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The first photometric study of the binary star WZ Cygni*

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Abstract. The first photoelectric observations of the binary WZ Cygni, are presented, analysed and discussed. They were made with the 48-in Cassegrain reflector at the Kryonerion Station of the National Obervatory of Athens, Greece during 1993 and 1994.

The light curves have been analysed using Wood's and W-D programs; the obtained solutions support a contact configuration for the system. The latter, along with the β Lyrae type light curve shape of WZ Cyg, suggest that it is a near-contact binary.

The times of the observed minimum light show that the orbital period increases.

Details for the flashes, detected during our observations, are also given. These flare-like phenomena might be related to a magnetic activity on the secondary cooler component of WZ Cyg, while the observed increasing of the system's orbital period might be due to mass transfer from the less massive star towards its mate.

Key words: stars: binaries: close – stars: binaries: eclipsing – stars: individual: WZ Cyg

1. Introduction

The eclipsing binary WZ Cyg (BD+ 38^o 4262) is a short period variable (P=3D0.5844 days) classified as a F0 V star, showing a β -Lyrae type light curve with a contact configuration (Brancewicz & Dworak, 1980; Giuricin et al., 1983; Kholopov, 1985). WZ Cyg is a poorly observed system (Koch et al., 1979); no spectroscopic data are available and only some old photographic data (Kurzemniece, 1950) can be found in literature, as well as some times of minimum light (Whitney, 1959; Flin, 1971;Isles, 1988; SAC 1988,1989,1991; Hanzl, 1991). Moreover, Koch (1974) measured and presented the blue cyanogen c_n absorption indices of WZ Cyg and recently, Shaw et al. (1996) analysing the RASS (ROSAT All-Sky Survey) data for 58 near-contact binaries, found its X-ray luminosity.

2. The data

Photoelectric observations of WZ Cyg were performed with the 48 inch Cassegrain reflector at the Kryonerion Station of the National Observatory of Athens, Greece equipped with a two-beam, multi-mode, nebular-stellar photometer (Goudis & Meaburn, 1973). The intermediate pass bands of the filters used (BV) are in close accordance to the UBV international system and the estimated uncertainty for a single observation was of the order of 0.006 magnitude. Reduction of the observations has been made in the usual way (e.g. Hardie, 1962) with exctinction coefficients calculated night by night while only the comparison and the first checking star were used in our computations.

Our first observations of WZ Cyg were obtained in five nights during June-July 1993, and the corresponding B & V light curves are presented in Fig. 1.

Although all phases had been satisfactorily covered -as is obvious from Fig. 1- we decided to re-observe the system during 1994, because of the three detected flashes during our first observations of the system (Rovithis & Rovithis-Livaniou, 1996). So, three more runs were made during 1994, which were purposely chosen to be done in different epochs; thus, WZ Cyg was observed: during May, June and September 1994 for 3, 2 and 2 nights, respectively, with the obtained light curves presented in Fig. 2. As is obvious from a comparison of Figs. 1 and 2, where our observations are presented, the light curves of WZ Cyg vary from night to night and some variability from year to year is present, too. The data of the comparison and checking stars are given in Table 1.

From our observations of WZ Cyg 873 individual points in B and 878 in V were derived and are given in Tables 2 and 3, respectively. The corresponding light curves are presented in Fig. 3. The phases in Figs. 1–3 have been computed using Kholopov's (1985) ephemeris formula:

$$MinI = 3D2440825.475 + 0^d5844659E \quad (1)$$

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* Tables 2 and 3 are only available in electronic form at the CDS (Strasbourg) via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

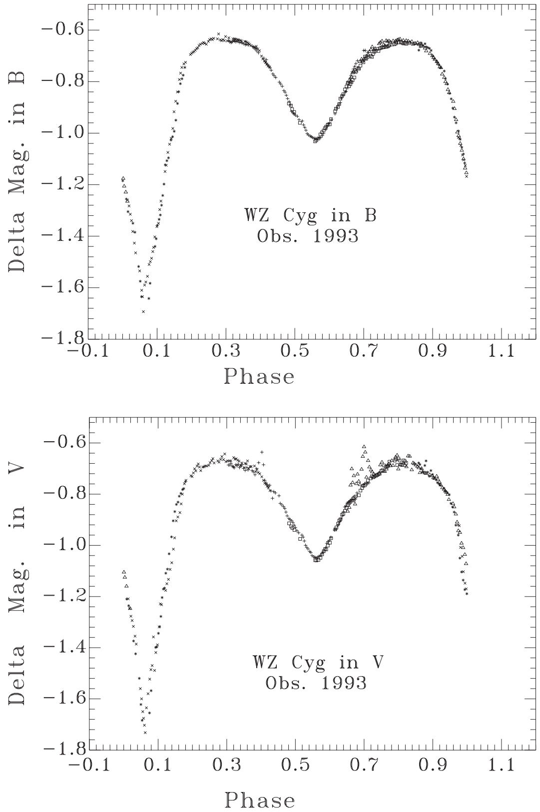

Fig. 1. B and V light-curve of WZ Cyg during 1993.

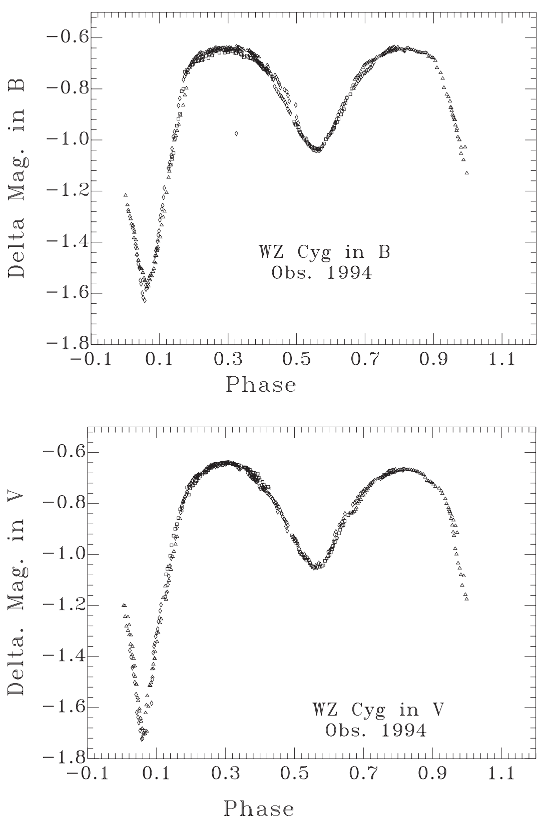

Fig. 2. B and V light-curves of WZ Cyg during 1994.

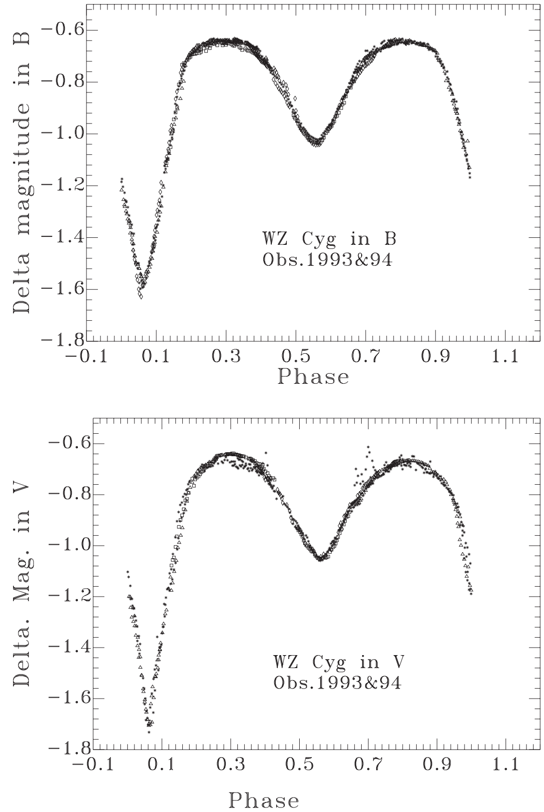

Fig. 3. B and V light-curves of WZ Cyg based on all obtained data during 1993 and 1994.

Table 1. Comparison stars

Star	Name	Magn.	Sp.T.
Variable	$DM + 38^o 4262$	10.5–11.5	F0V
	SAO		
comparison	$DM + 38^o 4293$	10.2	F2
	SAO 70705		
first checking	$DM + 38^o 4221$	9.6	F2
	SAO 70466		
sec. checking	$DM + 38^o 4279$	11.0	M0
	SAO 70669		

3. The period of WZ Cyg

The new minima times derived from our observations together with all other times of minimum light found in the literature were used to construct its (O-C) diagram which is presented in Fig. 4. In this, squares denote the photographic and crosses the photoelectric data, while spots stand for the visual ones. From our new times of minimum light it was found that the period of WZ Cyg had increased. So, the following new quadratic ephemeris formula was proposed (Rovithis et al.,1996), when only the photographic and photoelectric times of minimum light were considered:

$$MinI = 3D2440825.47999 + 0^d 58446763E + 2^d 82 \times 10^{-11} E^2 \quad (2)$$

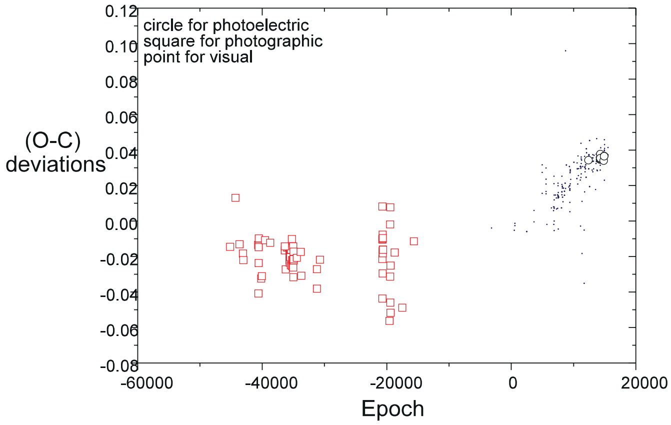

Fig. 4. (O-C) deviations of WZ Cygni.

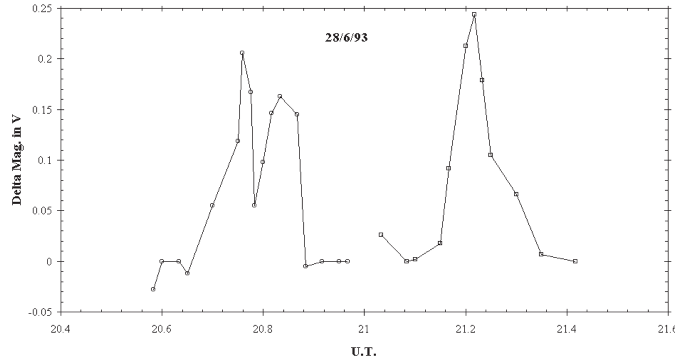

Fig. 5. The two “flashes” of the 28th of June 1993.

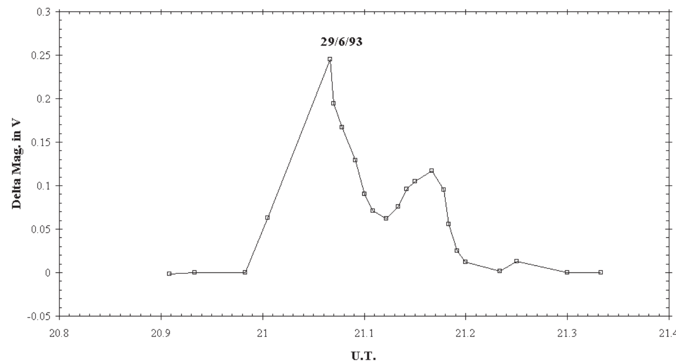

Fig. 6. The third detected “flash”

and the slightly different one, when all data were taken into account:

$$MinI = 3D2440825.47892 + 0^d58446764E + 2^d82 \times 10^{-11} E^2 \quad (3)$$

The small difference between the two quadratic ephemerides (2) and (3) is coming from the fact that the weight given to the visual times of minimum light was very small in comparison to that of the other two types.

Moreover, from the two new minima times observed by Müyesserŏglu (1996, priv. comm.) it seems that the orbital period of the system continues to increase. It has to be confirmed by further observational data, whether this period increase continues.

4. Flashes

During our observations on June the 28th 1993, two “flashes” -one after the other- were detected and are presented in Fig. 5. In this figure the Δm magnitudes have been reduced to zero level (that before the event). The duration of the first flash was 14 minutes and that of the second, 12. Moreover, during our observations of June 29th 1993, another “flash” occured and it is presented in Fig. 6 in a similar way as the first two. Its duration was 12 minutes. The two first flashes occured in the ascending branch, after secondary minimum towards MaxII, while the third was occured in the discending branch, after MaxI towards secondary minimum (Fig. 7). The energy characteristics of the observed “flashes” were calculated assuming the Planck’s energy distribution law in the spectrum of WZ Cyg with the mean effective temperatures of the two components taking the values of $T_{eff,1} = 3D6980\,K$ & $T_{eff,2} = 3D5710\,K$, respectively (as they came out from our present analysis) and adopting an absolute magnitude of 9.9 for the system (Brancewicz & Dworak, 1980). The results are given in Table 4 and are of the same order of flares-like phenomena occured in other kind of binary stars.

There are several reviews that discuss stellar flares, (e.g. Haisch, 1989; Kuijpers, 1990; Byrne, 1992). In particular, the theory of magnetic flares in close binaries has been presented by Kuijpers (1990), where in Fig. 5 of his paper, the possible generation of flares for various types of close binaries is shown and the mechanisms that produced them are explained.

Table 4. Characteristics of the detected “flashes” in WZ Cyg.

Flare	Peak Flare Luminosity $\times 10^{34}\, erg/sec$	Total energy released $\times 10^{35}\, ergs$
1	7.9	3.6
2	9.4	3.9
3	9.5	4.1

Moreover, flares or flashes have been reported in some contact systems (e.g. for 44i Boo: Eggen, 1948; for U Peg: Huruhata, 1952; for W UMa: Kuhi, 1964; for VW Cep: Egge & Peterson, 1983; for CN And: Yang & Liu, 1985 etc). Of course, WZ Cyg does not belong to the contact systems, since it exhibits a β -Lyrae light curve, but as was mentioned in the introduction and was confirmed by the present analysis it possesses a contact configuration, which puts it in the particular class of the so-called near-contact binaries (e.g. Shaw, 1990, 1994).

5. Light-curve analysis procedure

5.1. Analysis using Wood’s program

From our individual observations, 50 normal points in each observational band were formed; to these a phase correction was made and they were analyzed using Wood’s (1971) program. The initial parameters used were taken from Dworak’s (1975) work. The effective temperature of the primary component at

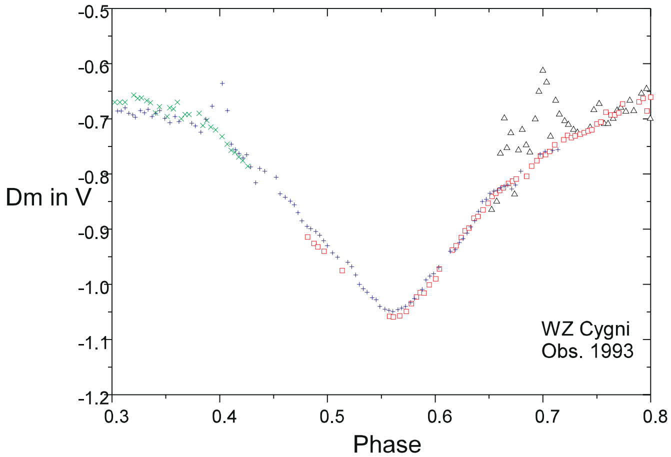

Fig. 7. The parts of the light curve of WZ Cygni, in which the "flashes" were detected.

the equator was assumed to be equal to 6980 K (consistent to its spectral type); the limb darkening coefficients u_h, u_c were taken from Diaz-Cordoves et al. (1995) tables and the gravity darkening exponents from Lucy (1967). Bolometric albedos A_h and A_c were taken equal to 1.0 and 0.5 for radiative and convective atmospheres, respectively. Regarding the mass-ratio it was fixed to 0.5.

5.2. Analysis with the W-D code

Subsequently, the B & V light curves of WZ Cyg were also analysed using = the W-D code (Wilson & Devinney, 1971); and since its configuration is refered to as one of contact -this was confirmed in our analysis with Wood's program- we performed our solution working on mode 3. Now as input parameters those coming from Wood's program solution were used. Moreover, a q search was made and the minimum value found and adopted in our analysis with the W-D code was q=3D0.54. The obtained final results are given in Table 5, while in Figs. 8 & 9 the normal points together with the the theoretical light curves and the corresponding Roche model for WZ Cyg are presented, respectively.

6. Summary, results and discussion

WZ Cyg is a poorly observed system classified as a F0 V star. It is an eclipsing binary exhibiting a β Lyrae-type light curve as one can notice from its photoelectric light curves firstly presented here (Figs. 1–3). Moreover, the observed phase shift in these figures, caused by the period change of WZ Cygni, was taken into account in the subsequent light curve analysis. Using Wood's program and the W-D code, solutions were obtained for our observations in both colours and those coming from the latter are given in Table 5. The $\Sigma(O-C)^2$ given in this table is referred to the difference between theoretical light curve (TLC) and the normal points of our observations. But the real rms errors between TLC and all individual points of our observations were found to be 0.034 and 0.040 in B and V colors, respectively. The Binary Maker program (Bradstreet, 1993) was used and yielded to the same results and to a pretty good fitting, at least concerning the V light curve. The small assymetries observed in the maxima could probably be faced with a spotted model, due to flare activity in the system. But this approach was not in the interest of this paper. According to our solution, both components of the system exceed their Roche lobes.

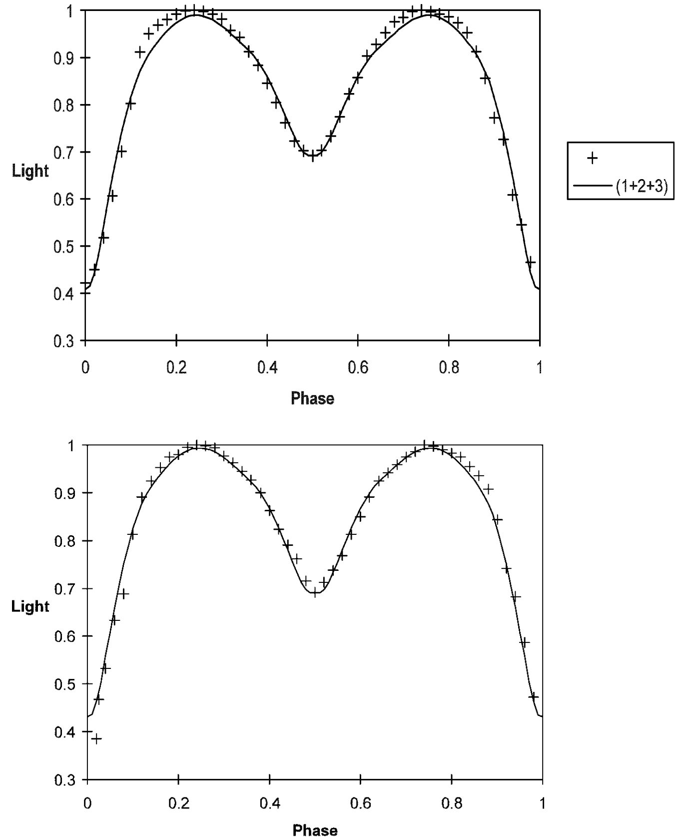

Fig. 8. Normal points and theoretical light curves from W-D code.

Table 5. Elements of WZ Cyg using the W-D code

Element	Value in B	Value in V
i	85.5 ± 0.5	85.5 ± 0.5
u_h	0.683*	0.589*
u_c	0.683*	0.589*
r_h pole	0.408 ±0.001	0.408 ±0.001
r_h side	0.433 ±0.001	0.433 ±0.001
r_h back	0.461 ±0.001	0.461 ±0.001
r_c pole	0.306 ±0.001	0.306 ±0.001
r_c side	0.320 ±0.001	0.320 ±0.001
r_c back	0.352 ±0.001	0.352 ±0.001
T_h	7050	7050
T_c	5800± 16	5700 ± 20
q	0.54	0.54
$L_h/fract(L_h+L_c)$	0.828	0.816
$L_c/fract(L_h+L_c)$	0.172	0.184
$\Sigma(O-C)^2$	0.07	0.127

* adopted

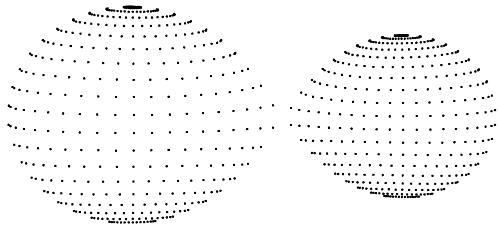

Fig. 9. The Roche model of WZ Cyg at phase 0.25

The orbital period of WZ Cyg was found to change, as one can see from Fig. 4 where its (O-C) diagram is presented. The increase of its period was estimated to be: $1.4 \cdot 10^{-11} days$ from the quadratic least squares approximation (Rovithis et al. 1996). If this period increase will be continued or not has to be confirmed from further observations of the system. We suggest to observers to pay special attention to this very interesting binary, not only for its period behaviour, but also for the flashes, found to occur in 1993, which are undoubly real. During their detection, sky levels were low and they are the only ones in about sixty (60) hours of photometric monitoring of the system during the five nights in 1993 and the seven during 1994. The flare-like phenomena detected in some contact binaries (44i Boo, W UMa, U Peg, CN And), in which we refered in Sect. 4, all have occured near maximum light. The same happened here, too: the double flash of June the 28th happened before maximum, while that of June the 29th occured just after maximum light. One can estimate the time that eclipses begin using i.e. formula 5.50 on p. 117 in Tsessevich's (1973) book. Doing so, and since WZ Cyg exhibits partial eclipses, we estimated that eclipses start around ($60^o - 65^o$) which corresponds to a phase of 0.16–0.18. So, during both flare events both components of the system were visible; thus, the flare-like phenomenon could have happened in any one of its two members and the question is to which one? Unfortunately, no spectroscopic study has been made for WZ Cyg so far; primary's spectrum is reported as F0 V, while nothing is known for that of the secondary. So, no definite conclusion can be made for which of the two members of WZ Cyg is able to develope magnetic activity; perhaps both, or only one: the cooler secondary. On the other hand, the increase of the orbital period may be related to mass transfer from the less massive cool secondary component to the more massive primary; this can be really the case, since the secondary star either fills exactly its Roche lobe (W-D's code solution) or exceeds it (Wood's program solution).

Regarding the total energy released during the observed flashes of WZ Cyg and given in Table 4, they are of the same order of magnitude (10^{35} ergs), if we assumed the system to be at a distance of 260 pc (Shaw et al., 1996). In our calculations the elements derived by Brancewinz & Dworak (1980) had been considered, according to which the paralax of the system is 0.0037 arc sec, corresponding to a distance of 270 pc. The 10 pc difference in the system's distance affects only slightly the amount of the total energy released; actually it becomes (3.88, 4.21 & 4.42) $\times 10^{35}$ ergs, respectively, instead of (3.6, 3.9 & 4.1) $\times 10^{35}$ ergs, given in Table 4.

Finally, since no spectroscopic data are available for WZ Cygni, as was already mentioned, it is difficult to obtain absolute elements for it and get an idea about its evolutionary status.

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References

Bradstreet D.H., 1993, Binary Maker 2.0 User Manual
Brancewicz H.K, Dworak T.Z., 1980, Acta Astron. 30, 501
Byrne P.B., 1992, In: Linsky J., Serio S. (eds.) Physics of Solar and Stellar Coronae. Kluwer, Dordrecht, p. 489
Diaz-Cordoves J., Claret A., Gimenez A., 1995, A&AS 110, 329
Dworak T.Z., 1975, Acta Astron. 25, 383
Egge K.E., Petterson B.R., 1983, In: Byrne P.B., Rodono M. (eds.) Activity in Red-Dwarf Stars. D. Reidel, Holland, p. 481
Eggen O.J., 1948, ApJ 108, 15
Flin P., 1971, IAU-IBVS No. 584
Giuricin G., Mardirossin F., Mezzetti M., 1983, A&AS 54, 211
Goudis C., Meaburn J., 1973, Ap&SS 20, 149
Haisch B.M., 1989, In: Haisch B.M., Rodono M. (eds.) Solar and Stellar Flares. Solar Phys. 121, 3
Hanzl D., 1991, IAU-IBVS No. 3615
Hardie R.H., 1962, In: Hiltner W.A. (ed.) Stars and Stellar systems. Vol.II, Astronomical Techniques, Univ. of Chicago Press, Chicago, p. 178
Huruhata M., 1952, PASP 64, 200
Isles J.E., 1988, J. Br. Astron. Soc. 98, 200
Kholopov P.N., 1985, In: General Catalogue of Variable stars. 4^{th} edition, Moscow
Koch R.H., 1974, AJ 79, 34
Koch R.H., Wood F.B., Florkowski D.R., 1979, IAU-IBVS No. 1709
Kuhi L.V., 1964, PASP 76, 430
Kuijpers J., 1990, In: Ibanoglu C. (ed.) Active Close Binaries. Kluwer Acad. Publ., p. 761
Kurzemniece I., 1950, Trudy Inst.Fz.i Mat. AN Latv.SSR (Astronomy) 2, 123
Lucy L.B., 1967, Z. Astrophys. 65, 89
Rovithis P., Rovithis-Livaniou H., 1996, In: Pallavicini R., Dupree A.K. (eds.) Cool Stars, Stellar systems and the Sun. 9^{th} Cambridge Workshop, p. 661
Rovithis P., Rovithis-Livaniou H., Kranidiotis A., 1996, IAU-IBVS No. 4309
SAC 1988, 1989, 1991, Rocznik Astronomiczny Observatorium Krakowskiego No. 59, 60, 62
Shaw J.S., 1990, In: Ibanoglu C. (ed.) Active Close Binaries. Kluwer Acad. Publ., p. 241
Shaw J.S., 1994, In: D'Antona F., Caloi V., Maceroni C.,, Giovanelli F. (eds.) Evolutionary Links in the Zoo of Interacting Binaries. Mem. Soc. Astron. Ital. Vol. 65, p. 95
Shaw J.S., Caillault J-P, Schmitt J.H.M.H., 1996, ApJ 461, 951
Tsessevich V.P., 1973, In: Eclipsing Variable Stars. John Wiley & Sons, New York, p. 117 (Translated from Russian)
Yang Y-L, Liu Q-Y, 1985, IAU-IBVS No. 2705
Whitney B.S., 1959, AJ 64, 258
Wilson R.F., Devinney F.J., 1971, ApJ 166, 605
Wood D.B., 1971, AJ 76, 701