A PHOTOMETRIC-SPECTROSCOPIC ANALYSIS OF THE ALGOL-TYPE BINARY U CRB

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U CrB is a well-known Algol-type eclipsing binary (P = $3^{d}.4522$, spectrum B6 V + G0 III-IV). Although the system has been closely observed since it's discovery (Winnecke, 1870), progress in unraveling its true nature has been slow.

Early spectroscopic work suggested an early-type spectrum for the secondary which was in variance with the near absence of a secondary eclipse in the lightcurve. Rapid variations were also noted in the lightcurve (Lause, 1938; Batten, 1964; Piotrowski *et al.*, 1974; Olson, 1982), which are only partly attributable to the variability of the commonly used comparison star HD 137147 (Olson, 1980; van Gent, 1982a).

The eclipse period of U CrB has long been known to be variable but the data accumulated thus far has been interpreted either as due to abrupt period-jumps, possibly induced by mass-transfer events (Batten, 1964; Catalano *et al.*, 1966; Frieboes-Conde & Herczeg, 1973) or as periodic, indicating the presence of a third body (Kreiner, 1971; Frieboes-Conde & Herczeg, 1973; Bakos & Tremko, 1981; van Gent, 1982b).

In order to obtain more precise estimates of the absolute dimensions of U CrB, the system has been observed in 4 narrow UPS passbands ranging from 474 to 871 nm (Heintze, 1988) during the period 1980-1987 (van Gent, 1988a). With respect to a constant comparison star (HD 136654), the lightcurve still shows seemingly irregular variations, notably during primary minimum (cf. Figure 1).

The photometric lightcurves were analysed in combination with Batten & Tomkin's (1981) radial-velocity measurements of both components (van Gent, 1988b). The results from the narrow-band UPS lightcurves were compared with those from the broad-band UBV lightcurves of Wood (1958) and Svolopoulos & Kapranidis (1972) by introducing accurate passband-weighted fluxes derived from modern model atmospheres in the standard Wilson-Devinney code (van Gent, 1988c). The albedo- and gravity-darkening coefficients were set at their standard values ($A_1 = g_1 = 1$, $A_2 = 0.5$, $g_2 = 0.32$). The T_{eff} of the primary was fixed at 13900 K (Plavec *et al.*, 1981) and the limb-darkening coefficients were taken from Wade & Rucinski (1985). Rotational-velocity measurements of the primary (Olson, 1984; Tan Huisong, 1986) are consistent with synchronous rotation and the rotation factors of both components were set at unity. Preliminary

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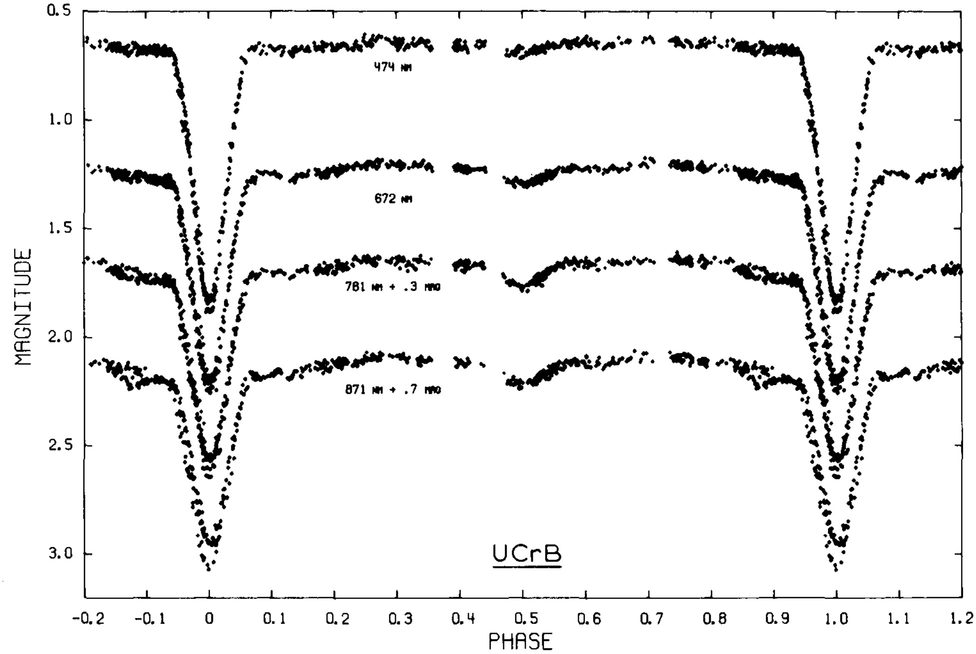

Figure 1. The UPS lightcurves of U CrB as derived from data collected during the period 1980-1987 (van Gent, 1988a). Magnitude differences are with respect to the comparison star HD 136654. Note the eclipse-depth variations at primary minimum and the variations near phase 0.85

iterations indicated that the secondary very nearly filled (or even exceeded!) it's Roche-lobe and the secondary was constrained at this critical volume in the final iterations (results are summarized in Table 1 and Figure 2).

The O-C curve of U CrB (Figure 3), as supplemented by recent UPS data, shows no evidence for a light-time effect and can be modelled by piecewise constant periods punctuated by abrupt period-jumps ($|\Delta P/P| \sim 10^{-5}$) on an approximately decennial timescale. A detailed study of the O-C curve of the past few decades (based on photoelectrical data only) reveals a more complex behaviour - around 1980 the period appears to have changed abruptly twice within an interval less than a year. On both occasions the change was of comparable amplitude ($|\Delta P/P| \gtrsim 10^{-4}$), but of opposite sign. After 1980, the orbital period is only slightly larger (circa $2^{s}.2$) than that before, but the O-C curve is shifted $0^{d}.01$ downwards - similar to the shifts observed in the O-C curves of RZ Cas (Herczeg & Frieboes-Conde, 1974) and U Cep (Crawford & Olson, 1979).

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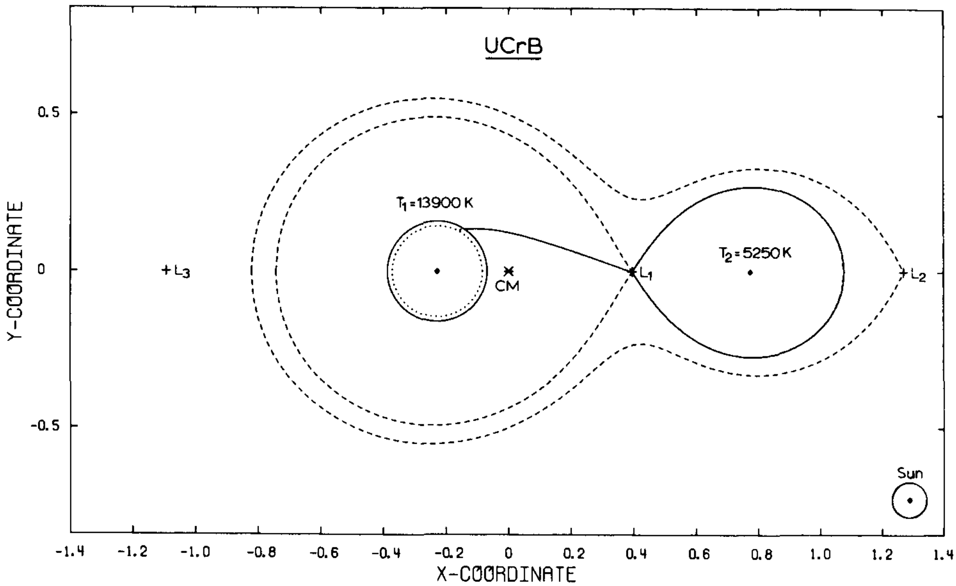

Figure 2. Absolute geometry of U CrB (dimensions in units of the semi-major axis) as determined from a combined lightcurve/radial-velocity Wilson-Devinney analysis (van Gent, 1988b). Also depicted are the inner- and outer Roche lobes with the canonical Lubow-Shu (1975) stream trajectory. The dotted circle just inside the primary delineates the maximum low-density disk radius.

TABLE 1. Absolute dimensions, masses, radii and luminosities for U CrB

	Batten (1956)	Cester et al. (1977)	Batten & Tomkin (1981)	van Gent (1982b)	van Gent (1988b)		
					W	SK	UPS
$a(R_\odot)$	20		17.5	17.8	17.8(3)	17.5(4)	17.9(3)
q	0.378(8)	0.38	0.29	0.289(8)	0.299(3)	0.310(9)	0.293(5)
$M_1(M_\odot)$	6.5	6.7	4.8	4.8(2)	4.86(24)	4.63(29)	4.98(25)
$M_2(M_\odot)$	2.5	2.6	1.4	1.5(1)	1.45(7)	1.43(9)	1.46(8)
$R_1(R_\odot)$	3.5	3.5	3.3	3.3(2)	2.83(5)	2.66(12)	2.73(7)
$R_2(R_\odot)$	5.5	5.3	4.5	4.4(1)	4.93(8)	4.91(11)	4.94(9)
$\log L_1(L_\odot)$	2.86	2.85	2.65		2.43(2)	2.38(4)	2.40(3)
$\log L_2(L_\odot)$	2.26	1.33	1.25		1.20(2)	1.21(4)	1.24(2)

Numbers between brackets denote standard errors in units of the last significant decimal.

Source lightcurves: W Wood (1958)
SK Svolopoulos & Kapranidis (1972)
UPS van Gent (1988a)

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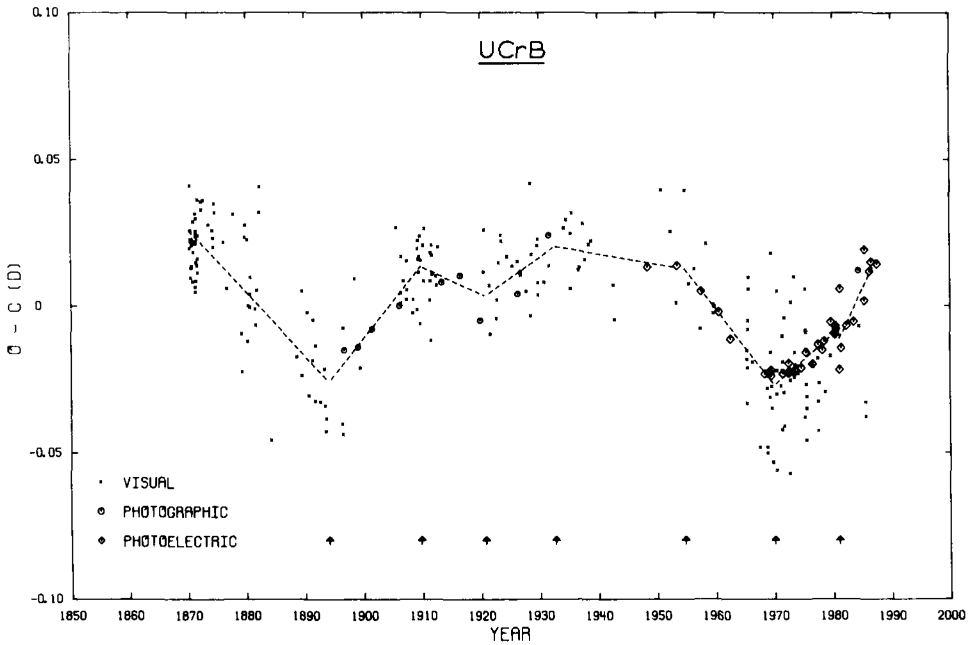

Figure 3. The O-C diagram of U CrB as delineated by visual, photographical and photoelectrical observations. Dashed lines delineate intervals of constant period between period-jump events (indicated by the bottom symbols).

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DISCUSSION

Olson commented that the effects of telluric lines are not important, since observations of check and comparison stars clearly show that they are cancelled out. He also stated that he had used RCA Ga As tubes for some years, both in differential and in all-sky standard photometry, without obvious problems. Finally he emphasized the importance of retaining short-wavelength filters, since the light-curves obtained with them provide important astrophysical information. Heintze replied that for some bright eclipsing variables the only suitable comparison star is not necessarily very close in the sky; telluric effects are then not fully cancelled in the differential measurements. He also said the tubes that he had experience with could be used for differential, but not for absolute photometry. Finally, he explained that light-curves were still being observed at short wavelengths, but experience had shown that reliable relative radii could be determined only from those obtained at 672, 781 and 871 nm. Rucinski commented that in his experience some RCA 31034 tubes gave problems, but this kind of tube had been used successfully for fundamental photometry - particularly by Cousins at S.A.A.O. He suggested checking the internal stability of the photometer and tube. Heintze replied that checks had shown that everything worked fine, so long as the photometer was kept in a fixed position.

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