COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5545

Konkoly Observatory
Budapest
30 July 2004

HU ISSN 0374 – 0676

CX CMa - AN EARLY-TYPE DETACHED ECLIPSING BINARY

NELSON, ROBERT H.[1,2]; TERRELL, DIRK[3]

[1] 1393 Garvin Street, Prince George, BC, Canada, V2M 3Z1; e-mail: bob.nelson@shaw.ca

[2] Visiting astronomer at Mt John University Observatory, Lake Tekapo, New Zealand and at the University of Canterbury

[3] Dept. of Space Studies, Southwest Research Institute, 1050 Walnut St., Suite 400, Boulder, CO 80302, USA, e-mail: terrell@boulder.swri.edu

The discovery of the variability of CX CMa (= CD $-25°4424$ = GSC 6541-1691, $7^h22^m00^s.99$, $-25°52'35''.9$, J2000.0) is credited to Hoffmeister (1931) who labelled it as "58.1931 CMa" although there was some early confusion regarding who discovered its variability (*viz.* Milone, 1986). Milone (1986) obtained photoelectric light curves in U, B, and V in late 1977. He noted that all three curves exhibited asymmetric maxima – for V, the maximum following the secondary minimum (max II) was some 0.05 magnitudes brighter than the other (max I). Unfortunately, both his comparison and check stars have turned out to be variable (NN CMa and MZ CMa, respectively). He also obtained spectra at CTIO enabling him to classify the system as B5 V.

All available times of minima were collected (see Table 1), enabling the present authors to refine the period.

Table 1. Times of Minimum

Source	Type	ToM (HJD-2400000.0)	Error (days)	n	O−C (days)
GCVS 4	I	28095.601	na	−25436	−0.0252
Milone 1986	I	43201.5740	0.0003	−9612	−0.0008
This work	II	52330.154	0.002	−49.5	0.0025
This work	II	52376.9277	0.0004	−0.5	7.3×10^{-6}
This work	I	52388.861	0.001	12	2.6×10^{-5}
Dvorak (2004)	II	52654.7236	0.0003	290.5	0.00075

The best-fit elements (omitting the first value from the fit) used for phasing were:

$$\text{HJD Min I} = 2452377.405 + 0.95462254 \times E$$

A total of 295 B and 316 V magnitudes were taken at the Mt John University Observatory at Lake Tekapo, New Zealand when RHN was a guest at the University of Canterbury in Christchurch, New Zealand in the first half of 2002. The telescope used was the Optical Craftsman 61 cm Cassegrain, equipped with a Santa Barbara Instrument Group ST-9e CCD Camera (on loan from the AAVSO) and using a telecompressor

Table 2. Positions, magnitudes and colour indices

Star	GSC ID	RA	Dec	V	$B-V$
Var	6541-1691	07:22:00.9898	-25:52:35.925	9.98	-0.119
Comp	6541-2881	07:22:12.9485	-25:53:41.608	10.19	-0.038
Check	6541-1436	07:21:50.2243	-25:54:22.143	11.09	$+0.465$

lens and BVR_CI_C filters. Thin, variable clouds proved to be a problem in the oceanic climate at this site, located as it is in the lee of the Southern Alps. Therefore, plots of the raw comparison magnitudes versus time were used as an unbiased criterion for eliminating questionable points. (An arbitrary limit of changes greater than 0.2 magnitudes in the sampling interval of 2 minutes meant that spatial variations across the chip gave unacceptable systematic errors.) The reduced numbers of points were 253 B and 259 V magnitudes.

Images were reduced in the usual way with dark and bias subtraction and flatfield correction using MIRA, by Axiom Research. Positions (J2000), magnitudes and colours (from the Tycho catalogue, ESA 1997) of observed stars are listed in Table 2.

Analysis of the light curves was done using the 2003 version of the Wilson-Devinney program (WD; Wilson & Devinney, 1971; Wilson, 1979) which employs Kurucz (1993) atmospheres as described by Van Hamme & Wilson (2003). Preliminary inspection of the light curves showed that the system was detached and, thus, mode 2 (Leung & Wilson, 1977) of the WD program was used. The large relative radii and short period argue against a non-circular orbit and no evidence of an orbital eccentricity was seen in the light curves, so we explored only solutions with $e = 0$. Based on the B5 V spectral type, we set $T_1 = 15,200K$ (Cox, 2000).

For a detached binary, the mass ratio (q) has very little influence on the light curve and hence cannot be reliably determined from photometry (*viz.* Terrell and Wilson, 2004). Thus, while q is of great interest in other contexts, our inability to determine it accurately does not adversely affect our ability to determine the other parameters of the system. Since an approximate value of q will suffice for the light curve solution, we estimated it as follows. A B5 V star should have a mass of $5.9M_\odot$ (Cox, 2000). Having assumed an effective temperature of the primary, the eclipse depths give an approximate effective temperature of the secondary of $T_2 = 10,600K$. If the secondary is also a main sequence star (likely, given the detached configuration of the binary), then its mass should be around $3.4M_\odot$, leading to $q = 0.57$. We allowed q to adjust and found that it changed very little. We also explored solutions with other initial values of q and found that it had little effect on the values of the other parameters.

Our solutions employed the detailed treatment of the reflection effect (Wilson, 1990) with five reflections which has previously proven to be sufficient (Terrell, 2002). We also explored solutions with the various limb darkening laws, namely the linear cosine, logarithmic and square root laws (Van Hamme, 1993), and found that the logarithmic law gave a marginally better solution than the square root law, while both of the two-parameter laws were significantly better than the linear cosine law. Our final solution, listed in Table 3, uses the logarithmic law with coefficients from Van Hamme (1993). Since both stars have radiative envelopes, we set their bolometric albedos and gravity darkening exponents to unity from theoretical considerations (von Zeipel, 1924a, 1924b, 1924c). Figure 1 shows the fits to the two light curves.

Table 3. Parameters from the Light Curve Solution

Parameter	Value	Std. Error
ϕ_0	0.0019	0.0001
i	89.°4	1.°3
T_2	10,502 K	25 K
q	0.56	0.01
Ω_1	3.64	0.02
Ω_2	3.87	0.06
$L_1/(L_1+L_2)_B$	0.837	0.001
$L_1/(L_1+L_2)_V$	0.822	0.001
$r_{1(pole)}$	0.322	0.002
$r_{1(point)}$	0.348	0.003
$r_{1(side)}$	0.331	0.002
$r_{1(back)}$	0.341	0.003
$r_{2(pole)}$	0.211	0.005
$r_{2(point)}$	0.222	0.006
$r_{2(side)}$	0.214	0.005
$r_{2(back)}$	0.220	0.006

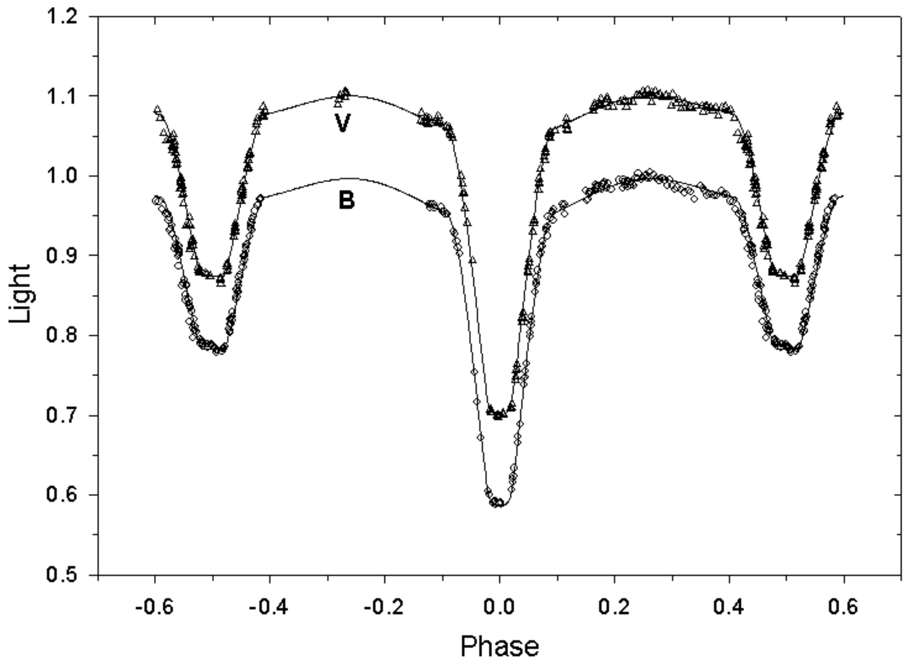

Figure 1. Fits to the B and V light curves of CX CMa.

CX CMa thus appears to be a relatively unevolved binary consisting of a B5V primary and a secondary with a spectral type in the B8 to A0 range. Although we have only a few observations in one of the maxima, we see no asymmetry between the maxima in our 2002 data as opposed to the noticeable asymmetries in the 1977 data reported by Milone (1986). It is unclear whether the asymmetries in the 1977 data were real and have since changed, as observed in other binaries like XZ CMi (Terrell and Henden, 2002), or whether they are an artefact of the use of comparison and check stars that have subsequently turned out to be variable. We hope to obtain high resolution spectra of the system as part of our program on early-type close binaries (*viz.* Terrell, *et al.*, 2003 on TU Muscae) so that absolute parameters and interstellar reddening can be determined.

The photometric data are available from the IBVS web site as `5545-t4.txt` and `5545-t5.txt`.

It is a pleasure for RHN to thank the staff members at MJUO (especially Alan Gilmore) for their splendid help and assistance. Thanks are also due to the faculty and staff at the University of Canterbury for their very warm welcome and hospitality. RHN would also like to thank E.F. Milone for suggesting this star as an observing target. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France

References:

Cox, A.N., 2000, Allen's Astrophysical Quantities, (American Institute of Physics Press)
Dvorak, S. W., 2004, *IBVS*, 5502
ESA, 1997, The Hipparcos and Tycho Catalogues (ESA SP-1200)
Hoffmeister, C., 1931, *Astr. Nach.*, **242**, 129
Kurucz, R.L., 1993, in *Light Curve Modeling of Eclipsing Binary Stars*, E.F. Milone, ed., p. 93 (Springer-Verlag)
Leung, K & Wilson, R.E., 1977, *ApJ*, **211**, 853
Milone, E.F., 1986, *ApJS*, **61**, 455
Terrell, D., 2002, in *Exotic Stars as Challenges to Evolution*, C.A. Tout and W. Van Hamme, eds. PASP Conference Series, **279**, 319
Terrell, D. & Henden, A.A., 2002, *IBVS*, No. 5310
Terrell, D., Munari, U., Zwitter, T. & Nelson, R.H., 2003, *AJ*, **126**, 2988
Terrell, D. & Wilson, R.E., 2004, *ApSpSc*, in press.
Van Hamme, W., 1993, *AJ*, **106**, 2096
Van Hamme, W. & Wilson, R.E., 2003, in *GAIA Spectroscopy, Science and Technology*, U. Munari, ed., PASP Conference Series, **298**, 323
von Zeipel, H., 1924a, *MNRAS*, **84**, 665
von Zeipel, H., 1924b, *MNRAS*, **84**, 684
von Zeipel, H., 1924b, *MNRAS*, **84**, 702
Wilson, R.E., 1979, *ApJ*, **234**, 1054
Wilson, R.E., 1990, *ApJ*, **356**, 613
Wilson, R.E., and Devinney, E.J. (WD), 1971, *ApJ*, **166**, 605