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# TIMINGS OF SELECTED VARIABLE STARS[1]

Changes in the periods of variable stars can be determined by timing the occurrence of a certain point in the light curve, usually the maximum or minimum value. It is necessary to have such timings at frequent enough intervals so that cycle counts can be reliably determined in between. Often in the course of other routine observations, such timings are obtained and the purpose of this paper is to make available such data to other researchers.

Most of the photometric data were obtained with telescopes at Lowell Observatory in Flagstaff, AZ but some came from CTIO in Chile ($\sigma$ Sco and $\nu$ Eri). The raw photometry was corrected for sky, and the atmospheric extinction was removed using a comparison star. Then differential magnitudes were determined and heliocentric corrections applied. For stars with a single mode, plots of the light curves were made and a cross-correlation technique between the ascending and descending branch was used to derive the time of maximum or minimum. The uncertainty of an individual timing varies with data quality, but is typically 0.0005 days. It is planned to submit all of the data upon which these timings have been made to the Journal of Astronomical Data, Twin Press, The Netherlands.

Table 1. Times of Photometric Minimum of Eclipsing Binary Stars.

| Star Name | HJD | notes |
|---|---|---|
| BX And | 2447108.7773 | primary min |
| | 2447535.7064 | secondary min |
| | 2447573.6826 | primary min |
| TY Boo | 2447641.7811 | primary min |
| | 2447641.9398 | secondary min |
| W Crv | 2447234.7467 | primary min |
| | 2447237.8561 | primary min |
| | 2447250.8553 | secondary min |
| | 2449108.7855 | primary min |
| | 2449109.7580 | secondary min |

[1]Visiting Observer, Lowell Observatory, Flagstaff, Arizona, USA. Also based in part on data collected at Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatories, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

Table 2. Times of Photometric Maximum/Minimum of $\beta$ Cephei Stars.

| Star Name | HJD | notes |
|---|---|---|
| $\nu$ Eri | 2444450.8184 | max for P1 = 0.173506 d |
| | 2444450.8937 | max for P2 = 0.178063 d |
| $\sigma$ Sco | 2444457.6980 | max for P2 = 0.246836 d |
| | 2444457.7130 | max for P1 = 0.239670 d |
| BW Vul | 2447704.7345 | max |
| | 2447704.8300 | min |
| | 2447803.6580 | max |
| | 2447826.6639 | min |
| | 2447833.6100 | max |
| | 2447827.5755 | max |
| | 2447833.7020 | min |
| | 2447840.6484 | max |
| | 2447840.7373 | min |
| | 2448062.8020 | max |
| | 2448062.8885 | min |
| | 2448084.8152 | min |
| | 2448193.6753 | max |
| | 2448193.7676 | min |
| | 2448194.6820 | max |
| | 2448403.8630 | min |
| | 2448403.9713 | max |
| | 2448421.7744 | min |
| | 2448421.8685 | max |
| | 2449662.6000 | min |
| | 2449662.7120 | max |
| | 2449663.6025 | min |
| | 2449663.7164 | max |

Table 1 lists the times of primary and secondary minimum for three close binary stars. There is enough new data only for W Crv to produce a new ephemeris at this time. For these close binaries, it might be expected that the orbital period might be changing due to mass exchange between the two stars, so both a linear and quadratic ephemeris were computed, combining 12 timings for W Crv from the literature with the five listed in Table 1. The least squares quadratic ephemeris yielded only marginally smaller residuals than the linear, and in any case produced a rate of period change of just 0.025 seconds/century, which is probably only an upper limit. The linear ephemeris can be used to schedule future observations; it is:

$$\mathrm{HJD} = 2427861.3634 + 0.388080835 \times \mathrm{E}.$$

Table 2 gives times of maximum and minimum brightness for three $\beta$ Cephei stars. For those with multiple modes, cosine functions were fit using the known periods, but solving for the best phase and amplitude of each mode, and the time of maximum was derived.

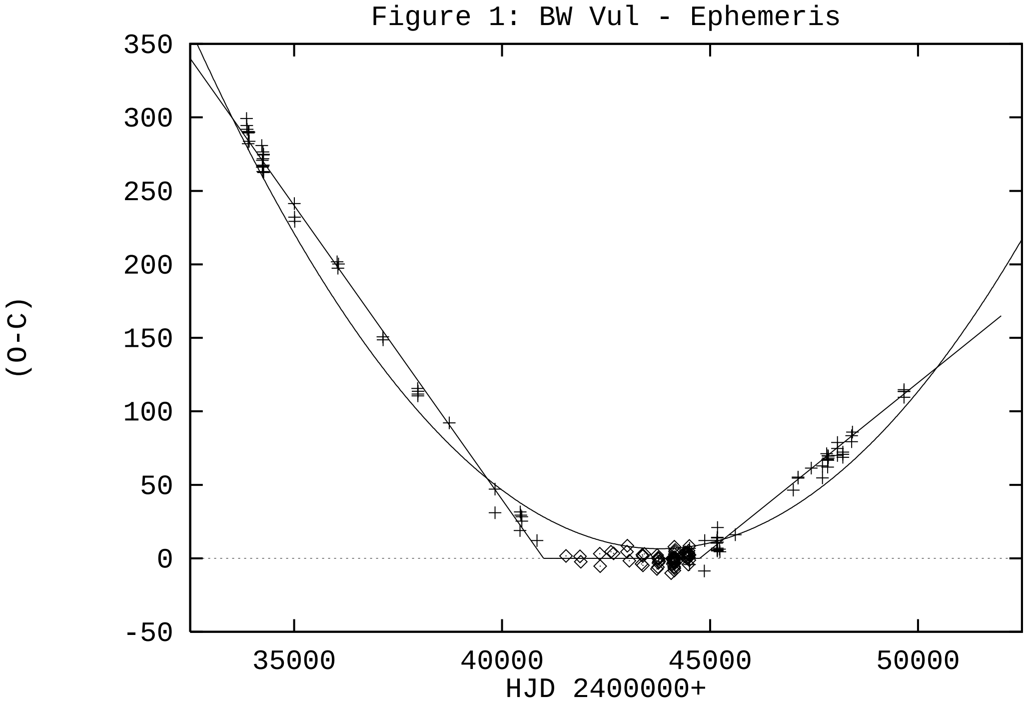


Figure 1. O−C diagram for BW Vul

These timings are completely independent of each other, and depend on the beat phase of the star at the time of the observation. For BW Vul, times of minimum light are included because of the suggestion by Sterken, Young, and Furenlid (1987) that the stillstand in this star's light curve could alter the timings derived for maximum brightness.

A least squares linear ephemeris was fit to all times of maximum brightness measured for BW Vul since 1980, which can be used for predicting maximum brightness for the near future:

$$\mathrm{HJD} = 2447700.1158 + 0.201044444 \times \mathrm{E}$$

with an rms residual of 1.25 minutes.

The period history of BW Vul has been controversial for about ten years, since the discovery of a periodic variation of the residuals after a quadratic ephemeris has been removed, made by Odell (1984). The quadratic ephemeris can be explained in terms of the star's evolution to larger size, and the periodic residuals can be explained either by the light-travel-time over a binary orbit or by two modes beating with a period of about 30 years. The controversy arises from the claim of Chapellier (1985) that the period has been constant except for sudden jumps in 1945 and 1968, and again in 1980 (Chapellier and Garrido, 1990). Pigulski (1993) has derived the properties of the binary star orbit, including an orbital period of 33.5 years.

In order to distinguish between the two proposed behaviors of this star, a linear ephemeris was fit to the previously published timings of maximum between 1968 and 1980, and the residuals computed for all timings since 1950; these are shown in Figure 1.

The diamond symbols in the figure represent timings used in the linear fit, while the pluses represent eras in which a different ephemeris must be used. It can be seen that the residuals are fit well by three straight lines, but the residuals predicted from a quadratic ephemeris also agree reasonably well, especially if a periodic variation on either side of the quadratic is allowed for.

Figure 1 gives a method of determining which of the two types of ephemeris is the correct one. If the quadratic-with-variations ephemeris is correct, the figure predicts that there must be another increase in the period by about 0.25 seconds at HJD about 2452000, or in the year 2000. If the piecewise-linear ephemeris is correct, there is no way to predict when the next period change will occur, or the magnitude, or even the sign of the change. Thus the monitoring of this star for the next ten years becomes important to distinguishing the correct ephemeris form.

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References:

Chapellier, E., 1985, *Astron. Astrophys.*, **147**, 135
Chapellier, E. and Garrido, R., 1990, *Astron. Astrophys.*, **230**, 304
Odell, A. P., 1984, *P.A.S.P.*, **96**, 657
Pigulski, A., 1993, *Astron. Astrophys.*, **274**, 269
Sterken, C., Young, A., Furenlid, I. 1987, *Astron. Astrophys.*, **177**, 150