THE ACCURACY OF VISUALLY DETERMINED TIMES OF PRIMARY MINIMA OF ALGOL-TYPE VARIABLES

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INTRODUCTION

The purpose of this paper is to evaluate the accuracy of visually determined times of primary minima of Algol-type variables. The results should aid visual observers in selecting stars having light curves which lend themselves to accurate determinations of minimum times. It will be shown that this selection can be made on the basis of two simple parameters. Also, persons studying the periods and period changes of Algol-type variables can use the same parameters to estimate the standard deviation in the available visual times of minima for the star under investigation.

METHODS

To evaluate the accuracy of the visually observed times of primary minima the author collected and analyzed O-C values for 15 Algol-type variables (all with periods less than 4.5 days). The values were taken from AAVSO data supplied by Marvin Baldwin, and from issues of the BBSAG Bulletin. In order to prevent complications from O-C changes that are noticeable on a time scale of years, the duration of observations that were analyzed was kept as small as possible (less than one observing season for non-circumpolar stars, less than one year for circumpolar stars). Of the 139 O-C values available, three were rejected as obviously spurious. The rule of rejection was that if a questionable O-C value would more than double the range of O-C values it should not be included. The accuracy of the O-C values for a star is expressed by the standard deviation (SD), given by:

$$\text{(1)} \quad SD = \sqrt{\frac{\sum_{i=1}^{N} [(O-C)_i - (\overline{O-C})]^2}{N-1}}$$

where N is the number of O-C values analyzed, and $\overline{O-C}$ is the arithmetic average of the O-C values. Table 1 lists the names of the variable stars, their periods (P), the number of O-C values analyzed (N), and the standard deviation (SD) in columns 1, 2, 3, and 4, respectively. The unit of measurement for the SD values is .001 day.

RESULTS

Table 1 demonstrates that SD values among the 15 stars vary over a wide range. The smallest SD value (.0018 day, XZ And) differs from the largest SD value (.0178, U CrB) by nearly a factor of 10. Two factors can be cited to account for this wide range of SD values: 1) the visual amplitude (A) for each star, and 2) the average rate of magnitude change per hour ($\Delta m/hr$) during primary eclipse. The values of A and $\Delta m/hr$ are given in columns 5 and 6 of Table 1. The $\Delta m/hr$ values are easily computed from the elements in the GCVS by the formula:

$$(2) \quad \Delta m/hr = \frac{A}{12\ P\ [D-d]}$$

where A = amplitude; P = period, in days: D = duration of primary eclipse, as a percent of the whole period; and d = duration of totality, as a percent.

Figure 1 shows SD as a function of A for the 15 stars. Large amplitude stars tend to have small SD values. This result is due to the fact that deep eclipses offer a better chance for accurate timing of mid-eclipse. Figure 2 shows SD as a function of $\Delta m/hr$. Analogous to the previous case, stars with rapid brightness changes can be more accurately timed than stars with slow brightness changes; therefore, the large $\Delta m/hr$ stars have smaller SD values. These results indicate that the accuracy of visually obtained minimum times for Algol-type variables depends strongly on both factors A and $\Delta m/hr$. Thus, observing programs should be planned keeping this fact in mind. For high accuracy in timing minima one must select objects with large light amplitudes or with rapid brightness changes. In Figure 3 the range of SD values for the stars in Table 1 is shown as a function of A and $\Delta m/hr$. The expected accuracy of observation for a variable star can be estimated from this graph. This may aid visual observers in selecting variables suitable for their own programs.

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REFERENCES

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NOTE: For $\Delta m/hr$, average rates have been used in this paper rather than maximum rates, because the average rates can be easily computed with the aid of formula (2) from the elements given in the GCVS, while accurate light curves are needed for calculation of the maximum rates. It actually makes little difference which is used in practice. This is because the light curves of Algol-type stars are fairly similar to each other in respect to shape, especially in the fairly straight parts of the descending and ascending branches usually observed by visual observers.

TABLE 1

DATA FOR FIFTEEN VARIABLE STARS

Variable	P	N	SD*	A	Δm/hr
XZ And	1.36	8	1.8	$2^m.2$	.65
SV Cam	.59	12	5.6	.8	.67
TV Cas	1.81	5	7.7	1.1	.24
U Cep	2.49	8	2.0	2.3	.64
EK Cep	4.43	6	2.9	1.2	.38
U CrB	3.45	4	17.8	1.1	.24
AI Dra	1.20	15	8.4	1.1	.50
Y Leo	1.69	10	1.9	3.3	1.18
U Oph	1.68	7	8.9	0.9	.38
RT Per	.85	7	3.3	1.4	.67
Beta Per	2.87	9	9.8	1.3	.27
V505 Sgr	1.18	10	5.2	1.2	.43
X Tri	.97	22	2.8	2.0	1.00
TX UMa	3.06	4	2.5	1.6	.33
BH Vir	.82	9	4.1	1.0	.63

* the unit is .001 day.

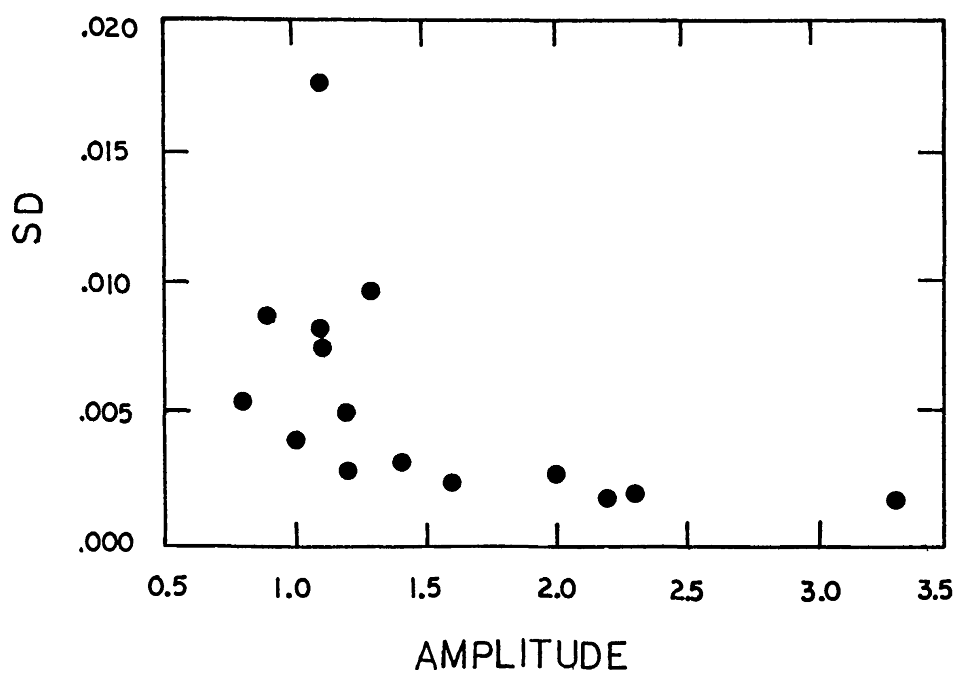

Figure 1. Standard deviation versus amplitude during primary eclipse. Standard deviation is measured in days; amplitude in magnitudes.

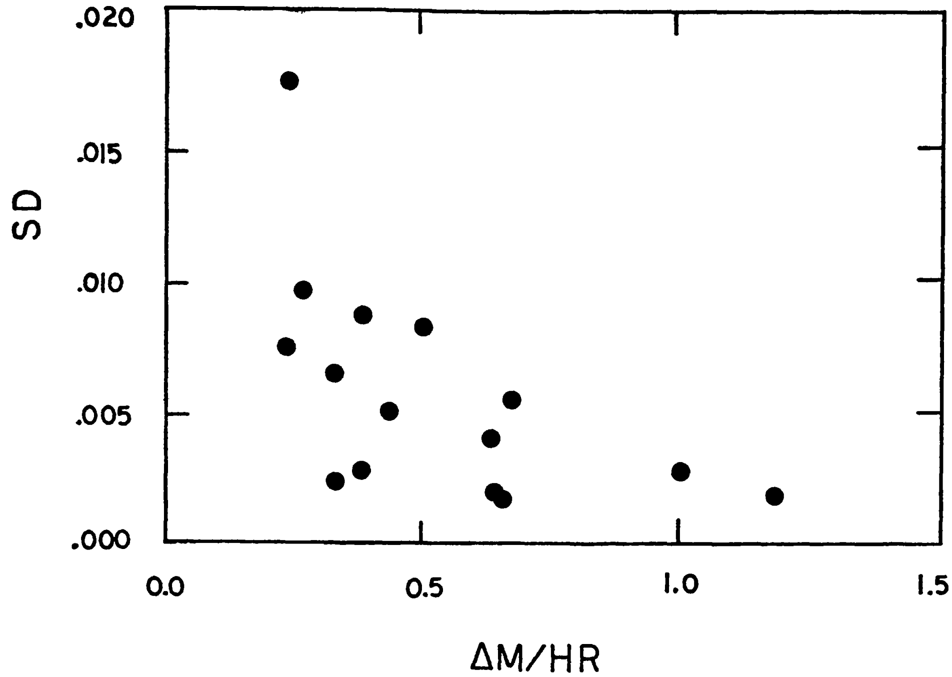

Figure 2. Standard deviation (in days) versus average magnitude change per hour during primary eclipse.

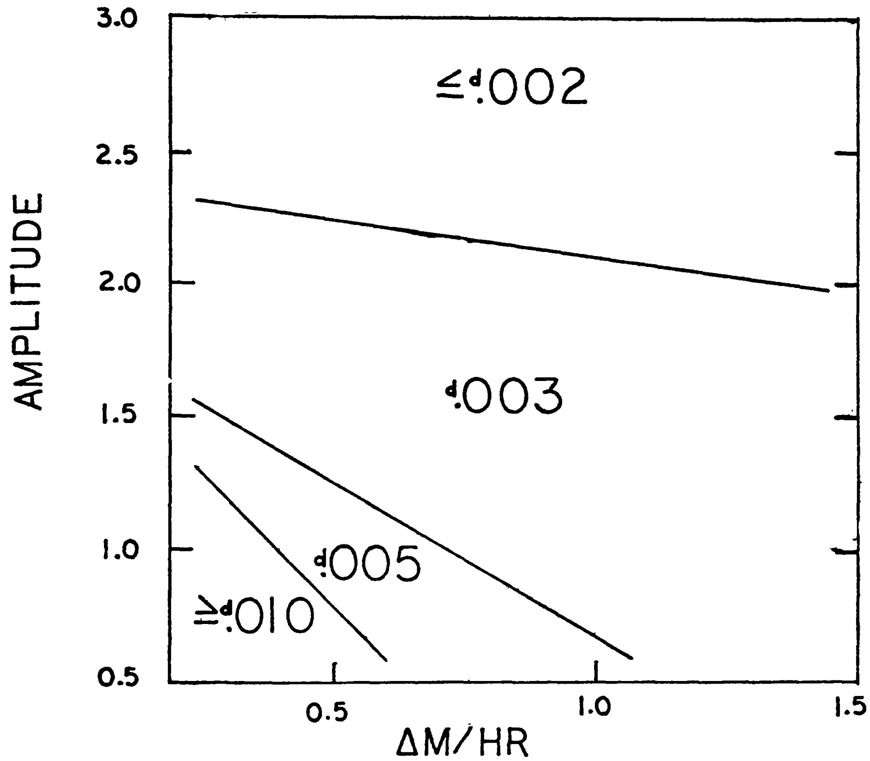

Figure 3. Smoothed plot of standard deviation as a function of amplitude and average magnitude change per hour during primary eclipse.