PERIOD CHANGE IN THE FIELD CONTACT BINARY V728 HERCULIS

Robert H. Nelson
College of New Caledonia
3330 - 22nd Avenue
Prince George, BC V2N 1P8
Canada

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Abstract

Three new times of minima have been obtained photoelectrically for the contact binary V728 Her at the Prince George Astronomical Observatory (PGAO) from 1996 to 1998. Analysis of various possible period changes is presented.

1. Introduction

Contact binaries are systems in which the two stellar components touch, usually creating a tidally-distorted common envelope through which stellar material and luminosity are exchanged. In the fourth edition of the *General Catalogue of Variable Stars* (GCVS) (Kholopov *et al.* 1985), which distinguishes systems on an observational basis, this is known as the EW class, after the prototype star W Ursae Majoris. In W UMa systems, it has been found that the components are of spectral type F or G, are close in surface temperature, and consequently yield light curves in which the primary and secondary minima are almost equal in depth. In addition, because of the close physical proximity of the two stars, there is no time interval between eclipses in which the light intensity is constant. Periods vary from about 7 hours to one day, and masses are unequal, with the average ratio being 2:1. Radial velocity and light curve synthesis methods such as the program of Wilson and Devinney (1971) have yielded parameters such as orbital inclination and semi-major axis, surface temperatures, mass ratio, and Roche lobe-filling parameter. Computer-drawn three-dimensional sketches at all phases can now be plotted.

Because of mass transfer, period changes will occur over time. Although much is known about individual systems, the origin and long-term evolution of such systems are not known with any certainty. It is for these reasons that it is important to keep track of period changes of contact binary systems.

The variability of V728 Herculis (GSC 3081 676) was discovered by Kurochkin (1977) who classified it as EW. The combined spectral type is F3, main sequence (Nelson *et al.* 1995), and varies from visual magnitude 10.9 to 11.5 (Kholopov *et al.* 1985). Its position was misreported, resulting in an incorrect position in the GCVS. The correct epoch 2000.0 coordinates are R. A. $17^h\ 18^m\ 04^s$, Decl. +41° 50' 40" (Agerer *et al.* 1988). Wilson-Devinney light curve modelling was performed by Samec (1990), and light curve and radial velocity modelling was performed by Nelson *et al.* (1995). A number of authors have determined times of minimum and therefore calculated ephemerides (see Nelson *et al.* 1995, and references therein).

2. Observations

Observations were made with a 24" (61-cm) classical Cassegrain operating at f/12 at the Prince George Astronomical Observatory (PGAO) on Tedford Road near Prince George, British Columbia, Canada. The photometer used was an OPTEC SSP-5a; it utilizes an uncooled Hamamatsu R1414 side-on photometer tube with a S-5 spectral response (identical to the S-4 response of the 1P-21, except for the extended UV response). The UBV filters match closely the standard Johnson filters. Data acquisition is also in the analogue-to-digital mode; therefore the "counts" do not actually represent individual photons. Although transformation coefficients to the standard system have been determined, instrumental magnitudes only (not corrected for differential extinction and not transformed to the standard system) were used for determining the times of minimum. The SSP-5a utilizes a RS-232 computer link and an automated filter slider. A 1-mm pinhole was used, corresponding to 27.6 arcseconds.

For the runs using the SSP-5a, a program written by the author specifically for the OPTEC photometer and named SSPDAxx was used (the xx is a version number, currently 54). This software accepts information as to observer location, objects viewed, object sequence, filter sequence, etc.; it then prompts the observer to center the correct object in the pinhole, and acquires the data and writes them to disk; it also reduces data on-line to instrumental magnitudes, and displays a light curve on demand, allowing the observer to monitor the progress of the eclipse. Internal errors are also displayed on demand. Times were read from the computer clock (calibrated nightly from radio station WWV in Fort Collins, Colorado) and, in the data reduction, converted to mid-exposure. In the data reduction, the program automatically rejects data points that deviate by more than 10% from the mean. (In difficult situations, the observer can re-reduce the data using compatible software, applying his/her own criteria.) The author would be pleased to make copies of this software (including source code) available gratis to OPTEC users.

At all times, the object sequences SCVCS or SCVVCS (where S = sky, C = comparison, and V = variable) were used. In the case where more than one filter was used, the symmetric sequence BVVB (where B = Blue and V = Visual) was used for each object. (The data acquisition software automatically uses symmetric filter sequences.)

The comparison star used was the same as in Nelson *et al.* (1995), namely GSC 3081 1072 (R.A. $17^h\ 19^m\ 18^s$, Decl. +41° 56' 02" in 2000.0 coordinates).

3. Data processing and results

All data were plotted on a spreadsheet and a parabola fitted by least-squares. In some cases, other methods, such as the bisection of chords or the method of Kwee and van Woerden (1956), were also used. In these cases, the actual values of the times of minimum by this method did not differ from those obtained by quadratic fitting by more than the estimated errors.

Points were rejected due to recorded errors such as the star slipping out of the pinhole, the appearance of thin clouds, or aurorae. Nevertheless, occasional obviously discordant points appeared due to unknown problems (such as undetected thin clouds); these were rejected.

Observations too close to advancing dawn were also found to be discordant, possibly due to the fact that the linear interpolation that the software uses to calculate the sky contribution is inadequate in this situation (sky brightness rise at dawn is approximately exponential).

After the least-squares parabola was plotted with the data, adjustments were made to the parameters to see if the fit could be improved visually. (In this case, corrections were usually less than 0.001 day.) To estimate the error, the time of minimum was adjusted until an obvious bad fit was seen; the difference in times of minimum was taken as the error. Results are shown in Table 1.

4. Analysis

The ephemeris for the primary minimum used for period analysis by Nelson *et al.* (1995) is their equation (3):

$$\text{HJD I} = \underset{\pm 0.00023}{2446949.83796} + \underset{\pm 0.00000027}{0.47128619}\,E \qquad (1)$$

Regrettably, it appears that the above ephemeris is slightly in error; the ephemeris that fits the existing data best (and corresponds to their Figure 3) is:

$$\text{HJD I} = \underset{\pm 0.00050}{2446949.83703} + \underset{\pm 0.00000017}{0.47128615}\,E \qquad (2)$$

Table 1. Times of primary minimum of V728 Her.

Date (UT)	Filter	Minimum HJD_o 2400000+	Est'd Error (days)
1996-09-23	B	50349.7097	0.0015
96-09-23	V	50349.7091	0.0015
98-07-26	B	51020.8257	0.001

The new times of minimum reported here plus those from Agerer and Hubscher (1995) were combined with the previously reported times (in Nelson *et al.* 1995 and references therein); these values were then compared with those calculated from equation (2) above. The resultant differences (O-C) were plotted versus epoch E to look for period changes (see Figures 1, 2, and 3). (The errors for the original set were omitted to avoid cluttering up the diagram but the scatter of points gives some idea of their size.) From the figures, it is evident that the period has changed from that given in equation (1) (or (2)).

In Figure 1, a straight line was fitted by the method of least squares. It is evident that it does not fit the data.

In Figure 2, a parabola was fitted by least squares giving the relation:

$$\begin{aligned} O\text{-}C \;=\; & -0.00031 + 3.2 \times 10^{-7}\,E + 2.31 \times 10^{-10}\,E^2 \\ & \pm 0.00025 \pm 2.1 \times 10^{-7}\,E \pm 0.30 \times 10^{-10}\,E^2 \end{aligned} \qquad (3)$$

This gives a revised ephemeris:

$$\begin{aligned} HJD\,I \;=\; & 2446949.83672 + 0.47128647\,E + 2.31 \times 10^{-10}\,E^2 \\ & 0.00056 \pm 0.00000027 \pm 0.30 \times 10^{-10} \end{aligned} \qquad (4)$$

In Figure 3, a straight line was fitted by least squares to the last four points, giving the relation:

$$\begin{aligned} O\text{-}C \;=\; & -0.0075 + 3.05 \times 10^{-6}\,E \\ & \pm 0.0055 \pm 0.80 \times 10^{-6} \end{aligned} \qquad (5)$$

This gives a revised ephemeris for later epochs:

$$\begin{aligned} HJD\,I \;=\; & 2446949.8295 + 0.47128920\,E \\ & \pm 0.0055 \pm 0.00000082 \end{aligned} \qquad (6)$$

This would imply a sudden period increase occurring at about cycle E = 2479, corresponding to HJD = 2448118.

At the present time, it is not possible to distinguish between the fit of Figure 2 and that of Figure 3, although Figure 3 appears to fit the original data set better. It is to be regretted that no times of minimum (of sufficient accuracy) were obtained in the interval E = 2000 to 5000, which would have cleared up the ambiguity. Further observations over a longer time base are clearly required; these are planned. [Note added in press: Two recent times of minima obtained from CCD images seem to favor the quadratic fit of Figure 2. More observations are planned.]

5. Conclusions

Three times of minimum have been successfully obtained for V728 Herculis, yielding information about period changes. At this time, it is unclear if there was a sudden period increase around epoch E = 2479 (corresponding to HJD = 2448118), or if there was (and is) a gradual increase in the period. More observations in the coming years are required to clear up this ambiguity; at that time it will be appropriate to discuss causes of this period change and how it impacts the parameters of this interesting system.

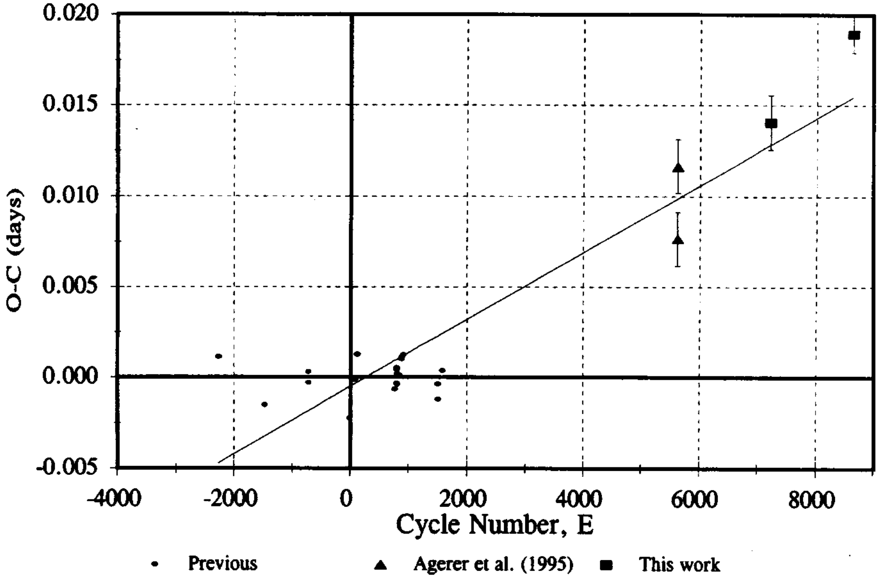

Figure 1. The O-C curve for V728 Herculis calculated using the ephemeris of equation (2). The data do not support a linear relation.

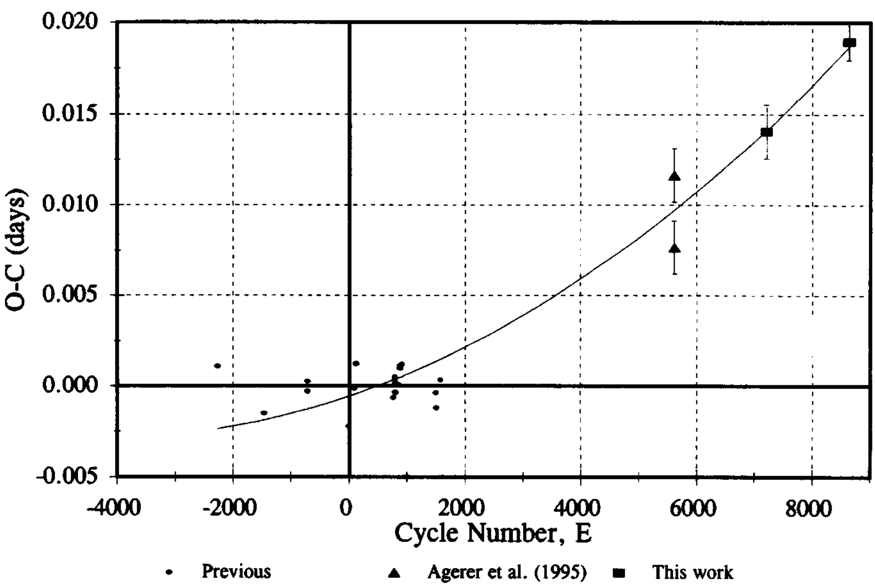

Figure 2. The O-C curve for V728 Herculis calculated using the ephemeris of equation (2). The quadratic fit of equation (3) appears to fit the new data well, but the original set less well.

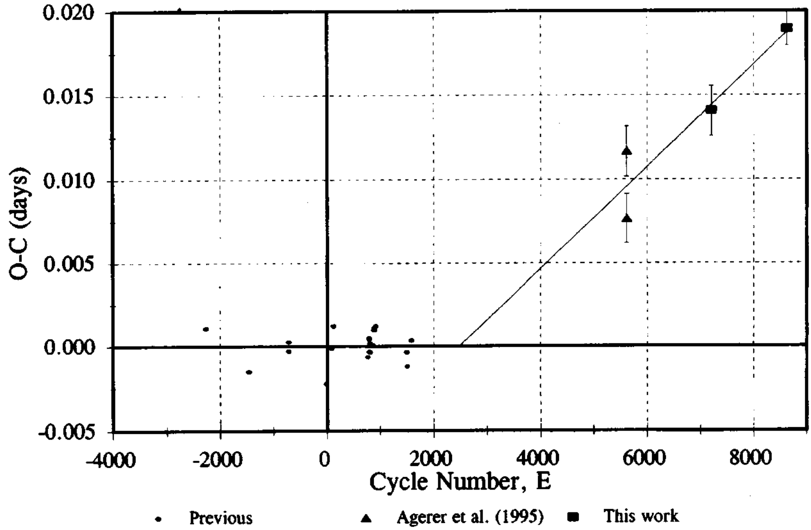

Figure 3. The O-C curve for V728 Herculis calculated using the ephemeris of equation (2). The original ephemeris, plus the linear fit of equation (5) for the last four points, appear to fit all the data well. This would imply a sudden period change at epoch E = 2479.

6. Acknowledgements

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References

Agerer, F., and Hubscher, J. 1995, *Inf. Bull. Var. Stars*, No. 4222.

Agerer, F., Kamper, B.-C., and Lichtenknecker, D. 1988, *Inf. Bull. Var. Stars*, No. 3234.

Duerbeck, H. W. 1996, in *Light Curves of Variable Stars, a Pictorial Atlas*, eds. C. Sterken and C. Jaschek, Cambridge Univ. Press, 183.

Henden, A. A., and Kaitchuck, R. H. 1982, *Astronomical Photometry*, Van Nostrand Reinhold, New York.

Hoffmeister, C., Richter, G., and Wenzel, W. 1985, *Variable Stars*, trans. S. Dunlop, Springer-Verlag, Berlin.

Kholopov, P. N., *et al.* 1985, *General Catalogue of Variable Stars*, 4th ed., Moscow.

Kurochkin, N. E. 1977, *Var. Stars Suppl.*, **3**, 201.

Kwee, K. K., and van Woerden, H. 1956, *Bull. Astron. Inst. Netherlands*, **12** (464), 327.

Nelson, R. H., Milone, E. F., and Penfold, J. E. 1988, *Inf. Bull. Var. Stars*, No. 3201.

Nelson, R. H., Milone, E. F., VanLeeuwen, J., Terrell, D., Penfold, J. E., and Kallrath, J. 1995, *Astron. J.*, **110**, 2400.

Samec, R. G. 1990, *Publ. Astron. Soc. Pacific*, **102**, 994.

Wilson, R. E., and Devinney, E. J. 1971, *Astrophys. J.*, **166**, 605.