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NEW TIMES OF MINIMUM FOR V444 CYGNI

The importance of the binary system V444 Cyg lies in the way it tells us so much about Wolf-Rayet stars (Cherepashchuk et al. 1984; St-Louis et al. 1993). The mutual eclipses of its WN5 and O6 components determine the structure of the wind of a WR star with a known mass and size. Furthermore, the rate at which the orbit of this binary system increases determines the mass loss rate of the WR star, provided some assumptions are made about the wind. Khaliullin (1974) first pointed out that impulsive isotropic mass loss from a component of a binary will produce a steady period increase and used this effect to determine a mass loss rate near 10^{-5} $M_{\odot}$/yr in V444 Cyg. Khaliullin et al. (1984) have refined the estimated mass loss rate further, while more recently Underhill et al. (1990) have added a few more times of minimum and argued for a somewhat smaller mass loss rate.

Table 1. Recent Times of Minimum Light

HJD	Type	O-C	Source
2,444,913.424 ± 0.004	pri	0.017	Eaton et al. (1982)
2,444,915.526 ± 0.004	sec	0.016	Eaton et al. (1982)
2,445,528.460 ± 0.003	pri	0.040	Underhill et al. (1990)
2,445,972.860 ± 0.006	both	0.032	this paper-KPNO
2,447,394.562 ± 0.006	pri	0.034	Underhill et al. (1990)
2,447,767.405 ± 0.006	sec	0.076	St-Louis et al. (1993)
2,447,773.678 ± 0.006	pri	0.031	Underhill et al. (1990)
2,449,519.78 ± 0.01	sec	0.078	this paper-APT
2,449,540.830 ± 0.002	sec	0.066	this paper-APT

We have decided to begin measuring times of minimum to determine whether the period continues to increase. We are concentrating on <u>secondary</u> eclipse, the eclipse

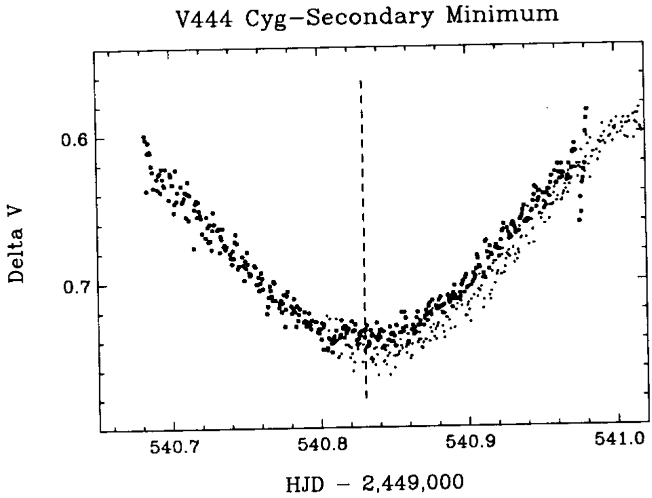

Figure 1. Observations of secondary eclipse of V444 Cyg made with the Vanderbilt-TSU robotic telescope. Magnitude differences are measured with respect to HD 193514, the standard comparison star. Two eclipses are plotted, one centered on JD 2,449,540 (large symbols) and another on JD 2449519 (small dots) moved forward by an integral number of cycles. The effect of morning twilight is seen in the large scatter at the end of the former night. The latter light curve is fainter by about 0.02 mag at all phases sampled, a typical photometric complication in this star. The dashed vertical line is the time of minimum light found from the later of these two eclipses.

of the WR star by the O6 star, because it is shorter and less likely to be affected by fluctuations in the WR wind. To this end we obtained differential photometry in B and V on two nights in summer, 1994, with the 16-inch Vanderbilt-Tennessee State robotic telescope (Henry and Hall 1994). Figure 1 gives the observed light curve in V. The time of minimum (combination of values from B and V) for the night that detected both ingress and egress was HJD 2,449,540.830 ± 0.002. We have determined a second time of minimum for the earlier partially observed secondary eclipse (small symbols in Figure 1) by fitting an average profile for secondary eclipse, determined by Cherepashchuk and Khaliullin (1973), to the observations in hand, viz., HJD 2,449,519.78 ± 0.01. A third time of minimum (HJD 2,445,972.860 ± 0.006) is found by simultaneously fitting the rising branch of primary minimum and falling branch of secondary minimum recorded

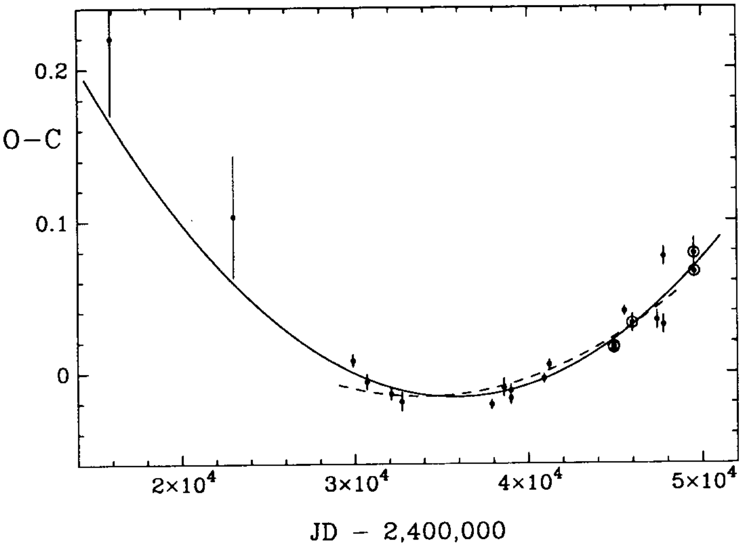

Figure 2. Residuals from a linear ephemeris for all available times of minimum of V444 Cyg. The new and ignored points from Eaton are circled. The solid curve is fitted by least squares to the residuals. The dashed curve is the fit to the points considered by Underhill et al. (1990).

in a partial V-band light curve we obtained in 1984 at Kitt Peak National Observatory (see Breger 1985, file 118). In addition, there are two obscure times of minimum that Eaton et al. (1982) obtained with the IUE satellite, another time of secondary minimum from St-Louis et al. (1993), and the three times of primary minimum from Underhill et al. (1990).

All these recent times of minimum are listed in Table 1, along with deviations from the linear ephemeris of Khaliullin (1974),

$$\mathrm{HJD(Obs.)} = 2{,}441{,}164.337 + 4.212435 \times \mathrm{E} \qquad (1)$$

We combine them with those of Khaliullin et al. (1984) in Figure 2. Our new residuals are seen to be following the trend toward longer periods expected for continuous mass loss. The rate of change derived by including the new times of minimum is greater than found by Underhill et al., but it is still somewhat smaller than originally derived by

Khaliullin et al. The rate of period change is $\dot{P} = 3.84 \pm 0.19 \times 10^{-9}$ days/day. If we adopt the masses of Underhill et al. (1988), $M_{WR} = 11.3\ M_\odot$ and $M_O = 37.5\ M_\odot$, this period increase corresponds to $\dot{M} = 8.1 \pm 0.4 \times 10^{-6}\ M_\odot$/yr for isotropic mass loss by the WR star. Uncertainties in the masses now appear to be critical to the mass loss rate, for the recent masses of Marchenko et al. (1994), $M_{WR} = 9.3\ M_\odot$ and $M_O = 27.8\ M_\odot$, give $6.2 \times 10^{-6}\ M_\odot$/yr.

An indication of the quality of the data obtainable with an automatic telescope is the clearly defined times of second and third contact evident in Figure 1. The third contact is seen in both nights' data. This effect would be much more difficult to detect in manual differential photometry with its lower data rate.

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