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B AND V LIGHT CURVES OF THE MASSIVE CLOSE BINARY DH CEPHEI

DH Cep (= HD 215835; SAO 34810; <V> = +8.58) is a double-lined, massive spectroscopic binary consisting of a pair of O5-6 V stars having an orbital period of 2.111 days. The spectrographic radial velocity study of Pearce (1949) indicates an orbital eccentricity of $e = 0.13$ and values of $M_1 \sin^3 i = 23.4 M_\odot$ and $M_2 \sin^3 i = 19.1 M_\odot$. Photoelectric photometry of DH Cep was carried out by Hill, Hilditch and Pfannenschmidt (1976) in which small ($\approx$ 0.05 mag) light variations were observed but the data were too few to define a light curve. In agreement with this photometry, observations of the star in the ultraviolet($\lambda\lambda$1550–3300) made with the *ANS* satellite during 1975 and 1976 show only low amplitude brightness changes which appear to arise from the distorted figures of the binary components (Wu and Eaton 1981). The membership of DH Cep in the young open cluster NGC 7380 (Hoag and Applequist 1965; Underhill 1969) and the inferred large masses of the stellar components make this an interesting and important binary system. Moreover, if the orbital eccentricity found from the early radial velocity study of Pearce (1949) is real, then DH Cep would be expected to have large apsidal motion from classical and relativistic effects.

Photoelectric photometry of DH Cep was conducted on 24 nights during 1985 August and September at Lines Observatory (Mayer, Arizona). The observations were made by H. C. L. and R. D. L. using the 20-inch reflecting telescope equipped with a 1P21 PMT and filters closely matched to the *UBV* system. Differential photometry of DH Cep was made with respect to the nearby comparison star, HD 215714 (= SAO 34785; V = +7.58; F8:) and HD 215868 (= SAO 34816; V = +8.41; B9) served as a check star. On the several nights on which the check star was observed, no significant light variations were detected between the check and comparison stars. Because of the angular proximity of the comparison check, and variable stars, the differential extinction corrections were very small. The familiar *sky-comparison-variable-comparison-sky* observing sequence was used. Differential extinction corrections were applied and the differential measures were transformed to Δ V and Δ B of the standard UBV system. The observations are plotted in Fig. 1 against orbital phase using the ephemeris,

$$T_{min} = \text{HJD}2446291.7784 + 2.^{d}11104.E,$$

in which the period is the spectrographic orbital period given by Pearce while the epoch is from the present observations and refers to the mid-point of the deeper light minimum. The deeper light minimum occurs within about 0.15P of the time of conjunction in which the more massive component is most distant from the observer according to Pearce's spectrographic elements. It should be recalled, however, that Pearce's study was carried out over 37 years ago and that small errors in the published period and possible period changes could cause the ephemeris to yield uncertain results.

As shown in the figure, the light curves are well defined and display two minima and two maxima within an orbital cycle. The two maxima of each light curve are equal in brightness within $\pm$ 0.005 mag while the corresponding minima are slightly different. For the V light curve the depth of deeper minimum and shallower minimum are 0.042 mag and 0.037 mag respectively, while for the B observations the depths of the deeper and shallower minima are 0.045 mag and 0.039 mag, respectively.

The small light amplitudes and the cos2Θ dependence of the brightness variation on the orbital phase indicate that DH Cep is an ellipsoidal variable star. As described by Morris (1985), ellipsoidal variable stars are close binaries whose components are distorted by their mutual gravitation, but have orbital inclinations that are too small to produce eclipses. Therefore, the observed brightness variations

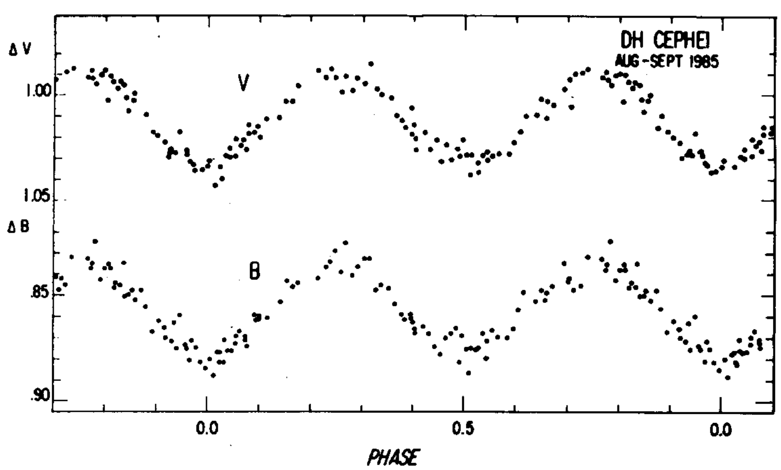

FIGURE 1. The differential B and V observations of DH Cep are plotted against orbital phase. The phases were computed with the light elements given in the text.

occur from the changing aspects of the tidally distorted stars as they undergo orbital motion.

A closer examination of the light curves reveals that the two minima of each light curve are about 0.50P apart. Unless we are viewing the binary system along its major axis so that the longitude of the periastron, ω, is nearly equal to 90° or 270°, so that $e\cos\omega \approx 0.0$, then it appears that the orbital eccentricity found by Pearce is too large or even spurious.

As shown in the figure, the shapes of the minima at 0.0P and 0.5P appear slightly different. The deeper minimum at 0.0P is sharper and narrower than the corresponding minimum at 0.5P in each wavelength. This behavior could be produced by the eccentric orbit if periastron and apastron occur near the conjunctions of the orbit at 0.0P and 0.5P, respectively. This would be consistent with values of the longitude of periastron of $\omega \approx= 90^\circ$ or 270°, implied from the occurence of the two minimum nearly one half period apart. The difference in the shapes of the two minima arise chiefly from the changes in orbital velocity between periastron and apastron. The observed differences in shape are small, however, and could be produced by other effects such as circumstellar gas or streams.

Exploratory modeling of the light curves was carried out using the Wilson-Devinney computer program (Wilson and Devinney 1971). We found that we could not fit the present light curves with an orbital eccentricity greater than about ≈ 0.05. The preliminary modeling also indicated that both stars are inside their Roche lobes and that the orbital inclination appears to lie between 45° and 55°. If we adopt Pearce's values of $M\sin^3 i$ obtained from the radial velocity study, then the masses of the two components are $42M_\odot \leq M_1 \leq 65M_\odot$ and $35M_\odot \leq M_2 \leq 54M_\odot$. With a total systemic mass of $77M_\odot \leq M_{1+2} \leq 119M_\odot$, DH Cep is one of the *most* massive binary systems discovered so far.

Additional photometric observations of DH Cep are planned at Lines Observatory and also at Villanova University Observatory. These observations should provide a check on the orbital eccentricity of the system, since, if the orbit is eccentric, the rate of apsidal motion is expected to be quite large from classical and relativistic effects($\dot{\omega}^{theor}_{CL+GR} \approx 30$deg/yr.). If this is the case, then a measurable displacement of the shallower minimum from the deeper minimum should be observed. A more detailed analysis of DH Cep will be made after the new light curves are obtained.

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