The Department of Physics and Astronomy website:
http://www.dartmouth.edu/~physics

Upcoming colloquia and seminars:
http://www.dartmouth.edu/~physics/news/calendar.html

Organization, Regulations, and Courses:

If you are thinking of majoring in astronomy, and have any questions, please contact any of the astronomy professors or the department undergraduate adviser.

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Cover photo: The 2.4meter telescope dome a MDM (Kitt Peak, Arizona). The telescope is partially owned by Dartmouth and undergraduate majors regularly observe at MDM. (photo courtesy of Tom Ritland)
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? Are there other worlds like the earth out there? Are we alone, or is there other intelligent life in the universe? 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. Astronomy is truly in a golden age – new technologies and telescopes are enabling discoveries which were impossible a decade ago. As an astronomy major, you will learn about these recent discoveries, and 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 offered by the Department of Physics and Astronomy. 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 basic 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 --the universe --and everything in it, in much the same way that geology is concerned with a particular object, in that case the earth. Astronomers use physics as a tool in their quest to understand the universe. 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! 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 that 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, astronomers make very clever use of statistics. Astronomy is not a mere subfield of physics, but a truly interdisciplinary quest to understand the universe.

Dartmouth Astronomy Research Opportunities

The astronomy major is quite small and with five astronomy faculty, all interested astronomy majors can do independent research under the direction of a faculty member. Students may take Astronomy 81 or Astronomy 87 and obtain credit for their research experience. Most undergraduate majors also work as paid research assistants for astronomy professors, often full time during their off term.
Much of the astronomy research at Dartmouth centers around the MDM Observatory, (located near Tucson, Arizona) and the Southern African Large Telescope (SALT) located 4.5 hours north of Cape Town, South Africa. MDM Observatory has a 1.3-meter telescope and a 2.4-meter telescope. The telescopes are instrumented with modern optical and infrared cameras and spectrographs. The Observatory is owned by Dartmouth, Columbia University, Ohio State University, the University of Michigan, and Ohio University. Dartmouth has 1/4 of the time on both telescopes, or about 150 nights per year in total. Dartmouth has a 9% share of SALT, amounting to about 30 nights/year. This 10-meter telescope is the largest optical telescope in the Southern Hemisphere, and is located in Sutherland, South Africa, one of the darkest sites in the world.

SALT observations are made by professional observers, and Dartmouth astronomers retrieve their data using the internet. During the astronomy FSP, students spend one week observing using the smaller telescopes at Sutherland and receive daytime and nighttime tours of SALT.

This 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. 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. Through the generosity of the Weed family, all student travel expenses to MDM are paid by the department.

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

• **Brian Chaboyer** does research on stars and 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. Much of his work involves tying together ground-based work with data from the Hubble Space Telescope and other space observatories.

• **Ryan Hickox**, studies active galactic nuclei – the black-hole-powered ‘monsters’ at the centers of galaxies – and how they have affected their environments over cosmic time.
• **John Thorstensen** studies cataclysmic variables, a type of binary star. In these systems 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.

* **Stephon Alexander** focuses on problems in the theoretical physics that connect cosmology to quantum mechanics, gravitation, and particle physics.

**Astronomy FSP**

Pending final college approval, an astronomy FSP will be offered starting in the Winter 2015 term. The FSP will be based in Cape Town, South Africa for nine weeks. Students will live near the University of Cape Town (UCT) in off-campus accommodations, and have full access to UCT facilities. One week will be based in Sutherland, South Africa at the South African Astronomical Observatory (the location of SALT), one of the darkest observatories on Earth. The view of the night sky from Sutherland is spectacular. The Large and Small Magellanic Clouds (nearby galaxies) are larger than the full moon and easily visible to the naked eye.
The center of our Milky Way galaxy can be seen high in the sky. In Hanover, the center of the Milky Way appears low on the horizon and is barely visible. No nearby galaxies are easily visible to the naked eye in the northern hemisphere. On a dark, clear night in Hanover, one can see approximately 1000 stars, while in Sutherland, South Africa one can see over 4000 stars. The astronomy FSP gives Dartmouth students an opportunity to see and observe the night sky as you have never seen it before.

Cape Town is a dynamic city with a cosmopolitan mix of cultures and a metropolitan population of 3.7 million. It is the second largest city in South Africa, the seat of the National Parliament and a popular tourist destination for European travelers. It is a city of contrasts, from modern shopping centers and high end stores to townships where residents do not have running water in their one room accommodations. From majestic Table Mountain to numerous white sandy beaches, Cape Town is known for its stunning scenery.

During the FSP, students take Astronomy 15 (Stars and the Milky Way) and Astronomy 61 (Observational Techniques in Astronomy) during the first 5 weeks. This is followed by one week observing in Sutherland, and students will spend their remaining time in Cape Town analyzing the data they obtained and receiving credit for Astronomy 81 (Independent Project).

During their stay in South Africa, students will participate in astronomy-themed after school programs and public observing sessions which are offered by SAAO. Students will be trained by, and assist SAAO staff in these activities. This experience will reinforce many of the basic astronomical concepts students have learned in class and expose students to a range of South African culture.
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, there are always jobs for the best people. Astronomy 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 offer free tuition and pay stipends, so you don't need to accumulate heavy debts.

There are some careers that require only an undergraduate degree in astronomy. Observatories, planetariums, and NASA centers (such as the Space Telescope Science Institute) often seek support personnel with astronomy majors, but without advanced degrees. 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, it's a fairly simple matter to 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 while 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.

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, 75 and 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:

*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 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.