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Asteroids, Teenagers, and Real Science

*Each year a unique coeducational program in Southern California offers
students a summer of fun and learning.* | **By Tracy Furutani**

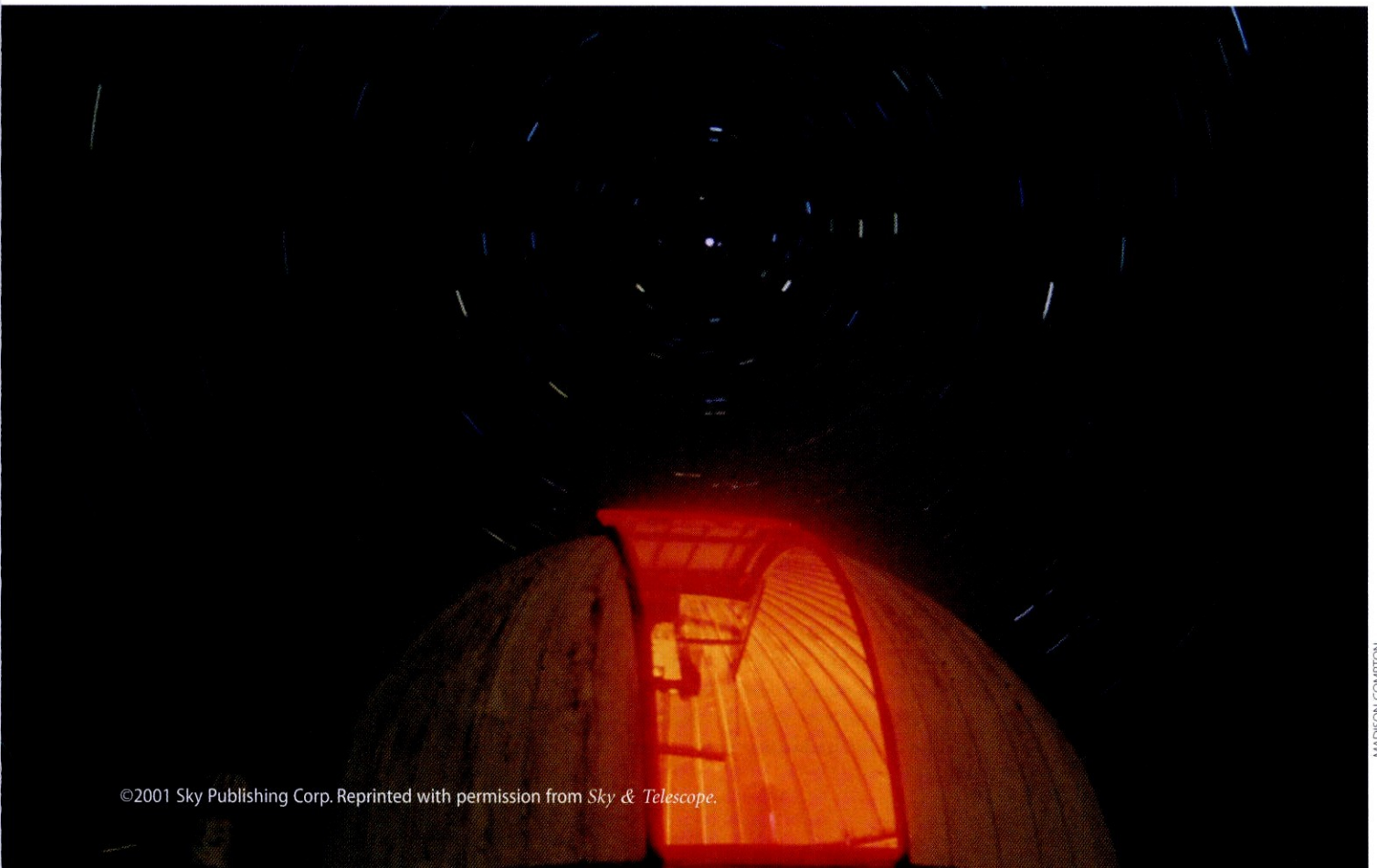
HOLLYWOOD THINKS THE END of the world is overdue: doomsday comets and asteroids are on an imminent collision course with planet Earth, as portrayed in movies such as *Deep Impact* and *Armageddon*. But each summer for the last 42 years, about three dozen teenagers have separated science fact from fiction at the Summer Science Program (SSP) in Ojai, California.

The SSP was born out of the academic panic that gripped America in 1957 after the Soviet Union beat the country into space with the launch of the first artificial satellite, Sputnik. The U.S. had to play catch up, and the obvious place to start was with young minds in the fields of mathematics and natural sciences. In 1959 Paul Routly, then professor of astronomy at Pomona College, and the late George Abell, professor of astronomy at

the University of California in Los Angeles, among others, founded the SSP, in cooperation with the California Institute of Technology and Harvey Mudd and Pomona colleges.

Now in its fifth decade, SSP's hands-on curriculum combines an asteroid observational research project with classroom lectures in college-level physics and math. For six intense weeks, high-school students who have completed their junior year and a few sophomores find SSP to be an enjoyable, unforgettable, and life-changing experience. In the course of learning a lot of science, they typically learn even more about themselves. These highly motivated teenagers come from all over America and abroad. They stay at the campus of a private boarding school in rural, orange-growing Ojai Valley, 130 kilometers northwest of Los Angeles. Accessible yet secluded

Since 1959 the Summer Science Program (SSP) has offered high-school students six weeks of advanced courses and training in mathematics and astronomy at the program's campus in Ojai, California. This view shows Polaris ringed by star trails above the campus's observatory dome.



and blessed with dark skies, Ojai (pronounced "OH-high") is an ideal setting for a summer of fun and learning.

A Hands-on Approach

Unlike many summer-program students, SSPers are not interns or watch-and-learn assistants in someone else's laboratory. They conduct original research from start to finish on classical problems in celestial mechanics. They experience the scientific method firsthand by acquiring, analyzing, interpreting, and presenting their own data. Working in teams of three, students select an asteroid, photograph it over several nights using a professional-grade telescope, develop the plates, precisely measure the asteroid's position relative to the background stars, and write a computer program to calculate the size, shape, and orientation of the asteroid's orbit. Their results are then submitted to the Minor Planet Center at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.

When students select their targets, they consider the objects' transit time ("Do you want to stay up until 3 a.m. to observe?") and brightness (magnitude 11.5 or brighter). For their quarry, the SSP '99 teams chose 3 Juno, 16 Psyche, 41 Daphne, 56 Melete, 63 Ausonia, and 737 Arequipa; the class of 2000 teams settled on 3 Juno, 4 Vesta, 8 Flora, and 135 Hertha.

Assisted by a faculty of two professors and five graduate students (almost all of whom are SSP alumni or alumnae), the teams use the campus's 7-inch Zeiss astrograph equipped with a 6-inch guide refractor to expose Kodak Technical Pan 4-by-5-inch glass plates. Virtually unchanged since 1959, this hands-on approach offers invaluable lessons in real-world science. Raised in an environment of PCs and prepackaged software, the students learn that observations of our analog world do not arrive predigitized and premeasured unless someone ("That's you, kid!") does the actual analysis and data reduction. Even SSP's two ancient but excellent measuring engines — tabletop devices for accurately determining an object's x and y positions — offer practical lessons that can be transferred to more modern scientific apparatus. (One of the engines was used decades ago by Edwin Hubble at Mount Wilson Observatory).

Ojai's temperate, cloudless summer nights make for pleasant observing conditions, leaving only the Moon to con-



Participants in the program get hands-on experience in such facets of astronomical research as photographing asteroids with the SSP's 7-inch Zeiss astrograph, making astrometric measurements of the asteroids' positions, and calculating the size, shape, and orientation of their orbits. SSP also features guest lecturers, field trips, sports activities, and social events.

tend with. Even so, obtaining a usable photograph can be a challenge. The students must manually correct the telescope's tracking during each 10- to 20-minute exposure (another lesson in the real world of instrument limitations). They learn that round star images mean a good plate, assuming, of course, that the telescope was aimed at the correct field!

After developing their plates, SSPers squint at what looks like a piece of fly-specked milk glass, searching for their quarry. Using star charts, sky photographs, and printouts from *TheSky* planetarium software (which the SSP also uses for remote CCD observing at Mount Wilson), they finally confirm that, yes, this seemingly insignificant dot is not a piece of dust or a flaw in the emulsion but the real thing.

Dominating the last two weeks of SSP is the orbit determination (OD), much of which involves writing a computer program for the complex set of calculations. Although all SSP students are computer savvy, most have never actually written a program. For some, this turns out to be an especially challenging part of the curriculum.

Most teams obtain reasonably accurate OD results, but occasionally teams must reexamine their measured data (the right ascension and declination coordinates obtained from a least-squares plate reduction), often leading to the discovery of systematic errors in reading the measuring engine's vernier scales. Eventually, almost all teams obtain physically reasonable orbital elements, even if it means round-the-clock reassessment of measurements and project methodology. (SSPers are warned before arriving that they may return home sleep deprived.)

SSP's OD focus has multiple benefits. Astronomy is a fascinating topic to many students, yet it is rarely taught formally in high schools. Understanding OD requires mathematical and physical concepts that have applications across many disciplines. The entire process — theory, observation, and data analysis — can be accomplished in six weeks (barely) and involves each student personally in every step.

A Transforming Experience

About twice a week a guest lecturer from NASA's Jet Propulsion Laboratory (JPL), various universities, or private industry

gives a formal presentation and then spends several additional hours working directly with the students, answering their questions and informally discussing a variety of topics. Guest speaker Paul MacCready, a human-powered-flight innovator, is an all-time favorite. So is Maarten Schmidt, the discoverer of quasars, who first lectured in 1960 and has been invited back almost every year since.

The academic curriculum includes 140 hours of lectures by the staff: 30 percent in mathematics, 30 percent in physics, 25 percent in astronomy, and 15 percent in allied disciplines. Depending on the staff's personal interests, topics as diverse as plate tectonics, petroleum genesis, environmental engineering, hurricanes, and the worldwide eradication of smallpox may also be discussed.

All faculty members live on campus, interacting with students around the clock — at the telescopes and measuring engines, at the light tables in the chart room, in the computer lab, and at meals. Field trips to Mount Wilson and JPL in Pasadena, beach outings, nature hikes, various sports activities, parties, a student talent show, and a long-standing tradition of intelligent pranks perpetrated by and against the teaching assistants round out the program.

The SSP encourages its graduates to continue their research projects after they leave, and two 1999 alumnae received na-



SSP 2000 students Eric Ma, Mika McKinnon, Tim Lu, Anya Li, and Meredith Hughes (left to right) pore over pages of asteroid ephemerides, trying to decide which asteroids to observe and study that summer. The program's academic curriculum also includes classroom lectures on such subjects as calculus, computer programming, and cosmology. Photograph by John C. Rabold.

tional recognition: Maryland's Elizabeth Epstein wrote a paper entitled "Sensitivity of Gaussian Orbit Reduction to Time Spacing" that got her named as one of the 40 finalists in the 2000 Intel Science Talent Search, and Michigan's Tiffany Titus garnered second place in the Astronomical League's National Young Astronomer Award for her paper entitled "De-

termining the Orbit of 737 Arequipa" (*S&T*: September 2000, page 87).

Of the SSP's nearly 1,500 graduates, ranging in age from high-school seniors to grandparents, most stay in touch with the staff, and about a third of them donate money to help subsidize the program's expenses. Many alumni and alumnae cite SSP as a turning point in their lives. Mitchell Kapor (SSP '66), founder of Lotus Development Corporation, wrote: "The SSP was a major positive influence in my life." Douglas Duncan (SSP '68), formerly the American Astronomical Society's national education coordinator, said: "The SSP is the best of any precollege program in the U.S. that I know of." And in 1999, graduate student Andrew West (SSP '94) wrote: "I owe a lot of where I am today to the SSP. I'm slated to become the first person in my entire extended family to obtain a doctorate degree."

The program can also have a transforming effect. SSPers find themselves surrounded by their intellectual peers, an experience that is both humbling and exhilarating. Instead of coasting, they find themselves racing to keep up; instead of competing for grades, they work in teams, helping one another. As a commitment to the principle of knowledge for knowledge's sake, the SSP gives neither academic grades nor formal credits. The program teaches talented kids how



The SSP class of 2000 at Happy Valley School. During the program, admission officers and representatives from various universities meet with the students to discuss college choices and applications, career planning, scholarships, and research opportunities. Photograph by John C. Rabold.

much they are capable of accomplishing when they are truly challenged, and how much fun that can be.

Transition

As remarkably stable as the curriculum has been, in 1999 the SSP underwent an organizational change that threatened its continued existence. Its former students came to the rescue.

From 1959 to 1999, the program was housed, administered, and underwritten financially by Thacher School, a venerable boarding school in Ojai. For a variety of reasons, however, Thacher decided it would no longer host and underwrite the event. Upon hearing the news, a group of SSP graduates banded together and created a nonprofit corporation to raise funds. For SSP 2000 the venue was moved to Happy Valley School, a nearby boarding school.

The SSP may now be the only summer education program controlled and managed by its graduates, acting as volunteers. Its independence presents new opportunities to extend its benefits to more than three dozen students a year. Space exploration is high in the public and academic consciousness. And, just as in the late 1950s, there is now an intense concern about the weakness of American science education. But there are remarkably few programs designed for the exceptionally bright students who can lead the way in scientific and commercial innovation. The SSP is currently investigating the possibility of expanding its activities by adding more sites, as well as extending its curriculum, perhaps into radio astronomy.

Open Season

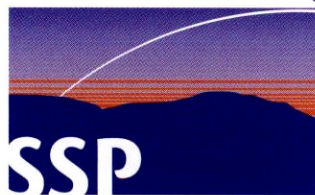
The SSP is open to academically qualified students worldwide who want to spend a memorable summer learning science by “drinking from a firehose.” The program is now accepting applications for this year’s summer session, which takes place June 24th to August 5th. The program’s fee is \$2,650; financial aid is available, based on the applicant’s needs. For more information visit www.summerscience.org or contact the SSP at 9198 Skyline Blvd., Oakland, CA 94611-1748; 510-333-2112; info@summerscience.org.

SSP academic director and college professor TRACY FURUTANI was an SSP student in 1979. He returned to Ojai in order to learn the bits that he didn't understand the first time around. He can be reached at tfurutani@summerscience.org.

We encourage high school teachers and students to learn more about The Summer Science Program by visiting www.summerscience.org

Program fees paid by students and their families cover less than half of SSP's costs. Donations from alumni, other individuals, businesses, and foundations make up the difference. Please contact us to discuss how you (or your organization) can help SSP fulfill its mission of inspiring bright young people to reach for the stars.

www.summerscience.org



Summer Science Program, Inc.

The Summer Science Program is established in cooperation with the California Institute of Technology, Pomona College, Harvey Mudd College, Stanford University, and UCLA, and is an accredited observing affiliate of the Harvard-Smithsonian Center for Astrophysics.

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