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AN OBSERVATIONAL DEMONSTRATION OF ANGLE ERROR IN VISUAL MAGNITUDE ESTIMATES

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Abstract

Two series of visual magnitude estimates were made during the same minimum of the eclipsing binary BX And, with the optical field of view rotated 180 degrees between the estimates in each series. The resulting light curves are displaced about a quarter of a magnitude, providing a graphic demonstration of the errors in visual estimates caused by changes in the orientation of a variable and its comparison stars.

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The utility of visual observations for monitoring large-amplitude stellar variations (>1 magnitude) is generally recognized, as indicated by the many requests for AAVSO data from professional researchers noted in the annual Director's Reports. But visual techniques can also produce data of surprising precision.

Two papers in this journal provide excellent examples. Percy et al. (1985) demonstrated that visual estimates of rho Cas can yield a very useful light curve of variations as small as 0.2 magnitude. Peel (1985) presented a remarkable visual light curve of T CrB in quiescence, also with an amplitude of just 0.2 magnitude. (See also Baldwin 1966.)

Visual brightness estimates are, however, subject to a large variety of random and systematic errors. These errors cannot be eliminated, but the precision of estimates can be increased and the errors can be minimized by adopting appropriate techniques for making and analyzing visual observations.

In a recent paper (Williams 1986) I briefly outline some of these techniques. The most powerful procedure is the formation of mean points. In the rho Cas study just cited, a large number of estimates by many observers were reduced to 30-day means, which were found to have standard formal errors of just 0.02 magnitude. The T CrB light curve was formed by reducing 322 estimates by one skilled observer into mean points according to the orbital phase of the binary system.

When the observing program allows, it is also useful to adopt estimating and recording methods that permit distinctions smaller than 0.1 magnitude (by using the "step method," for example, or decimal interpolation of the variable between comparison stars differing by less than 1 magnitude). Careful visual observers can, in fact, distinguish brightness differences smaller than 0.05 magnitude (Peel 1985; Williams 1986).

Systematic errors arise from the physiology of human vision. Color error can be minimized by selecting comparison stars similar to the variable in color index. Angle error results from change in the apparent difference between a variable and a comparison star when their orientation changes relative to the line between the observer's eyes.

Observations made using altazimuth instruments with fixed eyepiece positions are particularly prone to angle error - as are binocular and naked-eye observations because the observer normally faces in the direction of the variable and uses his or her body as an altazimuth mounting, the eyes remaining parallel to the horizon. The observer will face east to view a star field rising in the east, then face west to observe the same star field setting. As a result, the star field will appear completely reversed between the two observations, east changing from down to up, north from left to right.

Observers with equatorially mounted instruments tend to counteract the celestial motions of the mounting by rotating the telescope tube or eyepiece diagonal to keep the eyepiece at a convenient viewing angle.

Angle error is a particular source of difficulty in the visual timing of eclipsing binary minima. Estimates are made frequently during an interval of several hours, while the variable fades and then brightens. Determining an accurate time of minimum light depends on the resulting light curve being symmetrical. During the several hours of observation, however, the field of view will appear to rotate as the hour angle changes, unless the observer compensates by adjusting his posture and/or instrument. Since the amplitude of an eclipsing binary is often small, a cumulative angle error of 0.2 - 0.3 magnitude can create gross asymmetry in the light curve.

Figure 1 illustrates a series of observations of the eclipsing binary BX And using tripod-mounted 20x60 binoculars. Minimum light occurred as the variable crossed the meridian near the zenith, so the estimates on the descending branch were made facing east and the estimates on the rising branch facing west. After sadly pondering this distorted and therefore useless light curve, I suspected that angle error was the culprit.

To confirm this suspicion, I performed an observational experiment during a later eclipse of the same star. Reclining horizontally, I made one series of estimates with my feet toward the east and a concurrent series of estimates with my feet toward the west. I tilted my head back beyond the zenith when necessary, at the beginning of the west-facing series when the variable was east of the meridian and toward the end of the east-facing series when the variable had passed the meridian. Thus the field of view was rotated 180 degrees between the two series of estimates. The same comparison star values were used in both orientations.

Figure 2 shows the light curves of the two series of estimates, with a consistent displacement of about 0.25 magnitude. Since these observations were made on the same night by the same observer with the same instrument and comparison star values, the difference is entirely due to the 180-degree reversal of the field. This illustration of the reality of angle error should convince visual observers of the need to maintain the same orientation of the star field for all estimates of a variable star.

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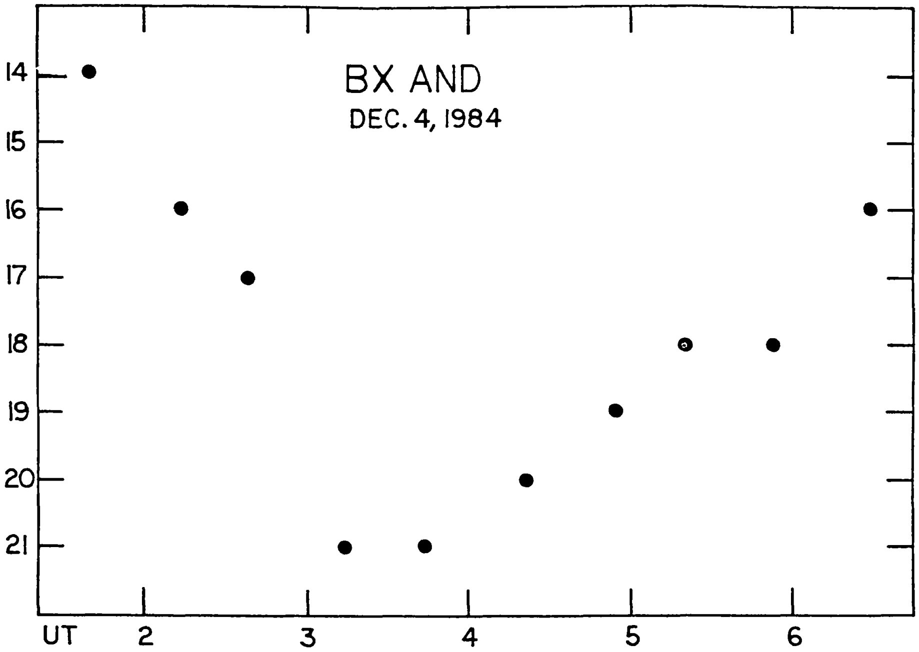

Figure 1. Observations of BX And with tripod-mounted 20x60 binoculars. Each step interval is approximately 0.1 magnitude. The asymmetry is due to angle error arising from reversal of the star field when the variable crossed the meridian near mid-eclipse and the observer changed from facing east to facing west.

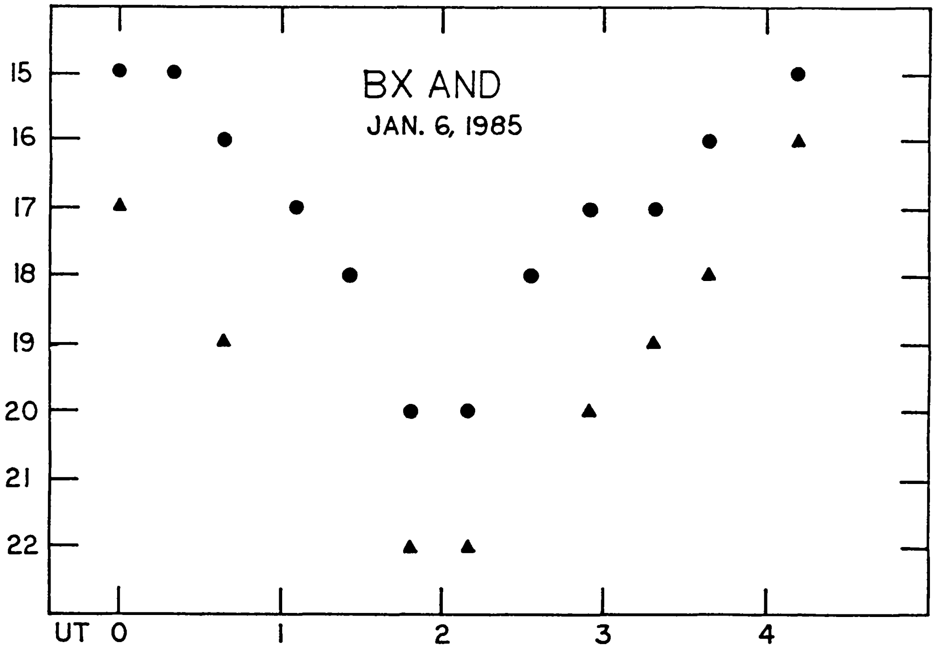

Figure 2. Observations of BX And using procedures described in text. The circles represent estimates made with the star field maintained in one constant orientation ("east down, north left") throughout the eclipse. The triangles represent a concurrent series of estimates with the star field reversed 180 degrees ("east up, north right").