

A Guide to the Astronomy Major at Dartmouth

Anyone who has seen the dark night sky is stirred by the sight of countless stars stretching off into infinity. The sight stirs not only the soul, but the intellect. What are all those things? How did they get there? What might this have to do with our existence on earth? Rather than idly wondering about these Big Questions, astronomers answer them. Astronomy today is a large, fast-moving enterprise, in which new instruments and theories are constantly evolving. We live in a golden age of science, and astronomy is enjoying more than its share of breakthroughs. As an astronomy major, you will come to understand how much of this works, and you will have opportunities to make your own contribution to humankind's understanding of the cosmos (you may wish to skip ahead to 'Dartmouth Astronomy Research Opportunities', below).

What is Astronomy?

The astronomy major is under the umbrella of the Department of Physics and Astronomy. Until recently, a separated major wasn't available. You may wonder, then, what astronomy is, and how it relates to the other subject in the department, physics.

Astronomy is among the oldest of sciences. In the Renaissance the clean, mathematically predictable motions of the planets played a decisive role in the birth of physics. Physics and astronomy became even more closely joined as discoveries in atomic physics opened the path to understanding the true nature of the stars, and the development of nuclear physics finally made it possible to understand how they shine for so long. Over the past twenty years or so it has become clear that astronomical observations may be the only way to get at certain very big questions in fundamental physics, since the conditions of the Big Bang may never be replicated.

Even though astronomy and physics are intimately co-mingled, they are not quite the same. The fundamental aim of physics is to uncover the fundamental laws of Nature, and to apply these rules in situations where they are helpful. Astronomy, in contrast, is concerned with a particular object which we find -- the Universe -- and everything in it, in much the same way that geology is concerned with a particular object, in that case the earth. There is a discipline of geophysics, just as there's a discipline of astrophysics, but in geophysics and astrophysics, the physics is often not an end in itself, but rather a tool used to understand what is there. Physics is used in the design of instruments, the interpretation of the data the instruments produce, and finally in the construction of the grand theories which explain the evolution of

stars, galaxies, and the universe (or the earth!). Other disciplines come into play as well. Computers are used at every step of the way, not just to simulate physical situations, but to deal with the reams of data modern instruments produce. Some astronomers specialize in telescope and instrument building, and become very good engineers. Even chemistry has its place in understanding molecular clouds in space, cool stellar atmospheres, and the composition of planets. And because randomness is everywhere, both in the sky and in our data, some astronomers make very clever use of statistics. Astronomy is not a mere subfield of physics, but a truly interdisciplinary quest to understand the universe.

Astronomy and Your Career

There are plenty of career opportunities for astronomy majors.

If you're talented, commit yourself strongly, and work hard, you may end up as a professional astronomer. Many of these are astronomy professors; others work as researchers for NASA or other research organizations. Virtually everyone in such a position has a Ph.D. in astronomy or physics, so to be a professional you'd need to go to graduate school. The number of new astronomy Ph.D.s generally outstrips the number of permanent jobs, so not everyone who wants to be an astronomer gets to be one. Nonetheless, the situation isn't as bad as people used to think it would be, and there are always jobs for the very best people. And even if you don't 'make the cut' somewhere along the way, you still get to work in astronomy for a while -- after the first year or two, graduate school is more like an apprentice scientist program rather than an academic grind, and it can be lots of fun. In addition, nearly all graduate programs pay modest stipends, so unlike your friends in (say) medical school, you don't need to accumulate heavy debts.

There are some jobs which require only an undergraduate degree in astronomy, but they are rather more limited. Observatories often seek support personnel with astronomy majors, but without advanced degrees. The NASA centers (such as the Space Telescope Science Institute) also employ bachelor's degree holders in support roles. It's fairly common for astronomy majors to get one of these jobs and take a breather for a while as they evaluate their career plans; many go on to graduate school.

But even if you don't decide to stay in astronomy, there's plenty you can do. Given the amount of science you will take anyway, it's a fairly simple matter to (for example) fulfill pre-medical requirements and head for medical school. Astronomers need to understand complicated arguments from principle, which is an excellent background for the study of law. With an astronomy background, you would most likely find the much-feared 'quantitative' parts of a business school curriculum to be relatively straightforward. To a prospective employer, an astronomy major will stand out

from the great herd of history, government, and English majors who troop through their interviews. Dartmouth isn't a place which encourages narrow, pre-professional training, but the talents and habits of mind you create studying astronomy are useful in a wide range of endeavors. You may want to check out further material from the American Astronomical Society, available at <http://www.aas.org>.

Dartmouth Astronomy Research Opportunities

Daniel Webster may have said that Dartmouth is a “small College”, but it is in reality a small University with a small graduate program. In the Department of Physics and Astronomy we try to offer the undergraduate student an experience which combines individual attention from faculty and access to real front-line research -- in other words, the best aspects of a small college and a large university. Because we have a graduate program, we can maintain a level of research vigor which would be difficult at a purely undergraduate institution, but at the same time we are strongly committed to undergraduate education.

Much of the astronomy research at Dartmouth centers around the MDM Observatory, near Tucson, Arizona. This observatory has two telescopes, a 1.3-meter telescope dating from the 1970s and a more modern 2.4-meter reflector. The telescopes are instrumented with modern CCD cameras, spectrographs, and an excellent infrared instrument. The Observatory is owned by Dartmouth, Columbia University, Ohio State University, the University of Michigan, and Ohio University (the initials date from when it was owned by Michigan, Dartmouth, and MIT). Dartmouth has 1/3 of the time on both telescopes, or about 200 nights per year in total.

This colossal amount of telescope time makes it possible for interested students to do projects with real research-class telescopes. Astronomy 81 is an independent study course involving a trip to Arizona, typically for a week, to do research at MDM. Occasionally a student may work with another telescope elsewhere, but the MDM connection makes this the most likely choice. *This opportunity to do a real project with a big telescope as an undergraduate is very unusual.* There is a long lead time for this, since telescope time must be obtained from three to nine months in advance. You should start working with a professor long in advance if you want to take advantage of this option.

Faculty with MDM research programs, and their areas of interest, areas follows:

- *Brian Chaboyer* does research on star clusters, especially trying to determine their ages and compositions to trace the history of our Galaxy. Much of his research is on stellar models, but he does observational work as well.

- *Rob Fesen* mostly studies supernovae and supernova remnants. Lately his MDM work has focused on infrared studies of supernovae. Much of his work involves tying together ground based work with data from the Hubble Space Telescope and other space observatories.

- *John Thorstensen* studies a class of close binary stars called cataclysmic variables. In these a normal star gradually spills matter over onto a white dwarf, leading to a host of interesting phenomena. Thorstensen mostly measures fundamental parameters of these systems, especially orbital periods.

- *Gary Wegner* pursues a variety of projects in extragalactic astronomy. Some of these are aimed at studying the dynamics of the local universe. A recent project involves obtaining deep pictures in the infrared as part of a survey of distant galaxies.

Other students may wish to do theoretical research. There are many opportunities here, too:

- *Robert Caldwell* is a theoretical cosmologist who studies the large-scale properties of the Universe; the cosmic microwave background, the origin and evolution of cosmic structure, the dark matter and dark energy. Recent work involves a hypothetical field called quintessence, which offers a possible explanation for why the expansion of the Universe is speeding up.

- As noted earlier, *Brian Chaboyer* combines extensive theoretical modeling with his observational work.

- *Marcelo Gleiser* is a physicist who works largely at the interface between cosmology and particle physics. His research focus includes theories of primordial inflation, cosmic phase transitions, and the origin of the matter-antimatter asymmetry in the Universe. He also works on nonlinear dynamics and emergent complex phenomena.

Planning Your Major Courses

The course requirements for the astronomy major include many of the same courses used for a physics major, and the prerequisites are essentially identical. Here is a formal listing of the courses:

Prerequisites: Math 3, 8, 13, and 23; Physics 13 and 14 (or 15 and 16).

Major: At least eight courses in physics and astronomy, including:
Astronomy 15, Astronomy 25, Astronomy 61, and Physics 19, 24;
One elective from Astronomy 74 and Astronomy 81;

Two electives chosen from Physics 41, 43, 44, and 74.
Students taking Physics 15 and 16 may substitute a third elective for Physics 19.

Obviously, if you receive AP credit for a prerequisite, you don't have to repeat the course at Dartmouth. For official descriptions of these courses, consult the *ORC*. Very briefly, the major courses are as follows:

- *Astronomy 15* is a basic introduction to astrophysics, with an emphasis on stellar astronomy. A background in elementary physics (at the 13/14 level) is assumed, and calculus is used.
- *Astronomy 25* is the sequel to Astronomy 15, emphasizing extragalactic astronomy and cosmology.
- *Astronomy 61* covers observational technique, and has a substantial observing lab component.
- *Physics 19* (and optionally 24) are courses in the standard physics sequence, which cover modern physics and quantum mechanics at an introductory level. They are the next in the sequence after Physics 13 and 14 (introductory physics for scientists and engineers).
- *Physics 41, 43, and 44* are the standard 'meat and potatoes' of the physics major; they cover, respectively, electricity and magnetism, statistical and thermal physics (which is much more interesting than it sounds!), and classical mechanics. If you're going to grad school and/or have a theoretical bent you may wish to round out the sequence with Atomic physics (42) and electromagnetic radiation (66; especially recommended for astrophysicists).
- *Astronomy 74 and 75* are more advanced astrophysics courses, to be taken after you've done the two required 40s level physics courses.
- *Astronomy 81* is an independent study course with an observational component, generally involving a trip to MDM observatory in Arizona. As noted earlier, you should *arrange this almost a year ahead of time* with one of the observational professors.
- *Astronomy 87* is an independent study course, but not involving an observing project.

Timing: In general, because astronomy is a technical subject, you'll want to start out on the prerequisites as soon as you can -- and if you discover as a first-year student that you can't stand physics, you may wish to reconsider the

choice of an astronomy major. Astronomy isn't physics, but they're joined at the hip.

Other courses. If you're intending to go on to grad school, you'll want to take other courses as well. More physics can't hurt, especially if you're theoretically inclined. Note that graduate courses are open to qualified undergraduates -- you may wish to take courses in either physics or astronomy (though, because of limited resources, the graduate astronomy courses tend to be offered every other year).

And don't forget the elementary courses! These don't carry major credit but can play an important educational role. A relatively straightforward and non-technical course such as Astronomy 2/3 can be a nice change and whet your appetite for the hard stuff. Astronomy 1 covers planetary science, a topic that isn't treated elsewhere in the major curriculum. Because these courses don't go into great technical detail, they tend to have more time to cover qualitative material, which is important general background. All this can be time well spent!

The Astronomy Minor

The Astronomy minor has the following course requirements:

Prerequisites: Mathematics 3 and 8 or equivalents; Physics 13 and 14 (or 3 and 4, or 15 and 16). Four courses are required in addition to the prerequisites. One of these must be Astronomy 15. The other three are Astronomy 25, 61, and 81. Any physics or astronomy course numbered 20 or above may be substituted for one of these three. Note that Astronomy 25 has Physics 14 as a prerequisite.

If you are thinking of majoring in astronomy, and have any questions, please contact the department major adviser:

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