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ANALYSIS OF THE NON-VARIABILITY IN THE 78-DAY BINARY HR 503

Lloyd Evans (1977) listed 24 binary systems containing giant stars that have periods short enough for the components to interact tidally. Of these, most with periods shorter than 40 days appear to be RS CVn binaries (Hall 1976), with enhanced surface activity resulting from tidally forced synchronous rotation. Others are clearly Algol systems with the less massive component filling its Roche lobe. Examples are RZ Cnc and AR Mon (Popper 1976), possibly also AL Vel (Wesselink 1963). The rest represent a fertile and, as yet, little explored field for studies of binary star evolution: systems with giant stars that are just beginning to initiate mass exchange or which will soon begin to do it. Depending on their masses and mass ratios, these binaries can be identified by the tidal distortion of the brighter member. A good example not included in Lloyd Evans' list is 5 Ceti, whose ellipsoidal light variation has been detected by Lines and Hall (1981). Another is HD 207739 for which ellipsoidal variation was found by Bloomer (1984).

Because of its similarity to 5 Ceti in period, spectral type, and radial-velocity variations (Northcott 1949), HR 503 (G8 III-IV, V = 6.31) might be expected to have the properties of this group. Consequently we have observed it photometrically on 109 nights at two observatories, obtaining 135 differential measurements. Most of the data were obtained at Fairborn Observatory (UBV) over a period of more than a year with an automatic photometric telescope (Boyd, Genet, and Hall 1984). In addition, Eaton observed it over an interval of two weeks at Kitt Peak National Observatory (BVRI -- Cape R and I bands) with the No. 4 16-inch telescope, obtaining 16 data on 8 nights.

The colors of HR 503 are as follows: (U-B) = 0.47, (B-V) = 0.89, $(V-R)_C$ = 0.47, and $(V-I)_C$ = 0.90. The colors do not match the G8 III spectral type especially well; rather they correspond to G4 III or K1 V on the standard relations of Johnson (1966). The brightness was essentially constant over the period of observation, as is apparent from Figure 1. Fourier analysis of the photometry on the 78.0073-day period of the orbit shows that ellipsoidal variation (cos2θ and sin2θ terms) was less than 0.2%; RS CVn-type wave distortion (cosθ and sinθ terms), less than 0.2%. The system was 0.521 mag fainter in V than the comparison star (HR 523) used at Fairborn Observatory.

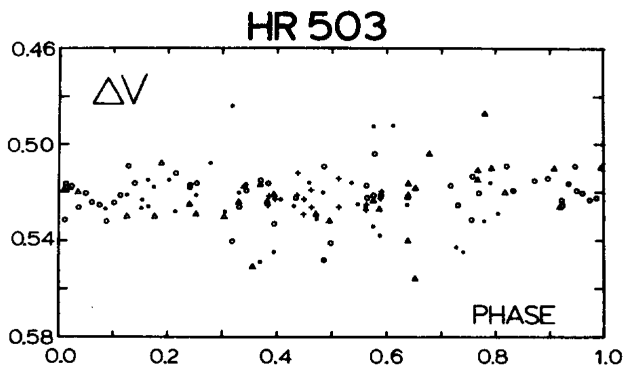

Figure 1. Differential photometry of HR 503 for the period JD 2,445,700 - JD 2,446,126. Plotted are magnitude differences, HR 503 minus HR 523. Phases have been computed with the spectoscopic ephemeris, $JD_{\odot}$(observed) = 2,431,730.5489 + 78.0073Phase (Northcott 1949). Data for three orbital cycles and for the two observatories are indicated with different symbols: dots for data before JD 2,445,757 (Fairborn Observatory), circles for data between JD 2,445,757 and JD 2,446,045 (Fairborn), triangles for data after JD 2,446,050 (Fairborn), and plusses for Eaton's Kitt Peak data between JD 2,445,957 and JD 2,445,974.

The colors, mass function, and low photometric variability of the star place stringent limits on the properties of the system. Since the radial velocity amplitude is fairly large (K_1 = 20.1 km/s -- Northcott 1949) for a 78-day binary, and since the system does not eclipse, the inclination cannot be extreme in either sense. We will assume that it has its most likely value, $i \approx 60°$. The lack of strong ellipsoidal variation requires the mass ratio to be fairly small, q = 0.5-0.33. On the other hand, if $q < 0.33$, the masses become uncomfortably large for reasonable values of the inclination. A best estimate, then, is $q = 0.4 \pm 0.1$, for which $R_1/a \leq 0.12$ to give the observed ellipticity. The radius of the G8 star is thus $R_1 \approx 13\ R_{\odot}$, consistent with its III-IV luminosity type. We thus have a system containing a 2.7 $M_{\odot}$ giant and a 1.2 $M_{\odot}$ dwarf. The position of the giant in the theoretical H-R diagram of Iben (1967) is consistent with this mass. The G giant will contribute roughly ten times as much light at V as a 1.2 $M_{\odot}$ F dwarf, and a combination of F5 V and G8 III stars with this light ratio and the intrinsic colors given by Johnson (1966) reproduces the observed colors of the system quite well. All colors agree to within 0.02 mag, except (U-B) where the agreement is a respectable 0.10 mag. The Roche lobe radius is large enough that the G giant could have already evolved through helium flash without initiating mass transfer.

The near constancy of HR 503 allows us to make an unbiased estimate of the quality of data coming from the automatic photometry program. Residuals of the Fairborn Observatory V-band data from the fitted curve in the Fourier analysis showed roughly a bimodal distribution, 85% of the data giving a roughly normal distribution with $\sigma = 0.006$ mag. The other 15% of the data formed a more extended distribution and probably represent nights that were not photometric. This degree of accuracy is comparable to the 0.004 mag shown by Eaton's data from the Kitt Peak 16-inch.

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