Department of Astronomy, University of Massachusetts, Amherst

Graduate Program Handbook

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Table of Contents

Introduction

The goal of the Graduate Program at the Department of Astronomy, University of Massachusetts, Amherst, (the Program henceforth) is to educate, train, and foster the development of research skills, in order to prepare our students to be:

1. critical thinkers;
2. researchers in academia, scientific laboratories, and industries;
3. educators; and
4. disseminators of scientific knowledge.

The Program currently consists of a single Ph.D. track in Astronomy. The education and training consist of course work covering the foundational areas of astronomy at the graduate level, two yearlong research projects, and a long-form independent dissertation research project. The Program provides early exposure of the students to active research to encourage them to become independent researchers by the time they reach the conclusion of their dissertation. The Program also provides students with a solid education in the physical sciences through a range of course offerings. Through rigorous training and involvement in a variety of activities at the Department and University level, the students leave UMass prepared for a wide range of career opportunities, both within and outside academia.

In addition to becoming familiar with this Handbook, graduate students are encouraged to read in detail the *Graduate Students Handbook* put together by the Graduate School at the University of Massachusetts:
https://www.umass.edu/gradschool/policies-forms/graduate-student-handbook

Program Requirements

The requirements for the Graduate Program in Astronomy were formulated and approved by the Astronomy Faculty in 2006. Recent reviews and revisions (the most recent one from 2016) have updated the original formulation. Reported below is the curriculum expected of all students admitted to the Program as of 2016.

General Description

a. Before Admission to PhD Candidacy

During the first 2.5 years in the Program, students learn a broad background of physical principles and astronomy knowledge as well as useful analytical and computational techniques, and gain experience in applying the physical principles to known and current astronomical phenomena. The base course work consists of: Computational Methods, Radiative Processes, Astrophysical Dynamics & Thermodynamics, and Astrophysics of Stars and Stellar Populations, which are offered every year. Additional required courses are: Interstellar Medium, Extragalactic Astronomy, Cosmology and General Relativity, which are offered every other year, and 2 electives from a wide range of Physics and Astronomy topical

courses (see Table below). The two elective courses can be taken any time before graduation. Courses from other Departments can count as electives, with prior approval from the Graduate Program Committee.

Most students are teaching assistants in their first year, and this duty enables the student to learn and develop teaching and communication skills. Every student is also required to participate in Journal Club each semester to broaden their knowledge base, keep informed on new discoveries and ideas, and hone critical thinking and oral communication skills. Students continue to take Journal Club every semester until they graduate, but after 4 years they only have to give a talk once per year.

Table 1: Graduate Astronomy Course Offerings

	Graduate Courses
	Base Courses (taught every year):
AST 643	Astrophysics of Stars and Stellar Populations
AST 644	Radiative Processes in Astrophysics
AST 645	Astrophysical Mechanics and Thermodynamics
AST 732	Computational Methods
	Core Courses (taught every other year):
AST 650	Extragalactic Astronomy
AST 741	The Interstellar Medium
AST 748	Cosmology and General Relativity
	Elective Graduate Courses (taught every 3-5 years):
AST 731	Radio Astronomy
AST 850	Astrophysical Dynamics and Thermodynamics
AST 850	Observational Cosmology
AST 850	High Energy Astrophysics
AST 850	Dark Energy
	Journal Club (taught every semester):
AST791A/92A	Review of Current Literature

To engage our students rapidly into astronomy research, we require all students to take part in two yearlong research projects during their first and second years in the Program.

First year students find or are assigned a supervisor for their first year project when they arrive, and start their project immediately. At the completion of the summer following the first-year, the project is written-up as a report and then presented by the student in a half-hour talk at a Journal Club early in the Fall semester (typically September or October) of the student's second year.

Second year students find a supervisor themselves for their second year project. This supervisor and the research topic must be different than their first year project supervisor and topic. The second research project is written-up, usually as a more formal report and ideally as a publishable paper, and then presented as an hour-long seminar the following Fall (typically around November/December of the student's third year).

Two oral examinations take place following the first year and second year research presentations. Two exam committees, one for the First Year Exam and one for the Second Year Exam, are formed each year; both committees include between 3 (First Year Exam Committee) and 4 (Second Year Exam Committee) members. Committee members are chosen among un-conflicted Faculty Members, i.e., among those who are not research supervisors of the candidates.

The First Year Exam takes place about one to three weeks following the student's research presentation, lasts about one hour, and mainly probes general knowledge linked to the topic of the research paper presented. Students will be told whether or not they passed the oral exam on the day of the exam.

The Second Year Exam takes place in January of the third year, and lasts about two hours. During the Exam, the student's specific effort in, understanding of, and contributions to the project are probed in the first hour and the student's grasp of basic physical principles and general astrophysical phenomena are examined in the second hour. Students will be told whether or not they passed the oral exam on the day of the exam.

If a student fails the Second Year Exam, it can be retaken within two months of the original date.

b. Admission to PhD Candidacy

Barring extraordinary circumstances, a student will be informed whether or not they are admitted to PhD candidacy within two weeks of the Second Year Exam.

Decision on admission of the student to Ph.D. candidacy is made by the Graduate Faculty based on their appraisal of: the student's performances in base and core courses, where a minimum of a B average is expected, oral presentations and written reports of the two research projects, and the oral examinations that follow the two research projects.

If a student is *not* admitted to PhD candidacy, they will receive a Masters Degree in Astronomy, assuming they have accumulated a minimum total of 32 credits between courses and independent studies. A student following the standard curriculum will be generally eligible for a Masters Degree by the middle of their third year. For additional requirements, please see:
https://www.umass.edu/gradschool/sites/default/files/checklist_for_masters_degrees.pdf

c. After Admission to PhD Candidacy

A student admitted to Ph.D. candidacy has one semester to: 1. find a PhD thesis advisor, 2. identify a Dissertation Thesis Committee, and 3. formulate and present a thesis proposal to the Committee. Work towards the Ph.D. dissertation typically begins between the Spring of a student's third year and the Fall of their fourth year.

In order to identify a PhD Thesis Advisor, a student will typically be talking with several faculty members, inquiring about available thesis projects.

A Dissertation Thesis Committee includes at least four members: the Chair (the PhD Thesis Advisor), two Faculty Members from the Department of Astronomy, and one Faculty Members from another Department at the University of Massachusetts. Faculty members from the Departments of Physics, Mathematics,

Computer Sciences, Geology, and Engineering have traditionally served on our Thesis Committees, but the candidate is free to choose from other Departments as well, as appropriate for the successful evaluation of their dissertation progress and outcome.

Faculty members from outside the University of Massachusetts can be added as extra members to the Committee, in addition to the four above. These external faculty members will need to be temporarily added to our Graduate Faculty; in order to do that, they will need to send their CV to the Graduate Program Director, who will forward the CV and request to the Graduate School.

Once a Dissertation Thesis Committee is formed, the candidate will formulate a thesis proposal. This will consist of a 10-15 page written document, that explains the research plan in detail. The Thesis Proposal must also provide a reasonable timeline of activities required for completion. The candidate will present the thesis proposal to the Thesis Committee; this will consist of a one-hour meeting, 45 minutes of which will be taken by the candidate's presentation. The presentation will be done within six months of admission to PhD candidacy.

After approval of the thesis proposal, the candidate will work on the thesis research. It is recommended that the candidate meet with the Dissertation Thesis Committee once per year to update the entire Committee on progress and discuss any potential issue that may have arisen in the meantime.

Minimum requirements for successful completion of graduate studies are detailed on the website of the University of Massachusetts Graduate School: https://www.umass.edu/gradschool/current-students/doctoral-degree-requirements-and-dissertation-information

d. Residency Requirement

The Graduate School at the University of Massachusetts has a Residency Requirement. This consists of two consecutive semesters (Fall/Spring or Spring/Fall) in which the student is enrolled with full time status and earning at least 9 credits each semester. Graduate students are responsible for verifying that they satisfy this requirement before submitting the paperwork for the Final Doctoral Examination. See: https://www.umass.edu/gradschool/sites/default/files/checklist_for_doctoral_degrees.pdf

Step-by-Step Curriculum

This section includes a step-by-step list of courses and milestones broken by year and semester in the Graduate Program.

Year 1

Fall Semester:

AST 645	Astrophysical Mechanics and Thermodynamics	3 credits
AST 732	Computational Methods	3 credits
AST 791A	Review of the Current Literature (a.k.a. Journal Club and Colloquium)	1 credit
AST 696	Independent Study (First Year Research Project)	3 credits

Spring Semester:

AST 643	Astrophysics of Stars and Stellar Populations	3 credits
AST 644	Radiative Processes in Astrophysics	3 credits
AST 792A	Review of the Current Literature (a.k.a. Journal Club and Colloquium)	1 credit
AST 696	Independent Study (First Year Research Project)	3 credits

Year 2

Fall Semester:

In September/early October, the student will submit a written research report to the First Year Exam Committee, no later than one week prior to the student's First Year Research Presentation. The Presentation will take place in September/early October, during a Journal Club slot, and will last about ½ hour. The First Year Oral Exam will take place within 2-3 weeks of the Presentation.

The course sequence 741/748 alternates with 650/nothing, and each sequence is offered every other year.

AST 741 or 650	The Interstellar Medium or Extragalactic Astronomy	3 credits
AST 748 or nothing	Cosmology and General Relativity or nothing	3 or 0 credits
AST 791A	Review of the Current Literature (a.k.a. Journal Club and Colloquium)	1 credit
AST 696	Independent Study (Second Year Research Project)	3 credits

Spring Semester:

	(Elective)	3 credits
AST 792A	Review of the Current Literature (a.k.a. Journal Club and Colloquium)	1 credit
AST 696	Independent Study (Second Year Research Project)	3 credits

Year 3

Fall Semester:

In late October/early November, the student will submit a written research report to the Second Year Exam Committee, no later than one week prior to the student's Second Year Research Presentation. The Presentation will take place in November, during a Journal Club slot, and will last one hour.

The course sequence 741/748 alternates with 650/nothing, and each sequence is offered every other year.

AST 650 or 741	Extragalactic Astronomy or The Interstellar Medium	3 credits
Nothing or AST 748	Nothing or Cosmology and General Relativity	0 or 3 credits
AST 791A	Review of the Current Literature (a.k.a. Journal Club and Colloquium)	1 credit
AST 696	Independent Study (Second Year Research Project)	3 credits

Spring Semester:

The Second Year Exam will take place during the last week of January/first week of February. A student will generally know whether they have been admitted to PhD candidacy by the end of February. If the Second Year Exam needs to be retaken, admission to PhD Candidacy will be discussed and voted by the faculty about two weeks after the exam re-take.

	(Elective)	3 credits
AST 792A	Review of the Current Literature (a.k.a. Journal Club and Colloquium)	1 credit
AST 696	Independent Study (Research Project/Beginning Thesis Project)	3 credits

Year 4 onward:

Fall Semester:

AST 791A	Review of the Current Literature (a.k.a. Journal Club and Colloquium)	1 credit
AST 899	PhD Dissertation	3 credits

Spring Semester:

AST 792A	Review of the Current Literature (a.k.a. Journal Club and Colloquium)	1 credit
AST 899	PhD Dissertation	3 credits

A minimum of 18 credits will need to be accumulated in AST 899 by the time of the dissertation oral defense, in order to graduate.

Base and Core Courses Description

Base and Core Courses provide a foundation for competency in the field of Astronomy. Students are required to have completed all seven Base and Core Courses before admission to PhD Candidacy. Here we provide a short description of each of those courses.

AST 643: Astrophysics of Stars and Stellar Populations. This course includes topics of gravitational equilibrium configurations, virial theorem, polytropes, thermodynamics, convective and radiative transport, stellar atmospheres, nuclear reactions and energy generation, pre-main-sequence contraction, evolution to red giant, white dwarf, and neutron star, and supernova explosions. Stellar Populations: observations and diagnostics of resolved and unresolved stellar populations.

AST 644: Radiative Processes in Astrophysics. This course covers topics of continuous emission mechanisms (synchrotron radiation, inverse compton, and free-free emission), dust emission, photo-ionization and recombination of atomic lines, line broadening. Applications to Astrophysics, such as definitions of star formation rates, are discussed.

AST 645: Astrophysical Mechanics and Thermodynamics. This course covers topics of dynamic and gravitational principles applied to astrophysics. Potential theory, orbital mechanics, virial theorem, Jeans' equations, equilibrium and stability of self-gravitating systems, kinetic theory. Applications to galactic structure and evolution,

mergers, dark matter, evolution of star clusters and galactic nuclei and solar system dynamics.

AST 650: Extragalactic Astronomy. This course covers structure, formation, and evolution of galaxies. Stellar/gas content, kinematics, spiral structure, chemical evolution, galactic nuclei, missing mass in galaxies and clusters, galaxy collisions, determination of the Hubble constant, large-scale structure, and motions in the universe.

AST 732: Computational Methods in Astrophysics. This course covers basic numerical methods: linear algebra, interpolation and extrapolation, integration, root finding, extremization and differential equations. Introduction to Monte Carlo techniques used to stimulate processes that occur in nature and methods to simulate experiments that measure these processes including random number generators, sampling techniques, and multidimensional simulation. Methods for extracting information from experiments such as experimental measurements and uncertainties, confidence intervals, parameter estimation, likelihood methods, least squares method, hypothesis tests, and goodness of fit tests. Chaotic dynamics and other special topics as time permits.

AST 741: The Interstellar Medium. This course describes the gas and dust components of the interstellar medium in ionized regions, atomic clouds, and molecular clouds. Shows how data from optical, infrared, and radio wavelengths can be utilized to determine density, temperature, composition, and dynamics of the various phases of the ISM. Comparison of these results with theoretical models. Includes an overview of the processes that affect the evolution of the ISM including the incorporation of gas and dust into stars, the effect of HII regions and young stellar objects, and the return of matter from evolved stars and supernovae.

AST 748: Cosmology and General Relativity. The course covers observational cosmology and cosmological principles. Background radiation and Olbers' paradox. Newtonian cosmology. General relativity, gravitational waves, relativistic cosmology, and gravitational collapse. Theories of the universe and origin of celestial structure.

Expectations

The previous section lists the minimum requirements to obtain a PhD in the Graduate Program at the Department of Astronomy, University of Massachusetts. In order to foster collegiality and professional growth, and improve the climate in the Department, graduate students are expected to participate in, contribute to and/or lead (as appropriate) several additional activities, including:

a. attend regular and ad-hoc relevant science talks and discussions, in addition to the regularly-scheduled weekly colloquium and journal club.

b. Attend the weekly lunch with the colloquium speaker and leverage other opportunities to meet individually with speakers and other visitors to the Department.
c. Remain current with the professional literature, beyond what is required of journal club. An example is to regularly participate in `morning coffee'.
d. Seek and apply for external sources of funding: e.g., NSF graduate fellowships, Space grant fellowships, etc. The prestige of these fellowships will help students in their future endeavors once they leave UMass.
e. Volunteer and participate in Committees as requested, at the Department, Graduate School, College, and University level. The experience and exposure acquired while serving in a variety of committees will better prepare the student for their post-PhD career.
f. Make every effort to manage and balance the many requirements of the graduate program: research, teaching, coursework, serving on commitees, and participate to the life of the Department.

Education Effectiveness Plan

Expected Learning Outcomes

This is liberally taken from the analogous document published by the Department of Astronomy, University of Arizona. The Plan discussed in that document applies well to our Program.
A range of Educational Goals (EG) are expected of students in our Graduate Program in Astronomy. The students will:

EG1: Demonstrate professional-level ability to understand and use principle findings, common applications, fundamental techniques, and the underlying theories of Astronomy, with an emphasis on developing critical thinking;

EG2: Demonstrate advanced skills necessary to utilize the observational and/or numerical and/or theoretical techniques, instrumentation, computational methods, and software applications used to investigate modern astrophysical phenomena and problems;

EG3: Develop expertise with communicating, translating, and interpreting fundamental astronomical concepts and research results in oral and/or written formats;

EG4: Conduct independent research and acquire mastery-level knowledge of a specific area of the discipline of Astronomy; and

EG5: Engage in the scholarly, ethical, and discipline specific practices of the field at a professional level.

The curriculum described in the previous section has been developed with the aim at accomplishing the Educational Goals listed above.

Assessment

In order to evaluate that the student is on track and is progressing towards competency in the five Educational Goals listed above, a series of assessments is performed throughout the graduate career.

1. All students are expected to successfully complete all seven Base and Core Courses by the middle of their third year, with a grade better than C in each course, and with an overall average grade of B or better. In addition, students are required to successfully complete two elective courses before graduation, with a grade better than C. Electives are offered by the Department of Astronomy and other Departments, such as Physics, Mathematics, Geology, Computer Sciences, Geology, and others as appropriate. Electives offered by other Departments require prior approval.
   All courses must be taken for a letter grade.
   This activity fulfills EG1 and EG2.
   Assessment is performed via final exams administered at the end of each course and during the general portion of the Second Year Exam.
2. All students are required to attend the course: Reviews of Current Literature (Journal Club and Colloquium) and participate in the activities associated with that course. The course will be taken every semester for the entire duration of the graduate career, but after 4 years the students only need to present one talk per year.
   The course can be taken for either letter or non-letter (e.g., SAT) grade.
   This activity fulfills EG3.
   Each student is required to present at least one paper on current literature during Journal Club, in each semester, for the first 4 years in the program.
   Assessment is performed via evaluation of student's participation and quality of presentations.
3. All students are required to successfully complete 5 semesters of Independent Studies, divided between 2 semesters of First Year Research Project and 3 semesters of Second Year Research Project. A grade better than C is expected in each semester. The students will select different advisors for each project.
   These courses must be taken for a letter grade.
   This activity fulfills EG2, EG3, EG4, and EG5.
   All students are required to produce a written report towards the end of their First and Second Year Research period, and present orally their research and results as described in previous sections. Assessment is based on the grade given by the advisor, the quality of the written report and the

oral presentation, and the performance during the First Year Exam and the research portion of the Second Year Exam.

4. All students admitted to PhD Candidacy are expected to take at least 18 credits of the PhD Dissertation course. The student selects the advisor, possibly different from the first and second year research advisors, and forms the Dissertation Thesis Committee. The Committee will approve the Thesis proposal of the candidate and will monitor progress towards completion of the research plan. The candidate will ensure to present a progress report to the Committee at least once per year.
   This activity fulfills EG1, EG2, EG3, EG4, and EG5.
   Assessment is performed via feedback to the candidate by the Dissertation Thesis Committee, which is expected to lead to successful graduation.
5. All students are expected to participate in the daily activities of the Department as appropriate and as listed in the section `*Expectations*', and to engage in activities at the University level and within the Profession.
   This activity fulfills EG5.
   No formal assessment is formulated for this activity.

Code of Conduct

The Department of Astronomy strives to maintain an inclusive and respectful climate, where all of its members feel valued, encouraged and supported to achieve their best. We put every effort in ensuring that our environment is free from discrimination, intimidation, humiliation, and hostility. At the same time we strive to protect scientific debate, constructive criticism, and differing opinions, when respectfully delivered and argued.

All academic members of the Department are required to abide to the principles of Academic Honesty, and our code of conduct mirrors the Code of Ethics set forth by the American Astronomical Society (https://aas.org/ethics#conduct). All new Department members should familiarize themselves with the AAS Code of Ethics.

In addition, The University of Massachusetts, Amherst, has established a Student's Code of Conduct which details expectations for all students associated with the University. The Code can be found at:
https://www.umass.edu/dean_students/codeofconduct

A recent development at UMass is the institution of a consensual relationship policy, which can be found at:
https://www.umass.edu/provost/sites/default/files/uploads/Policy%20on%20consensual%20relationships%20between%20faculty%20and%20students.pdf

The principles, ideas, and requirements contained in the documents above hold for all members of the Department.

Despite best efforts from all involved, unwanted situations may arise, which may be difficult for students to handle, as often an imbalance of power (such as, e.g., in a disagreement between a student and a faculty member) is involved. The next few sections describe how these situations will be handled for a variety of scenarios. For situations not covered by the list below, a student's best resource is the Astronomy Graduate Program Director. If applicable or required, the Head of the Department will intervene in cases that cannot be handled by the Astronomy Graduate Program Director. Beyond the level of the Department, additional resources are: the Director of Diversity and Inclusion at the UMass Graduate School, and the Associate Dean for Operations & Graduate Programs in the College of Natural Sciences.

What To Do in Case of Trouble

Sexual Misconduct
All University employees are `Responsible Employees', meaning that they are mandatory reporters and as soon as they learn about a situation that falls under any of the categories listed at the website:
http://www.umass.edu/titleix/
they need to contact a Title IX Officer (see list in website above) and report the potential incident. Responsible Employees include staff, faculty, and students while performing their duties as Teaching Assistant.

If you are a victim, remember that informing a faculty or staff member of the incident will prompt their contacting the Title IX Office. You will be provided with the necessary support to be separated from the abusive environment, as well as emotional and other forms of support. If you desire to maintain confidentiality or simply do not know what to do, the above website will guide you through your options, and provide a list of confidential resources. Remember: the *worst* thing you can do is to do nothing.

Emotional Abuse/Bullying
In the case of emotional abuse/bullying, the affected individual should report the incident(s) to the GPD or department head. Depending on the severity of the problem, the GPD may request a meeting with the perpetrator and the Department Head to discuss the issue and solutions, which may include, in severe cases, reporting the perpetrator to the appropriate disciplinary committee.

Conflict with your Supervisor/Advisor
In rare instances, a student may find themselves at odds with their supervisor/advisor. An example is when there is a mismatch in expectations, perceived performance, and/or style between the faculty advisor and the student. Situations like these may create tension between the student and the advisor, and possibly anxiety in the student.

Depending on the seniority of the student within the Program, two courses of action may be available.

a. Students not yet admitted to PhD candidacy: (e.g., students working on the First or Second Year Research Project). In such cases, either the student or the faculty meet with the Graduate Program Director (of the Department Head, if appropriate) in order to find a reasonable solution to the conflict. Depending on the gravity of the tension/disagreement, the Graduate Program Director may elect to involve the Graduate Program Committee, while ensuring the necessary confidentiality for the proceedings. Actions may include talking with the supervisor, helping update performance goals for the student; in the most extreme cases, the student may be assigned to a new supervisor or to a co-supervisor. To ease anxiety, it should be recognized that a single Faculty member has limited decision power on each individual student. As detailed in previous sections, admission to PhD candidacy is the result of a holistic review by the entire Graduate Faculty, where performance and accomplishments in coursework, journal clubs, research, research presentations, and exams are all considered. The entire Graduate Faculty vote on admission to PhD candidacy of each student.
b. Students who have been admitted to PhD candidacy. In the event of conflict, the first recourse for the student is to consult with the Dissertation Thesis Committee, and ask them for guidance and course correction as necessary. The Dissertation Thesis Committee remains involved with the student's scientific well-being and progress from the moment the Committee is formed until the student successfully defends their dissertation. The Dissertation Thesis Committee may request that the Faculty Supervisor/Advisor implements updates to the research plan to help the student towards a successful completion of the Program. For this reason, it is in the student's best interest to form a Dissertation Thesis Committee as soon as they are admitted to PhD candidacy. In case the Dissertation Committee is unable to resolve the issue, the same route outlined in point (a) above should be followed.

In case the parties feel that the conflict or source of conflict has not been addressed fully by the above process, either or both can contact the Ombus Person at the University of Massachusetts, to facilitate and mediate. Please, consult their website for specific information on the services provided (https://www.umass.edu/ombuds/).

Intellectual Property/Plagiarism

In the field of Astronomy, it is common for junior researchers to take leadership positions in publications if the junior researcher has produced most of the work reported in the paper, even if the original idea for the project is by a senior researcher working closely with the junior researcher. This is the case, for instance, of graduate students working with their advisors. Although not codified or

mandatory, the Faculty at the Department of Astronomy at the University of Massachusetts tend to follow this established custom.

For publications, all students in the Program are expected to abide by the same standards of professional ethical conduct as the Faculty. When submitting a paper or report for internal review or external publication, the student implicitly guarantees that the work contained in the report/paper is original, and any text or content reproduced from other papers is properly credited. While our Program cannot police every single written scholarly paper produced by members of our Department, Journals and online databases today employ very sophisticated programs to verify that the submitted manuscripts abide to common rules of original scholarly publication (http://iopscience.iop.org/journal/0004-637X/page/Ethics%20policy). Students found in violation of these rules will be first warned, and, in case of repeated behavior, dismissed from the Program.