Department of Astronomy,
University of Massachusetts, Amherst

Graduate Program Handbook
For students entering Fall 2021 and later

(Draft of 8 March 2021)

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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 PhD track in Astronomy. The education and training consist of course work covering the foundational areas of astronomy at the graduate level, a two-year long research project, and a long-form independent dissertation research project. The Program provides early exposure of the students to active research with multiple mentors 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 most recently formulated and approved by the Astronomy Faculty in 2020. This "new" program adds a new mentoring component, a new academic schedule, a new qualification exam, and a reworking of the initial research projects. All changes are designed to shorten the time to PhD and improve the overall experience of graduate education for our students.

General Description

Our graduate program requirements are designed to guide the average student from their bachelor's degree to a PhD within six years. The initial two years, or pre-candidacy period, encompass the majority of the course work and an initial research project. The following four years are devoted to dissertation research focused on a particular topic. This process culminates in a public thesis presentation followed by a dissertation defense with the thesis committee. The following sections describe the formal requirements and milestones along this path.

a. Before Admission to PhD Candidacy

a.1 Academic Coursework

During the first 2 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, the Astrophysics of Stars and Galaxies, the Astrophysics of Fluids and Spacetime, the Interstellar Medium, Stars and Compact objects, and Cosmology. In addition, we offer a suite of elective courses – any two of which are required – that include Radio Astronomy, Galaxy Formation, Computational Galactic Dynamics, and High Energy Astrophysics. 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.

Students who enter with an M.S. degree in astronomy may petition the Graduate Program Committee for a change in course requirements commensurate with their previous academic experience. These students will still be subject to all other Program requirements listed below.

In addition to the courses listed above, every student is required to participate in Journal Club each semester to broaden their knowledge base, keep informed on new discoveries and ideas, and hone analytical 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.

Since our courses alternate on a two-year cycle, a student's academic schedule will depend on their entry year into the program. Students entering the program in **even academic years** will have the course schedule listed in Table 2.[1]

Year In Program	**Fall Semester**	**Spring Semester**
Year 1	Astrophysics of Stars and Galaxies	Computational Techniques
	Astrophysics of Fluids and Spacetime	Cosmology
	IRP Independent Study	IRP Independent Study
	Journal Club	Journal Club
Year 2		Interstellar Media
	Radiative Processes	Stars and Stellar Populations
	IRP Independent Study	IRP Independent Study
	Journal Club	Journal Club

Table 2: Student Schedule for students entering program in even academic years.

Whereas students entering the program in **odd academic years** will have the course schedule listed in Table 3.

Year In Program	**Fall Semester**	**Spring Semester**
Year 1	Computational Techniques	Interstellar Media
	Radiative Processes	Stars and Stellar Populations
	IRP Independent Study	IRP Independent Study
	Journal Club	Journal Club
Year 2	Astrophysics of Stars and Galaxies	
	Astrophysics of Fluids and Spacetime	Cosmology
	IRP Independent Study	IRP Independent Study
	Journal Club	Journal Club

Table 3: Student Schedule for students entering program in odd academic years.

a.2 The Written Exam

The assessment of a student's academic coursework is made via both the course grades and a Written Exam (the Quals) that is taken in the spring semester of the student's second year in the

[1] Course offerings and schedules are subject to availability of graduate faculty.

program. The Quals will cover all aspects of astronomy covered in the courses to that point. Students must pass the Quals in order to advance to candidacy. A student who fails the exam may attempt the exam again in September of their third year in the program. In the event the student fails the Written Exam twice, they will leave the program at the end of the fall semester of their third year in the program.

The process of the exam is as follows:

- Early in the spring semester, the Written Exam Committee will solicit questions from faculty members. Each faculty member will submit two short-form questions and one long-form question (see below). Every submitted question will include a solution set with an associated grading rubric. The Written Exam Committee will choose from this body of questions to generate the exam.
- Part 1 of the exam will be made up of 16-20 short-form questions, at the discretion of the exam committee. Students must answer 80% of the questions. Short form questions are worth 5 points each and partial credit is assigned according to the grading rubric. Students will have 3 hours to complete Part 1 of the exam.
- Part 2 of the exam will be made up of 5-7 long-form questions from which the student must choose 3-5 to answer – the exact numbers being at the discretion of the exam committee. Long-form questions are worth 20 points each in the grading of Part 2. Partial credit will be given according to the associated grading rubric. Students will have 3 hours to complete Part 2 of the exam.
- Parts 1 and Parts 2 of the exam will be averaged with equal weight to determine the student's final score. A minimum score, chosen before the exam is given by the Written Exam committee, will be the threshold for passing.

a.3 Initial Research Project

To engage our students rapidly into astronomy research, we require all students to take part in a two-year long Initial Research Project (IRP) that spans their first and second years in the program. Students will select from a set of projects that are advertised to them soon after they accept a position in the program, prior to their matriculation. During the summer leading up to their first year they will connect with potential scientific advisors and choose a project to work on. Once they arrive, they start their project immediately.

A novel aspect of the IRP is that all projects will be supervised by two faculty members. This increases the access of the students to varying points of view, methodological approaches, mentoring styles, and personality types.

The assessment of the IRP will be based on three outcomes: an IRP report covering the full extent of the project, a scientific presentation to the Astronomy Department on the IRP, and a one-hour oral exam administered the IRP assessment committee. The oral exam is pass/fail and a student may choose to retake it if they fail the exam on the first attempt. All three of these assessments will take place early in the Fall semester of the student's third year in the program.

a.4 Student Mentoring

The Program's mentoring structure is intended to provide students with an accessible network of advisors that can develop supportive relationships with the student in different aspects of the student's academic experience. In addition, access to independent advisors that do not have vested interests, e.g., in a particular research project, provides the student with a place to turn in case of concerns or conflicts.

a.4.1 Scientific Research Advising

In accordance with the IRP Process, incoming students will start the program with two scientific project advisors. These advisors will fill the role of scientific mentorship throughout the 2-year IRP. Following the IRP, the role of scientific advising will be borne by the thesis advisor and the thesis committee. All research advising groups will submit a short report to the Graduate Program Director (GPD) each semester on the progress/performance of their advisee.

a.4.2 General Advising

Incoming students to the program will also be assigned two faculty members who will serve on the student's Mentoring Committee. The Mentoring Committee is tasked with periodically checking in with the student in terms of their overall well-being and status in the program. If one or more of the Mentoring Committee members becomes a student's research advisor, that member will be replaced with another member of the faculty. The Mentoring Committee will provide a brief written report to the GPD each semester on any non-confidential issues that may arise for the student. The Mentoring Committee will follow the student through to the completion of their PhD

a.4.3 Peer Advising

Incoming students to the program will be assigned a volunteer from the graduate student population (pending availability of volunteers) to act as a peer advisor to that student until they reach candidacy. Formal assignment of a fellow graduate student mentor will bridge the necessary gap of power-hierarchy for mentoring and provide an additional safety net to manage issues of well-being that may not be presented to the Mentoring Committee. Additionally, graduate student mentors may serve as an ally to encourage younger students to utilize support from faculty mentors and uphold the structure of the mentoring program as a whole.

b. Admission to PhD Candidacy

Decision on admission of the student to PhD 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, the IRP oral presentation and written report, and written reports by the students' IRP advisors and the IRP exam committee. Passing the Written Exam is required for advancement to PhD candidacy. Students who follow the standard Program schedule will be notified of their admission status to PhD candidacy during the Fall semester of their third year in the program.

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 PhD candidacy has until the end of the fall semester of their third year in the program to find a PhD thesis advisor and identify a Dissertation Thesis Committee. The student has until the end of the spring semester of their third year in the program to formulate and present a thesis proposal to their Thesis Committee. Work towards the PhD dissertation typically begins as soon as possible after the student has identified an advisor and thesis committee.

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. Students who wish to have non-UMass faculty on their Thesis Committee should contact the Graduate Program Director who will help facilitate their formal inclusion.

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 before the end of the spring semester of the student's third year in the program. Appendix B provides additional information about the Thesis Proposal Meeting.

After approval of the thesis proposal, the candidate will continue work on the thesis research. The candidate will meet with the Thesis Committee once per year to update the entire Committee on progress and discuss any potential issues 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 & Milestones
This section includes a step-by-step list of courses and milestones listed by year and semester in the Graduate Program.

Year 1
Fall Semester:
- Two academic courses (3 credits each)
- AST 791A - Journal Club (1 credit)
- IRP Independent Study (3 credits)

Spring Semester:
- One (even years) or two (odd years) academic courses (3 credits each)
- AST 792A - Journal Club (1 credit)
- IRP Independent Study (3 credits)

Year 2
Fall Semester:
- Two academic courses (3 credits each)
- AST 791A - Journal Club (1 credit)
- IRP Independent Study (3 credits)

Spring Semester:
- One (even years) or two (odd years) academic courses (3 credits each)
- AST 792A - Journal Club (1 credit)
- IRP Independent Study (3 credits)
- Written Exam (Quals)

Year 3
Fall Semester:
- Written Exam 2nd Attempt (if needed)
- IRP Presentation to Department
- IRP Oral Exam
- IRP Oral Exam 2nd Attempt (if needed)
- AST 791A - Journal Club (1 credit)
- IRP Independent Study (3 credits)
- Candidacy Vote by Faculty
- Identify Thesis Advisor and Thesis Committee

Spring Semester:
- AST 792A - Journal Club (1 credit)
- AST 899 – PhD Dissertation (3 credits)
- Thesis Proposal

Year 4 onward:
Fall Semester:
- AST 791A - Journal Club (1 credit)
- AST 899 – PhD Dissertation (3 credits)

Spring Semester:
- AST 792A - Journal Club (1 credit)
- AST 899 – PhD Dissertation (3 credits)

Dissertation Defense:

- Announce Date of Dissertation Defense (> 3 months prior)
- Submit Dissertation to Committee (> several weeks prior)
- Public Dissertation Lecture
- Dissertation Defense
- Final edits and signing of paperwork.
- Add “PhD” to your business card.

Base and Core Courses Descriptions

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, equations of state, radiative and heat transfer, stellar energy sources, stellar modeling and evolution, the connection between theory and observations, simple stellar populations, composite stellar populations, 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: Astrophysics of Stars and Galaxies. 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 717: Astrophysics of Fluids and Spacetime – description TBD

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.

Education Effectiveness Plan

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 while working on their Initial Research Project. A grade better than C is expected in each semester. 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 on their IRP and present 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 IRP Oral 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 IRP 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 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
The Graduate Program Director and the Department Head are both `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. Other faculty are not mandatory reporters and so students can feel free to engage in confidential discussions with them. The GPD and the Head cannot guarantee students confidentiality, but both will do their utmost to help students through the situation they are facing.

Conflict with your Supervisor/Advisor
In rare instances, a student may find themselves at odds with their supervisor/advisor. An example is when a faculty advisor believes the student is underperforming relative to expectations. Situations like this 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 should meet with the

Graduate Program Director (or the Department Head, if appropriate) or the student's General Mentoring committee 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.

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.