Astronomy Camp:

Adventures in Scientific Research

"I can't believe they gave us so little telescope time! What kind of priorities are they using?" "We've got time on the 60-inch tonight for the dwarf Cepheid project. When is your team scheduled?" It is easy to imagine hearing lines like these in the halls and offices of observatories and astronomy departments, but not from high school students. However, these students were involved in the Advanced Astronomy Camp held at one of the University of Arizona's observatories this past summer. Here, for a full week, they were completely immersed in doing science and engineering with modern astronomical equipment under the guidance of professional astronomers and qualified graduate and undergraduate students.

The Advanced Astronomy Camp models the full scientific process: The participants formulate questions, devise observing plans, assess the feasibility of their projects, submit plans for critical review, conduct observations, analyze data, and present findings to their peers. In the process, they experience the thrills of discovery, the sometimes capricious nature of research and scientific equipment, and the usefulness of coursework in mathematics and science.

Nine women and twenty men from nine different states enrolled in the 1993 Advanced Camp. They ranged in age from 14 (high school freshmen) to 18 (college sophomore) years. All had completed the basic entrance requirements: a letter of recommendation from a science or math teacher, a creative 500 word essay on a topic in astronomy or space science, and satisfactory completion of algebra II or geometry. Seven students had previously attended the Beginning Astronomy Camp (there is also an adult camp).

Astronomy Campers observe with all of the University of Arizona Observatory's telescopes in the Catalina mountains north of Tucson, including exclusive use of a 30-inch and a 60-inch telescope on Mt. Lemmon, as well as a 16-inch Schmidt telescope and one night on a fully computer-controlled 61-inch telescope on Mt. Bigelow. Campers also enjoy access to a CCD detector, photometers, darkroom and an extensive library. A SUN workstation, along with IBM and MAC computers are available for image processing, planning nighttime observations, calculating the visible passes of orbiting satellites, accessing CD-ROM images, etc.

Research Proposals

Prior to arrival in Tucson, this year's campers received a letter encouraging them to contemplate observing goals and potential projects. Many arrived with personal observing agendas for the week, some modest, some formal, some hopelessly grandiose. During the first two days, the staff provided some additional suggestions and encouraged the entire group to exchange ideas, help each other, and forge collaborations. The students embraced this process with enthusiasm and engaged in often-animated brainstorming. The vehicle for organizing and disciplining their thoughts was an observ-

Eric J. Hooper and Donald W. McCarthy

Steward Observatory, University of Arizona

Astronomy Campers using a CCD-spectrograph on the 40-inch telescope at Mt. Lemmon. (Courtesy Lori Stiles)

right: Campers John Barentine and Marc Swanson present galaxy results. (Courtesy Don McCarthy)

far right: Campers and counselors analyzing research results. (Courtesy Don McCarthy)

above: Astronomy Campers at the 60-inch telescope on Mt. Lemmon. (Courtesy Lori Stiles)

ing proposal, a simplified version of the proposals professional astronomers must write to conduct their research. Groups of collaborating campers were asked to write a brief scientific justification of their proposed work and a defense of their choice of telescope and instrument.

They produced an impressive array of creative, insightful, often practical, and occasionally humorous proposals. Ideas ranged from exploring the technical capabilities of equipment to comparing observations with model predictions. For example, one group proposed to conduct time-series photometry of a variety of short-period variable stars. They then wanted to use the same photometer in a dark room to measure the light curves of illuminated styrofoam balls, which would be shifted relative to each other to simulate the theoretical orbital motions of the binaries. One ambitious camper suggested the very thoughtful but unachievable task of analyzing the spectrum of the black hole candidate Cygnus X-1 to search for abnormal abundances of elements other than hydrogen, which might indicate the presence of nucleosynthesis in an accretion disk surrounding the black hole.

The telescopes did not sit idle while the students developed and honed their ideas. The staff and campers devoted the first full night to "engineering," testing telescope and instrument combinations to determine instrument noise, how faint an object could be positioned in the instrument apertures, fields of view, and telescope tracking. In the process the campers learned the mechanics of operating the instruments and pointing the telescopes. The students used the engineering results to assess the workability of their ideas and to justify telescope size and exposure time. In the course of these efforts they dealt directly with some of the basic aspects of instrumentation, including read noise, dark currents, flat fielding, and plate scales.

The proposals were due on the second full day of Camp. The Camp director and counselors served as the Telescope Allocation Committee, evaluating proposals and awarding telescope time. Fourteen of the twenty proposed projects received telescope time, and every camper participated in at least one scheduled project.

Astronomy: Day & Night

Virtually all of the projects proved to be more difficult and complex than the investigators initially imagined, and they learned valuable lessons about tackling real-world problems. Some found that they needed to employ more mathematics than expected to interpret the results. Others found the systematic and random uncertainties inherent in empirical data frustrating.

One ambitious group undertook a quasar survey with the Schmidt telescope titled "Short-term photographic survey of quasi-stellar objects." The concept was deceptively simple: merely take long-exposure photographs through blue and red filters of a high-galactic-latitude

field, then scan the 5-inch X 6.25-inch (6.0 X 7.5 degree) films by eye for point-like objects which were bluer than the majority of stars in the field. Tracking problems and a miscalibrated setting circle cost some observing time, which substantially reduced the exposure times of the films.

Nevertheless, the group excitedly set out to scan the films and discover quasars, until they realized how many thousands of stars the photographs contained. They devised a simple blink-like search method which quickly produced a very blue object not on published star charts. Their elation soared with the realization that they had discovered an "exotic variable blue object." However, this marvel soon disappeared from the photograph, a tenacious dust particle which finally gave way. The disappointment was deep but short-lived, and they focused on the enjoyment and challenge of the process.

A project titled "Solar observing with a CCD" combined astronomy and engineering. The investigators proposed to image sunspots with the CCD mounted to a Celestron 8-inch telescope. In consultation with the Camp director, these students decided the CCD would not be destroyed if an aluminized mylar solar filter were attached over the telescope aperture and the CCD exposed through a narrowband filter. Because the largest mylar filter available was 3.5 inches in diameter, a special mounting (cardboard and duct tape) had to be devised.

A spectrograph and CCD combination was used extensively for "Spectroscopy of nebulae in the summer sky" and "Spectra of a dwarf Cepheid." The investigator for the first project recorded emission lines in M8 (Lagoon nebula) and M57 (Ring nebula) and successfully identified lines arising from hydrogen, oxygen and nitrogen on the basis of their wavelengths relative to comparison spectral lines. The campers who conducted the latter project interpreted their data to indicate that the temperature and luminosity of CY Aquarii, an RR-Lyrae-class pulsating star that varies in brightness over a period of 88 minutes, had changed significantly over a time span of 20 minutes.

The other observing programs included both imaging and photometry. For example, the CCD was employed to image the jet in the active galaxy M87, and Pluto was detected and its orbit monitored for the duration of the Camp. "Photometry of galaxies in the Virgo Cluster" indicated that spiral galaxies have bluer colors than ellipticals. Another group recorded light curves for several eclipsing binaries.

In all of their observations, campers quickly came to appreciate the importance and ubiquity of computers and detector technology in modern astronomy and, by extension, in virtually all scientific and engineering disciplines. They glimpsed the large amount of work and attention to detail required to conduct careful scientific research.

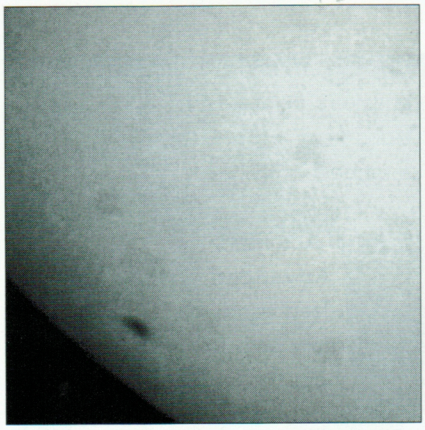
The week of observational efforts culminated in a "conference" on the last full day of the Camp. Each research team presented its ideas, methods, and findings to the entire group, which had assembled in the gymnasium atop Mt. Lemmon. They made free use of some of the common tools of professional presenters, such as overhead projectors and computer displays. At the end of each talk the speakers fielded often-pointed questions from other campers and staff members.

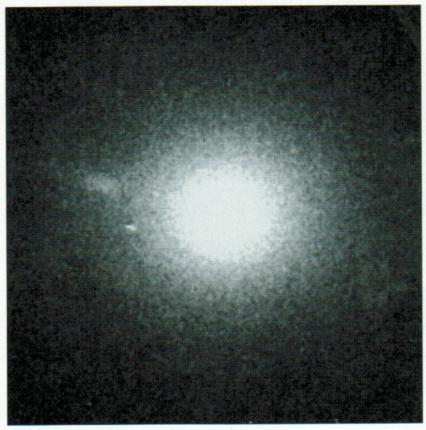
Parallel Activities

While Advanced Camp primarily emphasized hands-on research, complementary activities were scheduled throughout the week. The main academic activities consisted of lectures and demonstrations by the staff and invited speakers covering a wide range of subjects. The staff began with discussions of the basic properties of light and telescopes, including laboratory demonstrations of the CCD, photometer, and spectrograph. The campers saw an extensive liquid nitrogen demonstration and heard about galaxies, archaeoastronomy, and cosmology. Some talks were designed to be very challenging, including a little calculus, to give those who were considering a technical career a taste of what awaits them.

Above:
Ben Oppenhemier at VLBA station on Kitt Peak.
(Courtesy Don McCarthy

The guest speakers presented a fascinating array of talks, from tales of personal discoveries to a review of a current hot topic in astronomy. Jim Christy and his wife Charlene described Jim's discovery, naming, and announcement of Pluto's moon Charon. In the 61-inch dome at sunset, David Levy recounted the story of his recent discovery of "The Comet of the Century" (Comet Shoemaker-Levy 9; for more on the comet see page 15). He described





ight CCD image of unspot and limb darken-ng taken through rigged olar filter. (Courtesy Don McCarthy)

enter: CCD image of M87, taken by Astronomy Campers. (Courtesy Don McCarthy)

ar right: CCD image of Saturn. (Courtesy Don McCarthy)

the predicted impact of SL9 with Jupiter and related how the comet was discovered with light-corrupted photographic plates on a partly cloudy night. Following his talk, all campers viewed SL9 and Jupiter through the 61-inch telescope. Fulvio Melia, a University of Arizona theoretical astrophysicist, reviewed the intensely-studied but still-mysterious gamma-ray bursters and propounded the view that, whatever their nature, they are cosmological in origin.

Time away from the fatiguing work schedule was provided for rest and recreation, which included hikes in the beautiful alpine surroundings of the observatory, billiards, often-spirited volleyball matches, and whatever else the campers concocted during the free time scheduled every day. At mid-week, after a short night's observing, the entire group journeyed down through Tucson to Kitt Peak National Observatory. Astronomers from Steward Observatory, the National Radio Astronomy Observatory, and the Lunar and Planetary Laboratory conducted in-depth tours of the 25-meter and 12-meter radio telescopes, the largest (3.8 meters) optical telescope on the mountain, a solar telescope, and the Spacewatch telescope which searches the skies for asteroids whose orbits bring them close to Earth. After a pizza dinner back in Tucson, the group visited the University's Mirror Laboratory and viewed the newly-cast 6.5-meter mirror. The final stop before returning to Mt. Lemmon for a night of observing was at a convenience store. Imagine 40 hungry and sugar-starved campers and counselors loose in a Circle K.

Astronomy as a Career

On the final full day of Camp, the staff conducted an informal seminar concerning the realities of a career in scientific research, particularly astronomy. The primary aim of the Advanced Camp is not to shunt students towards careers in astronomy or other sciences or engineering. In fact, under some considerations, the most important participants are those who will not enter technical careers, given the lack of knowledge of science and the scientific method among the general public. Nevertheless, many of the students express a very strong desire to pursue a career in astronomy, and at least ten of the 16 former campers now enrolled at the University of Arizona have chosen physics/astronomy majors.

The staff did not discourage careers in astronomy but rather tried to give a balanced and unconstrained view of the potential joys, opportunities, fierce competition, and disappointments which might lie ahead. The seminar covered the entire educational and career ladder in detail with current and frank information, since the staff is composed of undergraduates who are former Camp participants, graduate students, and faculty. The campers heard about the college workload, varied quality of instruction, and the 20:1 or greater oversubscription rates for the best graduate programs. They were exhorted to learn to read, write, and speak well, regardless of their future disciplines. Many people do not realize the critical importance of communication in technical fields and its role in career advancement. For those intent on careers in astronomy, the staff stressed the importance of a very solid undergraduate preparation in math and physics, high Graduate Record Exam scores, and warned of the pressures of graduate school and the very difficult job market at all levels.

Graduation Day

The final day of Camp featured a unique graduation ceremony. Each individual student was "roasted" for something funny s(he) did during the week. The awards included "development of the Schmidt list," "best rendition of Irish folk song at 5 AM," "best hat," "kamikaze volleyball serve," "immaculate grammar," etc. Special recognition went to the young theorists who developed "The

Belgian Waffle Universe" which began in the "Big Batter" and has since evolved four forces (thick, thin, textured, and smooth) along with six known elementary particles called the "elementary strawberries" (ripe, unripe, fresh, decaying, seeded, and seedless). Each camper received a certificate, and individuals who accomplished exemplary research or wrote especially meritorious creative essays for the entrance requirement received some special awards donated by the Astronomical Society of the Pacific and *Astronomy* magazine.

Operating Philosophy

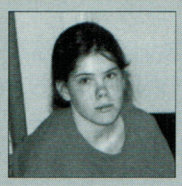
Astronomy Camp operates on a minimal budget in order to provide a rewarding educational experience at the lowest possible cost and to do so with truly dedicated personnel who are enthusiastic about their science and about sharing it with lay men and women. A tuition cost of $485 for the full week provides the primary funding (this figure has not changed in the last five years). Each year graduates of the Adult Camps, the NASA Space Grant Consortium, and the Planetary Science Institute fund about 10 scholarships, which can aid students attending either Beginning or Advanced Camps.

Although outside funding probably is available, the Camp has not sought it for operating expenses in order to demonstrate what dedicated individuals can accomplish on their own. Additionally, some funding agencies require so many evaluations, follow-ups, justifications, visitations, etc. that much of the fun of educating is lost. They also have difficulty evaluating the intangible influences that an experience such as Astronomy Camp can provide, such as the motivational and emotional impact that a single counselor has as a role model or that results from the inspiring experience of controlling a large telescope. ◗

Astronomy Camp is sponsored by The University of Arizona Alumni Association under the guidance of Lisa Roubal and former camper Teresa Longazo. The Camp Director, Donald W. McCarthy, is an Associate Astronomer at Steward Observatory. Eric Hooper, a graduate student at the University of Arizona, was a counselor at last summer's Astronomy Camp. The Camp is grateful for support received for capital equipment and materials from NASA, Kodak, numerous local vendors, and astronomers from the Tucson-area observatories and laboratories. Requests for information can be directed to the Alumni Association at 1-800-BEAT-ASU and (602)621-9026.

How I Spent My Summer Vacation

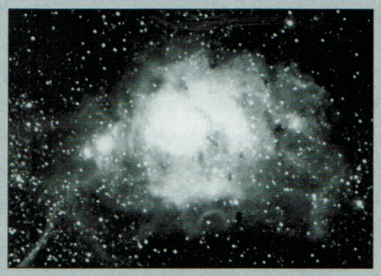
Becky Fox, Phoenix, AZ - Advanced Camp Participant



My interest in astronomy began when I was four and spent evenings counting stars with my father in the back yard, dreaming of someday finding out what was "up there." This dream became an obsession, and when my parents offered me the chance to go to Astronomy Camp, I enthusiastically said, "YES!" When Don asked me to write about my experience, though, I found myself at quite a loss - how do you cram the experience of a lifetime into a few hundred words?

I will always remember the crazy stunts we pulled and the friends I made at camp, but I think the memory I will treasure most is the excitement of doing real science. Today, most teachers sternly remind teenagers, "Don't touch it, you'll break it," so Astronomy Camp, where we are encouraged to use (but not break) anything available, is nothing short of incredible.

Where else would I get an opportunity to conduct a spectroscopy project I dreamed up, much less use a 60-inch telescope to do it? During the week I spent on Mt. Lemmon, I took spectra from the Lagoon and Ring nebulae, recorded them with a CCD, and processed the data to discover the composition of the nebulae. Going was tough sometimes (especially 3 a.m. sessions with logarithms and the evening I spent with IRAF image-processing software), but the sheer joy of discovery made it all worthwhile. (I never expected to be jumping for joy when He I and H beta showed up in my spectra, but I was!)



The week I spent at Astronomy Camp opened a whole universe for me, and cemented my determination to become a professional astronomer. After experiencing firsthand the thrill of astronomy, I can't see myself doing anything else. That little girl who was counting stars has grown up — and thanks to Astronomy Camp, her dream is finally coming true.