TOPS Telescope Projects on Variable Stars and Other Objects

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Abstract Teachers and high school students who attended the University of Hawaii's "Toward Other Planetary Systems" workshop in June 2002 gave presentations on introductory telescope projects on lunar photography, variable stars, and Messier Objects at the AAVSO 91st Spring meeting in July 2002. Other participants discussed advanced projects on photometry, CCDs, and spectroscopy. Former student participants presented the discovery of a new variable star and an on-going remote observing project utilizing the Lowell Observatory 31-inch telescope. These various projects are described and/or summarized.

1. Introduction

This paper describes and/or summarizes telescope projects and photometry, CCD, and spectroscopy projects carried out by teachers and students from the University of Hawaii TOPS astronomy summer workshop and given as Powerpoint presentations and/or dramatic skits at the AAVSO 91st Spring meeting. The presenters of each project are given in Table 1. The *Toward Other Planetary Systems* (TOPS) program is a Teacher Enhancement program for high school science and math teachers and high school students, sponsored by the National Science Foundation, the University of Hawaii, and private donors (Meech *et al.* 2000). The program is an intense 3-week in-residence summer program, with pre- and post-workshop activities and classroom integration throughout the year. Participants come primarily from Hawaii and the U. S.-affiliated entities in Micronesia. This year's teachers came from Hawaii, Wyoming, Florida, Oregon, Arizona, and Massachusetts, and participants came from areas including Hawaii, Pohnpei, Palau, and Majuro. The program theme relates to the search for habitable worlds, planetary origins, and primitive bodies. The program goals are to enable teachers to integrate hands-on astronomy into their math and science classrooms, and to give students ideas about careers in astronomy, as well as highlight some of the forefront astronomical research being conducted in Hawaii from the summit of Mauna Kea. A very strong component of the program is the hands-on training through nightly observing sessions, and daytime sessions with the *Hands-on Astrophysics* curriculum developed by the AAVSO (AAVSO 1997).

The Hapuna Beach Prince Hotel donated use of the observing site: its golf course located on the lower flanks of Mauna Kea on the Big Island of Hawaii, a dark

Table 1. Presentations by TOPS participants at AAVSO 91st Spring Meeting.

Presentation	*Participants*
"Messier Objects"	Diane Campbell, middle school science teacher Pebble Richwine, biology teacher Rosa Hemphill, chemistry teacher Timothy Slater, astronomy teacher
"Variable Stars"	Donna Governor, science teacher Pebble Richwine, biology teacher Corey Johnson, student Janelle Bailey, astronomy education graduate student and former TOPS teacher Brian Rogan, physics teacher Janet A. Mattei, astronomer Mike Mattei, optics specialist
"Remote Observing of Variable Stars"	Serena Dameron, student Melissa Ferreira, student Nicholas Bradley, student Jim Bedient, AAVSO mentor
"Discovery of a Variable Star"	Chad Nishizuka, TOPS student Clyde Kobashigawa, TOPS teacher Jim Bedient, AAVSO mentor
"Challenges and an Application of Lunar Photography"	Jeff Giacobetti, elementray teacher Andrea Pisacano, outreach resource teacher Sophie Hu, biology teacher Rosa Hemphill, chemistry teacher
"Photoelectric and CCD Photometry of a Variable Star"	Clyde Kobashigawa, biology teacher Tom Chun, physics teacher Jean Hamai, mathematics teacher Brenda Wolpa, astrobiology teacher Karen J. Meech, astronomer
"Lunar and Stellar Spectroscopy"	Scott Mecca, outreach resource teacher Victor Kim, mathematics teacher John Keller, astrophysics graduate student and former physics teacher
"Star Night VIII—The Worlds Above"	Alyce Ikeoka, elementary teacher Sophie Hu, biology teacher
"TOPS Related Teacher Observations"	Rosa Hemphill, chemistry teacher

isolated area a few hundred feet above sea level, with a flat paved road and facilities, including electrical power (see Figure 1).

For two weeks in June 2002, these participants learned how to set up and polar align telescopes, and were trained in the use of other instruments for the more complex projects. The skill level of the participants ranged from advanced amateurs to complete beginners who had to learn to use star charts to identify constellations and stars. Having only eight evenings of observing to complete their projects made for a challenging program. The TOPS participants appreciated the loan of telescopes from local amateurs who also trained them in the use of telescopes.

Figure 1. *Left:* Unloading the 20+ telescopes from the equipment truck. *Right:* Teachers and students set up for a night of observing at the Hapuna Beach Prince golf course.

Beginners with no telescope experience were assigned to search for Messier objects, or to locate and estimate the magnitude of variable stars. Each group was assigned a mentor with expertise in that field who guided them both with content and observing skills. Many pairs of teachers and students used Dobsonian telescopes with Telrad view finders so technology would not hinder their progress.

The moon, which moved from first quarter to past full during our observing period, provided another team with an opportunity to learn to do lunar photography. This project required technical skills in tracking the moon with the telescope and using the camera. The objective of the project was to use the photographs to calculate the heights of lunar topographic features.

The second group of projects dealt with more technical instruments attached to 8- and 10-inch Schmidt-Cassegrain telescopes for photoelectric and CCD photometry and spectroscopy. Teachers in their third and fourth summers at TOPS and those with the necessary background were assigned to these projects.

2. Messier lab

The Messier Objects team found the bright moon to be a nuisance, making it difficult for them to locate any of their objects, including M6. Their humorous adventures in navigating the Hawaiian skies for the first time in search of the elusive

Messier objects were described at the AAVSO meeting in a skit. A contest for finding the greatest number of Messier Objects inspired all industriously to ignore the moonlight and sharpen their vision to see those "fuzzy cotton balls" in the sky. On the last night of the observing program, they had two hours before the moon rose, and the Messier Teams were delighted with the beauty of the night sky. (The advanced teams didn't notice; they finally had enough skills to start getting useful data!)

3. Variable star lab

The Variable Star team had the fortune of having Janet Mattei, AAVSO director, as their mentor. To locate the variable star, team members used imaginary triangles and developed skills in visual-spatial patterning to star hop between the variable and its comparison stars. (One frustrated teacher had difficulties in finding the constellations. Instead of using her observations, she graphed her frustration level, creating an equation that predicted her frustration would reduce to 0 in only 187 years! She was encouraged by the negative slope of her graph.) Despite the moon, perseverance prevailed and the team successfully found quite a few variable stars (see Table 2) and were able to make magnitude estimates. These data were sent to the AAVSO to be officially recorded.

Table 2. Target Variable Stars.

Name	*Type*	*Mag. Range*	*Period days*	*Description*
R Hya	Mira	4.2–9.5	405	Post-main sequence cool red giant
R CrB	Irregular	5.7–14.8	Irregular	F or G supergiant, C-rich, H-poor
RR Lyr	RR Lyr	7.06–8.12	0.566868	Spectral class A white giant
δ Lib	Eclipsing	4.91–5.9	2.32735	Spectral types A0IV–V and G2III
Z UMa	Semiregular	6.5–9.4	195.5	Post-main sequence cool red giant

4. Lunar photography

Another beginner project was lunar photography. The challenge for this team was learning to mount and use 35-mm cameras, figuring out the best exposure time and aperture size based upon conditions, developing the black-and white film, and calculating the height of mountains found on the moon from the photographs. The use of a barlow lens to magnify the surface of the moon increased the precision and accuracy of the length of shadow measurements needed for the calculations. Postdoc Jana Pittichová at the University of Hawaii Institute for Astronomy and graduate student Lauren Lippiello mentored this group.

The application of geometry and trigonometry humbled even the top student participants and teachers as they struggled to comprehend the process. They decided to ignore spherical trigonometry since their technique did not have enough precision. Many variables, such as differences in the quality of the photographs, approximations of the shadow length, and best line to draw the terminator that separated the dark and lighted sides of moon, all contributed to the error of the calculated height. Judging the suitability of equations to use was also an important lesson. The height was calculated from:

$$h_c = \frac{s \times l}{r} \quad (1)$$

where h_c is the calculated height, s is the length of the shadow, l is the perpendicular distance from crater to terminator, and r is the radius of the crater.

The teams successfully identified 11 lunar craters and calculated the heights of all. Because they could not find the height of Aliacensis, it is not included (see Table 3). The table gives a sample of measured data and calculated results. The six groups, working in pairs or as indiviuals, had 30 height calculations for 11 craters with an average of 21.5% difference compared to the reported height (designated h) in the table. These errors seem negligible compared to the accomplishments of these novice astronomers and photographers.

Table 3. Heights of Lunar Craters.

Crater	*Group*	*r* [cm]	*l* [cm]	*s* [cm]	h_c [km]	*h* [km]	% *Diff*
Albategnius	A	10.8	1.5	0.20	4.47	4.27	4.7
Albulfeda	B	10.8	0.5	0.30	2.23	3.11	28.3
Aristillus	C	11.0	0.6	0.25	2.15	3.65	41.1
Arzachel	D	28.9	1.6	1.10	3.65	3.62	00.8
Eudoxus	E	09.2	1.1	0.24	4.52	4.42	02.3
Maurolycus	F	10.8	2.8	0.10	4.17	5.03	17.1
Ptolemeaus	C	13.1	1.0	0.30	3.04	2.40	26.6
Purbach	A	13.1	1.5	0.20	3.02	2.98	1.4
Walter	E	23.1	2.0	0.33	2.17	4.13	47.5
Werner	B	11.0	1.5	0.2	4.74	4.22	12.3

5. Photometry and CCDs

Photometry is defined as the precise measurement of the brightness of an object in the sky, and is described by either the apparent or absolute magnitude of the object. A CCD is a charge-coupled device which can precisely measure both the number of incoming photons over a large dynamic range and the two-dimensional spatial distribution of the photons. Although some of our participants had more advanced observing skills, the operation of a CCD camera, complete with learning the computer software, the appropriate calibration frames to acquire, and the image reduction sequence, was new to them. Our equipment involved the use of two SBIG CCD cameras. Participants were grateful to James Bauer and Henry Hsieh, Institute for Astronomy graduate students, who had spent time developing this project.

A photoelectric photometer can make even more accurate measurements of single sources. The disadvantage is that only one object at a time can be measured, but the beauty of this project was the simplicity; participants focused on the science, not the equipment. We used a basic OPTEC SSP-3 photometer for this work.

Photometry is a fundamental concept in astronomy with several applications. For eclipsing binaries, it is used to determine the sizes, shapes, and mass exchange between the binaries. Photometry done on open clusters gives astronomers a clue to the age of a cluster from the star colors and luminosity plotted on a Herzsprung-Russell diagram. Also, the period and magnitude of variable stars can be determined accurately with photometry and this last was selected as the purpose of this TOPS 2002 telescope project.

The post-main sequence giant RR Lyrae star V703 Sco was selected for this project because of its short period (just over 2 hours), bright magnitude, large range, and visibility during the early evening hours when we were observing (in fact, it was the only star that met all the requirements and was accessible from our observing site). Its location, sitting in the direction of the galactic center, made finding V703 Sco a challenge. Equally frustrating was the moon inhabiting the same part of the sky for several evenings. Teams spent the first nights fighting both moonlight and clouds while they developed necessary skills for the project. Doing the photometry of the variable star required several groups collecting images from the CCD cameras and photometers and recording brightness readings from the photometers.

The total brightness through the *R* filter is computed from:

$$m_R = m_{obs} - k_\lambda \chi + \varepsilon_\lambda (V - R) + Z_\lambda \tag{2}$$

where k_λ is the extinction coefficient, χ is the airmass, ε_λ is the color term, Z_λ is the zero point, and m_{obs} = -2.5 log (cnts s^{-1} – skycounts). The airmass was calculated from:

$$\chi = \sec(z) = \frac{1}{[\sin(\lambda)\sin(\delta) + \cos(\lambda)\cos(\delta)\cos(HA)]} \tag{3}$$

where δ is the declination, λ the site latitude, and *HA* the hour angle of the observation.

The amount of light that is lost when it passes through the atmosphere is obviously increased with the presence of clouds. Besides other variables such as humidity and temperature which affect the airmass, cloud cover reduces the apparent magnitude of a standard star which has a constant absolute magnitude. The above formulation is appropriate only under clear conditions, which we had on the last night.

The photometry team was finally successful in collecting data on their last night of observing and even required extended time beyond the usual 22:00 shutdown time.

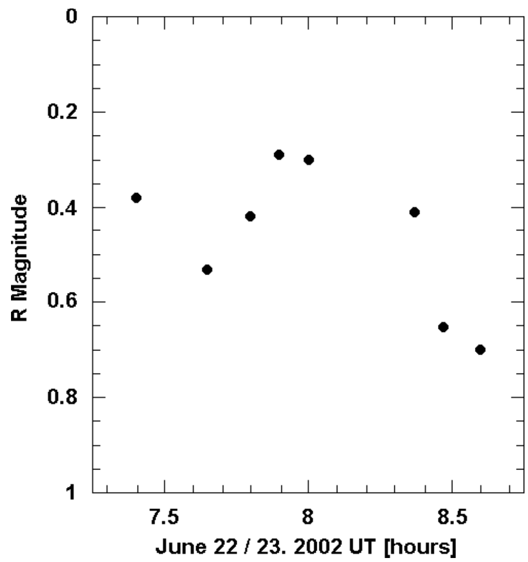

Figure 2. Differential *R* light curve of V703 Sco from the photometry team.

After painstaking analysis team members were able to produce a meaningful light curve of V703 Sco (Figure 2). Although the actual magnitudes range from 7.8 to 8.6, the data used for the light curve are based upon differential photometry for comparing differences in magnitude. Team members concluded that the period of V703 Sco is about 0.115 day.

6. Spectroscopy

Another difficult project involved stellar spectroscopy, utilizing the TOPS program's new SBIG CCD spectrograph. This team—with an astronomy graduate student mentor John Keller (University of Arizona), a resource teacher with astronomy and computer networking background, and a mathematics teacher—performed superbly by acquiring the spectrum of Antares, Spica, and other stars. Limited time prevented spectral analysis to determine the elements present in these stars. Astronomical *tai chi* supplemented this team's presentation with colored strips representing the spectrum of elements.

7. Other projects

Besides the 2002 TOPS telescope projects, follow-up projects by former student participants as well as multi-year teachers were carried out. The results of these projects indicate the impact and the effectiveness of the TOPS program to improve student performance in astronomy.

A 2001 TOPS student, Chad Nishizuka, mentored by an AAVSO member in Hawaii (James Bedient), has made an exciting discovery of a new variable star. He was taught how to retrieve images from the University of Chicago Stardial project website. Chad found a Mira-type variable star in the constellation Aquila after spending hours comparing magnitudes. This led to his project receiving his school district blue ribbon prize as well as awards at the 2002 International Science Fair.

Another project conducted by former TOPS 2000 and 2001 students (Serena Dameron, Melissa Ferreira, and Nicholas Bradley) in their senior year was discussed at the AAVSO meeting. The same AAVSO member assisted them in the use of the Lowell Observatory 31-inch telescope as a test bed for long distance remote observing. The observing procedure involved target selection of suitable variable stars and the development of night observing scripts which were based upon software written by Mark Buie (2001). Students needed to distinguish between sidereal and UT times, remembering that the telescope location was Flagstaff, Arizona, and not Honolulu, Hawaii. Initially, script errors resulted in too many minutes wasted between images. A single night of observing can produce 700 CCD images on 50–60 variable stars, if the script is flawless. Now the task of data reduction needs to be done followed by photometry. One student now in college has agreed to continue with this project.

Two TOPS teacher veterans shared with AAVSO meeting attendees the activities of their Star Night VIII, an annual educational partnership involving parents, community, and their McKinley High School Complex. This astronomy annual event for parents and 4th and 5th grade students at Lanakila School located in Honolulu, Hawaii, brought volunteers from the Hawaii Astronomical Society plus other TOPS teachers with their students to help. Another sponsor for this collaboration was the McKinley Service-Learning Grant funded by the Federal Department of Education.

8. Finale

The entire TOPS group treated the AAVSO conferees with a musical skit, entitled "The Moon Sprite," based upon a Japanese folktale about a fisherman finding a cloak of feathers belonging to a spirit from the moon. The simple costumes to depict cranes, trees, a butterfly, and other creatures, dancing to the music of a flute, and the story telling by the museum education TOPS participant completed the total integration of the arts with the science of astronomy.

9. Conclusions

The 2002 spring AAVSO meeting was held in Hawaii, in part, to provide an opportunity for educators, students, and their mentors to interact with the larger community of amateur and professional observers. This opportunity created the awareness that there is ample support in the community for continued mentorship after the completion of the TOPS program, and it showed the AAVSO members how remarkably quickly new observers can be inducted into the love of astronomy as a lifelong habit.

10. Acknowledgements

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