A New Universe to Explore: Careers in Astronomy Brochure

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Introduction

> "A professional research astronomer does not merely appreciate the beauty and wonder of the objects in the sky. This is the daily challenge - to come to some sort of understanding of the basic underlying physics that gave rise to the universe and the objects in it. It is this challenge and the satisfaction gained by solving these puzzles that drew me to astronomy."

— Tereasa Brainerd, California Institute of Technology. Primary research of interest: the origin and evolution of structure in the universe.

A New Universe to Discover

When astronomer James Scotti was asked to photograph a newly discovered comet with the University of Arizona's 36-inch telescope, he was not prepared for the image that appeared on his computer screen. What he saw was not one comet but a chain of comets that looked like a string of pearls. "I was struck by the unique appearance of a train of individual [comet] nuclei all lined up in a row," Said Dr. Scotti. "I had never before seen such a unique image in a comet." In fact, nothing like it had been seen by other astronomers either. The pearls were the remnant of a comet that had come too close to Jupiter and broke into at least 21 fragments. Even more extraordinary, 18 months later these comet fragments, known collectively as Comet Shoemaker-Levy 9, would collide with Jupiter, providing

astronomers the opportunity to study such an event for the first time!

The Magellan spacecraft had already mapped over 84 percent of the surface of Venus with its imaging radar when it revealed a surprising new feature: a narrow channel snaking its way 4,200 miles across the hellish surface. The channel is 55 miles longer than the Nile River, the longest river on Earth. Water could not have carved out this channel, because the planet's high surface pressure and temperature would have quickly transformed liquid water to vapor. Lava is one possibility, but to carve the narrow channel, it would have had to flow rapidly and with the consistency of paint. "The very existence of such a channel is a great puzzle," said Dr. Steve Saunders, project scientist for the Magellan mission. "If the long channel were carved by something flowing on the surface, the liquid must have had some unusual properties."

Astronomer C. Robert O'Dell of Rice University aimed NASA's Hubble Space Telescope at the rich star-forming region known as the Orion Nebula to study newborn stars. What he and his colleagues found instead were solar systems in the making. The images from the Space Telescope revealed stars so young they were still embedded in the disks of dust from which they formed. Dr. O'Dell calls these objects proplyds. "These disks are a missing link in our understanding of how planets like those in our solar system form," said Dr. O'Dell. "It is likely that many of these stars have planetary systems."

It is often said that astronomy is the oldest science, but in many respects it is also the newest science because year after year discoveries and new insights such as the ones above continually remake and revise our perspective of the universe. In the past two decades alone, astronomy has experienced a flurry of discoveries unprecedented in its history. Many of these discoveries sound more like science fiction than science fact: light echoes around exploding stars; gamma ray bursters; "great walls" of galaxies; voids in space; cosmic jets; gravitational lenses; Einstein rings. Such discoveries not only reveal a universe richer and more varied than had been suspected by previous generations, but pose bold, new challenges for scientists.

Modern astronomy is flourishing. Interplanetary spacecraft have observed eight of the nine planets in phenomenal detail, mapped and landed on the surfaces of the moon, Mars, and Venus, and returned the first close-up images of a comet nucleus and several asteroids. Orbiting observatories scrutinize star clusters, nebulae, the violent cores of galaxies, and distant quasars. Another orbiting spacecraft, the Cosmic Background Explorer, has mapped the faint background glow of energy that is believed to be the remnant radiation from the big bang 15 billion years ago.

Meanwhile, astronomers are using ground-based telescopes, equipped with the latest electronic light-gathering instruments, to measure the chemical composition of stars, the mass of galaxy clusters, and looking for planets around other stars. Future years will see an armada of new large telescopes brought to bear on some of the most important astronomical questions being asked today. How old are the oldest stars? How did the first galaxies form in the universe? Why is most of the mass in the universe not directly observable? What is the nature of this "dark matter?" Will the universe expand forever?

Of course, astronomers don't just use telescopes in their studies of the universe. In recent years, powerful supercomputers have been employed to, among other things, model cosmic jets and the environment around pulsars and black holes, simulate galaxy collisions, and devise better theories on how galaxies clustered into large-scale structures in the early universe.

Astronomers also study data gathered by physicists using particle accelerators. Key questions about the big bang and the nature of matter in the universe can only be answered by studying the behavior and forces of elementary particles and, perhaps, discovering new particles. Hence, in order to understand how the very large came to be, astronomers must learn what they can about the very small.

Theme

Preparation for a Career in Astronomy

You may have heard somewhere that astronomy is "hard" or difficult to grasp. This may seem to be the case because astronomers don't have laboratories like chemists, biologists, or paleontologists; they can't put stars in test tubes or galaxies in a centrifuge. Their "fossils" lie millions and even billions of light-years away. Most of the time, astronomers derive information from an analysis of the light or the motions of celestial bodies, a process that, to the uninitiated, may seem more like sorcery than science.

In fact, astronomy is a challenging science, but not because the universe is inaccessible in the conventional sense. Rather, astronomers must apply equal measures of analytic thinking and imagination, logic and intuition, to answer the most fundamental questions about the cosmos: What are stars and planets? How did they evolve? Why does the night sky look the way it does? Does life exist among the stars? How did the universe get here? How will it end? If astronomy seems a rigorous science, it's because the objective of astronomers is nothing less than to understand the nature of the universe. It takes a special person to pursue this objective; one who likes to challenge and be challenged.

High School

Decisions made in high school can have a big effect on a science career. Generally, students who take mathematics or science courses after the tenth grade have the best chance of successfully pursuing a science or engineering career. Although most colleges require at least one year of high school science and two years of high school mathematics, this minimum background is insufficient for students planning to major in science. A better approach is to complete math through pre-calculus in high school. This gives students who plan to major in astronomy or physics the necessary grounding in mathematics needed to start their science courses as soon as they begin college. Both chemistry and physics courses are also strongly recommended in high school as adequate preparation for the first year of college. Many entering students have taken advanced placement calculus and/or physics, though these courses are not required.

Students are also encouraged to get involved in high school science groups, state junior academies of science, and local amateur astronomy clubs. There are literally thousands of such organizations in the United States.

College

College undergraduates planning careers in astronomy must obtain a solid foundation in physics and mathematics. An astronomy major with a strong background in physics, or a physics major with some astronomy coursework, should have a sufficient foundation in physics and math to seek a graduate program in astronomy. Specifically, a student planning to go on to graduate school in astronomy should have had physics courses covering electricity and magnetism, atomic and nuclear physics, thermodynamics, statistical mechanics, and quantum theory. For some astronomy specialties, however, studies in geology or chemistry may be more appropriate.
Computer science, too, permeates all facets of astronomy today. In recent years, supercomputers have allowed astronomers to simulate processes that before were nearly impossible to study. A good grounding in computer science, therefore, will benefit prospective astronomers, especially those considering a specialty in theoretical astronomy.

In addition, a good scientist must also have the ability to read and write clearly and to communicate well with people, often across cultural boundaries. Do not neglect college courses in writing, the humanities, and the social sciences.

Theme

Graduate School

Most astronomy positions require a Ph.D. degree, which can take five or six years of graduate work. This path enables the astronomer to do much independent work, which is what makes astronomy enjoyable: finding a problem and finding a way to solve it. Admission to graduate schools generally requires completing an undergraduate physics or astronomy/physics major with a B average or better and satisfactory performance on the Graduate Record Exam. Once admitted, the astronomy graduate students take advanced courses in astronomy and astrophysics while beginning to undertake some research. The specific courses depend on the requirements of the department and on the student's research interests. After the first two years of course work, the graduate program generally requires research projects to be conducted under the supervision of faculty members, culminating in a Ph.D. dissertation.

Where Astronomers Work

Where the Jobs Are!

Employment Potential

> "Discovering new information about how our universe works is always an incredible experience, but sharing that information is also a source of satisfaction. As a planetarium directory, I transport audiences to distant planets and stars daily. I am constantly rewarded by children's amazed gasps and squeals as I make the sky move, and give them their first look at the wonders of the stars. Astronomy is an excellent way of exposing young minds to the thrill of scientific discovery. Ideally, by writing articles, giving shows, and holding special events, astronomy educators are creating a world where science is not difficult or boring but is instead a key to our future."

— Christine Brunello, planetarium director, Don Harrington Discovery Center, Amarillo, Texas.

As science professions go, astronomy is a relatively small field, with about 6,000 professional astronomers in North America. Because of its size, astronomers get to know and collaborate with many colleagues across the U.S. and around the world. This can lead to an advantageous dialogue among astronomers.
On the other hand, there is a small turnover of positions each year and, therefore, strong competition for positions. In recent years, there have been about 150 job openings for astronomers in North America, while the number of Ph.D.s conferred annually in recent years has averaged about 125. It is common for astronomers to spend from three to six years in postdoctoral positions before finding a steady position in a university department, national facility, or government lab.

In such a small and popular field, only those with a quality education, ability, and passion for the subject are likely to find a permanent position. Astronomy training, however, emphasizes a remarkably broad set of problem-solving skills. With careful selection of graduate school courses and experiences, one may prepare for an interesting and productive career in a related field, such as industrial research, education, and public information.

Where the Jobs Are

> "I've been interested in all the sciences since grade school. Astronomy was particularly appealing

> because it addressed some of the most basic questions of who, what, and where we are [in the universe]. Later I was happy to discover that being a good observer means using tools from a lot of other fields: optics, chemistry, atomic physics, computer science, mechanical and electrical engineering, biology, and fluid dynamics, to name a few. Astronomy is interdisciplinary.
> A word of caution: Astronomy is not a high-profit business. Our 'product' is knowledge about the universe, something you can't own or sell. Salaries are reasonable, but competition for jobs is stiff and the hours are very long. If you are considering a career in astronomy, you must be motivated by a love of discovery and the pursuit of knowledge."

— Joe Harrington, Massachusetts Institute of Technology. Primary research interest: Planetary science.

Most professional astronomers (about 55 percent) are either faculty members at universities and colleges, or affiliated with universities and colleges through observatories and laboratories. (Universities require a Ph.D. for a faculty position and hire new people based on recommendations by the astronomy or astronomy/physics faculty.) For these astronomers, teaching is their major activity. Astronomers in academic positions can spend a portion of their time on their research, depending on their teaching schedule.

Often an astronomer will be a member of a physics department or a physics/astronomy department rather than a separate astronomy department. Such faculty members may be called on to teach some physics courses as well as astronomy courses. Because of their training, both undergraduate and graduate, astronomers are well qualified for this expanded role.

Even though teaching is an academic career, astronomers at leading colleges are a major source of astronomical research activity. In addition to the observatories and research institutions operated by individual universities, there are a number of national observatories and research institutes that make research time available to observational astronomers at academic institutions and to others.

Observational astronomers spend between 10 and 30 nights per year working at an observatory or getting observations from spacecraft, and the rest of their time analyzing the data they've collected. Others, such as theoretical astrophysicists, may not even work with observing equipment but conduct a great deal of their astronomy research using supercomputers. Much of the astronomer's work day consists of analyzing data, interpreting observations, or planning observational programs.

Recent university graduates start their careers at universities, colleges, and other institutions with postdoctoral research positions (one to three years of research work for people with new doctoral degrees) and research associateships that allow full time for research.

Median salaries at universities and colleges depend upon the size, quality, and competitiveness of the school. Starting salaries for assistant professors start at about $50,000 for 9-10 months, the range for senior professors is $80,000-100,000 for 9-10 months. Typical postdoc pay ranges between $35,000-45,000 per year. Contrary to popular belief, scientists at national or government labs earn the highest median salary, followed by those employed by business or industry. Many faculty members augment their salaries with summer work at their universities or with summer research support.

In addition, astronomers as a group are striving to encourage a vigorous affirmative-action approach to recruiting. Significant changes have already occurred in the male-to-female ratios. Already more than one-quarter of the young astronomers are women, and this fraction is growing. It is hoped that future years will see a healthy and more equitable balance of men and women of all races in astronomy.

National Observatories and Government Laboratories

> "I find that astronomy is a fascinating subject to work in, because we deal with so many different

> and exotic objects, yet the field is still small enough that it's possible to have some idea of the big picture. It's also very rewarding because the general public is often very interested in our subject. When you tell someone you're an astronomer, the response is usually, 'How interesting!' followed by a flood of questions."

— Christine Wilson, McMaster University. Primary research interest: Radio and submillimeter astronomy.

About a third of the professional astronomers are directly employed by the federal government or by federally supported national observatories and laboratories. A Ph.D. in astronomy or physics or, in some cases, a specialized field of engineering, is generally required for these positions just as for academic positions. While the individual astronomer may devote some time to research of personal interest, the research area is more often defined by the employer than is the case with universities and colleges. This is because governmental agencies such as the National Aeronautics and Space Administration (NASA) [13], the Naval Research Laboratory (NRL) [14], the US. Naval Observatory, etc., have very specific goals and interests.

The national observatories such as the National Astronomy &Ionosphere Center (Arecibo Observatory), National Radio Astronomy Observatory (NRAO) [15], the National Optical Astronomy Observatory (NOAO) [16], and the Space Telescope Science Institute (STScI) [17], encourage individual research. They do require, however, that effort be devoted to instrument design and operation as well as cooperation with visiting scientists. A form of tenure, or guaranteed continued employment, can be granted to scientists in these jobs either according to civil service rules or in a manner similar to that at universities. Salary levels are comparable to those in other government agencies and in the larger universities.

Business and Private Industry

About ten percent of all astronomers work in business or private industry. A few industries, such as the aerospace field, hire astronomers to do research that may give their company a competitive edge. A number of consulting firms supply astronomy talent to the government for specific tasks. In addition, there is are large number of companies that, rather than conduct astronomy research, make use of the background and talents of the astronomer in related areas. Astronomers are generally well-versed in instrumentation, remote sensing, spectral observations, and computer applications to unusual problems. Job security may be somewhat less certain than in government and academia since there is no tenure or civil service in industry. The salaries, however, are often correspondingly higher, especially at mid-management levels and above. In practice, most companies protect their good employees, but the choice of work within a given company may be limited. In exchange for some loss of choice, there is the likelihood of getting a job that is technically challenging and that provides great opportunity for both intellectual and professional growth. Industrial employment offers a wide variety of nontechnical career paths as well. Although a Ph.D. is useful for industrial jobs, it is less often a formal requirement.

Other Related Jobs

> "When I was a child, my parents sat me in front of the TV to watch the space flights. I didn't miss a single launch until the 8th shuttle lift-off! My dad bought me a telescope when I was five, and we often used it to look at the planets, or we'd lie on the hood of the car and just look up. In 4th grade, my teacher read A Wrinkle in Time to the class. I was immediately hooked on becoming a nuclear physicist so I could travel in time like the characters in the book.
> I pursued my Bachelor's degree in physics, but with an astrophysics option. I continued with a Master's degree in physics using the VLA to map the radio emission from the nearby radio galaxy

> M87. I am now completing my Ph.D. in astronomy.
> I wanted to do astronomy since I was a little kid. There are some who stumble into astronomy late in the game, but the majority of us have always had our eyes on the stars."

— Dean C. Hines, the University of Arizona. Primary research interest: Active galactic nuclei.

Astronomers working in planetariums, science museums, or in other public service positions provide an important information link between the world of professional astronomy and the general public. These jobs require a broad range of astronomy knowledge and the ability to communicate clearly and effectively with the public. Some jobs are available in secondary schools teaching physics or earth sciences, as well as in the science journalism field. Jobs in these categories generally do not require an advanced degree, although a Ph.D. or master's degree might prove useful at the more technical levels.

Although most astronomers have advanced degrees, people with an undergraduate major in astronomy or physics can find jobs in support positions at national observatories, national laboratories, federal agencies, and sometimes in large astronomy departments at universities. An undergraduate astronomy degree is excellent preparation for science teachers, laboratory technicians, computer programmers, and science journalists. It can also serve as the basis for graduate degrees in other fields, such as law or medical school. Some universities may not offer a major in astronomy for undergraduates, but may instead have a program in physics with a specialization in astronomy.

Astronomical Organizations and Resources

There are a variety of clubs and societies for individuals interested in astronomy. These include many local amateur astronomy clubs as well as several national organizations. In addition, science museums, planetariums, and astronomy departments at major universities are good sources of astronomy information.

American Association of Variable Star Observers [18]

25 Birch Street
Cambridge, MA 02138
An organization of amateur and professional astronomers interested in the study of variable stars.

Astronomical League [19]

National Office
9201 Ward Parkway, Suite 100
Kansas City, MO 64114
A federation of local amateur astronomy clubs.

Astronomical Society of the Pacific [20]

390 Ashton Avenue
San Francisco, CA 94112
An international society promoting astronomy and astronomy education among professionals, amateurs, educators, and the general public.

Royal Astronomical Society of Canada [21]

136 DuPont Street
Toronto, Ontario CANADA M5R 1V2

A Canadian society open to anyone interested in astronomy.

- Education

Theme