated for transfer credit to avoid unnecessary duplication and speed the student's entry into research.

### **1b. Astrophysics Core Course Requirements**

Students must complete these courses in the first two years of graduate study:

- **ASTR 8010:** *Radiative Processes in Astrophysics*
- **ASTR 8030:** *Stellar Astrophysics*
- **ASTR 8040:** *Structure and Dynamics of Galaxies*
- **ASTR 8050:** *Structure Formation in the Universe*
- **ASTR 8001:** *Order of Magnitude Astrophysics*

The first four of these are three-credit courses. Order of Magnitude Astrophysics is a single credit class and must be taken every semester before the qualifying exam is passed. This adds up to 16 credit hours of Astrophysics core courses.

### **1c. Elective Courses**

The remaining 12 credit hours of formal coursework may be filled from any graduate-level courses that are appropriate for the student's program. Examples are any 8000 level ASTR or PHYS courses. All elective credits taken must be approved by the student's advisor or the GPC in Astrophysics.

### **1d. Teaching Experience**

Teaching experience is an important component of graduate students' education and their preparation for future careers. All students must take

- **ASTR 8002:** *Teaching Practicum*

for a minimum of two semesters before the qualifying exam is passed. Typically, graduate students in Astrophysics would teach for 4-6 semesters during their first few years of study. Teaching Assistants are generally assigned about 15 hours per week of work for duties such as grading, leading lab sections, and meeting with students. Teaching Assistants are not expected to be "instructors of record", i.e., to have the responsibility for preparing an entire course, syllabus, lectures, course materials, etc. However, in exceptional circumstances, students in advanced standing may request this opportunity by petitioning the GPC.

### **1e. Astrophysics Seminars**

Attending colloquia, seminars, journal clubs, and other research-focused community events are a vital component of graduate education. All students must take

- **ASTR 8003:** *Astrophysics Seminars*

four semesters before the qualifying exam is passed. To successfully complete this class, students must attend a minimum number of Physics Colloquia, Astronomy Journal Clubs, and Astronomy Lunches. Moreover, students must give a formal presentation in Astronomy Journal Club. These events are described in more detail in section 2.

### **1f. Research Hours**

In addition to taking formal courses, students in their first two years of study are expected to be making progress in research projects under the supervision of a research advisor. In consultation with their advisor, students should normally enroll in **ASTR 8999: *Non-candidate Research*** for as many credit hours as they need up to the maximum of 13 credit hours per semester. After passing the Qualifying Examination, students should enroll in up to 13 credit hours of **ASTR 9999: *Dissertation Research*** each semester, until they have completed the 72 credit hours required by the Graduate School. After completing 72 credit hours, students should continue enrolling in ASTR 9999 each semester for zero credit hours.

## **2. Beyond the For-Credit Curriculum**

The training of Ph.D. candidates in astrophysics goes beyond formal coursework and the doctoral research project. The astrophysics program runs several informal activities that are aimed at giving students experience with giving professional talks and reading the scientific literature. All students are expected to attend these events regularly (required in the first two years as part of ASTR 8003). These events are:

- *Journal Club*: All graduate students in this program are expected to attend a weekly, one-hour journal club. At each Journal Club meeting, one or two students make a presentation, explaining a recently published paper in the astrophysical literature. Each student is expected to make at least one presentation at Journal Club each semester. In this forum, students gain experience in presenting research to an audience and receive feedback from faculty and their peers on their presentation.
- *Astro Lunch*: All graduate students in this program are expected to attend a weekly one-hour lunch meeting at which the group informally discusses recently published or submitted papers.
- *Department Colloquium*: The Department of Physics & Astronomy holds weekly, late-afternoon colloquia during the academic year. All graduate students in this program are expected to attend all colloquia with an astrophysics orientation and at least a selection of other colloquia.
- *National and International Meetings*: All graduate students in this program are expected to attend national and/or international astrophysics conferences during their tenure as graduate students. Students are especially expected to attend conferences at which they will make research presentations.

## **3. The Qualifying Examination**

To be awarded the doctoral degree in Astrophysics a student must write and defend a dissertation that presents the results of independent research. To progress to that point, each student must

first pass the Qualifying Examination to become a Doctoral Candidate. According to the Graduate School bulletin, “the purpose of the Qualifying Examination is to test the student’s knowledge of the field of specialization, to assess familiarity with the published research in the field, and to determine whether the student possesses those critical and analytical skills needed for a scholarly career.” In the Astrophysics program, the Qualifying Examination requires each student to independently write and orally defend a research proposal. The topic is of the student’s choosing, and may be the same as her/his current research. The Qualifying Examination is administered by the student’s Ph.D. committee and only the committee members and the student are present. Passing the Qualifying Examination marks the student’s formal entry into dissertation research under the supervision of her/his dissertation advisor and the Ph.D. committee.<sup>2</sup> The Qualifying Exam should not be seen as a hurdle, but as an important part of one’s training to become an independent scientist.

### **3a. Ph.D. Committee**

The Ph.D. committee administers the Qualifying Examination and subsequently monitors the student’s progress towards the completion of the dissertation. The committee comprises at least four members of the Graduate Faculty. To ensure consistency among Qualifying Examinations, at least one member of the committee should be a current or recent member of the GPC in Astrophysics. In addition, by Graduate School rule, at least one member of the committee must be from outside the Astrophysics program. This external committee member may be a member of the Physics faculty at Vanderbilt, a faculty member from a different department at Vanderbilt, or it may be a faculty member or equivalent at another university or National Lab. One of the committee members serves as the committee chair. While this is often the student’s research advisor, this does not need to be the case. The composition of the committee is delivered to the DGS in Astrophysics by the advisor in consultation with the student for certification of compliance with the above rules.

### **3b. Preparing For The Qualifying Examination**

The Qualifying Examination in the Department is taken during the fourth semester (under exceptional circumstances, a student may petition the GPC to delay the Qualifying Exam until as late as the sixth semester<sup>3</sup>). The Qualifying Examination is offered in just one annual cycle – culminating in the oral examination by mid May. By Graduate School rules, students taking the oral Qualifying Exam must have completed all requirements of the Graduate School for formal course work (24 credit hours) at the actual time of the oral exam with a GPA of 3.0 or better in all courses taken for credit. However, in order for the student to advance to candidacy, a student must first complete all the course requirements for the Astrophysics PhD program.

The steps needed to prepare for the Qualifying Examination are:

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<sup>2</sup> Advancing to candidacy makes one eligible to register for dissertation research credit hours (ASTR 9999).

<sup>3</sup> The Graduate School requirement is that the Qualifying Examination must be passed by the end of the 8<sup>th</sup> semester, but this is too late to permit completion of an acceptable dissertation project in the desired time frame of approximately five years.

- The student should get involved in research as soon as possible – certainly no later than the summer after the first year of study. To begin by summer, the student should interview potential faculty advisors no later than the spring of the first year to identify those with space to take on a summer research assistant. During the first two years of study, a student may explore research opportunities in several groups, but she/he must select a faculty Ph.D. advisor at least one semester before an anticipated Qualifying Exam date.
- The student and the advisor agree on the members of the Ph.D. committee, including who will serve as chair of the committee. The student then contacts members of the committee to ascertain their willingness to serve. Once the composition of the Ph.D. committee is decided and all the proposed committee members have agreed to serve, the advisor completes the “Request to Appoint Committee” form to the DGS for certification and notification of the Graduate School. The committee membership should be finalized and the form submitted by February 1.
- The student prepares a 1-page abstract that outlines the proposal’s research topic, hypothesis and specific aims. The student may discuss potential topics with her/his advisor, but the abstract itself must be the student’s completely independent work; there should be no editing of the abstract by anyone other than the student for any reason. This abstract should be submitted electronically (.pdf preferred) to the DGS in Astrophysics. The exact due date will be set by the DGS, but will be approximately February 15. The abstract will be reviewed by the GPC in Astrophysics, focusing on the following questions: Is the research topic appropriate? Is the hypothesis well formed and testable? Is the scope sufficiently focused (doable during a typical graduate career of three to four years)? The GPC will provide the student with written feedback on the appropriateness of her/his proposal in approximately one week. The student will then revise the abstract and resubmit it to the DGS and to all members of the student’s Ph.D. committee. The exact due date will be set by the DGS, but will be approximately March 1. The student’s Ph.D. committee will perform a similar review of the abstract and determine whether it provides an adequate basis for a full proposal. If so, the committee will provide additional written feedback and inform the student to begin preparing the full proposal. If not, the committee will provide written feedback and require the student to submit a revised abstract within two weeks.
- After receiving permission to prepare the full proposal, the student should contact all committee members to set a date for the oral Qualifying Examination. The student is advised that getting a committee of four to five faculty persons to be available simultaneously in time and space is not a trivial task! During the annual exam cycle, the oral exam should be scheduled for the last two weeks of April or first two weeks of May. Only in extraordinary circumstances should the exam be delayed beyond this point. Once a date is agreed upon, the advisor notifies the DGS and Graduate School no later than three weeks before the proposed date. Note that the Graduate School issues the notice of the Examination at least two weeks in advance.
- Regardless of when the oral Qualifying Examination is scheduled, the written proposal must be submitted to the DGS and the student’s Ph.D. committee by a specific date. This date will be set by the DGS, typically April 1, and will be the same for all students taking the exam during a specific cycle. The written proposal must not exceed 8 pages (single-spaced, 12-pt font). Within this space, the proposal should have four sections:

1. Rationale or Background & Significance. This section provides background information and justification for the proposal. An important part of preparing the proposal is a thorough review of the current literature. This review should be concisely summarized here.
2. Hypothesis. This short section (~1 paragraph) should describe the specific hypothesis to be tested.
3. Specific Aims or Research Objectives. This section will largely follow the previously approved abstract, but the student can make changes as she/he more fully develops the proposal.
4. Research Plan. This section should detail the experimental/theoretical plan to meet the Specific Aims. The student is advised to number the specific aims and use the same numbering scheme for sub-sections of the Research Plan. This section should describe the experimental/theoretical strategies and design, but it should not provide the sort of detailed Materials & Methods section one would find in a journal article. This section should sketch anticipated outcomes and some discussion of how the plan might be adjusted with different outcomes.

The written proposal should certainly cite the relevant literature and include a bibliography. The bibliography itself does not count against the 8-page limit. The student may include figures and tables in the text, but these do count against the page limit. As with the abstract, the written proposal must be solely the student's work; there should be no editing of the proposal by anyone other than the student for any reason.

- The student's Ph.D. committee will review and evaluate the written proposal. This evaluation will be completed at least two days before the scheduled oral examination. If the written proposal is deemed adequate, then the oral examination will proceed as scheduled; however, if the committee identifies serious deficiencies in the written proposal, then the oral exam will be postponed. If postponed, the scheduled exam time will be used for the committee to provide constructive criticism to the student on how she/he can address the identified deficiencies. The student will then have two weeks to submit a revised proposal and reschedule the oral examination as soon as possible.

### **3c. The Qualifying Examination**

During the oral Qualifying Examination, the student defends her/his research proposal. The exam is limited to a maximum of two hours. The student is allotted a maximum of 15 minutes to provide an overview of the proposal. This is a strict limit, so committee members are asked to restrict questions to points of clarification during the student's presentation. The remainder of the two hours is reserved for the committee to ask questions in which the student should be prepared to discuss the general background of the proposal and its significance; to discuss relevant experimental approaches, including their theoretical bases and limitations; to outline anticipated results; and to interpret the meaning of these results. The student should be particularly prepared to discuss the interpretation of alternative results proposed by the committee. Although the primary focus of the questions will be on the research proposal, the committee may and likely will probe into the student's core knowledge of astrophysics.

In contrast to the rules for the written proposal, students are strongly encouraged to prepare for the oral examination by gathering student peers for mock oral exams. Copies of the student's prepared slides must be made available to the committee members at least one working day before the examination. By rule of the Graduate School, attendance at the Qualifying Examination is limited to only the Ph.D. committee members and the student. The committee will decide within one day whether the student has passed the Qualifying Examination. Within one week, the advisor will provide a written report to the student and to the GPC describing the student's performance on the examination. Even if the student was judged to have passed the examination, the report should address any deficiencies in preparation that were evident during the examination. If the student was judged to have failed the examination, the report should note the serious deficiencies that caused this failure; the committee may also offer their judgment on whether retaking the examination would be in the best interest of the student. A second attempt at passing the Qualifying Examination may be made by the student within three months of the date of the failed examination. By Graduate School rule, only two attempts are allowed for passing the Qualifying Examination.

## **4. The Ph.D. Dissertation**

### **4a. Proposal For The Ph.D. Dissertation**

After passing the Qualifying Examination, the student is officially admitted to candidacy for the Ph.D. He/she will develop a topical focus for the Ph.D. dissertation grounded in the subfield chosen for that Examination. The dissertation topic should be an original research proposition that advances the frontiers of science in the field of specialization. While consultation with the advisor will be crucial to this process, it is to be emphasized that *the proposal for the dissertation is the responsibility of the student*. Within two semesters of passing the Qualifying Examination, the student will present a specific proposal to the Ph.D. committee. This proposal can be, and likely should be, based on the proposal that the student successfully defended during her/his Qualifying Examination. At this stage, the proposal should contain at the minimum a chapter-by-chapter outline of the dissertation, a report on the research already carried out, and a specific plan for completing the remainder. As a general rule, students should plan to complete the dissertation within three years of passing the Qualifying Examination, so that the dissertation can be submitted five to six years after entering the Graduate School. By Graduate School rule, all requirements for the degree of Doctor of Philosophy must be completed within four years of passing the Qualifying Examination.

### **4b. Annual Meetings Of The Ph.D. Committee**

After the dissertation topic is approved, the student will meet with the Ph.D. committee at least annually to report on research completed to date, publications planned or in progress, and an estimate of the time, resources and analysis that are required to complete the dissertation project. The committee members may ask questions, critique the work presented by the student, or make suggestions about the project. The Chair of the Ph.D. committee (usually the Ph.D. advisor) is responsible for preparing a brief written report of the meeting that will be sent to the candidate and to the DGS. This report may also be reviewed by the GPC as it monitors student progress.

#### **4c. Publication Requirements**

The research in any dissertation project is expected to contribute measurably to scientific progress in the field of specialization; thus publication in peer-reviewed journals is an essential component of the Ph.D. research program. While the venue, number and timing of publications varies according to subfield, students should expect to play a major role in a first paper no later than the end of the third year of graduate study. By the time the dissertation is completed, the student must present to the Ph.D. committee at least one paper in which they played the primary role and that has been accepted in a peer-reviewed journal. Most students are expected to have more than one such paper published or accepted for publication at the time of the dissertation defense.

#### **4d. Completion Of The Dissertation And The Ph.D. Defense**

The *Graduate School Bulletin* and the Graduate School Web site give the essential information about the timing and format of the Ph.D. dissertation and the defense. According to Graduate School rules, the defense must take place no later than four years after the student passes the Qualifying Exam and advances to candidacy. Students may petition the Graduate School for an extension; however, financial support from the Graduate School is unlikely past the fourth year of candidacy. The defense is a public examination, and should be characterized by a spirited scientific debate on the strengths and weaknesses of the dissertation presented by the student. In addition, the Department of Physics and Astronomy stipulates the following:

- The Ph.D. advisor will inform the Dean of the Graduate School at least two weeks in advance of the date and place of the defense, so that the event can be published in the Vanderbilt University electronic calendar. The Department administrative staff will advertise the dissertation title, and the date and place of the defense in order to promote attendance by faculty, research staff and other students.
- The Ph.D. candidate must present a complete copy of the dissertation to the committee members *at least two weeks before the defense. This is both a Departmental and Graduate School requirement.*
- At the defense, the candidate will present the critical points of the dissertation for no more than 45 minutes; during this presentation, questioning will be generally restricted to matters of clarification. After the presentation is finished, questioning by attendees other than the Ph.D. committee will be permitted for about half an hour.
- After the public questioning is concluded, the Committee will continue the questioning of the candidate in executive session for up to an hour. The Committee will then caucus in private to evaluate the defense and decide the outcome.

The possible outcomes for the defense are (1) pass, (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 that the recommended changes are made. The members may sign the paperwork certifying completion of a passing dissertation, but the advisor will submit the committee's report to the Graduate School only after the changes made are satisfactory in the opinion of the advisor.



## **5. Applying for Fellowships**

There are several national fellowships and external awards that provide support for graduate students in their study. These fellowships come with many tangible benefits for students: (1) they allow students to focus fully on research right from the start; (2) they are prestigious and strengthen students' CVs; (3) they provide valuable experience in planning and writing grant proposals. Graduate students are expected to apply for one or more of these opportunities. Some example programs are the NSF GRFP (deadline: late October), NASA JFPF (deadline: early February), NASA ASTAR (deadline: early May).

## **6. Important Milestones and Checklist**

This is a list of all the important milestones that students reach while they are in the Astrophysics Ph.D. program. All forms that are required may be downloaded from the Graduate School website here: [http://gradschool.vanderbilt.edu/academics/steps\\_to\\_graduation.php](http://gradschool.vanderbilt.edu/academics/steps_to_graduation.php)

<b>Milestone</b>	<b>Deadline</b>
1 Find a research advisor	Spring of first year at the latest
2 Begin research project	Summer after first year at latest
3 Form Ph.D. committee and select chair	February 1 of second year
4 Submit research proposal abstract draft	February 15 of second year
5 Submit a revised proposal abstract	March 1 of second year
6 Schedule the Qualifying Exam	Three weeks before proposed date of exam
7 Submit research proposal	April 1 of second year
8 Complete all required coursework	End of second year
9 Take the oral Qualifying Exam	May 15 of second year
10 Present a dissertation proposal	Within two semesters of Qualifying exam
11 Play a major role in a publication	End of third year
12 Schedule the dissertation defense	Two weeks before the proposed date
13 Submit the dissertation	Two weeks before the defense date
14 Defend the Ph.D. dissertation	Four years after Qualifying exam