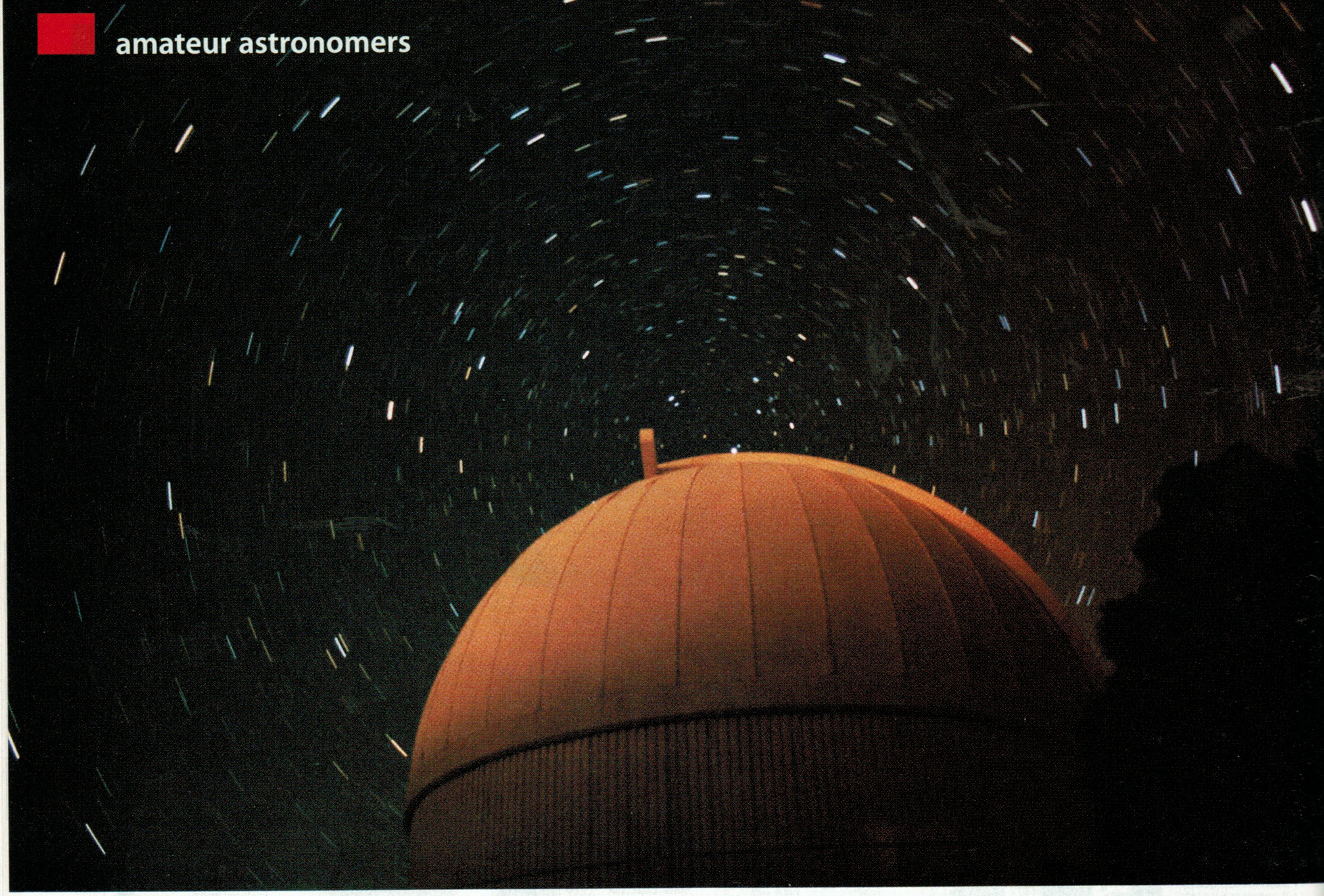


High Observatory Adventure at Astronomy Camp

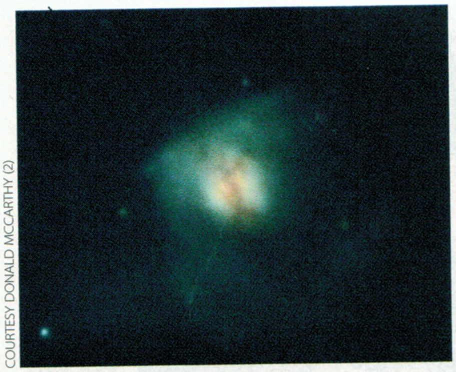
This program lets kids and adults alike do real science under dark Arizona skies using world-class research facilities. | **By Donald W. McCarthy Jr.**

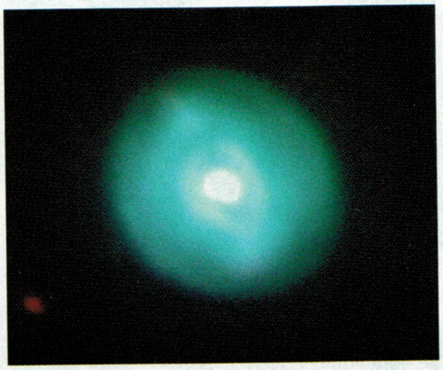
"CEPHEIDS ARE GIANT STARS that have entered an unstable stage in their evolution. As the Cepheid contracts and gets hotter, the heat flowing in the star's atmosphere energizes singly ionized helium. . . ."

This might sound like a presentation at a meeting of the American Astronomical Society, but it was delivered by 15-year-old Kristen Pettey at last summer's week-long Advanced Teen Astronomy Camp. This exciting annual program is sponsored by the University of Arizona Alumni Association at mountaintop observatories north of Tucson. Here students aged 13 to 19 observe the Sun through a variety of instruments, spot Venus in the daytime with the naked eye, hear talks by well-known astronomers and space artists, hike through a scale model of the solar system, try catching the green flash at sunset, observe with 60- and 61-inch telescopes, and conduct their own research projects on such topics as comets, globular clusters, the Hubble constant, and Einstein Cross.

The idea is to combine serious academic study with world-class research facilities and a fun atmosphere — to *do* real science and experience the excitement of discovery in a personal, hands-on fashion. This combination has attracted students from all over North America, including

Above: **A friendly atmosphere, dark skies, and telescopes up to 61 inches in aperture await participants at the University of Arizona Alumni Association's annual Astronomy Camp programs. Held at research observatories atop mounts Lemmon and Bigelow near Tucson, the camp encourages students and adults to explore new worlds and unusual phenomena through their own observations and measurements using modern instruments routinely employed by professional astronomers. This view of circumpolar star trails over the dome housing the 61-inch reflector on Mount Bigelow was recorded by Cramer Silkworth during the 1999 Advanced Teen Camp.**





COURTESY DONALD McCARTHY (2)

Far left: **This tricolor image of the peculiar galaxy Arp 220 was obtained at the 1997 Advanced Teen Camp with the 61-inch Mount Bigelow telescope and a 1,024-pixel-square CCD camera. Arp 220 is an "ultraluminous galaxy" caused by the collision of two spirals.** ***Left:*** **The planetary nebula NGC 6826, the "Blinking Nebula" in Cygnus, imaged with the camp's SBIG ST-6 CCD camera on the Mount Lemmon 60-inch. Three 60-second exposures through red, green, and blue filters were combined to produce this view during the 1998 Beginning Teen Camp.**

14-year-old Maria von Stamwitz of St. Louis, Missouri, who wrote in her application essay, "I think stars are my passion. Some people like helping other people, some love animals, and some like doing experiments. For me it's the stars."

The Astronomy Camp program began in 1988 as a public outreach effort by Steward Observatory astronomer Ray White and the University of Arizona Alumni Association. Since 1989 I have directed the program. The camps are not meant to produce future astronomers or even scientists. Instead, they are designed to promote a lifelong love of learning and an understanding of our cosmic environment. Most young people are enthusiastic about astronomy. We capitalize on this interest to educate them about mathematics, science, and engineering in general. A student from the 1999 Advanced Teen Camp, Lindsay Renick-Mayer, 17, of Wauwatosa, Wisconsin, summarizes both our goals and hers: "Exploring and studying space stretches our minds, allows us to view one another in a more peaceful manner, provides us an opportunity to understand our own origins, and fulfills one of the most basic of human characteristics: curiosity."

The program currently offers at least five sessions each year: beginning and advanced levels for teenagers and adults, as well as a camp for educators and, occasionally, for school groups. More than 1,000 students have attended. The Beginning Camps are filled on a first-come, first-served basis, while the Advanced Camps have a competitive application process for students who have completed geometry or algebra. Last year 60 teens enrolled from 24 states and Mexico. At the Advanced Teen Camp girls outnumbered boys, 17 to 12. The two Adult Camps had 37 participants representing 14 states, and more than 40 teachers attended our two Camps for Educators in 1999.

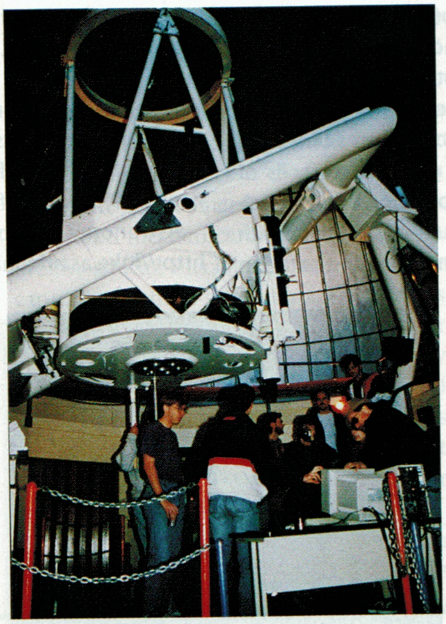
The staff is a dedicated and energetic mix of past and present undergraduate- and graduate-student "counselors" who work alongside me and Jeff Regester, an astronomy instructor from Wellesley College in Massachusetts. Some of these counselors are former campers themselves. They serve as role models; six former campers are now graduate students in physics and astronomy, while others are obtaining other advanced degrees. The faculty and counselors develop close relationships with the campers, sharing chores as well as studies.

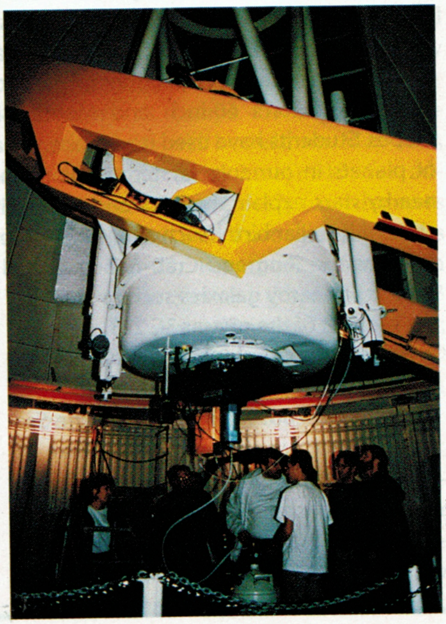
Mountaintop Observing

At 9,160 feet Mount Lemmon offers relief from the summer heat of Tucson. Campers are often incredulous when told to pack a heavy winter coat, but in the wee hours of the morning those coats are treasured. The cold, dry site of Mount Lemmon Infrared Observatory enabled the facility to help pioneer the development of infrared astronomy. Today two 60-inch reflectors and one 40-inch are in use there. Seven miles down the road is 8,250-foot Mount Bigelow, where a 61-inch reflector was built in 1965 to provide high-resolution images of the Moon in support of NASA's Apollo program. Astronomy Campers have routine access to all these instruments as well as a 16-inch Schmidt camera being used for the Catalina Sky Survey (www.lpl.arizona.edu/css/).

Professional astronomers normally apply for telescope time by writing proposals that explain their research and justify their request for observatory resources. The Astronomy Camp program also applies to the University of Arizona Obser-

Left: **At the Advanced Adult Camp in April 1996, counselor and astronomy graduate student Craig Kulesa demonstrated the operation of the CCD spectrometer in preparation for an observing run with Mount Lemmon's 60-inch reflector.** ***Right:*** **Participants cool a 2,048-pixel-square CCD camera (blue unit below center) with liquid nitrogen for a night of electronic imaging with the 61-inch. As a result of her stay at Astronomy Camp, Marsha Wolf (far left) changed careers and is now an astronomy graduate student at the University of Texas.**

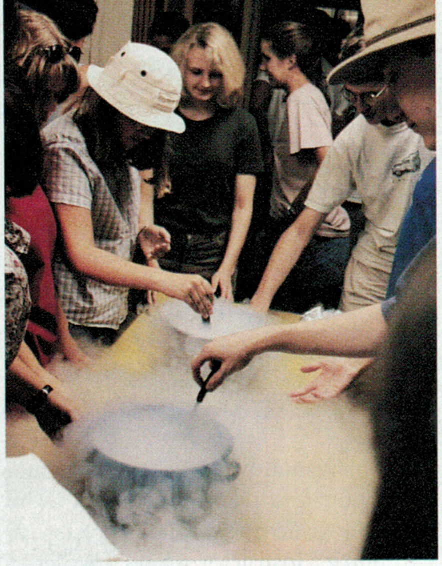




JOHN CHUMACK (2)

vatories Telescope Allocation Committee (TAC) for observing time on the two mountains. Our application is evaluated along with many other, more typical research proposals. At the Advanced Teen Camp we, in turn, have the campers themselves go through this same process. Teams of students devise projects and submit proposals to our own small TAC. The TAC allocates time for a dozen or more projects on three telescopes over the camp's week-long duration. Once the TAC issues a schedule, the observing begins.

To help teams develop their proposals, the first evening is an "engineering night," when campers learn the basics of operating the various telescopes and instruments. These include an SBIG ST-6 CCD camera, a professional CCD imager with 2,048 by 2,048 pixels and cooled by liquid nitrogen, a grating spectrometer, a photodiode photometer, a 1,024-pixel-square infrared camera, a 4,096-pixel-square CCD camera for ultrawide-field imaging with the 16-inch Schmidt, 35-millimeter film cameras, eyepieces, filters, and various tools for imaging the Sun. A radio telescope is available at the university campus and can be accessed remotely via the Internet. During engineering night campers also learn about such concepts as readout noise, dark current, flat fielding, tricolor imaging, and plate scale.


CRAMER SILKWORTH

Advanced teen campers learn how properties of matter change in supercold (–320° Fahrenheit) liquid nitrogen. Experiments include making liquid-nitrogen ice cream and launching projectiles with the camp's liquid-nitrogen cannon.

During the day the students analyze the data they have obtained. Advanced Campers process both images and spectra using the Image Reduction and Analysis Facility (IRAF), a program used by professional astronomers worldwide.

Advanced Campers typically undertake ambitious research projects. In 1999 they obtained spectra of emission nebulae and Wolf-Rayet stars, measured the redshift of the quasar 3C 273, and took images of

Spectroscopy at Astronomy Camp

By Craig Kulesa

"What evidence is there for black holes?" "How do we measure distances to other galaxies?" "How much dark matter is there in our galaxy . . . and in the universe?"

The Astronomy Camp staff often field such questions from inquisitive participants. The camp offers an overwhelming array of astronomical instrumentation with which many such questions can be explored directly.

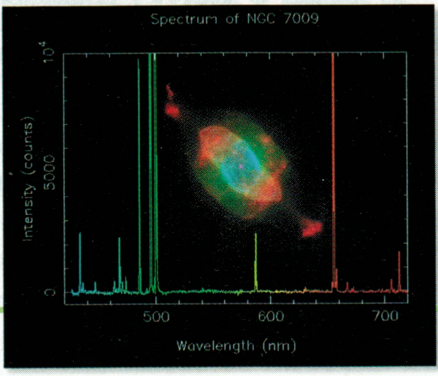
Perhaps the most powerful tool available to astronomers is spectroscopy. Instead of acquiring an image of a celestial object, a spectroscopist dissects the object's light — dispersing it into a rainbow of colors (wavelengths) called a spectrum. By measuring the smoothly varying intensity across the whole spectrum as well as the sharply defined absorption and emission signatures of specific atoms, we can learn much about the object's nature and composition.

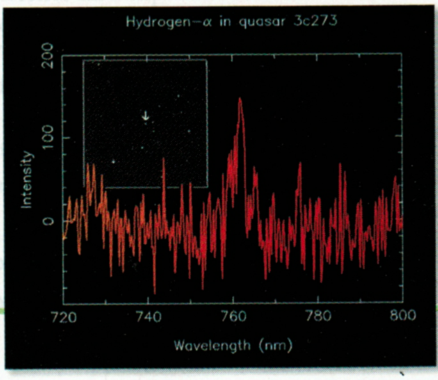
Astronomy Camp's spectrograph is routinely mounted on Mount Lemmon's 60-inch and Mount Bigelow's 61-inch telescopes. Students have used it to probe the atmospheres and rings of planets in our solar system, explore the gaseous surfaces of nearby stars, explain the color and composition of nebulae associated with stellar birth (such as the Orion Nebula) and stellar death (such as the Ring and Crab nebulae), and measure the rotation speeds of nearby galaxies such as M77 and the redshift of the quasar 3C 273.

Here are a couple of spectra obtained by our campers. The one of the planetary nebula NGC 7009, also known as the Saturn Nebula, was made with three 4-minute exposures using the 60-inch reflector. The nebula's central star is a white dwarf, the naked core of the nebula's progenitor star. The dwarf may have a surface temperature exceeding 100,000° Kelvin — hot enough to cause the various atoms in NGC 7009's ejected envelope to fluoresce. Students were able to identify more than two dozen spectral signatures of 11 different ions and atoms. The brightest emissions, near 4800, 5000, and 6500 angstroms (480, 500, and 650 nanometers), are due to hydrogen, doubly ionized oxygen, and hydrogen, respectively. The intense glow of these atoms gives planetary nebulae their color.

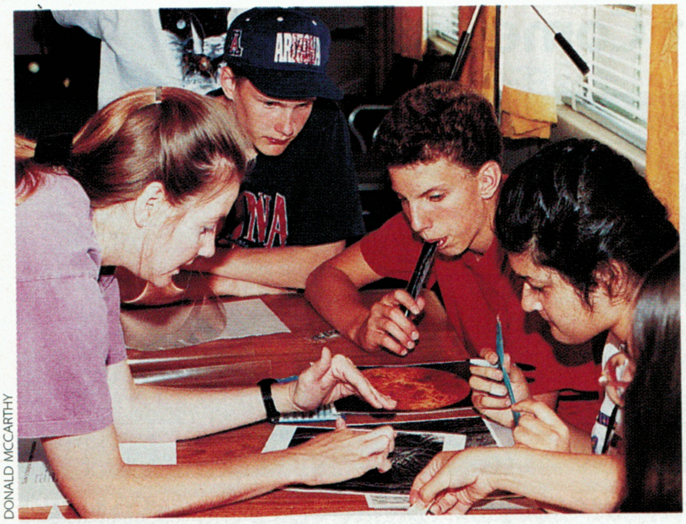
Quasars are the most luminous steadily glowing objects in the universe, the violently active nuclei of mostly distant, young galaxies. A few quasars outshine their host galaxy by orders of magnitude. The first quasar discovered, 3C 273, appears as a 13th-magnitude "star" in Virgo. Its spectrum, made with two 10-minute exposures through the 60-inch, shows a broad hydrogen-alpha emission line. This line is normally seen at 6563 angstroms when at rest but is shifted to about 7600 angstroms in 3C 273. This redward shift indicates that the quasar is receding from us at 47,000 kilometers per second, yielding a distance of almost 2 billion light-years. Thus, the light leaving 3C 273 has traveled for nearly 20 percent of the age of the universe!

Astronomy Camp's spectroscopy Web site can be found at http://loke.as.arizona.edu/~ckulesa/camp/.





NEBULA IMAGE COURTESY HUBBLE SPACE TELESCOPE AND NASA; QUASAR IMAGE COURTESY 1998 BEGINNING ASTRONOMY CAMP



DONALD MCCARTHY

CRAMER SILKWORTH

***Left:* Camp counselor Teresa Longazo (left) works with students James Mackey, Ben Jackson, and Saleela Salahuddin during the 1994 Beginning Teen Camp in studying surface features on Venus using Magellan radar images. Longazo, a former advanced camper, is now a geophysics student at Arizona State University. *Right:* Campers Ariel Fisher, Elizabeth Young, and Cramer Silkworth (left to right) analyze spectral data they obtained of planetary nebulae with the 60-inch during last year's Advanced Teen Camp.**

the gravitationally lensed Einstein Cross with subarcsecond resolution. Using their own CCD images, other students measured the angular diameters of globular clusters and determined the distance to our galactic center to an accuracy of 8 percent. Still others recorded the light curve of the asteroid Juno and discovered a comet, C/1999 F1 (Catalina)!

In 1996 a student team led by Elizabeth Waterhouse measured the Hubble constant, the universe's expansion rate. The team obtained CCD images of the brightest elliptical galaxies in galaxy clusters using the 61-inch. By analyzing the apparent diameters and magnitudes of these galaxies, the students derived a value of 61.5 kilometers per second per megaparsec, in line with most of the latest estimates. The following year Waterhouse's paper placed second in the Astronomical League's National Young Astronomer Award competition.

Daytime Activities

During the day students attend lectures by noted personalities such as comet discoverer and *Sky & Telescope* contributing editor David Levy, space artist Kim Poor, supernova expert Phil Pinto, and the discoverer of Pluto's moon Charon, Jim Christy. Students also dissect obsolete astronomical instruments, launch rockets, develop film, play volleyball and billiards, hike the forests surrounding the observatory, and tour Kitt Peak and Mount Graham or Mount Hopkins observatories and the Steward Observatory Mirror Laboratory.

Always a big hit at the camp are experiments with liquid nitrogen. Normally used for cooling astronomical instruments to –320° Fahrenheit, it is effective in demonstrating various concepts in physics, chemistry, and astronomy. The camp's liquid-nitrogen cannon, capable of launching a softball or three-pound can of soup more than 500 feet into the air, is a dramatic and popular demonstration tool. Campers calculate the expected muzzle velocity and maximum altitude of a projectile and compare their predictions with values measured from video footage, triangulation, and time of flight. As a final twist, they compute how small a planet or asteroid would have to be so our cannon could launch a softball at escape velocity. (Answer: about 37 miles in diameter.) We also celebrate birthdays with liquid-nitrogen ice cream!

One especially novel project involves astrophotography with barndoor tracking mounts and reused disposable cameras. Students first dissect a discarded Kodak "one-time use" camera, learning about its optics and mechanics. Next they reconfigure the shutter mechanism and reload the camera with high-speed film. The camera is then mounted on a barndoor tracker (*S&T:* October 1985, page 391) that they build using hinges, screws, and pieces of wood. This combination allows students to make long exposures under Mount Lemmon's dark skies. They then take their cameras and film home for developing.

The final day at the camp includes an informal career seminar. Here campers and counselors discuss college choices, scholarships, career planning, research opportunities for different college majors, and the importance of science, mathematics, English, *and* liberal arts regardless of one's ultimate major field of study. Some students decide to change their course of study, such as Abby Youngblood, then 18, now a physics major at Bryn Mawr College in Pennsylvania. "As a result of attending Astronomy Camp, I switched high schools to a special program for science and engineering," she says. "Astronomy Camp has influenced my college choice and my plans to major in physics. It really made an impact in my life."

Astronomy Camp is supported by the students' tuition and fees ($495 to $550 for a 7- to 8-day session) and the dedication of its volunteer staff. Full and partial scholarships are available for financially needy students.

This year's camps for beginning/advanced adults will be held on May 5–8, for beginning teens June 6–13, for advanced teens June 19–27, for educators June 29–July 2, and for beginning adults October 27–29. For more information contact me at Steward Observatory, 933 N. Cherry Ave., Tucson, AZ 85721; phone 520-621-4079; e-mail dmccarthy@as.arizona.edu; or visit http://ethel.as.arizona.edu/astro_camp/.

Donald W. McCarthy Jr. *is a research astronomer at the University of Arizona.* *He thanks Craig Kulesa, Jeff Regester, Chris Gottbrath, Susan Kern, and Greg Rudnick for their assistance in preparing this article.*