EVIDENCE FOR THE ROCHE LOBE OVERFLOW IN VV CEPHEI

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ABSTRACT. The VV Cep close binary system (O8V + M2 Iab; P=20.3 yrs.) is described from published spectral, radial velocity, photometric, and astrometric results. A long-term photometric monitoring program shows intrinsic variability in a red bandpass. Variability exists on several time scales and the longest of these is attributed to tidal distortion of the cool supergiant by the equally massive hot companion. A theoretical "distortion" light curve, when faced against the observations, indicated the radius of the supergiant to be significantly smaller than the accepted value of $\sim 1600 R_\odot$. This conclusion is examined in the context of a pulse of polarized red light occurring near the time of periastron and interpreted as Roche Lobe overflow of the supergiant envelope. It is shown that the photometric and polarimetric results may be made accordant, not by appeal to a very large level of scattered red light, but rather by invoking the loss of constraint originally imposed by the Roche Lobe geometry.

1. INTRODUCTION

VV CEP (HD 298816, BD+ 62°2007) is the very long period prototype of the small class of objects summarized by Cowley (1969). Relatively bright, it embodies an O8 V star (Hutchings and Wright 1971) embedded in a shell and an M2 Iab companion which, at least sporadically, contributes to the shell mass. It is clear that the mass ratio is approximately unity and that the astrometric orbit is close to the limit of ground-based capability. From visual and photographic estimates there is informative continuity of light curve coverage outside eclipse. The eclipse itself is a composite of body occultation plus atmospheric attenuation and scattering and has twice been measured photoelectrically. Photoelectric

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coverage outside eclipse has been discontinuous but sufficient to show intrinsic variability--presumably due to pulsation--on a variety of time scales. Because the intrinsic variability is most conspicuous in the red, it may be ascribed to the red supergiant.

2. PHOTOMETRY

With the assistance of several students, EFG and GPM have sustained photoelectric monitoring of the VV Cep system since 1975, i.e. from before apastron, through primary eclipse, ascending nodal passage of the M-star and periastron, until past the secondary conjunction during the present observing season. Although several bandpasses were used, the red data alone form the subject of the present report. They demonstrate semi-regular variability on time scales from about 50 to a few hundred days. More emphatically, through the midst of these variations, there runs a longer time scale variation of some 1,300 days with a peak-to-peak amplitude of about 0.2 mag. It is suggested that this is due to the tidal distortion of the M-star as seen by the observer. A display of this sort, including the "O'Connell periastron effect," has been recognized and successfully modelled for 32 Cyg by Guinan and McCook (1974). The code used for 32 Cyg was initialized for the parameters of VV Cep and was faced against the red light curve. This procedure permitted evaluation of numerous (and partly correlated) orbital and stellar parameters, among them the M-star radius independently of the eclipse analysis. The morphology of the theoretical light curve so calculated was quite recognizable: an insignificant eclipse, followed by a gradual rise of about 0.06 mag to a maximum light level as the star presented more of its distorted photosphere to the observer when approaching its ascending node, succeeded by a localized light minimum (about 0.3 mag deep) due to the more nearly end-on presentation of the star around secondary conjunction, and finally recovery to a higher light level during the other nodal passage. Even though the cycle has not yet been entirely observed, the 12-year coverage through the critical phase interval after 1983 was believed to offer ample observational weight to evaluate the M-star radius. Because the observed minimum around secondary conjunction was of small amplitude (about 0.1 mag) it was concluded that the fractional radius was of the order of 0.2$\underline{a}$, in which $\underline{a}$ is semi-major axis of the orbit. This value is significantly smaller than the published value of about 0.35$\underline{a}$.

3. POLARIMETRY

From 1976 through the present, RHK and RJP have sustained linear polarization monitoring of VV Cep. Several bandpasses were employed but only red data are invoked here. Because the systemic light ratio in the red is so powerfully dominated by the M-star, any scattered and polarized red photons have originated from that star although the scattering may occur far from the star itself. No eclipse effects were detected but variability on short (about 50 days) to long (about 150 days) time scales was easily seen. These semi-regular variations were not consistently time-locked to the red light variations of comparable time scales. From the polarimetric coverage in other bandpasses it was possible to model the scattering and polarization effects from the M-star's distorted photosphere, a systemic envelope, the O-star shell, and from a stream passing from the M- to the vicinity of the O-star. Superimposed upon this variability there appeared a transient (lasting about 400 days) associated with, but preceding, perisastron passage. We construe this transient to arise in the following way. Because the orbit is quite eccentric (e = 0.35), the dimensions of the Roche Lobes scale themselves continuously to the changing radius vector in a first approximation. The published radius of the M-star (derived from eclipse analysis and subject, of course, to all its other intrinsic variability) first attains Roche Lobe contact just before periastron and this results in substantial mass outflow. Because the orientation of the electric vector does not suffer a significant transient, it is possible to say that the greatest concentration of the gas is confined to the orbital plane but some 3-dimensional overflow must also occur. This particular transient, then, offers evidence for the large radius of the M-star already in the literature.

4. CONCLUSIONS

We have been able to reconcile the photometric distortion claim for a small M-star and the eclipse plus spectroscopic plus polarimetric requirement for a large one by the following reasoning. The validity of the distortion light curve code is intact only as long as no substantial outflow occurs. If the periastron encounter results in large outflow, the requirement of a substantial light minimum through the following phase interval cannot be sustained. This interval is the sensitive one demanding a small-size star. The polarimetry by itself gives ample evidence of a scattering envelope. Because the intrinsic red polarization is of the order of 0.75%, the scattered radiation level must be much greater than 1%. M-star photons scattered from the envelope substantially above and below the orbital plane will mimic a more spherical, less-distorted star leading to an inference of a small radius for the given q. This possible interpretation may be checked numerically: if the observed and theoretical amplitudes of the local light minimum are taken at face value, a simple calculation leads to a scattered red light level of about 0.7L(M-star). This value is incredibly large. We conclude that the absence of the theoretically-expected photometric distortion effect is caused predominantly by the overflowing M-star envelope diffusing into a quasi-spherical distribution and that the M-star radius really is of the order of size given by the eclipse and spectroscopic anslyses.

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REFERENCES

Cowley, A. P. 1969, Publ. A.S.P. 81, 297.
Guinan, E. F., and McCook, G. P. 1974, Publ. A.S.P. 86, 947.
Hutchings, J. B., and Wright, K. O. 1971, M.N.R.A.S. 155, 203.

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