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Observational Research for All Students

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Abstract

Undergraduate Research Studies in Astronomy (URSA), a Web-based robotic observatory, has been in use for almost a year as part of an introductory astronomy laboratory for non-majors. The system was constructed from off-the-shelf components at a cost of around $25,000. About 500 students per year use URSA to do research-based mini-projects that follow a particular learning cycle model. Over 114,000 images have been obtained by the system to date for student and faculty research, some of which has been published. We discuss some of the lessons learned in this implementation and the extent to which our goals are being realized.

Because I am an avid observational astronomer, I want all of my students to experience for themselves the thrill of doing their own observational research. That is really the basic goal of this project. It is a worthy goal because at least some of those students will become so interested in observational work, they will want to continue to learn about astronomy, and all of the students will learn how to think scientifically about many kinds of questions. The main problem with achieving this goal is that there are about 500 students per year taking undergraduate astronomy courses at the University of Arkansas, most of them in the introductory descriptive course. There is no way to teach each individual student how to set up and use a telescope and camera system; it would take an army of teaching assistants and a football field full of equipment. My solution to this challenge is to create a Web-based robotic telescope imaging system that is as easy as possible to use, yet produces research-grade images.

I am not the first person to build a Web-based telescope. Several automated observing systems have been developed previously in the United States, three of which (the University of Iowa, the University of California at Santa Barbara, and the University of California at Berkeley) currently offer limited observing time to the general Internet community. Robert L. Mutel of the University of Iowa has developed such a system, which has both imaging and spectroscopic capabilities (Mutel 2002). The main advantage of my design is that it is made from relatively inexpensive, off-the-shelf hardware. The telescope is a Meade

LX-200 10-inch f/6.3 mounted equatorially on a Superwedge; the camera is a Santa Barbara Instruments Group (SBIG) ST8 with UBVRI filters in a CFW8 filter wheel; the dome is a Technical Innovations Robo-Dome; and the control computer is an Apple PowerMac G4 (see Figure 1).

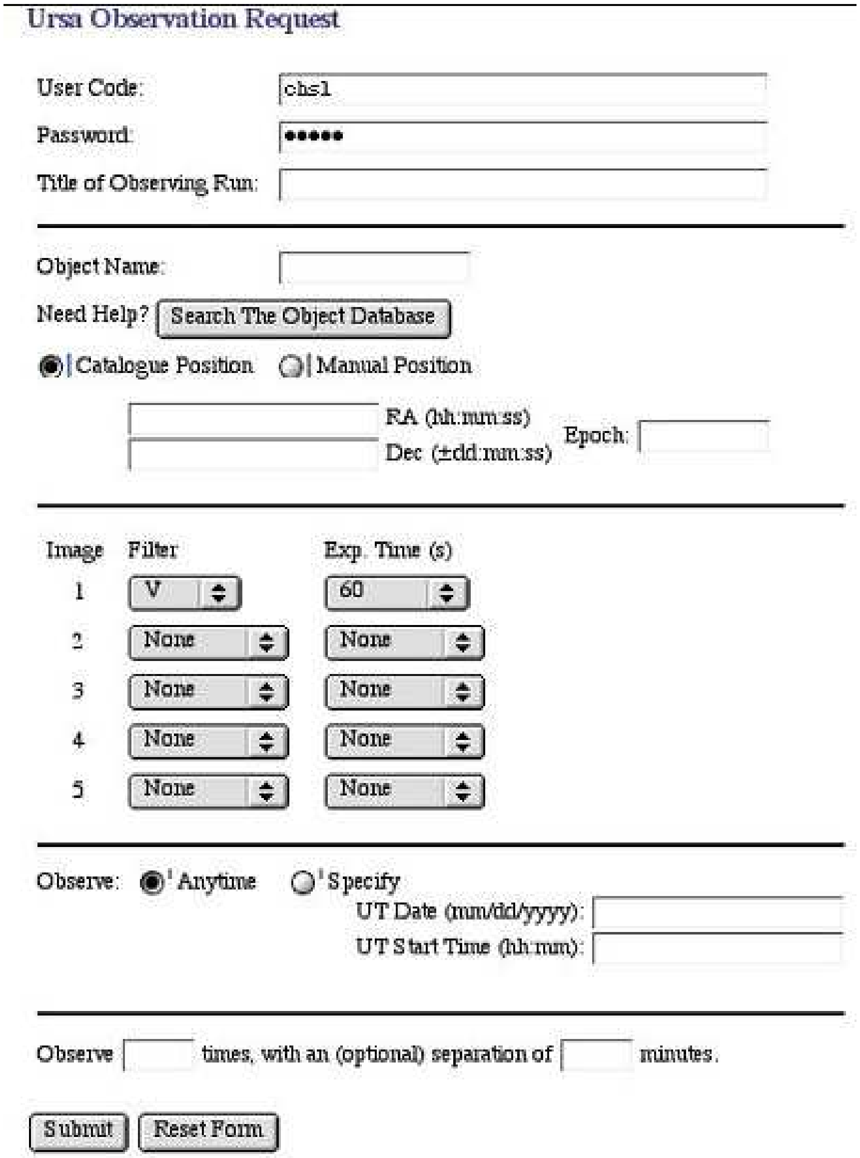
Figure 1. The URSA robotic observatory

Our field of view is 20 x 30 arcminutes, about the size of a first-quarter Moon (see Figure 2).

Figure 2. An URSA image in V of M34, an open cluster we are monitoring for extrasolar planetary transit events

Because of imperfect optics and building vibrations, our image resolution is about 4 arcsec at best. The hardest part of the project was writing and debugging the software to control the observatory. This was written by me in FutureBasic for telescope and dome control, by my graduate student Jeffrey Sabby in C++ for camera control, and by my colleague Tamera Snyder in RealBasic for the Web interface. It does take considerable effort to keep the observatory running; every major piece of hardware has broken and been fixed at least once.

This is how the system works: The authorized student accesses a server (http://ursa.uark.edu), logs in, and then requests observations by filling in the edit fields of a Web page. Objects may be selected from standard lists (Messier Objects, Globular Clusters, Galaxies, and so on), or they may be specified by coordinates. The user must select filters and exposure times, choose the number of exposures and spacing, and specify whether the exposures may be made anytime or at a specific time and date (see Figure 3).



Ursa Observation Request

User Code: chsl
Password: •••••
Title of Observing Run:

Object Name:
Need Help?
● Catalogue Position ○ Manual Position
RA (hh:mm:ss)
Dec (±dd:mm:ss)
Epoch:

Image	Filter	Exp. Time (s)
1	V	60
2	None	None
3	None	None
4	None	None
5	None	None

Observe: ● Anytime ○ Specify
UT Date (mm/dd/yyyy):
UT Start Time (hh:mm):

Observe times, with an (optional) separation of minutes.

Figure 3. The URSA image request page by which observing requests are made

When the system has completed the observations, it automatically notifies the user by email. The user then accesses the Web site to retrieve the observations. The resulting images are in standard SBIG compressed format and may be specified for either Macintosh or Windows operating systems. The free image viewing software may be obtained from http://www.sbig.com. If you want to try it out, just log on to http://ursa.uark.edu as *guest* and use the password *astro*. Include your email address as part of the run ID, and I'll let you know when it's ready. We do not allow general Internet users at this time.

Each night, I personally make the decision whether the telescope should observe. So far, we've only been rained on (just a little bit) once. If the telescope will observe, I run a scheduling algorithm. Even at the peak time of the semester, there are fewer requests than available observing time (several hundred observations), so after the Web requests are scheduled, any remaining time is automatically allocated for my background science projects (currently to get light curves for about three dozen eclipsing binary stars). We literally do not waste more than a few minutes of observing time per night. So far, we have accumulated 114,000 images occupying 45 GBy of storage on a high-capacity FireWire hard drive. (Images are also backed up.) About half of the nights are usable here at Fayetteville, but there are at least some clouds on about half of the usable nights. We just detect when the clouds were there after the fact while doing photometric reductions, and eliminate the unusable data then. We average 38% of the nighttime hours as photometric.

The quality of the image data acquired can be assessed from the results of differential photometry of eclipsing binary stars and comparison stars in the same frame. The images are background-subtracted and flat-fielded automatically by a virtual measuring engine (*Measure*, available at http://ursa.uark.edu), then the target objects are located automatically and differential magnitudes are measured. The virtual measuring engine processes the frames at a rate of about two per second on a 450 MHz G3 iMac. For magnitude 10-11 objects, the standard error is about 0.007 mag. Results for the eclipsing binary star WW Cam have been published (Lacy et al. 2002). Twenty-five point normals and the fitted light curve model are shown in Figure 4.

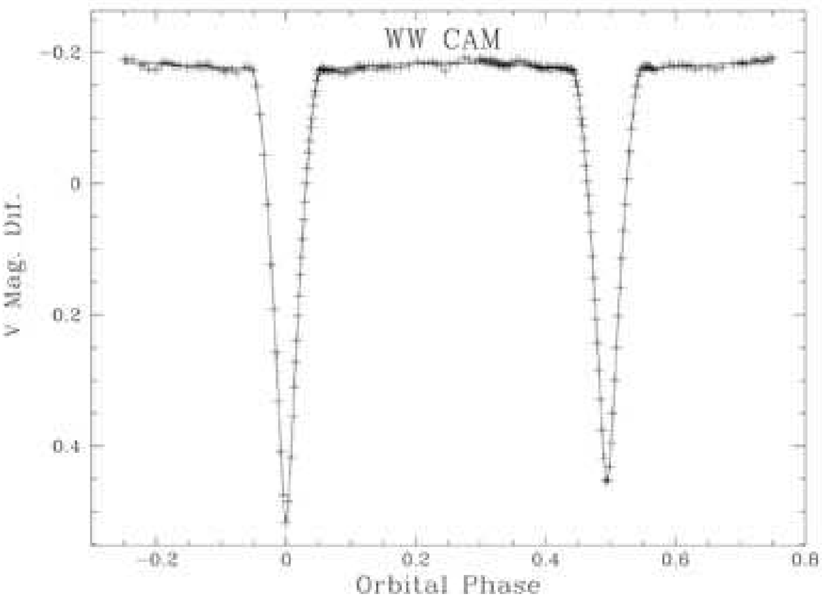


Figure 4. The light curve and fitted photometric model for WW Cam based on URSA observations over a four-month period in 2000-2001

We set a record in that work for the number of points in a light curve obtained in less than one observing season (5,759 observations). Other observational publications resulting from this work, most of them with student co-authors, are: Lacy, Hood, & Straughn (2001); Torres et al. (2001); Lacy, Straughn, & Denger (2002); Lacy, Torres, & Guilbault (2002); Lacy (2002); Sabby & Lacy (2003); and Lacy & Grimes (2003).

The URSA project seeks to serve several student audiences simultaneously: (1) beginning students in the introductory lab; (2) intermediate-level students in the junior-senior level courses; and (3) advanced/honors students doing more ambitious projects. Our goal is to serve all levels of students by requiring participation in appropriate research projects. Early in each semester, students are introduced to observing methods and shown sample projects of the appropriate level. They can choose one of the outlined projects or propose one of their own devising for completion during the semester. The type and complexity of appropriate projects vary with the students' preparation. One must understand a great deal of astronomy just to decide if a potential target will be accessible to the observing system at the desired time of observation. A planetarium simulator like Voyager II is the appropriate tool, and it is now the major piece of software being used by students in the introductory lab course. Determining an appropriate filter and exposure time also requires learning something about technical matters, like magnitudes and color indices. Just working through this selection process to request an observation and getting an acceptable result is interesting, and in the end exciting. With the addition of a few simple measurements and analysis, this in itself is enough for a raw beginner.

An example of such a simple project appropriate for beginners is estimating the distance to a globular cluster by measuring its angular size. An outline of the project is provided to the student. Students are first asked to sketch the galaxy and show where globular clusters are found (they may consult their textbooks or other sources for this information), show a distance scale, and give a rough estimate of the range of distances to typical globular clusters based on the sketch. Once the student has submitted an observing request and obtained a well-exposed image, he or she may measure the cluster's size in pixels with any image analysis software, such as CCDOPS from SBIG (which is free). The student must then convert this size in pixels into an angular size by: (1) computing the image scale from the focal length of the telescope and the linear size of a pixel; and (2) estimating the cluster's distance by using the small angle equation, assuming a canonical value for a globular cluster's size (5 pc, say), which is an equation discussed in the associated introductory lecture class. The students are then asked to compare their answers with their original rough estimates based on their drawings, and if they differ significantly, to try to explain why. Note the learning cycle of prediction, observation, and comparison, which is used in all of our undergraduate research studies. I believe that the use of this interactive engagement learning cycle will optimize student learning at all levels. This teaching style also serves as a good model for the teaching majors in our classes (about 30 per year) to adopt. These teaching majors are encouraged to continue using URSA after they become in-service teachers. We have several high school teachers now using URSA. As an outreach effort, we plan to advertise the availability of URSA to regional high school science teachers and encourage them to make use of URSA in their classrooms.

There is good evidence that introducing research studies throughout the astronomy curriculum will lead to improvements in the quality and quantity of undergraduate majors, and will improve non-majors' understanding of astronomical research. In their recent study, McCullough & Thakkar (1997) found strong supporting evidence for this belief based on the use of a small (50-mm) automated telescope in their astronomy curriculum at the University of Illinois. There is a long history of studies of the impact of integrating physics experiments into lecture classes (Hake 1998; Thornton & Sokoloff 1998; Arons 1995; Laws 1991). These studies document dramatic improvements in student interest and comprehension of the subject matter when "interactive-engagement" experiments are done in conjunction with the lecture or in place of the lecture, and with a learning cycle of prediction, observation, and comparison. Such results may be expected to occur in our astronomy classes when observational student research studies are integrated into the classes using similar active learning cycle methods, and these improvements at the introductory level are expected to result in increased enrollments in advanced courses, more physics majors, better-prepared teachers, and improved student understanding of astronomy. I have experienced already remarkable gains in the introductory lecture course by adding active learning methods to it (Ebert-May, Brewer, & Allred 1997; Johnson, Johnson, & Smith 1991). My student ratings on Purdue evaluation forms responding to the statement "Overall, this instructor is among the best teachers I have known" almost doubled, from 2.3/5 to 4.0/5. It was with the hope of achieving similar gains in the introductory lab that I embarked on this project.

Appropriate projects for more advanced students require more technical knowledge and often involve repeated observations to measure changes. Thus, the total observing time needed by the advanced students may be as great as for all of the introductory level students, even though there are an order-of-magnitude fewer advanced students. Determining an accurate orbital period or light curve for an eclipsing binary star, for instance, may require hundreds of images obtained over many weeks or months.

What do the students think about these ideas? There have been some surprises. When I first envisioned the project in the fall of 1999, I talked to one of our physics majors, Ben Hood. He had some high-powered scholarships with money for equipment and offered to buy the telescope in order to get the project started! Amazing! I was then able to leverage the department into buying the dome. We were actually able to jump-start building up the observatory before we got grant money from the NSF in 2000. We began fully automated operations, not Web-based at first, in November 2000. Ben Hood was the Fulbright College Valedictorian in 2002.

I first tried out my teaching ideas with a fully Web-based system in the summer of 2002. I talked to the introductory lab class about the project and handed out sample images of pretty things like planetary nebulae, galaxies, and so on. The responses I got were unexpected; basically, the students said, "Is this all you get?" It took me a while to figure out their disappointment, the root of which was black and white images instead of the pretty color images they were used to seeing from the Hubble Space Telescope! I quickly wrote a tri-color imaging application (Tri-Color, available at http://ursa.uark.edu)—then they were happier.

In that first summer, the project descriptions I gave to the students were pretty sketchy, not much more complete than the one on globular cluster distances above. Almost none of them could handle it; they had never been asked to figure out problems that complex before. What they were used to doing was filling in the blanks on a worksheet, so I rewrote the descriptions as fill-in-the-blanks projects—then they were happier. All of our current observational exercises are available at http://ursa.uark.edu.

How does one evaluate the educational merit of a project like this one? We already have had a number of formative evaluations where we tried to determine problems and measure student attitudes. These revealed a number of problems with the procedures and write-ups, but also provided some encouragement. We used a scale where 10 = agree completely, and 0 = disagree totally. To the statement "The URSA telescope performed well, doing just what I wanted," the average response these days is 9.3, which is pretty satisfying. To the statement "My images were of excellent quality," the average response is 8.9, probably because we sometimes do not do an excellent job of temperature-compensated focusing, and the tracking on some four-minute exposures is not always perfect. To the statement, "I enjoyed doing the observational exercises," the average response is 9.1, which makes me very happy! The poorest response, which was to the statement, "It was easy to retrieve my images from URSA," was 8.5, probably because of the restrictions that the Macintosh Multiple Users Mode imposes on the lab’s Web browser. Some of the more favorable remarks from the students include:

"The Observational Labs were better than the normal labs."
"I liked to be responsible for getting my own images."
"It was a good experience."
"It was fun doing the observational exercises."
"It's a really neat program! Thanks for letting us work with it."

My qualitative conclusion is that the project is succeeding at producing many satisfied student users, and that is a gratifying result for me.

Another more quantitative indication of the success of this innovation is that the inclusion of observational research in the introductory lab has resulted in higher ratings for the teaching assistants. The average student rating on the Purdue evaluation form to the statement, "Overall, this instructor is among the best teachers I have known" has increased significantly (0.95 rejection of null hypothesis), from 4.4/5 to 4.7/5. This increase is for the same veteran TA before and after the observational exercises were added, with 86 students. To the statement, "Overall, this course is among the best I have ever taken," the response has improved markedly from 4.0/5 to 4.5/5 (0.99 rejection of null hypothesis, 87 students). Average grades earned by students in the associated lecture part of the introductory course also have improved slightly but significantly, from 2.5/4 to 2.8/4 (0.90 rejection of null hypothesis, 351 students), possibly pointing to better interest and preparation. This is also consistent with my qualitative impression. It is still too soon to know if the number of physics majors has been affected significantly by this experiment. While a full summative evaluation of this teaching innovation will only be possible in the future, initial indications are definitely encouraging.

References

Arons, A. B. 1995, Generalizations To Be Drawn from Results of Research on Teaching and Learning, *Thinking Physics for Teaching*, C. Bernardini, C. Tarsitani, & M. Vicintini (Editors), New York: Plenum.

Ebert-May, D., Brewer, C., & Allred, S. 1997, Innovation in Large Lectures—Teaching for Active Learning, *Bioscience*, 47, 601.

Hake, R. R. 1998, Interactive-Engagement Versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses, *American Journal of Physics*, 66, 64.

Johnson, D. W., Johnson, R., & Smith, K. 1991, *Active Learning: Cooperation in the College Classroom*, Edina, MN: Interaction Book Co.

Lacy, C. H. S. 2002, Times of Minima of Eclipsing Binaries, *Information Bulletin on Variable Stars*, No. 5357.

Lacy, C. H. S., & Grimes, S. 2003, Exoplanet Search and Teaching, paper presented at the conference Scientific Frontiers in Research on Extrasolar Planets, Washington, DC, June 18, 2002. In *Astronomical Society of the Pacific Conference Series*, vol. 294, D. Deming & S. Seager (Editors), in press.

Lacy, C. H. S., Hood, B., & Straughn, A. 2001, Times of Minima of Eclipsing Binaries, *Information Bulletin on Variable Stars*, No. 5067.

Lacy, C. H. S., Straughn, A., & Denger, F. 2002, Times of Minima of Eclipsing Binaries, *Information Bulletin on Variable Stars*, No. 5251.

Lacy, C. H. S., Torres, G., & Guilbault, P. R. 2002, TY Leo Is Not an Eclipsing Binary Star, *Information Bulletin on Variable Stars*, No. 5301.

Lacy, C. H. S., Torres, G., Claret, A., & Sabby, J. A. 2002, Absolute Properties of the Main-Sequence Eclipsing Binary Star WW Camelopardalis, *Astronomical Journal*, 123, 1013.

Laws, P. W. 1991, Calculus-Based Physics Without Lectures, *Physics Today*, 44, 24.

McCullough, P. R., & Thakkar, U. 1997, Stardial: An Autonomous Astronomical Camera on the World Wide Web, *Publications of the Astronomical Society of the Pacific*, 109, 1264.

Mutel, R. L. 2002, Project Rigel: A Progress Report, *American Astronomical Society Meeting 201*, 28, 1.

Sabby, J. A., & Lacy, C. H. S. 2003, Absolute Properties of the Eclipsing Binary Star RT Coronae Borealis, *Astronomical Journal*, 125, 1448.

Thornton, R. K., & Sokolov, D. 1998, Assessing Student Learning of Newtons Laws: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula, *American Journal of Physics*, 66, 338.

Torres, G., Lacy, C. H. S., Guilbault, P. R., Diethelm, R., Baldwin, M. E., & Lubcke, G. C. 2001, The Period of LV Herculis Revisited, *Information Bulletin On Variable Stars*, No. 5201.

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