in observational astronomy research projects resulting in significant and publishable outcomes. Although faculty may not initially have an established research agenda, interesting and productive research questions often arise naturally as faculty and students gain experience.

References

A Global Astronomy Research & Education Initiative
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Introduction
One of the most pressing issues in higher education today involves developing greater student understanding and appreciation of science, scientific knowledge and research, and the use of the scientific method to inquire about the universe in which we live. Surveys assessing basic scientific literacy among the U.S. population continue to produce results suggesting that major segments of the population are not receiving or retaining basic knowledge. According to the National Science Foundation survey in 2006, 34% of men and 54% of women did not know the Copernican-era realization that our planet orbits the Sun (National Science Board, 2008).

While higher education can only address those citizens who attend colleges and universities, the important question of how to effectively connect textbook science learning to the actual conduct of scientific research remains valid. Textbook-only learning misses the important link between research and the acquisition of new knowledge. Scientific "facts" are often considered static and unchanging by students; that belies the inherent evolutionary nature of scientific inquiry and new discovery.

The textbook-experiential learning connection is vital so students will realize science is not some abstract activity, perpetrated by white-coat-laden scientists who impose their discoveries on society. Rather, helping students to learn and conduct research projects, in addition to textbook learning, promotes the understanding and application of scientific principles, engages students in applying their knowledge, and helps them to develop practical research skills that can then be used personally or professionally.

This philosophy embodies an emerging astronomy program at the University of North Dakota (UND). From chronically under-funded and under-staffed facilities to an emergent global network of remote observatories, the UND Department of Space Studies is working to give students and faculty the tools to conduct research and education projects from almost any location on Earth.
History

Prior to 2005, UNO Space Studies had built and maintained two small observatories on a plot of land ~10 miles west of the university. Called the Planetary Sciences Observatory (PSO) at the time, the facility included an 18-inch-aperture Newtonian telescope and a 16-inch-aperture Meade LX200 Schmidt-Cassegrain telescope—the latter was envisioned to be controllable via the Internet. These facilities were of limited use through 2005, as insufficient staffing and funding was provided to make effective use of these telescopes. Cold North Dakota winters also inhibited use of the facilities, as the cold can be life-threatening at times and the equipment becomes difficult to use at temperatures that are often below 0°F.

In 2005, however, UNO Space Studies made a renewed commitment to the newly-renamed UNO Observatory (http://observatory.space.edu) and has currently invested ~$150,000 in facility renovations and upgrades. Sources for this funding were diverse and came from a combination of departmental, college, alumni and private donations, the North Dakota NASA Space Grant Consortium (NDSGC: http://www.nd.spacegrant.org), the North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR: http://www.ndsu.nodak.edu/epscor), and North Dakota NASA EPSCoR (http://www.ndnasaepscor.space.edu). The first Internet telescope became operational in late 2005 and has been consistently used for a 400-level undergraduate observational astronomy course as well as contributing to Master’s level thesis research (Higley, 2007). See Figures 1 and 2 that display an aerial view of the UNO Observatory site and Internet Observatory #1.

Figure 1: Aerial view of the UNO Observatory, September 2008. The roll-off roofs for the three optical observatories are open.

Figure 2: UNO Internet Observatory #1. Originally built in 1996/1997, this observatory was renovated in 2005. This observatory includes a Meade classic LX200 SCT with an SBIG STL-6303e CCD. Primary uses have been for undergraduate instruction and M.S. thesis research.

Three new remote telescopes—two optical and one Small Radio Telescope (SRT)—were built in 2006, 2007, and 2008 to expand UND’s astronomy infrastructure, provide more observing time to students, and to expand the types of supportable research projects. The SRT was used for the first time for a graduate-level introductory distance education course in radio astronomy during Summer 2008. Students used the SRT to conduct drift scan observations of the Sun and to record neutral hydrogen (i.e., H I) solar emission to attempt to detect any energetic solar events.

Facilities and Staffing

Building and operating Internet-controllable telescopes at colleges and universities requires an institutional investment that involves much more than simply the purchase and operation of telescopes. Without doubt, the most important factor necessary when building small remote astronomical observatories is a faculty or staff member who is committed to this effort. This person must not only be committed to accomplishing this goal, but must also be willing to write proposals and search for funding; work extra hours beyond the regular job description; devote significant time building, testing, operating, and maintaining hardware; and be willing to mentor students who are interested in working at the observatory.
Robust operations require a high-speed Internet connection, staffing to monitor the telescope complex during use, adequate facilities to protect people and equipment from cold weather, and the use of software and hardware that facilitates remote operations. These requirements led to the installation of a T1 network line; purchase of roof control, telescope control, and weather monitoring software, and telescope focusers; all-weather computer enclosures with heating, cooling, and filtering capabilities; a port-a-potty; and a sufficient supply of tools to maintain the assembled equipment.

ACP Observatory Control Software (http://www.dc3.com) is the primary web browser software for the three optical telescopes, while the SRT uses software developed by the MIT Haystack Observatory (http://www.haystack.mit.edu/edu/undergrad/srt). ACP was chosen as the best available commercial remote telescope control software because it does not require a constant Internet connection, runs scripts that allow the conduct of complex observing programs, offers responsive customer service, and is mature software with a robust performance record. User learning of ACP typically requires only a few hours and script writing is supported in a simple text-based format that is easy to learn and use.

All three optical telescopes are housed in roll-off roofs while the SRT is a free standing, 2.1-meter-aperture observatory. The SRT was purchased from CassiCorp (http://www.cassicorp.com) and developed by MIT's Haystack Observatory. Figures 3 and 4 show Internet Observatory #2, Internet Observatory #3, and the SRT. Table 1 below lists the major features of each observatory.

As Table 1 shows (next page), the optical telescopes can support multiple observational projects that include astrometry, broadband photometry, RGB color imaging, and visible-wavelength stellar spectroscopy. Stellar spectroscopy research is the only project that must be conducted on-site, as the wavelength calibration and orientation of the spectrograph to the parallactic angle must be accomplished manually.

The SRT includes a receiver tuned to 1420 MHz, which can detect neutral hydrogen (i.e., H I) emissions from bright radio sources. The receiver can be configured into one of several modes, but the relatively small aperture of this radio telescope limits the SRT to bright radio sources and, consequently, educational projects. As Solar Cycle 24 has just begun and solar activity should increase significantly into 2009 and beyond, the SRT will be used to monitor solar emissions and attempts will be made to correlate H I emissions with X-ray emissions detected by orbiting geosynchronous GOES satellites.

Operations

The key to any successful astronomical observatory is the ability to consistently conduct robust observations that utilize all available clear nights and produce high-quality data for the observers. While rather obvious, this is a non-trivial task for most universities that do not have dedicated, permanent observatory staff to manage operations. One scenario, applicable to the UND
Observatory, is one faculty member who manages the observatory year-round while also conducting myriad other teaching, research, and service tasks for the university. At times, students are available to help with observatory tasks, but students are, by nature, ephemeral and they are usually not able to devote many hours to this effort unless adequately motivated.

<table>
<thead>
<tr>
<th>Observatory #1</th>
<th>Observatory #2</th>
<th>Observatory #3</th>
<th>SRT</th>
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Table 1: Multiple observational projects supported by optical telescopes

Preparing an optical observatory for use on a clear night follows a standard routine. Approximately 1-2 hours before sunset, a worker travels to the observatory, opens the roof, and starts the ACP/MaximDL software that controls the telescope. A temperature-compensating focuser is readied, but usually has been trained to adjust focus vs. temperature at the beginning of the season. The two primary tasks are then to align and focus the telescope. Aligning is a simple process using ACP and requires centering and synchronizing on two stars centered in the CCD field of view. Focusing, typically on a globular star cluster, is done with the coarse focus knob on the telescope, followed by fine focusing by the Optec TCF S(1) auto focuser software. The telescope is then ready for use.

The observatory worker then contacts the scheduled observer and tells the observer that he or she can begin their work. The local observatory worker then remains at the observatory and monitors the activity and is on-call in case of any problems. As most observers are very distant from the actual observatory, communications occur via some combination of web site chat room and telephone. Another reason to keep a worker on site is to facilitate roof closing in case of unexpected rain showers (even though automatic roof closing software is used).

These procedures have proven to be successful and observers from across the United States—and as far away as Bulgaria—have successfully used the UNO Observatory for the conduct of research or educational projects. Future challenges are to increase observatory robustness to allow observing on every clear night throughout the year. This may not be possible during the coldest months of January and February, but the remainder of the year will be available for use.

Undergraduate Instruction

In concert with the development of the astronomical infrastructure at the UNO Observatory has been the development of new course offerings for both undergraduate and graduate students. Undergraduate students have traditionally had limited astronomy course offerings at UNO because the university has never had a large and vibrant astronomy program. The same situation has been true for graduate students in the past.

Space Studies 425: Observational Astronomy is the primary undergraduate astronomy course that is available to students beyond the typical introductory astronomy course offered on campus. Evolution of the course has progressed in tandem with changes at the UNO Observatory and now fully encompasses the joining of the theoretical and the practical when teaching students.

The first one-third of SpSt 425 focuses on basic knowledge of the night sky, coordinate systems, telescopes, and charge-coupled-devices (CCDs) and their characteristics. This instruction is necessary as this course is an elective and students enrolled usually have little or no astronomy background. In-depth instruction is also given on the understanding and operation of CCD cameras, as it is important for students to grasp the many factors that contribute to CCD image quality and calibration.

During this precursory instruction, students are also given a tutorial on ACP Observatory Control Software, learn how to write text-based scripts, and practice using both online ACP simulations and logging on to an actual UNO Observatory telescope to become familiar with the web browser software.
The middle part of the course involves learning how to utilize on-line astronomical databases, understanding statistics and their proper use when analyzing astronomical data, and learning basic properties of solar system and stellar objects.

Finally, the last part of the course involves learning how to plan, conduct, reduce, and analyze both astrometric and broadband photometric astronomical data. A premium is placed on giving students as much individual observing time as possible, but this has been rather difficult due to scheduling, weather, and instructor exhaustion constraints. All students either reduce their own astrometric data of a main-belt asteroid or are given a dataset obtained from one of the UND telescopes. For example, during Fall 2008 astrometric data of 71 Niobe was used in a homework assignment. Software for the data reduction has included both Astrometrica (http://www.astrometrica.at) and MPO Canopus.

Learning how to conduct broadband BVRI photometric research rounds out the semester and utilizes the MPO Canopus software (http://www.minorplanetobserver.com). Basic theory of photometry is reviewed, as are methods for deriving both first- and second-order extinction coefficients, as well as transformation coefficients. Understanding how and when to conduct differential or absolute photometry, for example, is emphasized based on the science and observing goals for the project.

Students often comment that this course is more time-intensive than many of their courses. This is the case because it requires students to attend several out-of-class sessions either at the observatory learning how to remotely control a telescope, or conducting homework assignments.

Bringing all of the telescopes online in 2009 will be a major accomplishment and will dramatically facilitate the goal of giving all students observing time in future classes. It is vital to utilize all clear nights because the North Dakota weather typically becomes cloudier later in the fall semester and the cold weather always has the potential to stop operations if conditions become too severe.

Graduate Instruction

Graduate astronomy instruction at UND is somewhat different from the undergraduate situation because the UND Space Studies M.S. program is primarily a distance education program (http://www.space.edu). Graduate Space Studies students, who have widely varying backgrounds for the multi-disciplinary program in which they are enrolled, often take undergraduate Space Studies 425, but have historically had few other course opportunities in astronomy.

In 2006, an Advanced Observational Astronomy course was offered for the first time and focuses on two types of astronomical spectroscopy: near-infrared (NIR) reflectance and visible wavelength stellar spectroscopy. The former is an area of research expertise for two Space Studies faculty and is applied in studying the surface compositions of both main-belt and near-Earth asteroids. Several M.S. students have successfully graduated from UND Space Studies with thesis research of asteroids, and codifying this work into Space Studies 526 is a way to attract more students to this work. The stellar spectroscopy component of the course has been heavily theoretical thus far, but practical observational, data reduction, and analysis opportunities will begin in 2009 as a visible-wavelength stellar spectrograph will be available at the UND Observatory.

Summer 2008 saw the first offering of a graduate-level introductory course on radio astronomy. The course taught both theoretical and practical aspects of radio astronomy, focusing on single-aperture radio astronomy and utilizing the Small Radio Telescope (SRT) at the UND Observatory. All students obtained drift scan and continuous H I observations of the Sun for several hours and were able to reduce and interpret the basic results of this data.

The next course offering will be in Fall 2009 when a solar astronomy course titled Space Environment and the Sun will be offered in the UND Space Studies program. This course will delve into the details of solar physics, solar instrumentation, and solar research projects that have the goal of understanding some of the key properties of the Sun.

Space Grant Internet Telescope Network

Due to the progress being made at the UND Observatory, a decision was made in mid-2007 to create the Space Grant Internet Telescope Network (SGITN: http://sgitn.space.edu), which is envisioned as a geographically distributed network of Internet-controllable astronomical observatories for research and education. As this Network is associated with the NASA Space Grant program (http://education.nasa.gov/edprograms/national/spacegrant/home/index.html) and headquartered at UND Space Studies and the North Dakota NASA Space Grant Consortium, eligible students and faculty must be located at a participating Space Grant institution. Furthermore, students and faculty should also have observing experience—the SGITN is not meant to be open to the general public or be a place where students learn how to conducts projects.

Currently, North Dakota and South Dakota are members of the SGITN, Bareket Observatory in Israel (http://www.bareket-astro.com) is also participating in the Network and adds a beneficial international component that can support unique projects such as parallax observations of near-Earth asteroids. Observatories in Utah and Illinois are scheduled to join the Network late in 2009. The eventual goal is to add 15-20 observatories to the Network and, potentially, to include observatories in countries such as India and Australia.
Future Challenges

While much has been accomplished and astronomy course offerings are increasing at the university, much work remains. Establishing regular, reliable operations at the UND Observatory will be the top task in 2009 and beyond as the facility must be able to provide convenient, reliable, and high-quality data to its user base. This goal will require additional staffing to not become an excessive burden on current observatory staff and must be resolved.

Advertising and expanding the SGITN is also another major goal. While universities with major astronomy departments have access to better resources, the vast majority of colleges and universities do not have similar access and the SGITN will hopefully become a resource to those institutions willing to expand their astronomy course offerings and have the goal of giving students experiential learning opportunities.

References


Introduction

In 2008, as an extension of the Cuesta College astronomical research seminar for undergraduate students, Russ Genet initiated a student summer research workshop at University of Oregon's Pine Mountain Observatory (PMO) near Bend, Oregon. The workshop's primary objective was to complete several research projects that would result in published papers in a short length of time, initially one week.

Pine Mountain Observatory has two main functions: research and public outreach. The research program concentrates on CCD photometry of galaxies with low surface brightness. This research is carried out primarily by the Director of the Pine Mountain Observatory, Dr. Gregory D. Bothun, University of Oregon, Department of Physics. Most of the observations are made by the Resident Observer, Alan Chambers, with a 32-inch Sigma Research telescope located inside a large dome. The summer research workshops also became part of the research program at Pine Mountain Observatory, albeit with smaller telescopes and rather modest scientific goals.

The public outreach program at PMO features public nights every Friday and Saturday evening during portions of the year when the observatory is open to the public (the observatory is closed to the public during the winter). Kent Fairfield gives public lectures on these nights, and the visiting public views objects through the 24-inch Boller and Chivens telescope as well as smaller telescopes often set up by amateurs. Dan Gray recently retrofitted the 1950s 24-inch Boller and Chivens telescope with a modern control system from Sidereal Technology (which Dan owns).

Keeping a remote, mountaintop observatory functioning is a major task that is handled primarily by Mark Dunaway, the on-mountain Manager for the observatory.