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PHOTOMETRIC ANALYSIS OF THE CONTACT BINARY V513 HERCULIS

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Hoffmeister (1959) discovered variability in the light of V513 Herculis (Son 5300, GSC 2076-01720, $\alpha(2000) = 17^{\rm h}40^{\rm m}22^{\rm s}$, $\delta(2000) = +24^\circ15'47''$) and classified it as a W UMa system. He observed 50 times of minimum (Hoffmeister 1960) and gave an ephemeris of 2430024.654 + 0.3037689 · E. Two times of minimum by Krajci (see Nelson 2004) in 2004 complete the list of previous observations. Apparently, no other observations have been published prior to 2005 and no study of the light curve has ever been done.

Photometric observations of V513 Her were made on seven nights between June 18 and August 19, 2004, using the 46-cm Ritchey-Chrétien telescope with attached Santa Barbara Instrument Group (SBIG) ST-8XE CCD camera equipped with standard Johnson UBVRI filters. An SBIG ST-4 camera attached to the finder served as the tracking camera.

The images were calibrated and the magnitudes extracted using standard image reduction procedures with MIRA Pro (Mirametrics Inc.). Differential magnitudes in the natural system are available upon request of author NLM. Approximately 170 observations were made in each of the R, I, and V filters of V513 Her.

The comparison and check star data for V513 Her were as follows: comparison star (C)(GSC 02076-01849, $\alpha(2000) = 17^{\rm h}40^{\rm m}18\overset{\rm s}{.}6$, $\delta(2000) = +24^\circ16'3\overset{''}{.}6$); check star (K1) (GSC 02076-01976, $\alpha(2000) = 17^{\rm h}40^{\rm m}24\overset{\rm s}{.}74$, $\delta(2000) = +24^\circ15'11\overset{''}{.}2$); and check star (K2) (GSC 02076-01885, $\alpha(2000) = 17^{\rm h}40^{\rm m}25\overset{\rm s}{.}1$, $\delta(2000) = +24^\circ16'43^{\rm s}$). These stars are labeled in Figure 1.

We observed two primary and three secondary minima for V513 Her. The mean epochs of minimum light were determined from these eclipses using the bisection of chords. Table 1 contains the average times of minima for the three observed colors. The five minima of Table 1, together with the previously minima yield the following new ephemeris.

$$\text{HJD Tmin I} = 2453282.58088 \ + 0.3037690 \text{ d} \times \text{E}. \qquad (1)$$

We have calculated models for the light curves of V513 Her using the Wilson-Devinney code (Wilson 1993). Common parameters that were varied include inclination of the orbit (i), temperature of the secondary star (T_2), modified potential of the stars ($\Omega_1 = \Omega_2$), mass ratio (q), relative luminosity of the primary star (L_1), and monochromatic linear limb darkening coefficient of the primary star ($x_1 = x_2$). We assumed the star to be a

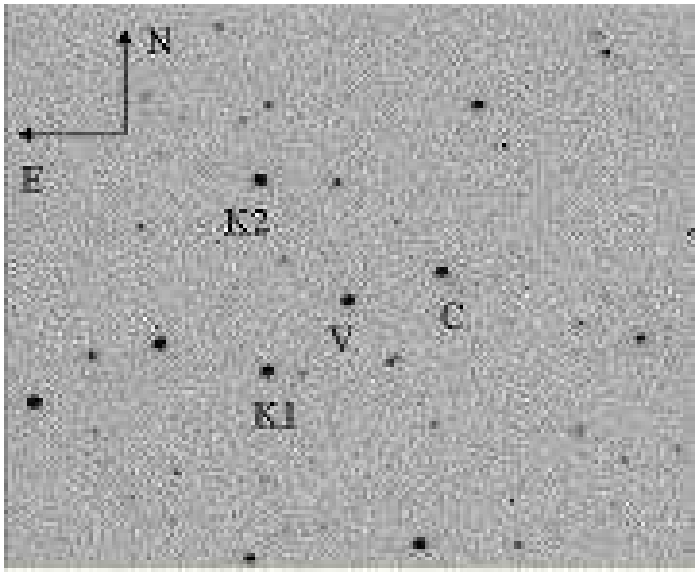

Figure 1. Finder chart V513 Her

Table 1. Times of Minimum Light

JD Hel. 2450000+	Min	O-C (days)
3175.8112	II	0.0023
3188.7198	I	0.0008
3192.6689	I	0.0009
3193.7325	II	0.0013
3200.7194	II	0.0015

contact binary system (Mode 3). The values of gravity brightening and bolometric albedo were set at their suggested values for convective atmospheres (Lucy 1968), i.e., $G_1 = G_2 = 0.32$, $A_1 = A_2 = 0.5$. Synchronous rotation was assumed for each star ($F_1 = F_2 = 1.0$). Linear limb darkening coefficients were initialized at the model atmosphere values of Carbon and Gingerich (1969). The model atmosphere option was employed for each star.

Since no previous analytical work has been done on V513 Her (in particular, no spectroscopy), we devised a method to estimate the temperature of the primary star (T_1). We observed the cluster IC 4665, computing all available color indices for stars of known spectral type (Henden and Kaitchuck 1982). This cluster was chosen for having stars of widely ranging spectral types. We then compared these color indices to the observed color indices for V513 Her. We used color index values observed near secondary minimum for V513 Her in order to minimize contributions from the secondary star. From these comparisons, we estimate the spectral type of primary star to be F5, resulting in a temperature of 6600 K (Johnson 1965).

The solution presented here comes from careful examination of the matrix of correlation coefficients and the use of the method of multiple subsets (Wilson and Biermann 1976). Solution was taken to be achieved when the parameter corrections all fell below their probable errors for all subsets. The errors listed in Table 2 are the formal errors of the

partial differential least squares technique employed in the Wilson-Devinney method. The values of the errors are used as a guide in determining the number of decimal places each parameter is given. We should note that the actual errors of the parameter determination may be higher.

The solution makes V513 Her a typical, A-type W UMa system. A steady period, a temperature of 6600 K for the primary star, and no evidence of spots supports the stable environment associated with A-type systems. The solution indicates only a slightly over contact system with a fill out factor of 10.3%.

Table 2. Wilson-Devinney Solution for V513 Her

Wavelength Independent Parameters - Mode3

i	T_1	T_2	Ω_1	Ω_2	q	F_1	F_2	G_1	G_2	A_1	A_2
74.80	6600 K	6071 K	3.436	3.436	0.840	1.00	1.00	0.32	0.32	0.5	0.5
±0.34		±65	±0.021		±0.010						

Wavelength Dependent Parameters

Band	L_1	L_2	x_1	x_2
Vis	0.623	0.377	0.6	0.6
	±0.014		±0.1	
Red	0.606	0.393	0.6	0.6
	±0.011		±0.1	
IR	0.594	0.406	0.6	0.6
	±0.008		±0.1	

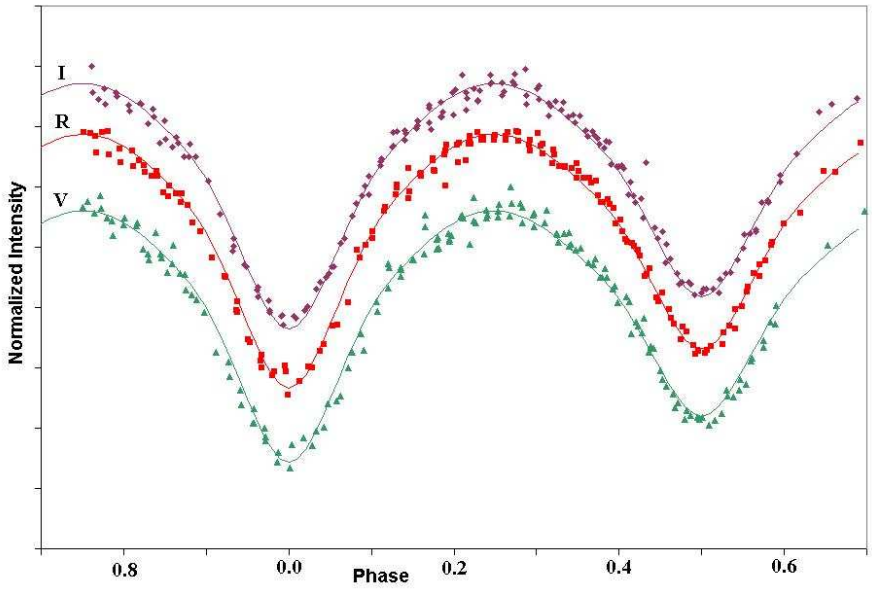

Figure 2. Light curves for V513 Her

Solid curves are the Wilson-Devinney solution given above

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