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TIMES OF MINIMA OF FIVE ECLIPSING BINARIES

We report photoelectric times of minima of double-lined detached eclipsing binaries derived from photometric observations made with a six channel Strömgren photometer attached to the 0.9m reflector at Observatorio de Sierra Nevada (Granada, Spain), and a single channel Strömgren photometer attached to the 1.52m reflector at Observatorio Astronómico Nacional (Calar Alto, Almería, Spain). The observations, performed in u, v, b, y, H_{β_w} and H_{β_n} filters in the case of PV Cas, V442 Cyg and V477 Cyg, and in H_{β_w} and H_{β_n} in the case of CW Cep and U Oph, were corrected for system deadtime and atmospheric extinction. The adopted heliocentric times of minima were computed from the weighted average over all filters, which were in all cases concordant. Uncertainties in the times of minima are the standard deviation of the computed values for the various filters used.

PV Cas, CW Cep, V477 Cyg and U Oph have been included in a published list of eccentric eclipsing binaries to be eclipse monitored (Giménez, 1995).

In order to compute the values O−C we have selected precise ephemeris especially because the observed systems are detached and some of them eccentric, showing a substantial amount of apsidal motion. In general, the rotation of the apsidal line, considering only secular terms, produces a sinusoidal displacement of both primary and secondary eclipse with respect to linear predictions. The most general expression to compute times of minima taking into account this effect, considers an infinite Fourier series as a function of the true anomaly. The coefficients of the series can be computed by means of the eccentricity, the orbital inclination and the anomalistic period. In fact, a fifth order equation is usually sufficient regarding the precision of the photoelectric measurements, since it includes powers of eccentricity up to 5. This fifth order equation gives the times of minima of the eclipsing binary as a function of a reference time T_0, the sidereal period P_s, the anomalistic period P, the periastron longitude ω, the orbital inclination i and the eccentricity e. Light curve analysis provides good values of e and i, and times of minima can be used to obtain the rest of parameters. A detailed discussion about the determination of nonlinear ephemeris can be found in Giménez & García-Pelayo (1983). For three of the observed systems, complete studies of apsidal motion have been performed, leading to more accurate expressions than linear ephemeris.

The ephemerides were adopted as follows:

PV Cas:

$$T_{min,j} = HJD\ 2441729.2905 + P_s E + 0.5(j-1)P + 0.01795(2j-3)\cos\omega + 0.00022\sin 2\omega$$

With $P_s = 1.750470$ d, $P = 1.750562$ d and $\omega = 197.0 + 0.0189\ E$ in degrees. The index j is 1 for primary eclipses and 2 for secondaries. The ephemeris was taken form the apsidal motion study performed by Giménez & Margrave (1982), and the obtained parameters are in excellent agreement with those computed in the recent studies of Barembaum & Etzel (1995) and Wolf (1995). The adopted expression was tested with recent times of minima, showing a low dispersion ($\simeq 0^d.0015$) and no systematic deviations.

CW Cep:

$$T_{min,j} = HJD\ 2441669.5722 + P_s E + 0.5(j-1)P + 0.02581(2j-3)\cos\omega + 0.00029\sin 2\omega$$

With $P_s = 2.729139$ d, $P = 2.729588$ d and $\omega = 201.6 + 0.0593\ E$ in degrees. The index j is 1 for primary eclipses and 2 for secondaries. The apsidal motion parameters for this system were obtained by Giménez *et al.* (1987) and the final expression was computed using the previously described method (Giménez & García-Pelayo, 1983).

V442 Cyg:

Min I =HJD 2444919.561+2.3859437 × E (Lacy & Frueh, 1987)

The secondary minimum was assumed to be at phase 0.5.

This system is known to be eccentric although no detailed studies of apsidal motion have been performed. The adopted linear ephemeris does not show a very good agreement with recent times of minima, although the value O−C in our case is outstandingly low.

Table 1

System	Type of eclipse	HJD (−2400000)	O−C (days)	Comparison Stars
PV Cas	Secondary	50048.4031	−.0012	HD 220760
		±0.0003		BD +60°2509
CW Cep	Primary	50045.2793	.0029	HD 218342
		±0.0007		HD 217035
V442 Cyg	Secondary	50043.3757	.0006	BD +31°3924
		±0.0025		HD 188725
V477 Cyg	Secondary	50043.3598	−.0144	BD +31°3924
		±0.0019		HD 188725
U Oph	Secondary	49905.5077	.0060	HD 156208
		±0.0006		HD 154445

V477 Cyg:

$$T_{min,j} = HJD\ 2439762.6724 + P_s E + 0.5(j-1)P + 0.22986(2j-3)\cos\omega + 0.02698\sin 2\omega$$
$$-0.00380(2j-3)\cos 3\omega - 0.00054\sin 4\omega + 0.00008(2j-3)\cos 5\omega$$

With $P_s = 2.3469768$ d, $P = 2.3470199$ d and $\omega = 145.6 + 0.00661\ E$ in degrees. The index j is 1 for primary minima and 2 for secondaries. The most recent apsidal motion study of this system was undertaken by Giménez & Quintana (1992), and we adopted the nonlinear ephemeris proposed in that work. The agreement with recent times of minima is not very good, showing O−C significantly negative for secondary minima. The same trend is shown in our observation presented in Table 1.

U Oph:

Min I = HJD 2440484.6890 + 1.67734598 $\times E$ (GCVS, Kholopov, 1985-87)

The secondary minimum was assumed to be at phase 0.5.

This system is known to be eccentric and shows apsidal motion, but the adopted linear ephemeris shows a better agreement with recent times of minima than the nonlinear ephemeris computed from the apsidal motion parameters given in Kämper (1986).

C. JORDI and I. RIBAS
Dept. d'Astronomia i Meteorologia
Universitat de Barcelona
Avda. Diagonal, 647
E-08028 Barcelona
Spain

J.M. GARCÍA
Dpto. de Física Aplicada E.U.I.T.I.
Universidad Politécnica de Madrid
Ronda de Valencia, 3
E-28012 Madrid
Spain

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