The Use of 35mm Slides of Variable Stars in Astronomy Education

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Abstract We describe two sets of 35mm slides which can be used as part of the AAVSO's *Hands-On Astrophysics* education project, or for other variable star activities in astronomy, science, or math education.

1. Introduction

The American Association of Variable Star Observers (AAVSO) has developed an education program, *Hands-On Astrophysics*, which uses the AAVSO observing procedures and electronic database to enhance science and math education at the high school level and above (http://hoa.aavso.org). One of the components of the program is a set of 35mm color slides of five constellations in the northern sky. Such slides are very useful for several purposes.

First of all, the slides can be used to illustrate the variability of stars in a qualitative way. For instance, we have shown a time series of slides of the large-amplitude Mira star χ Cyg, in both small and large groups, for this purpose. The effect is dramatic. The audience can also note that the star is intensely red.

The slides can also be used to practice the identification and measurement of a variable star. For instance, we have used a wide-field slide of Cassiopeia, Cepheus, and Ursa Minor, which corresponds exactly with one of the *Hands-On Astrophysics* charts, to identify Cepheus, the variable star δ Cep, and the comparison stars ζ Cep and ε Cep. The audience then estimates the brightness of the variable. This results in a large number of measurements, which can then be analyzed for mean, standard error, and standard error of the mean.

Finally, a time series of slides can be used in the classroom to generate a set of measurements of brightness, which can then be plotted as a light curve, analyzed for range and period, and compared with the predicted behavior of the star. One example is given below. Students use a work-sheet to record their measurements, along with group means, standard errors, and standard errors of the means. For large groups, we have found it useful to prepare an overhead transparency to record the individual measurements, on squared paper, in the form of a tally sheet. The vertical

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squares correspond to magnitude estimates; the horizontal squares correspond to time. The tallies then produce a crude "light curve" with the distribution of the measurements clearly illustrated.

The slides can also be used for individual study. If suitably protected, they can be inspected and measured with a low-power magnifier on a light table. For the *Hands-On Astrophysics* project, we also produced some of the images in the form of prints. These are even more convenient for individual study.

In addition to the slide sets which we have developed, it is useful to have general constellation slides. Two sets which we have found useful, and which are available, are: (i) the set of forty constellation slides available from the Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112; these show photographs of the constellations, alongside diagrams identifying specific stars and other objects in the constellation; (ii) slides of selected regions of the sky, available from MMI Corporation, 2950 Wyman Parkway, Baltimore, MD 21211; each of these wide-angle slides shows several constellations, so they can be useful in showing how to use one constellation to find another.

2. The *Hands-On Astrophysics* slides

As a core element in the *Hands-On Astrophysics* project, we have produced time series of thirty-one slides of each of five northern circumpolar constellations. There are eighteen constellation slides, two of Auriga, two of Cassiopeia, six of Cepheus, seven of Cygnus, and one of Ursa Major. There are seven slides of the variable star W Cyg. In addition, there are six finder slides. The slides were taken by one of us (John Chumack) who is an experienced astrophotographer. It took many nights of effort to produce a set of slides that were of uniform quality.

Also included are photographic prints of each of the seven Cygnus constellation slides, and the seven W Cyg slides. The activities that go with these slides and prints give several suggestions about how they can be used.

3. Slides taken by teachers or students

By taking their own slides, teachers or students can gain the satisfaction of creating a teaching tool which can be used in their classroom on an ongoing basis. We describe one example. Slides of the constellations Auriga and Cassiopeia (two of the five northern circumpolar constellations featured in *Hands-On Astrophysics*) were obtained by one of us (Laura Syczak), a high school student, using a standard 35mm camera, tripod, and ASA400 film, commercially developed. The slides were taken from a back yard in the suburbs of a city (Toronto) of over three million people, so both local and general light pollution were a problem. Sky brightness was least when the constellations were highest in the sky, and when neighbors could be persuaded to turn their outdoor lighting off.

To avoid sky fog, and star trailing, exposures had to be limited to thirty seconds. At these exposures, the limiting *V* magnitude of the slides ranged from 6.4 to fainter

than 7.0, as determined from sequences of stars of known brightness. After some initial experiments to test the procedures, and determine optimum exposure times, slides were taken on every clear night. By good fortune (considering the nature of Toronto's climate), there was a series of eight consecutive clear nights in mid-March 1996.

Several bright variables were visible on the slides, but we concentrated on the bright, short-period (3.72811 days), large-amplitude (5.00 to 5.82 in *V*) Cepheid RT Aur. Using a standard AAVSO chart showing the variable and comparison stars, we measured the slides in two different ways: (i) individually, using a low-power magnifier and a light table, and (ii) by projection, to a group of grade twelve physics students at Bishop Allen Academy in Toronto.

Both methods had their advantages, and both gave the same results. The variability of RY Aur was quite evident. The observed range—5.1 to 5.9—was in excellent agreement with the known range. The period was determined, graphically, to be 3.85 days—acceptably close to the catalogue value. The observed time of maximum brightness was in excellent agreement with the most recent ephemeris of the star. For further details, see (Percy *et al.* 1997).

4. Conclusions

Slides provide a convenient visual tool for introducing variable stars in the math and science class. They provide a reasonable approximation to the real night sky, for both qualitative and quantitative use.

5. Addendum, 2006

Between 1997 and 2006, 35mm slides, and 35mm slide projectors, have become almost obsolete. But a similar result can be obtained by using a digital camera, as long as the resolution is sufficient. Again, the best results are obtained if many students make measurements from projected images, and compare them with those of their classmates. This combines the benefits of hands-on (or eyes-on) science, with the social aspects of this educational experience.

Reference

Percy, J. R., Syczak, L., and Mattei, J. A. 1997, *The Physics Teacher*, **35**, 349.