PHOTOMETRIC MONITORING OF SHORT-PERIOD CONTACT BINARIES

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ABSTRACT. The first photoelectric B, V light curves of the contact binary FU Dra, as well as new B, V light curves of the contact binaries AH Aur, UV Lyn and YY CrB, obtained at the Stará Lesná and Skalnaté Pleso Observatories, are presented. New photometric elements of AH Aur, FU Dra and UV Lyn computed from these light curves were combined with published spectroscopic elements to derive the absolute parameters of the systems.

Key words: Stars: binary: contact; stars: individual: FU Dra, UV Lyn, AH Aur, YY CrB

1. Introduction

Last year we started at the Astronomical Institute of the Slovak Academy of Sciences the program of photometric monitoring of neglected and faint short-period contact binaries. The aim of this program is to obtain the photoelectric light curves (LCs) of contact binaries, to study their orbital period and LCs changes. The LCs analysis provides photometric elements and in combination with published radial velocity curves also the absolute parameters of the studied systems. The LCs of contact binaries and their analysis presented in our paper were obtained in the frame of this program.

2. Our observations

New photoelectric BV observations of UV Lyn, FU Dra, AH Aur and UBV observations of YY CrB were performed from December 2000 to May 2001 at the Stará Lesná (SL) and Skalnaté Pleso (SP) Observatories of the Astronomical Institute of the Slovak Academy of Sciences. At both observatories a single-channel photoelectric photometer installed at the Cassegrain focus of the 0.6m reflector was used. The detailed description of the observational technique and reduction of the data to the international photometric system is given in Pribulla et al. (2001). The stars BD+38°1990, BD+28°1109, GSC 4181-1726 and GSC 3054-640 were used as the comparison stars for UV Lyn, FU Dra, AH Aur and YY CrB, respectively. Our new photoelectric LCs of these contact binaries are shown in Fig. 1 and Fig. 3.

Our observations enabled us to determine 5 minima times (MT) of UV Lyn, 5 MT of FU Dra, 4 MT of AH Aur (Vaňko et al., 2001) and 3 MT of YY CrB (Vaňko et al., 2002).

3. Interpretation

The W&D (Wilson & Devinney, 1971) code was employed to determine the photometric elements of UV Lyn, FU Dra and AH Aur. We have used the Mode 3 appropriate for the contact configuration. All our BV observations were used to compute about 150 normal points for each passband. The normal points were determined by running averages of phased observations calculated using ephemerides (1), (2) and (3). The standard deviations (σ) used for weighting of the LC in each passband were evaluated as described by Wilson (1979).

For the computation of monochromatic luminosities, the approximate atmospheric models option of the W&D program was used. Since all three systems have late F type spectra, we have assumed coefficients of gravity darkening and bolometric albedo appropriate for convective envelopes (T_{eff} <7500 K). Therefore, we adopted $g_1 = g_2 = 0.32$ (Lucy, 1967) and $A_1 = A_2 = 0.5$ (e.g., Rucinski, 1969). The limb darkening were interpolated from Tab. 1 of Al-Naimiy (1978). The mean temperatures of the primary components were fixed according to their spectral types (UV Lyn-F6V, FU Dra-F8V, AH Aur-F7V, YY CrB-F8V) using the spectral type - T_{eff} callibration of Popper (1980).

The initial parameters of UV Lyn and FU Dra were taken from Maceroni & van't Veer (1996) and Heiner (2000), respectively. Both systems are W-type contact binaries, i.e. the smaller and hotter component is eclipsed during the primary minimum. Hence using the W&D code we have interchanged them shifting the orbital phases by 0.5. Throughout the article we adopted the following notation: the primary component is always the more massive one - mass ratios $q = m_2/m_1 \leq 1$. No reliable photometric elements were published for AH Aur.

The resulting photometric and absolute parameters are given in Tab. 1 and Tab 2, respectively.

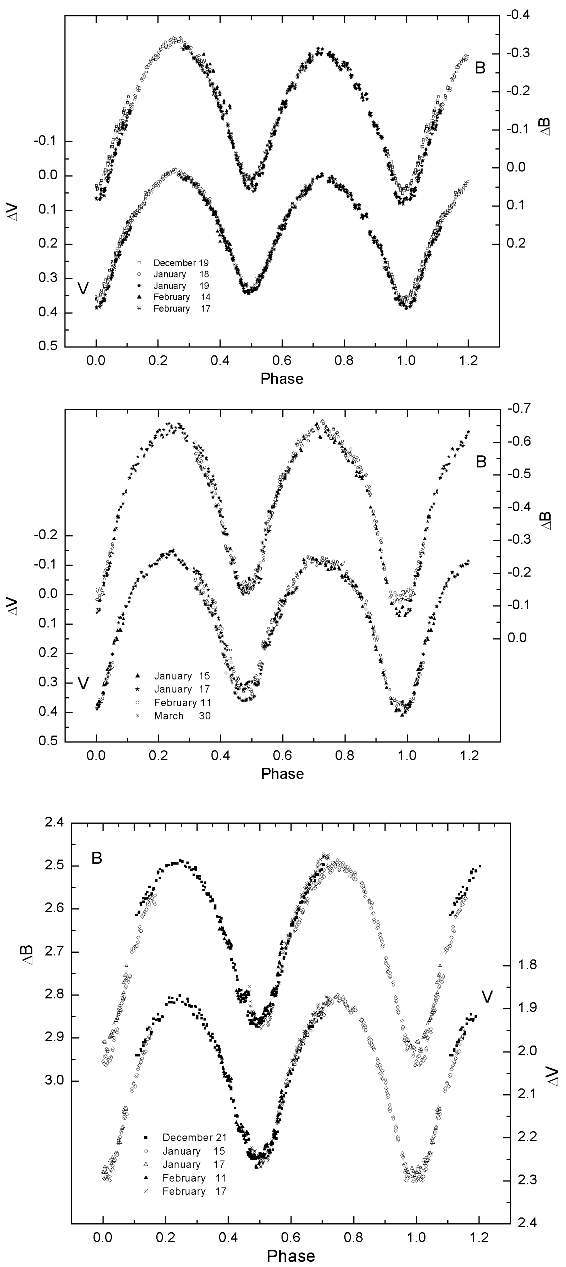

Figure 1: The photoelectric BV LCs of UV Lyn (top), FU Dra and AH Aur (bottom) obtained at the SL and SP Observatories in 2000 and 2001, respectively

2.1. UV Lyn

UV Lyn was discovered to be a variable by Kippenhahn (Geyer et al, 1955). Bossen (1973) classified UV Lyn as a W UMa type binary with a period 0.415 day, maxima of unequal brightness and the distance of the system $d = 176$ pc. The first spectroscopic orbit of UV Lyn was determined by Lu & Rucinski (1999).

We have collected more than 140 minima times of UV Lyn. The photovisual minima with a very large scatter (about 0.05 day) were only available until 1968. More recent photoelectric and CCD minima times clearly show the increase of the orbital period. The (O-C) diagram of all available minima times from the mean linear ephemeris is shown in Fig. 2.

The period increase $\Delta P/P$ = (4.88±0.47) 10^{-7} year^{-1} can be interpreted by the mass transfer from the less to more massive component. Using the masses of the components given in Tab. 1 we need the mass transfer rate $\Delta m/\Delta t$ = (1.28±0.12) $10^{-7} M_\odot$ year^{-1} to explain the observed period increase. Since the broadening function of the system does not show the third component, an explanation of the observed period change by a light-time effect is questionable.

The recent photoelectric and CCD minima times were used to determine the linear ephemeris:

$$\begin{array}{lll} \text{Min I} = 2\,447\,000.4197 & + 0.41498460 & \times E. \\ \qquad\qquad \pm 10 & \qquad \pm 15 & \end{array} \quad (1)$$

This ephemeris was used for phasing our new photometry and it is suitable for the future minima forecast.

UV Lyn is a W-subtype contact binary (Lu & Rucinski, 1999). During our observations, the BV LCs were clearly asymmetric - the maxima I (phase 0.25) was brighter than the maximum II (phase 0.75) about 0.02 mag in the V and 0.03 mag in the B passband. The depression of the observed LCs was largest around the phase 0.85. The colour index was $\Delta(B-V)$ = -0.345±0.005 and $\Delta(B-V)$ = -0.324±0.004 at the phase 0.25 and 0.85, respectively.

2.2. FU Dra

Contact binary FU Dra was discovered by Hipparcos. Although the system is relatively faint (V_{max} = 10.55), it was observed spectroscopically by Lu & Rucinski (2000). On the assumption of the Hipparcos determination of the primary eclipse the authors concluded that the object belongs to W-type binaries. The system is known to have large proper motion (see Rucinski & Lu, 2000). Combining radial velocity of the mass center V_0 = -11 km s^{-1} and the Hipparcos proper motions in the right ascension and declination one gets the spatial velocity 195 km s^{-1}.

The system was observed at the Baja Observatory in June 2000 as a part of the diploma thesis (Heiner, 2000). The CCD observations yielded two times of

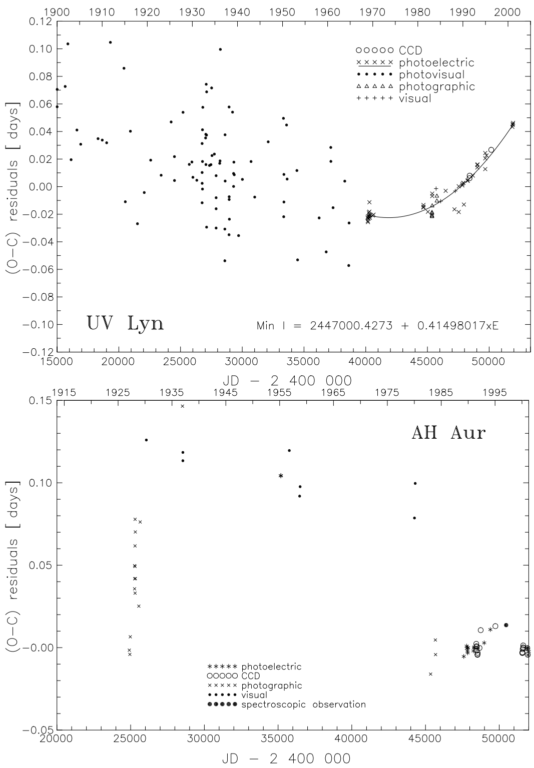

Figure 2: The (O-C) diagrams of UV Lyn (top) and AH Aur (bottom).

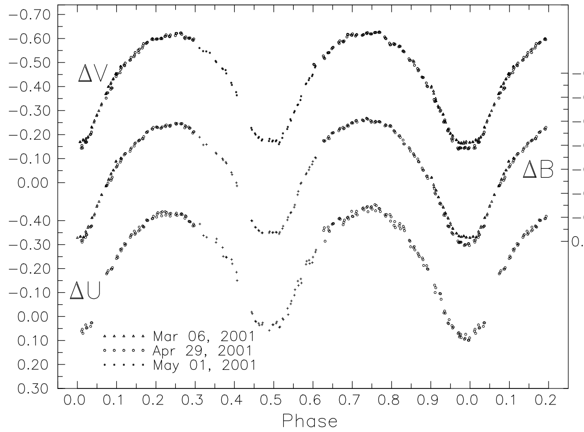

Figure 3: The photoelectric *UBV* LCs of YY CrB obtained at the SL Observatory in 2001. The phases of the light curve correspond to the ephemeris: Min I =2 450 955.8688(12) + 0.37656421(9) × E.

the secondary minima and approximate geometric elements: inclination $i = 80.8^{o}$ and fill-out f=0.05 assuming the spectroscopic mass ratio $q = 0.25$.

The linear fit to the available 12 minima times provides the following ephemeris:

$$\text{Min I} = 2\,450\,866.2770 \underset{\pm 3}{} + 0.30671686 \underset{\pm 9}{} \times E. \quad (2)$$

The (O-C) residuals do not exceed 0.003 day. Hence the period of the system seems to be stable since its discovery. The ephemeris (2) was used for phasing of our photometry. The maximum I of the LC is about 0.02 mag brighter than the maximum II. We have detected small perturbations of the LC during the primary minimum. The small interval of constant brightness during the primary eclipse suggests that the system is totally eclipsing (subtype W).

2.3. AH Aur

Contact binary AH Aur was discovered by Prager & Guthnick (1929). Photographic LC obtained by Bodokia (1938) shows clear asymmetry of the minima. The system has been neglected since its discovery. The photoelectric observations of AH Aur were published only by Hinderer (1960). The first spectroscopy of the system was performed by Rucinski & Lu (1999).

The available minima times consists mainly of the minima published in BAV Mitteilungen (Huebscher et al., 1989, 1990, 1991), minima determined from the Hipparcos photometry (Kreiner, 2000) and our observations. The photoelectric and CCD minima times are rather ample after about JD 2 445 000. The weighted linear regression gives:

$$\text{Min I} = 2\,448\,500.3296 \underset{\pm 8}{} + 0.49410834 \underset{\pm 21}{} \times E. \quad (3)$$

The (O-C) diagram for all available minima corresponding to the ephemeris (3) is presented in Fig. 2. The period behaviour before 2 445 000 was very unusual. The minima in the interval JD 2 426 000 - 2 445 000 occurred about one quarter of the period later than predicted by the ephemeris (3). The shift is so large that the primary and secondary minimum could be interchanged. The fact that it is almost impossible to determine the type of the minimum in older observations could cause, that the O-C diagram is ambigues. The *B* passband LC of Hinderer (1960) suggests, however, that the minima HJD 2 435 186.4372 and 2 435 191.3788 determined from the Hinderer's photometry by Lichtenknecker (1986) are secondary. Two visual minima just prior to JD 2 443 000 and three photographic minima after HJD 2 445 000 give orbital period P = 0.494074(8). After HJD 2 445 000 period increases by about $\Delta P/P = 6.9\ 10^{-5}$!. Since Rucinski & Lu (1999) did not detect the third component in the broadening functions the LITE explanation is questionable. Also the LC analysis does not indicate the third light. It is possible that the hypothetical third body is not a main-sequence object.

The LC of the system seems to be rather stable. There are only slight variations in the minima depth - the secondary minima are relatively deeper during the

2000 CCD photometry. The short interval of constant light during the secondary minimum indicates that the system is just totally eclipsing.

For the determination of the photometric elements we have used the phototoelectric BV observations obtained in December 2000 - February 2001. We have accepted spectroscopically determined mass ratio $q = 0.169$. Due to the fact, that the broadening functions did not indicate the presence of the third component in the system (Rucinski & Lu, 1999), we have fixed the zero third light. Since the mass ratio was also fixed, the differential corrections converged rather fast.

Table 1: Photometric elements and their standard errors (σ). Parameters not adjusted in the solution are denoted by a superscript "a"

Parameter	**UV Lyn**	**FU Dra**	**AH Aur**
i [°]	66.80(12)	78.64(24)	75.46(26)
q	0.367^a	0.251^a	0.169^a
Ω	2.5590(19)	2.3180(16)	2.0805(19)
Fill-out	0.455	0.235(10)	0.674(18)
r_1	0.4821	0.5143(5)	0.5647(7)
r_2	0.3091	0.2788(6)	0.2737(11)
T_1 [K]	6045^a	5800^a	6215^a
T_2 [K]	6262(12)	6133(8)	6141(8)
$L_1^B/(L_1^B+L_2^B)$	0.6769(8)	0.7216(5)	0.8270(2)
$L_1^V/(L_1^V+L_2^V)$	0.6769(7)	0.7290(4)	0.8260(2)
$L_1^R/(L_1^R+L_2^R)$	–	–	–
$\sum(O-C)^2$	0.00073	0.00534	–

Table 2: Absolute parameters and the distance of the observed systems. The masses of the components were derived from spectroscopic elements and new inclination angles (Tab. 1).

	UV Lyn(W)	FU Dra(W)	AH Aur(A)
M_1 $[M_\odot]$	1.356(19)	1.169(39)	1.683(47)
M_2 $[M_\odot]$	0.498(8)	0.293(10)	0.284(8)
A $[R_\odot]$	2.875(13)	2.172(24)	3.294(31)
R_1 $[R_\odot]$	1.386(6)	1.117(12)	1.853(17)
R_2 $[R_\odot]$	0.889(4)	0.605(6)	0.891(8)
$\log g_1$ [cm s^{-2}]	4.29	4.41	4.12
$\log g_2$ [cm s^{-2}]	4.24	4.34	3.99
M_V	3.386	4.160	2.831
d [pc]	134	175	282
$\overline{\rho_1}$	0.717	1.181	0.372
$\overline{\rho_2}$	0.998	1.863	0.401

4. Conclusion

The first photoelectric B, V light curves of the contact binary FU Dra, as well as new B, V light curves of the contact binaries AH Aur, UV Lyn and YY CrB are presented. The absolute parameters of the contact binaries UV Lyn, FU Dra and AH Aur were determined using the published spectroscopic elements and photometric elements computed by the WD code from our photoelectric LCs. The absolute maximum visual magnitudes of the systems were determined from the temperatures of the components (Tab. 1) and absolute radii (Tab. 2) using Popper's (1980) radiative calibration for the main-sequence stars. The distance were computed using the Hipparcos maximum visual magnitudes assuming interstellar or/and circumstellar extinction.

Acknowledgements. This study was supported by VEGA grant 2/1157 of the Slovak Academy of Sciences.

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