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# Developing an Undergraduate Astronomical Research Program

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## Abstract

Time-series astronomical photometry is an area of scientific research well suited to amateurs and undergraduates, and their backyard and campus observatories. I describe two past one-semester community college research programs, one six years ago and one last fall (2006), as well as a program planned for this coming fall (2007). The 2001 program, a course at Central Arizona College, utilized a robotic telescope at the Fairborn Observatory. Results were presented at the 200<sup>th</sup> meeting of the American Astronomical Society. This past fall, three students, in a 17-week, one-semester course at Cuesta College, were able to plan a research program, make several thousand CCD photometric observations, reduce and analyze their data, write up their results and, on the last day of class, send their paper off to a refereed journal, the *JAAVSO*. A course is being offered this coming fall (2007) that will involve about a dozen students (including high school students), several local amateur astronomers, and at least three CCD-equipped semi-automatic telescopes. Potential solutions to “scaling up” challenges created by increased class size are discussed.

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## 1. Amateur Research

Two decades ago, at the Eighth Annual Fairborn-IAPPP Symposium, *New Generation Small Telescopes*, held at the Saguaro Lake Ranch in Arizona, Robert A. Stebbins, a sociologist from the University of Calgary, stated the following:

In the wider community, the thought that amateurs might contribute anything other than, perhaps, money and goodwill to professional science is only slightly less than preposterous. Science, according to the popular conception, is a highly technical and oftentimes abstract undertaking mastered only by [those] with a unique bent for intellectual esoterica and a passion for such cloisters as the library and the laboratory. The scientist is a special strain of humanity who develops into a social curiosity after years of specialized education and unstinting dedication to the solutions of problems so arcane that the average citizen can only marvel at their incomprehensibility. This is the public’s image of science and the profession of scientists.

That some people might try from time to time to enter this lofty realm purely for the fun of it, for leisure, is even more inscrutable than science itself and the professionals who work there. And when some of these leisure-seeking “eccentrics” indicate that they occasionally contribute something new to the science they are pursuing, the man in the street is more likely than not to disintegrate in utter disbelief. Science is for the spectacled, half-bald, wild-eyed genius, not for the ordinary being who lives next door. (Stebbins 1987.)

Stebbins went on to remark that “notwithstanding these stereotypes, amateur scientists abound.” He suggested they had, over the years, “made important contributions to archeology, ornithology, and astronomy.”

Almost a decade before the conference at Saguaro Lake Ranch, I had conducted my own informal survey of amateur science and had selected astronomy as the field most likely to result in published papers—the hallmark of science. I had examined every paper in five years of a leading publication, the *Astronomical Journal*, asking myself, as I reviewed each paper, could I have accomplished this research? Writing many of the papers would have required a theoretical background beyond my grasp, while others would have required making observations through telescopes much larger than I could afford to purchase or build. Over two-dozen papers caught my attention, however. All were photoelectric observations of variable stars or asteroids with telescopes of 16-inch aperture or less.

It should not have been surprising that time-series photometry appeared to be the major contribution of smaller telescopes to astronomical science. Photometry makes efficient use of the meager photons available to smaller telescopes, while time-series observations are well suited to those who operate their own observatory.

## **2. Undergraduate Student Research**

The public perception of undergraduate student researchers is similar to its perception of amateur researchers. It is, of course, well accepted that graduate science majors should conduct research. In fact, they must prove themselves capable of original research if they are to receive a doctoral degree. But it is not widely recognized, as is the case with amateurs, that undergraduate students, including non-science majors, are quite capable of conducting scientific research and that they, their schools, and their local communities—not to mention the larger scientific community—all benefit from undergraduate scientific research.

While it is entirely appropriate that undergraduate students should learn the essentials of one or more of the sciences in lecture courses, as well as master basic laboratory skills while conducting “experiments” with known outcomes, they may, in this process, obtain a distorted view of science and scientists. Science, after all, is primarily concerned with the unknown, not the known. While it could be argued that science majors will, soon enough, be exposed to research in graduate school, might they benefit if exposed to research while still undergraduates? Would non-science undergraduate majors gain an entirely different impression of science if they participated in actual research?

An increasing number of schools recognize the positive contributions undergraduate research can make to student learning and the furtherance of the true spirit of science—exploration of the unknown—on the campus and also within the local community. In this paper I discuss my own experience with undergraduate research at community colleges.

## **3. Research Program I: Cepheids**

Six years ago, while teaching astronomy and mathematics at the Superstition Mountain campus of Central Arizona College, I organized, with the assistance of Cheryl Genet, a one-semester astronomical research class (Fall 2001). Nine students were formed into three teams. All three teams chose to observe bright Cepheid stars using a robotic telescope at the Fairborn Observatory in southern Arizona.

Astronomer Kenneth Kissell discussed the project with the students during several conference calls and assisted them in selecting appropriate Cepheids. Michael Seeds, the Principal Astronomer for the Phoenix-10 robotic telescope at the Fairborn Observatory, also spoke with the students during conference calls and helped them with their observational requests. Douglas Hall aided the students in selecting

appropriate comparison and check stars, while Louis Boyd operated the robotic telescope.

The Phoenix-10 robotic telescope obtained the student-requested UBV photometric observations of the selected Cepheids. Results became available toward the end of the semester and, in several late-night sessions, the students tabulated and plotted differential magnitudes as time series which, of course, appeared quite random. They then produced phase plots and, as if by magic, the Cepheid lightcurves appeared. They were most impressed!

One student, only 16 years old at the time, presented his results on T Vul at the 200<sup>th</sup> meeting of the American Astronomical Society (Lappa 2002). Cheryl Genet presented her results on U Aql (Genet 2002) at the same meeting, while Cheryl and I described the research course itself (Genet and Genet 2002).

## **4. Research Program II: GNAT**

The following year, Cheryl and I moved to California’s Central Coast (near San Luis Obispo) to be near her aging parents. I established the Orion Observatory and equipped it with a 10-inch Meade LX-200 telescope and SBIG ST-8 CCD camera. Thomas Smith, at the nearby Dark Ridge Observatory, and I collaborated in observations of short-period W UMA eclipsing binaries. I also taught introductory astronomy part time at nearby Cuesta College,

Cuesta College seemed to be an appropriate venue for another community college astronomical research course, and I was allowed to offer such a course as a physics research seminar in the fall of 2006. Three students—Neelie Jaggi, Casey Milne, and Noll Roberts—worked together as a team to obtain lightcurves and determine the periods of GNAT MG1 catalog stars whose periods, due to heavy aliasing, were unknown. CCD photometry was obtained on nine MG1 stars at the Orion Observatory. Two were found to be continuously variable, and their periods were determined with precision. The students wrote up their results, obtained reviews, and submitted their paper to the *Journal of the American Association of Variable Star Observers*, a respected, refereed journal, for the editor’s consideration (Roberts et al 2006). This research was also summarized at the 209<sup>th</sup> meeting of the American Astronomical Society (Roberts et al 2007).

The three keys to the student’s success were: (1) the considerable help of an experienced local amateur astronomer, Thomas Smith; (2) suggested observational candidates, assistance, and visits by the director of the Global Network of Astronomical Telescopes (GNAT) program, Eric Craine, and (3) much

hard work by the students themselves. Cuesta College faculty and staff were very supportive of this “pilot” program, although it was understood that any repeat of the course, to be viable, would need to enroll a dozen students.

## 5. Research Program III: Scaling Up

Cuesta College has scheduled a second physics research seminar for this coming fall (2007). We plan, again, to observe potential short-term variables selected from the GNAT MG1 catalog. We also plan to obtain an asteroid lightcurve and determine its rotational period. This research seminar should involve about a dozen students (including a few high school students and several local amateur astronomers) and several CCD-equipped, semi-automatic telescopes. Potential solutions to problems in “scaling-up” last fall’s pilot program are discussed below.

A single research team of a dozen or more students would be unwieldy, so the research seminar will be organized around multiple teams—each provided with the use of its own CCD-equipped, go-to telescope. A student, Brittany McCrigler, loaned the Orion Observatory a Meade 12-inch LX-200, and the observatory supplied a permanent pier, equatorial wedge, and guidescope for this telescope. Two additional CCD cameras with built-in B, V, and I filters (SBIG ST402) were purchased with funds granted by the American Astronomical Society. James Carlisle, at the Hill House Observatory in nearby Atascadero, recently purchased a Meade 14-inch RCX 400 telescope and SBIG ST402 camera. He will make these available at his observatory to one of the teams. Finally, Tom Smith will be providing time (remotely) on his 14-inch LX-200 GPS telescope from the Dark Ridge Observatory’s new home under the clear skies of New Mexico.

Last fall, the single team with just three students was able to use the computer and software at the Orion Observatory for data reduction and analysis, although this required considerable student travel. Such an arrangement would be cumbersome for a seminar with a dozen students, multiple teams, and telescopes at several different locations. It would be more efficient for each student to have reduction and analysis software installed on their own laptop computer, which they could take to the weekly seminar meetings for software instruction, to observing runs to retrieve data and, of course, to their homes for data reduction and analysis.

There are many excellent software programs available for the reduction and analysis of time-series CCD photometry that can be installed on laptop PCs. These include Maxim-DL, AIP4WIN, CCD Soft, and

MIRA. In choosing software for this coming fall’s research seminar, two factors were paramount: (1) completeness in terms of reduction and analysis for both variable star and rotating asteroid time-series photometry, including period determination; and (2) low cost per student. MPO Canopus/Photometric Reduction software was chosen for the seminar this coming fall. It met our technical requirements and its cost (educational license for five students) is only \$13 per student.

Last fall, students learned the basics of CCD photometry and lightcurve analysis through informal discussions at the Orion Observatory. The seminar this coming fall will, instead, meet formally every Monday evening at Cuesta College where students will learn the fundamentals of time-series photometry via lectures. A textbook, *A Practical Guide to Lightcurve Photometry and Analysis* (Warner 2006), will provide the essentials of variable star and asteroid time-series CCD photometry and analysis. This book is available from Amazon for less than \$40.

This coming fall’s research seminar will not only include Cuesta College students taking other courses at the college, but also a number of high school students enrolling in this research seminar as their first college course. In addition, several seasoned observers—members of the Central Coast Astronomical Society—will be enrolling in the course. Finally, we expect a few undergraduate students from California Polytechnic State University to participate. The mix of high school students, community college students, university undergraduate students, and local amateur astronomers should not only be enriching to all concerned, but should help to inform and involve the local community with respect to the rewards (and tribulations) of scientific research.

Three preparatory activities are being undertaken prior to this fall’s research seminar. They are: (1) an informal spring student research effort; (2) a conference, *Time Series Astronomical Photometry*, 22-24 June, at California Polytechnic State University; and (3) a two-day training workshop on MPO Canopus/Photometric Reduction software that will be taught by Brian Warner July 27-28 at a workshop in Ft. Collins, Colorado.

## 6. Conclusions

Amateurs, undergraduate college students, and high school students are quite capable of scientific research and have, for years, been successfully completing projects resulting in published papers. Time-series CCD photometry of intrinsically variable stars, eclipsing binaries, asteroids, and planets transiting distant stars are a particularly fertile area for such

research because the combination of compact Schmidt-Cassegrain go-to telescopes, highly sensitive CCD cameras, and very capable personal computers has transformed backyard and college campus observatories into powerful scientific research facilities.

Large-scale automated surveys at a number of professional observatories have uncovered tantalizing hints of astronomical objects whose true nature can be determined through the dedicated time-series CCD photometry that properly-equipped amateur and campus observatories can provide. Affordable, high-tech telescopes, cameras, and computers have opened the door wide to amateurs and students who wish to conduct cutting-edge scientific research.

Of course there is a catch—there always is! Science is never easy. A basic understanding of CCD photometry of variable stars and asteroids is required. CCD time-series photometry also requires understanding and operating highly complex (albeit affordable) equipment. Observations must be made for many hours on multiple nights. Gigabytes of data have to be reduced and analyzed with sophisticated software. Finally, results must be described in a paper, the paper reviewed by outside experts, rewritten, and submitted for publication. In the upcoming Fall 2007 research seminar discussed above, all this will, as in last fall's course, have to be accomplished by busy students within the confines of a single semester.

Although daunting, the rewards of successfully completed undergraduate (and high school) research are significant. As coauthors of published scientific research papers, students not only receive a boost with respect to their future educational opportunities, but gain an understanding of the true nature of science and an appreciation of how research is actually conducted. The word gets around; there are other areas besides football and basketball where students can shine!

## **7. Acknowledgements**

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