2006-2008 Assessment for:
Department of Astronomy: Astronomy, Ph.D.

Mission
The Ph. D. in astronomy aims to prepare students for professional careers in astronomy, astrophysics, and related physical sciences. Graduates may work in higher education, government, and the private sector.

Responsibility and Implementation Process
Overall responsibility for the PhD program rests with the Graduate Studies Committee (GSC), consisting of all faculty and some research scientists who frequently direct research projects. The Executive Committee of the GSC (GSCEC) provides oversight across the program, led by the Chair of the GSC. The GSCEC is composed of the Chair of the GSC, the Graduate Advisor and the Assistant Graduate Advisor, with the Chair and Associate Chair of the department as ex-officio members.

The most direct responsibility for the education and assessment of each graduate student lies with the Research Supervisor. The Research Supervisor is a member of the GSC chosen by the student during the first year. The student can change supervisors. Secondary responsibility lies with the 2nd Year Project Committee, formed during the first year and replaced after the qualifying exam by the PhD Committee. Assessments by the Research Supervisor and the committee of progress are provided to the GSCEC, and these provide information for the overall assessment of the program.

During the first two years and perhaps beyond, students take courses in addition to performing research. The Chair of the GSCEC oversees and evaluates the curriculum and assigns instructors. The Graduate Advisor oversees individual student progress in classes and research. Together, the Chair of the GSCEC and the Graduate Advisor assess the success of the program, in consultation with the Chair of the Department. Changes to the program are made by vote of the full GSC, which meets at least once per semester.

Performance of students is measured against program goals in three main ways: performance in classes; annual meetings of the students' 2nd Year Project Committee or PhD Committee; performance on a qualifying exam taken at the end of the second year, and performance at the dissertation defense, taken at the end of the program. The qualifying exam is made up of four sections: written report/thesis, public presentation, oral exam by committee and course work review. The dissertation defense is made up of three sections: written dissertation, public presentation and oral defense of the thesis. For each of these, cognizant faculty members provide quantitative and/or narrative assessments. These are assimilated into assessments of program success in the outcomes listed below. Adjustments to the program can be made based on these assessments. The detailed policies, rules, schedule and curriculum of the graduate program are described in a document called *The Graduate Astronomy A-Z*, or the *A-Z*. Annual adjustments to the *A-Z* are made by vote of the GSC, and major reviews and changes typically occur every 5 years. Details of implementation can be changed by the GSCEC.

The education and training provided by the graduate program is intended to prepare

students for professional careers which unfold over a period of time much longer than the time spent in graduate school. As such, the most significant assessment of our program is done by assessing the career success of our graduates. The Graduate Advisor, assisted by the Graduate Coordinator (Staff) maintains contact with graduates, and we use publicly available resources (AAS and AIP Directories) to learn about their employment and (SAO/NASA Astrophysics Data System) publication statistics.

Program Educational Objectives (PEOs)

PhD recipients will go on to successful careers in higher education, government, or the private sector. We have tracked the current positions for 90% of our PhDs since 1966, and have heard back from 25% of them in response to our latest annual inquiry.

For most career tracks, the next step after the PhD is a Postdoctoral Research Fellowship. Among these, a few types are regarded as Prize fellowships because they offer more freedom and are even more highly competitive, selected by committee; others may be decided by individual researchers with grant funding. We track the success of our PhDs in getting both Prize and regular postdocs.

Within ten years of obtaining the PhD, graduates expect to be in more permanent positions, which include faculty at major research universities, faculty at institutions focused on teaching, research scientists at national or international observatories, other government labs, or industry. We track the success of our graduates by following their employment.

Most of the career paths require abilities in some combination of independent research and communication, including teaching, and teamwork. The balance between these depends on the career path; within broad guidelines, PhD candidates work with their Research Supervisor to tailor the program to their career goals. For example, someone seeking positions in institutions focusing on teaching will spend more time developing teaching experience, without slighting their research.

The ability to do independent research rests in turn on having an appropriate foundation. The details of the foundation depend on the style and area of research, but they all include a broad knowledge of the physics of astrophysics and familiarity with the important literature in the subfield. For theorists, computer skills typically involve performing calculations and numerical simulations; mathematical methods play a large role. For observers, computer skills are more likely to involve data reduction and statistical analysis, and broad experience with actual observations is crucial. For instrumentalists, designing software and hands-on laboratory experience are vital.

We translate these PEOs into Program Outcomes and discuss how we assess student performance below. The aggregate measures of student performance, during and after the PhD, then provide the means of assessing the program itself.

Program Outcome 1.: Ability to do Independent Research

Original, independent research is a primary goal, which we discuss first, followed by foundational outcomes.

Method of Appraisal: 1.A Performance on the Qualifying Exam

The first comprehensive assessment of the ability to perform independent research is the qualifying exam. The student must have completed the required course work and delivered to the 2nd Year Project Committee a written report on the first research project. The student must present the work in a 50 minute public presentation. The student's performance is assessed with an overall evaluation and with 4 specific questions measuring different outcomes. These are (1) the quality of the research, (2) the public presentation, (3) the performance on the oral exam (research specific), and (4) performance on the oral exam (general knowledge). A score of 2.00+ (pass) is acceptable. The 2nd Year Project Committee plus two members of the GSCEC evaluate the student at the qualifying exam. Possible overall assessments include failure, re-examination, pass with terminal Masters degree, and pass with qualification to proceed to the PhD.

Results of Appraisal: 1.A Performance on the Qualifying Exam

The statistics over the last 4 years are as follows, based on a 0 to 3 score on each portion, 0 being no pass, 1 is low pass, 2 is pass and 3 is high pass. Average scores for all students were 2.61 for item 1 (Research), 2.58 for item 2 (Public Presentation), 2.37 for item 3 (Specific Oral Exam), 2.14 for item 4 (General Oral Exam) and 2.43 for overall exam. Of all 33 students taking the exam, only one received a "High Pass" in all areas, and 26 received a "Pass" in all areas.

Rubric Outline for Qualifying Exam:

(currently each 2nd Year Project Committee member uses his or her own criteria for the rubric shown here)

	0 no pass	1 low pass	2 pass	3 high pass
(1) quality of the research				
(2) public presentation				
(3) performance on the oral exam (research specific)				
(4) performance on the oral exam (general knowledge)				

Method of Appraisal: 1.B Performance on the PhD dissertation and Defense

The PhD dissertation generally consists of 3-10 chapters, many of which are typically submitted or published journal articles. In addition, the candidate must present the results in a 50 min presentation, open to all members of the Astronomy Department and to the public, and then defend the results in a closed examination by the PhD Committee. This public presentation must prove a deep knowledge of what was presented in the written report/thesis. These are evaluated by the PhD Committee in written form. The dissertations are also evaluated by each committee member and these evaluations form the basis for nominations for University and external prizes, such as the Trumpler Prize of the Astronomical Society of the Pacific. The Trumpler award is a national prize for individual research that is "considered unusually important to Astronomy."

Results of Appraisal: 1.B Performance on the PhD dissertation and Defense

Over the last 5 years, 90% of the PhD candidates have successfully completed. Two have been nominated for the Trumpler prize, which one of them has won, and 6 have received University awards.

Method of Appraisal: 1.C Career Research Records

The ultimate measure of our program's success in developing this ability is whether our graduates are employed in positions that involve independent research, both short-term as postdocs, and long-term. A second measure is publication statistics by our graduates, while they are students and over their careers.

Results of Appraisal: 1.C Career Research Records

The records of employment show that 10% of our PhD recipients over the last decade received Prize Fellowships, and 64% received a postdoc of some kind. The other 36% are made up of graduates who got positions in private industry, or other positions which may or may not include independent research. Among those who received their PhDs more than 10 years ago, 10% have faculty positions at major research universities, 25% have positions at universities where some research is expected, and 27% have permanent positions at observatories or government labs.

Averaged over the years 2002 to 2007, graduate students have produced 0.8 first-author peer-reviewed publications per year per student. Over the same period the student produced an average of 2.8 first-authored conference proceedings publications. In addition to these first-authored publications in major journals, students also publish conference proceedings and peer-reviewed papers of which the student is not first author. In this same time period the students produced an average of 4.4 publications of all types per student per year.

Action Summary: 1 Ability to do Independent Research

For 1.A:
The rubric outlined in the results will be enhanced to make a common set of criteria for each score, in consultation with the GSC.

For 1.B:

Action Summary: 1.B Performance on the PhD dissertation and Defense

A rubric will be implemented in order to standardize the expectations for student performance and the criteria used to evaluate it, and to enable us to gather more detailed data on our students' performance on their PhD defense. Here is a tentative rubric grid that is being created.

	0 no pass	1 low pass	2 pass	3 high pass
Mastery of Dissertation Subject				
Mastery of Field				
Mastery of Dissertation Research Methodology				
Quality of Research				
Public Presentation (Content and Delivery)				
Ability to Defend Dissertation: Research and Answer Questions				
Evidence of Independence				

Program Outcome 2.: The Physics of Astrophysics

A sound knowledge of the physical basis for astronomical research is a foundational skill for independent research. It is acquired through coursework and through guided work with the Research Supervisor.

Method of Appraisal: 2.A Course Work

It is assessed in course work, through meetings of the student's 2nd Year Project and PhD Committees, and on the qualifying exam via item 4. A rubric is used at the qualifying

exam by each committee member to gauge a student's general subject knowledge in Physics and Astronomy.

Results of Appraisal: 2.A Course Work

We have no results from specific graduate courses yet, as a new rubric is being developed to provide results for the future, as discussed in the Action Summary.

Method of Appraisal: 2.B Qualifying Exam – General Knowledge Oral Exam

Narratives of progress are collected from the Research Supervisor after each 2nd Year Project Committee meeting, but the most quantifiable measure is provided by the first category on the rubric for assessing student performance on the Qualifying Exam. The 2nd Year Project Committee plus two members of the GSCEC evaluate the student at the qualifying exam. The student's background knowledge is assessed in according to the Qualifying Exam rubric (see in Results of Appraisal). The questions asked by committee members during the oral exam vary. A specific example of a question often asked of observers is to trace the path of photons from the astronomical source through the observing apparatus into the final data product. This question tests the knowledge of the instrument, the limitations of the data, etc.

Results of Appraisal: 2.B Qualifying Exam – General Knowledge Oral Exam

The statistics over the last 4 years are as follows, based on a 0 to 3 score on each portion, 0 being no pass, 1 is low pass, 2 is pass and 3 is high pass. Average scores for all students were 2.14 for item 4 (General Knowledge Oral Exam). Of all 33 students taking the exam, only one received a "High Pass" in all areas, and 26 received a "Pass" in all areas.

Rubric Outline for Qualifying Exam:(currently each 2nd Year Project Committee member uses his or her own criteria for the rubric shown here)

	0 no pass	1 low pass	2 pass	3 high pass
(1) quality of the research				
(2) public presentation				
(3) performance on the oral exam (research specific)				
(4) performance on the oral exam (general knowledge)				

Action Summary: 2. The Physics of Astrophysics

For 2.A:
A rubric will be used to gather data on performance in our graduate courses to assess knowledge of the physical and mathematical principles of astrophysics. A new rubric is under development which will reflect the generic expectations of course work for developing the skills and knowledge necessary to enable students to perform successfully as independent researchers and teachers. This rubric will provide a standard set of student performance evaluation categories and allow us to collect data from each course instructor to assess the success of the courses in training students in these categories.

A preliminary outline of the course evaluation rubric is shown here:

	Not Applicable	0 No Pass	1 Low Pass	2 Pass	3 High Pass
Problem Solving Skills (e.g. homework assn. problem solving)					
Ability to Assimilate Literature					
Term Project					
Oral Presentation					
Tests					
Classroom Participation: ability to ask and answer questions					

For 2.B:

The rubric outlined in the results will be enhanced to make a common set of criteria for each score, in consultation with the GSC.

Program Outcome 3.: Familiarity with Current Research and the Literature

The Research Supervisor, assisted by the 2nd Year Project and PhD Committees, helps the student to find and read relevant literature, usually starting with reviews and including recent, particularly relevant research articles. Students also enroll and participate in one of several Astronomy research seminar courses, which meet weekly, to hear and discuss current research presented by faculty, research scientists, and fellow students, including at least one presentation by the student per semester. In addition, students participate in

discussion groups and journal clubs in various subfields, in which they read and discuss new research papers as they appear. Finally, students attend the weekly Astronomy Colloquium series to hear visiting scientists describe their research.

Method of Appraisal: 3.A Qualifying Exam

This outcome is assessed during 2nd Year Project Committee meetings, but the most quantifiable measure is item 1 (Quality of Research) on the qualifying exam rubric. That item measures whether proper referencing was done in the written report. Item 3 (Specific Knowledge Oral Exam), based on research specific questions during the oral exam, also tests this outcome. The 2nd Year Project Committee plus two members of the GSCEC evaluate the student at the qualifying exam.

Results of Appraisal: 3.A Qualifying Exam

The statistics over the last 4 years are as follows, based on a 0 to 3 score on each portion, 0 being no pass, 1 is low pass, 2 is pass and 3 is high pass. 2.00 is an acceptable score. Average scores for all 33 students were 2.61 for item 1 (Quality of Research) an 2.37 for item 3 (Specific Knowledge Oral Exam).

Rubric Outline for Qualifying Exam:

(currently each 2nd Year Project Committee member uses his or her own criteria for the rubric shown here)

	0 no pass	1 low pass	2 pass	3 high pass
(1) quality of the research				
(2) public presentation				
(3) performance on the oral exam (research specific)				
(4) performance on the oral exam (general knowledge)				

Method of Appraisal: 3.B Committee Meetings

This outcome is assessed during the annual 2nd Year Project and PhD Committee meetings by the faculty and research scientist members who report the progress of the students.

Results of Appraisal: 3.B Committee Meetings

Familiarity with the literature is now assessed as part of the 2nd Year Project and PhD Committee meetings, and data will be collected in the future. Currently, we have only anecdotal evidence from our committee meeting reports that shows our students progressing successfully.

Action Summary: 3. Familiarity with Current Research and Literature

For 3.A:
The rubric outlined in the results will be enhanced to make a common set of criteria for each score, in consultation with the GSC.

For 3.B:
We are planning to include a separate rubric item assessing familiarity with the literature to the reports from the committee. A tentative rubric outline follows which will be added to the current tool which currently only gathers narrative assessments of each student each semester.

Rubric Outline for Committee Meeting:

	No Pass	Low Pass	Pass	High Pass
Knowledge of Research and Literature				
Knowledge of physics of astrophysics				
Progress on the research project				
Skill in communication				

Program Outcome 4.: Oral Communication

Students learn oral communication skills by giving talks about research; these may be journal club talks or talks about their own research. Each student must give at least two such talks during their time as students, but they typically give at least one talk per semester, either in a seminar course or a lecture course, including their talks for the Qualifying Exam and Ph.D. defense. Many students give talks or present posters on research at local, national, or international meetings. They generally obtain feedback and advice from their peers and from their research committee. Their oral presentation of their research preceding the qualifying exam is evaluated quantitatively. Many students spend at least some part of their time as Teaching Assistants, where they learn to interact with students, explain concepts, and communicate science to non-science majors.

Method of Appraisal: 4.A Qualifying Exam

This outcome is assessed by item 2 on the qualifying exam rubric regarding the quality of the oral presentation. In addition, the candidate must present the results in a 50 min presentation open to all and then defend the results in a closed examination by the 2nd Year Project Committee plus two members of the GSCEC.

Results of Appraisal: 4.A Qualifying Exam

Average scores for the past 4 years (a total of 33 students) on item 2 (Public Presentation) are 2.58. The statistics over the last 4 years are as follows, based on a 0 to 3 score on each portion, 0 being no pass, 1 is low pass, 2 is pass and 3 is high pass. 2.00 (pass) is an acceptable score.

Rubric Outline for Qualifying Exam:

(currently each 2nd Year Project Committee member uses his or her own criteria for the rubric shown here)

	0 no pass	1 low pass	2 pass	3 high pass
(1) quality of the research				
(2) public presentation				
(3) performance on the oral exam (research specific)				
(4) performance on the oral exam (general knowledge)				

Method of Appraisal: 4.B Committee Meetings

This outcome is also assessed each year during the annual 2nd Year Project and PhD Committee meetings. We ask the faculty and research scientists on student committees to report on the progress of the students research and on how the student communicates their research progress and goals.

Results of Appraisal: 4.B Committee Meetings

We have only anecdotal evidence from our committee meeting reports that shows our students progressing successfully.

Method of Appraisal: 4.C Performance as a Teaching Assistant

Teaching assistants are evaluated by the supervising professor for the course and on student evaluations administered by the university. The university conducts a Course Instructor Survey which separately evaluates Teaching Assistants every semester. We utilize this as an additional tool to measure the success of our instructors.

Results of Appraisal: 4.C Performance as a Teaching Assistant

The Course Instructor Survey for Teaching Assistants asks eight questions using a 5-point scale with 5 being the most favorable score (1=very unsatisfactory, 2=unsatisfactory, 3=satisfactory, 4=very good, 5=excellent). Then, there is an overall "Teaching Assistant Rating" which we have used to evaluate our students' performance. Over the last 5 years our students have averaged a 3.95 for the Teaching Assistant Rating, with the highest semester average of 4.80 and the lowest semester average of 3.70. These scores are satisfactory.

Action Summary: 4. Oral Communication

For 4.A:

The rubric outlined in the results will be enhanced to make a common set of criteria for each score, in consultation with the GSC.

For 4.B:
Oral Communication is now assessed as part of the 2nd Year Project and PhD Committee meetings informally. We are planning to include a separate rubric item assessing communication to the reports from the committee and the qualifying exam.

A tentative rubric outline follows which will be added to the current tool which currently only gathers narrative assessments of each student each semester.

Rubric Outline for Committee Meeting:

	No Pass	Low Pass	Pass	High Pass
Knowledge of Research and Literature				
Knowledge of physics of astrophysics				
Progress on the research project				
Skill in communication				