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The UCI COSMOS Astronomy & Astrophysics Cluster: A Summer Program for Talented High School Students

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Abstract. COSMOS is a month-long, summer residential program in science and engineering for high school students held each year at four University of California (UC) campuses. Its goals are to expand the scientific horizons of our most talented students by exposing them to exciting fields of research and encouraging them to pursue STEM careers. Students live on campus and choose to study one of seven or eight different subject areas called "clusters." We run the extremely successful Astronomy & Astrophysics Cluster at UC Irvine (UCI). Over four weeks, students take lecture courses in astrophysics, perform computer lab experiments, and complete a research project conducted in a small group under the supervision of a faculty member or teaching assistant (TA). Here we discuss our curriculum, lessons learned, and quantify student outcomes. We find that putting on a summer program for high school students is highly rewarding for the students as well as the faculty and graduate students.

1. Introduction

The California State Summer School for Math and Science (COSMOS) was designed to give California high school students who are exceptionally talented in math and science an opportunity to learn about STEM fields they normally would not encounter in their high school curriculum, to expose them to exciting research, and to motivate them to pursue STEM research careers. Each summer COSMOS is held at four UC campuses (Irvine, San Diego, Santa Cruz and Davis) with seven or eight different subjects offered at each campus. Details include:

- Approximately 150 students attend the UCI COSMOS program each year.

- 23 students enrolled in the UCI Astronomy & Astrophysics Cluster in 2012 (see Figure 1a). They were all high school seniors with an average GPA of 4.3. They were 50% male and 50% female, and they came from families that span a wide range of ethnic, socioeconomic and geographic diversity.

- Students live on campus for the four weeks of COSMOS. In the dorms they are supervised by Resident Assistants (RAs), who are UCI undergraduate students. COSMOS students get valuable insight into what college life will be like.

- Tuition was $2,810 per student in 2012. COSMOS is funded by the state of California and scholarships grants to students are funded by private donations.

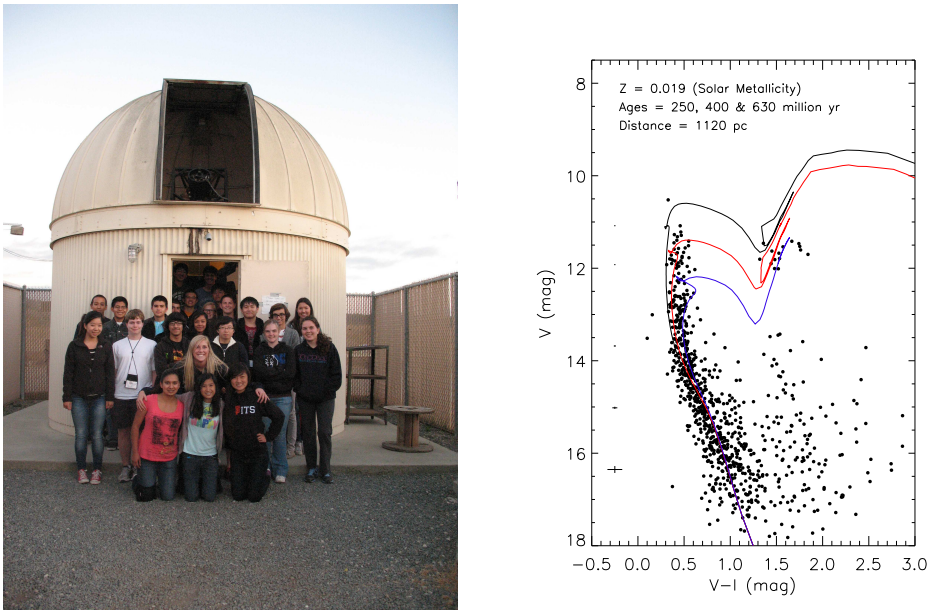

Figure 1. *Left:* The COSMOS students and Teacher Fellow in the Astronomy & Astrophysics Cluster in 2012 at the UCI Observatory. *Right:* A color-magnitude diagram for the open cluster M11 produced by students in 2012 overlayed with Padova isochrones from which they derived the cluster's distance and age.

Approximately 30% of students receive some form of financial scholarship, either 25%, 50%, 75% or 100% of the cost of tuition.

• Each subject cluster receives 2 months of faculty salary with a maximum cap of $20,000. We also receive $6,000 for graduate student salaries.

2. Astronomy & Astrophysics Cluster

We run the Astronomy & Astrophysics Cluster in the UCI COSMOS program. Our course includes four key components: (1) lectures from two faculty members on astronomy and astrophysics based on an introductory astronomy textbook entitled *21st Century Astronomy*, (J. Hester et al., 2010), (2) Contemporary Lab Exercises in Astronomy (CLEA; Marschall, et al. 2012) performed in the computer lab under the direction of three graduate student TAs, (3) a research project done by groups of two or three students led either by a faculty member or a graduate student TA, and (4) a technical writing class taught by our Teacher Fellow, a local high school teacher hired to work with our cluster and chaperone the students during the day.

2.1. The Research Projects

A key component of our cluster is that students do realistic research projects in astrophysics either with data they themselves take at the UCI Observatory or with data taken in the past by others conducting research with larger telescopes. Students greatly enjoy

using our advanced technology (telescopes, CCD cameras and spectrographs). They learn about basic observational techniques in astrophysics: astrometry, photometry and spectroscopy. While learning a lot about a specific subject, they also learn what scientific research is all about. The research projects we offer are shown below. Those that use data taken with UCI Observatory telescopes are labeled "UCIObs."

- Students image Jupiter or Saturn with an 8-inch telescope to measure the orbital properties of their brightest moons and derive the mass of the planet (UCIObs).

- Students image preselected regions of the sky, discover asteroids in them, and calculate the asteroids' motion (UCIObs).

- Students image an open or globular star cluster with the 24-inch telescope to derive its distance and age using isochrone fitting; see Figures 1b (UCIObs).

- Students image an eclipsing binary over a full period to determine the stars' temperatures, radii and masses (UCIObs).

- Students obtain spectra of stars to determine their spectra types based on the strength of absorption lines and estimate the stars' masses (UCIObs).

- Students measure the rotation curves of spiral galaxies using the Halpha emission lines in spectra of spiral galaxies to deduce the amount of dark matter in them.

- Students use images to count the number of galaxies as a function of their magnitude to determine whether or not space is Euclidean.

COSMOS students analyze their data, derive results and make their conclusions then collaborate on writing a poster paper, using Powerpoint, to convey their results. They present their poster papers on the last day of the program at sessions open to all 150 students in COSMOS, as well as their parents and families. In creating the posters, students reflect on and synthesize what they learned and get the message that scientific research is something they themselves can do.

3. Important Lessons Learned

We have learned some important lessons over the 12 years we have run the Astronomy & Astrophysics Cluster. First, this cluster consistently has been the most popular UCI COSMOS course each year. The oversubscription rate is so large that this year we only accepted students who would be entering their senior year in high school in the Fall. Nearly all of our students are interested in majoring in astronomy, astrophysics, physics, or aerospace engineering when they attend college. Second, we have learned that these high school students are extremely motivated and enthusiastic about learning astrophysics. Both faculty and TAs find that COSMOS has been their most rewarding and enjoyable teaching experiences. Third, these high school students are very capable of working on basic astrophysics research under the guidance of our faculty and graduate student TAs. Graduate students benefit, too, by learning about research in areas different than their individual Ph. D. research. This has been particular beneficial since many of our COSMOS TAs have gone on to become faculty at colleges and universities

where they are expected to get their students involved in research. Last, but not least, motivated by the success of our COSMOS research projects and the enormously positive effect is has had on our COSMOS students, we designed and implemented a new required laboratory astrophysics class for junior/senior undergraduates physics majors specializing in astrophysics. Therefore, our experience teaching talented high school students has had a positive effect on our undergraduate physics majors' curriculum.

4. Student Outcomes

To evaluate the effects we had on students, we surveyed them on the last day of the program in 2011 and 2012 and asked them to anonymously respond on a Likert scale to a number of different statements. With 32 students responding, our response rate was 74%. Students picked a number that corresponded most closely to their feeling about each statement. The response choices were: 1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, and 5 = Strongly Disagree. The average, median and the standard deviation of their responses to the some statements are shown below.

Statement	**Student Responses:**		
	Avg	**Median**	**StDev**
1. I would recommend COSMOS to other HS students.	1.32	1.00	0.48
2. COSMOS showed me that research was something I could do.	1.97	2.00	0.82
3. COSMOS had a positive influence on the choice I will make for my major in college.	1.69	2.00	0.78
4. COSMOS inspired me to have a career in astronomy, astrophysics, physics or aerospace engineering	1.69	1.00	0.90

Clearly our COSMOS students have benefited greatly from the program. Students go back to their high schools and tell their fellow students and teachers about their amazing experience. As word of mouth continues to spread, our oversubscription rate increase as does the quality of our students.

5. Further Information

We would be happy share our syllabus, curriculum, student and TA lab manuals, etc. with others. Contact Tammy Smecker-Hane at tsmecker@uci.edu with inquiries. More information also lies at http://www.physics.uci.edu/~observat/cosmos_index.html.

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