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NEW ELEMENTS FOR THE PERIOD OF BI CVn

SUMMARY

A study of the period of BI CVn has been conducted using all the information published on that W UMa eclipsing variable, new photoelectric measurements and instants of minima. BI CVn varies from magnitude 10.22 to 10.67 (V) with a variable period corresponding approximately to the linear formula :

JD hel 33064.05743 + 0.384210198 day x E (4)(5).

The evolution of its light curve is also discussed.

RESUME

Une étude de la période de BI CVn a été effectuée avec toutes les informations publiées sur cette variable à éclipses du type W UMa, de nouvelles mesures photoélectriques et de nouveaux instants de minima. BI CVn varie de la magnitude 10.22 à 10.67 (V) avec une période variable correspondant approximativement à la formule linéaire : JJ hél 33064.05743 + 0.384210198 jour x E (4)(5).
L'évolution de sa courbe de lumière est également débattue.

RIASSUNTO

Lo studio del periodo di BI CVn (una variabile ad eclisse del tipo W UMa) é stato effettuato utilizzando sia tutte le informazioni reperibili in letteratura che nuove misure fotoelettriche e nuovi tempi di minimo. BI CVn ha un periodo variabile ; l'effemeride lineare,

JJ hel 33064.05743 + 0.384210198 giorno x E (4)(5),

descrive appossimativamente la sua variazione liminosa (10.22–10.67 V).
L'evoluzione della sua curva di luce é discussa.

RESUMEN

Un estudio del período de BI CVn ha sido efectuado con todas las informaciones publicadas sobre esta variable eclipsante de tipo W UMa, nuevas dedidas fotoeléctricas y nuevos instantes de mínimos. BI CVn varía de la magnitud 10.22 a 10.67 (V) con un período variable que corresponde aproximadamente a la fórmula lineal DJ hel 33064.05743 + 0.384210198 día x E (4)(5).
Así mismo, se discute la evolución de su curva de luz.

INTRODUCTION

BI CVn (= BD +37 2356 = NSV 6077 = CSV 6984 = BV 97) (13h 03min 17s + 36° 37.1') (2000) was first discovered by R. Kippenhahn (E. Geyer et al., 1955) when he compared Bamberg photographic plates from 1929 to 1939. The star is listed with maximum magnitude 10.8 (p), amplitude 0.7 magnitude and spectrum F8.

The following information about BI CVn comes from G.S. Filatov (1960) who wrote that it was probably a W UMa star and gave 12 instants of minima from Tadjikistan Observatory photographic plates (1939 to 1959).

E.I. Zaïtséva (1973) determined the G0 spectrum of the variable by examination through a prism lens.

Then came the first photoelectric measurements published by G.V. Zhukov (1982 and 1986). It concerned 300 measurements in B and V made in May 1980 at the Crimea Station of the Sternberg Institute. These measurements were used by D. Q. Zhou and K.C. Lejung (1986) in order to find the photometrical solution of the system, but they failed.

Furthermore, O. Demircan (1987), analysed the star using the photoelectric measurements he made on one night only, during a half cycle of the variable.

There are also 7 instants of minima published by the BBSAG from the visual and CCD observations of A. Paschke and some of my own.

1. VISUAL ESTIMATES AND PHOTOELECTRIC MEASUREMENTS

BI CVn was not a regularly observed variable and its period was suspected to be variable. This is why I began to observe it visually in 1991 and encourage other GEOS members to do so. I have now 12 instants of minima determined from my estimates, 8 from D. Dalmazio's and 3 from M. Dumont's.

As the evolution of BI CVn period promised to be very interesting but difficult to understand, I began to collect all the material that had been published about it and added photoelectric measurements of the star made with the B and V filters of the Geneva system using the photometer attached to the Jungfraujoch observatory 76-cm telescope. 43 measurements were obtained in each filter during several GEOS missions performed from December 94 to April 95. They cover most of the star's cycle.

2. STUDY OF THE STAR'S PERIOD

List 1 shows all the minimum instants of BI CVn I could collect. The first 12 instants were determined from 73 photographic plates (G.S. Filatov, 1960). 7 were determined from photoelectric measurements, 3 from CCD measurements and 27 from visual estimates.

a) Research method and comments about the different ephemerides

(1) JD hel 44365.2497 + 0.38416 d x E

This is the ephemeris given in the GCVS 85, which was determined by G.V. Zhukov from the Crimea Station photoelectric measurements. "The period could not be determined correctly enough for the short observational set. Therefore, all published epochs of minima could not be represented with a common period" (G.V. Zhukov, 1982). The numbers of the cycles after JD 48000 are arranged considering an actual somewhat longer period as supposed by O. Demircan (1987). We have consequently larger and larger O-Cs.

(2) JD hel 44364.9120 + 0.3842036 d x E
± 0.0023 ± 0.0000017

As I found coherent results after JD 2448000, I made a linear regression using these instants only, giving a triple weight to the photoelectric timings. In this way, I reached an accuracy to allow going back to the first photographic instant so that all the cycle numbers could now have an actual value.

list 1 : BI CVn instants of minima

OBS.	METH.	JDH (2400000 +)	E (1)	O−C (1)	E (2) (3)	O−C (2)	O−C (3)	E (4)	O−C (4) (5)	E (5)
FIL	phot	33064.246	− 29417.5	+ 0.0231	− 29413	− 0.0853	− 0.0135	− 29413	− 0.0035	0.5
FIL	phot	33409.260	− 28519.5	+ 0.0614	− 28515	− 0.0861	− 0.0157	− 28515	− 0.0103	898.5
FIL	phot	34149.230	− 26593	− 0.0528	− 26589	− 0.0923	− 0.0249	− 26589	− 0.0291	2824.5
FIL	phot	34150.195	− 26590.5	− 0.0482	− 26586.5	− 0.0878	− 0.0204	− 26586.5	− 0.0247	2827
FIL	phot	35599.261	− 22818.5	− 0.0337	− 22815	− 0.0457	+ 0.0157	− 22815	− 0.0074	6598.5
FIL	phot	35602.337	− 22810.5	− 0.0310	− 22807	− 0.0433	+ 0.0180	− 22807	− 0.0051	6606.5
FIL	phot	35604.274	− 22805.5	− 0.0148	− 22802	− 0.0273	+ 0.0340	− 22802	+ 0.0108	6611.5
FIL	phot	35638.266	− 22717	− 0.0210	− 22713.5	− 0.0373	+ 0.0239	− 22713.5	+ 0.0002	6700
FIL	phot	35653.242	− 22678	− 0.0272	− 22674.5	− 0.0453	+ 0.0159	− 22674.5	− 0.0080	6739
FIL	phot	35654.190	− 22675.5	− 0.0396	−22672	− 0.0578	+ 0.0033	− 22672	− 0.0205	6741.5
FIL	phot	35659.201	− 22662.5	− 0.0227	−22659	− 0.0414	+ 0.0197	− 22659	− 0.0042	6754.5
FIL	phot	36688.312	− 19983.5	− 0.0763	− 19980.5	− 0.0198	+ 0.0371	− 19980.5	− 0.0002	9433
ZHO	p.e.	44365.445	0.5	+ 0.0032	1.5	− 0.0433	− 0.0180	1	+ 0.0367	29414.5
ZHO	p.e.	44367.559	6	+ 0.0043	7	− 0.0424	− 0.0172	6.5	+ 0.0375	29420
ZHO	p.e.	44370.439	13.5	+ 0.0031	14.5	− 0.0439	− 0.0187	14	+ 0.0360	29427.5
ZHO	p.e.	44374.4732	24	+ 0.0037	25	− 0.0439	− 0.0187	24.5	+ 0.0360	29438
Aps	vis	46148.371	4641.5	+ 0.0427	4642	− 0.0141	− 0.0038	4641.5	+ 0.0353	34055
Aps	vis	46173.331	4706.5	+ 0.0323	4707	− 0.0274	− 0.0096	4706.5	+ 0.0216	34120
DEM	p.e.	46180.4496	4725	+ 0.0439	4725.5	− 0.0165	+ 0.0012	4725	+ 0.0323	34138.5
Aps	vis	46200.418	4777	+ 0.0360	4777.5	− 0.0267	− 0.0090	4777	+ 0.0218	34190.5
Aps	vis	46220.406	4829	+ 0.0477	4829.5	− 0.0173	+ 0.0003	4829	+ 0.0309	34242.5
VBR	vis	48329.510	10319	+ 0.1133	10319	+ 0.0010	+ 0.0099	10318.5	+ 0.0130	39732
VBR	vis	48387.528	10470	+ 0.1231	10470	+ 0.0042	+ 0.0129	10469.5	+ 0.0152	39883
VBR	vis	48400.405	10503.5	+ 0.1307	10503.5	+ 0.0104	+ 0.0190	10503	+ 0.0212	39916.5
VBR	vis	48717.361	11328.5	+ 0.1547	11328.5	− 0.0016	+ 0.0058	11328	+ 0.0038	40741.5
VBR	vis	48733.492	11370.5	+ 0.1510	11370.5	− 0.0071	+ 0.0001	11370	− 0.0021	40783.5
VBR	vis	48747.524	11407	+ 0.1612	11407	− 0.0015	+ 0.0087	11406.5	+ 0.0063	40820
VBR	vis	48791.503	11521.5	+ 0.1539	11521.5	− 0.0109	− 0.0038	11521	− 0.0068	4093.5
Aps	CCD	49137.486	12422	+ 0.2008	12422	− 0.0032	+ 0.0024	12421.5	− 0.0051	41835
Aps	CCD	49479.430	13312	+ 0.2424	13312	− 0.0004	+ 0.0038	13311.5	− 0.0082	42725
VBR	vis	49484.431	13325	+ 0.2493	13325	+ 0.0059	+ 0.0101	13324.5	− 0.0019	42738
VBR	vis	49502.473	13372	+ 0.2358	13372	− 0.0096	− 0.0055	13371.5	− 0.0178	42785
VBR	vis	49503.439	13374.5	+ 0.2414	13374.5	− 0.0041	− 0.0001	13374	− 0.0123	42787.5
Aps	CCD	49516.508	13408.5	+ 0.2489	13408.5	+ 0.0019	+ 0.0060	13408	− 0.0064	42821.5
JUV	p.e.	49722.6325	13945	+ 0.2716	13945	+ 0.0012	+ 0.0044	13944.5	− 0.0107	43358
DDL	vis	49786.413	14111	+ 0.2815	14111	+ 0.0039	+ 0.0068	14110.5	− 0.0091	43524
DDL	vis	49797.354	14139.5	+ 0.2740	14139.5	− 0.0049	− 0.0020	14139	− 0.0181	43552.5
VBR	vis	49798.519	14142.5	+ 0.2865	14142.5	+ 0.0075	+ 0.0104	14142	− 0.0057	43555.5
DDL	vis	49799.471	14145	+ 0.2781	14145	− 0.0010	+ 0.0018	14144.5	− 0.0142	43558
DDL	vis	49801.400	14150	+ 0.2863	14150	+ 0.0070	+ 0.0098	14149.5	− 0.0063	43563
DDL	vis	49810.420	14173.5	+ 0.2785	14173.5	− 0.0018	+ 0.0010	14173	− 0.0152	43586.5
JUV	p.e.	49810.4258	14173.5	+ 0.2843	14173.5	+ 0.0040	+ 0.0068	14173	− 0.0094	43586.5
DDL	vis	49827.326	14217.5	+ 0.2815	14217.5	− 0.0008	+ 0.0020	14217	− 0.0145	43630.5
VBR	vis	49830.592	14226	+ 0.2820	14226	− 0.0005	+ 0.0022	14225.5	− 0.0143	43639
DDL	vis	49841.341	14254	+ 0.2747	14254	− 0.0092	− 0.0065	14253.5	− 0.0232	43667
DMT	vis	49843.450	14259.5	+ 0.2711	14259.5	− 0.0133	− 0.0106	14259	− 0.0273	43672.5
DMT	vis	49858.460	14298.5	+ 0.2989	14298.5	+ 0.0127	+ 0.0153	14298	− 0.0015	43712.5
DDL	vis	49863.433	14311.5	+ 0.2775	14311.5	− 0.0089	− 0.0063	14311	− 0.0232	43724.5
DMT	vis	49869.403	14327	+ 0.2927	14327	+ 0.0059	+ 0.0085	14326.5	− 0.0085	43740

The O−Cs (2) are very small after JD 2448000, but they are more and more negative in the past with a certain homogeneity within a short lapse of time.

(3) JD hel 44364.88674 + 0.38420519 d x E

This is the ephemeris found by linear regression of all the instants of minima (p.e. x 3) from E (2). Now the photographic instants show at least fairly reasonable O−Cs, the larger being of 0.0371 day. But, if the period of BI CVn is constant, the Zhukov photoelectric instants are still too unwedged.

(5) JD hel 33064.05743 + 0.384210198 d x E

To come to ephemeris (5), I proceeded differently. I took the 12 photographic timings only to find elements :

JD hel 44365.05321 + 0.384211753 d x E
± 0.0070 ± 0.0000026

with accuracy allowing going down to the Zhukov photoelectric timings whose minima are shifted by a half cycle. Then I made a new linear regression with the Filatov and Zhukov timings together and acquired elements : JD hel 44365.06047 + 0.38421205 d x E
± 0.0038 ± 0.00000032

with the accuracy needed to go down to the last minima. E (5) is a single new numbering of the instants with primary and secondary minima determined from the JUV photoelectric measurements (this work) and epoch set just before the first instant.

Ephemeris (3) and (5) are the two best solutions found for all the extrema with a linear formula according to whether we start with the present minima or with the first photographic minima. The evolution of the O−Cs is not the same in the two cases because there is a difference in the numbering of the cycles : at least one of the two solutions is not acceptable and it is obvious (see fig 1 and fig 2) that the period of BI CVn has not been constant during the lapse of time et has been observed.

fig 1 : O−C graphic of BI CVn obtained from ephemeris (3)

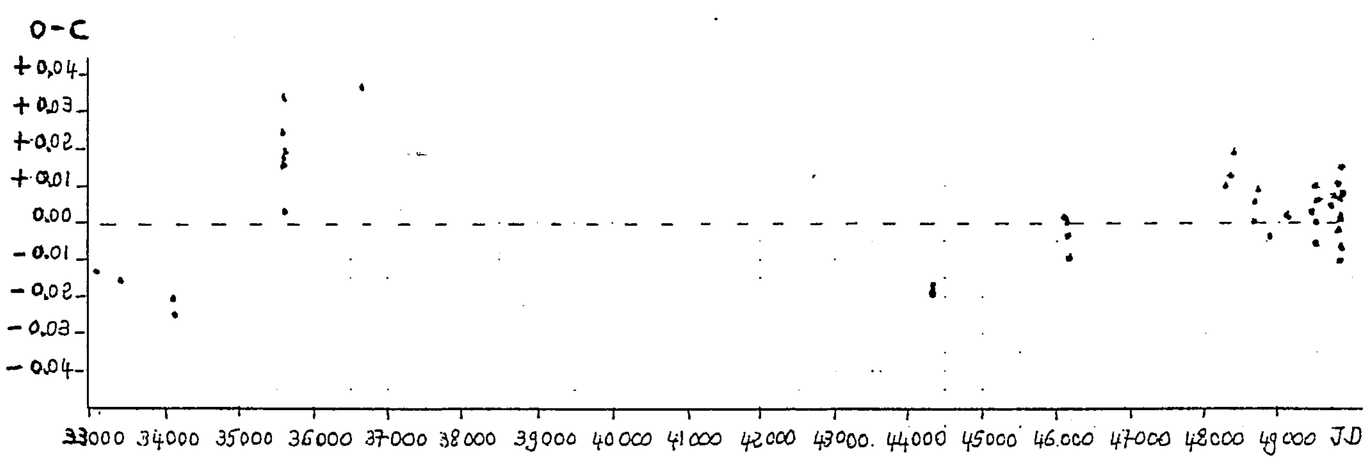
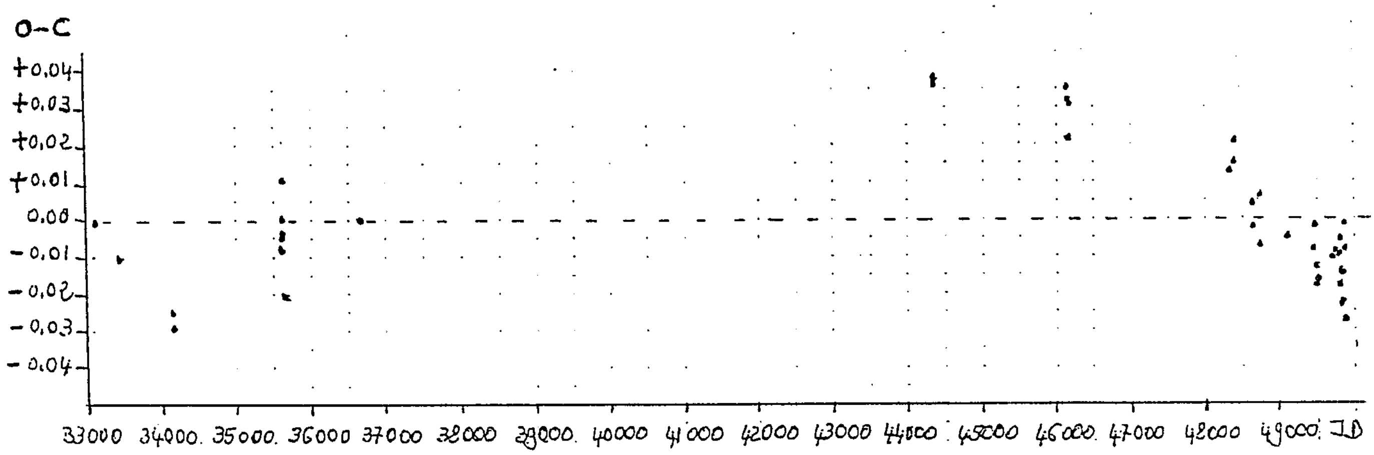


fig 2 : O–C graphic of BI CVn obtained from ephemeris (5)

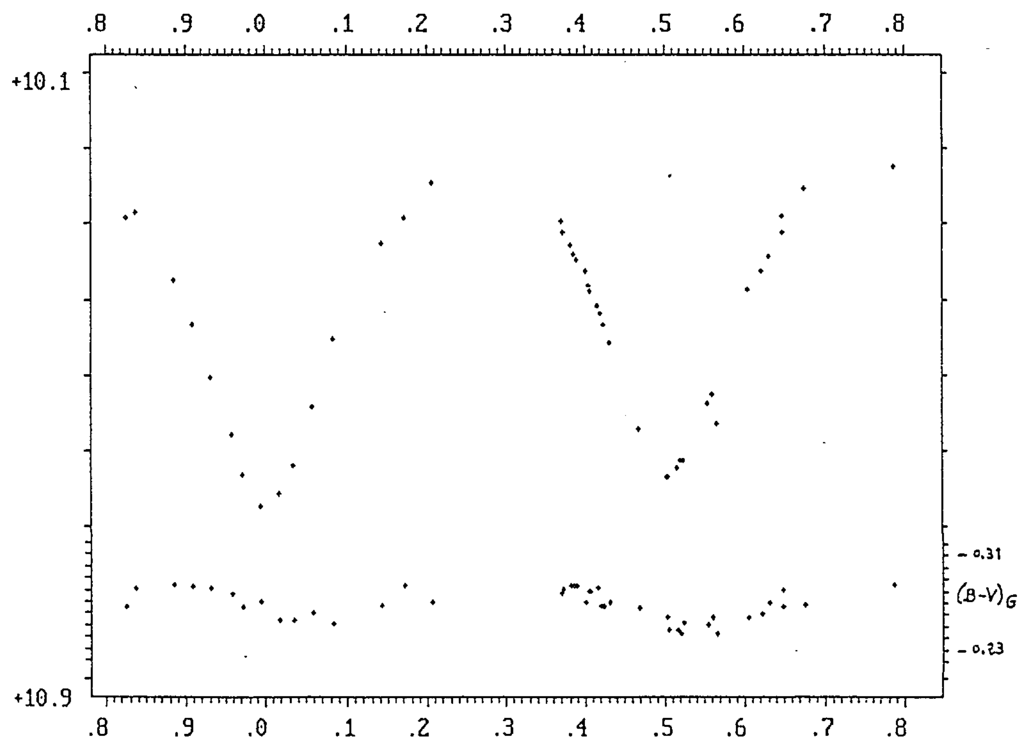


It is impossible to give preference to either of the two solutions because of the lack of observations between JD 2437000 and JD 2422000. Since, the period was possibly constant between JD 2433000 and JD 2437000 (period = 0.384211753 day) and from JD 2448000 to present (period 0.384166674 day). A solution would rest on making a distinction between the primary and secondary minima.

b) Distinction between primary and secondary minima

The differences between the two minima of BI CVn are so tenuous that only the photoelectric measurements can be useful here and still it is not that obvious.

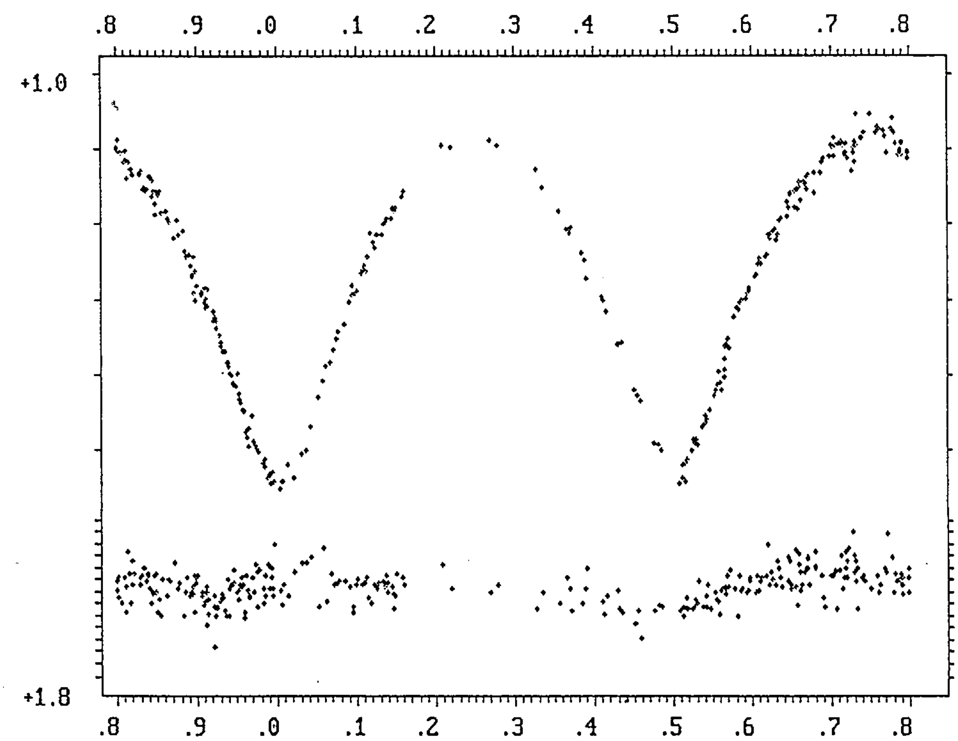
fig 3 : composite light curve of 43 measurements in V and 43 B–V indices of BI CVn, made in the Geneva photometric system, from December 94 to April 95 with ephemeris (2)



There is no doubt here that the minimum at JD 2449722 is certainly deeper that the one at JD 2449810.

As regards the Demircan's photoelectric minimum, there is a problem because he measured the star only during a night and over a half cycle of BI CVn with only one minimum. In his paper (Demircan, 1987), he writes that he measured a primary minimum because BI CVn is then apparently redder and that since the system is expected to be in the W–subclass of W UMa–type binaries, then the primary eclipse of BI CVn should be an occultation with the larger and slightly cooler component in front. But what he did not suspect, is that the B–V light curve of BI CVn has the same shape during primary and secondary minima (see fig 3). The B–V indices consequently cannot help us. Furthermore, the amplitude differences between the two minima are too faint to allow us to discriminate which minimum Demircan measured in differential magnitudes. From ephemeris (3) and (5), it is considered to be a secondary minimum.

fig 4 : composite light curve of the 300 Zhukov photoelectric measurements in V and the 300 B–V colour indices with ephemeris (1)



As regards the Zhukov photoelectric minima, the problem is different. From his composite light curve, Zhukov considered the JD 2444367 and JD 2444374 minima as primary and the JD 2444365 and JD 2444370 minima as secondary, a solution which agrees with the results of ephemeris (5) but not with those of ephemeris (3). I composed his photoelectric measurements in differential V magnitudes and the B–V colour indices with ephemeris (1) (see fig 4), the only one giving a very little O–C which is similar to the fig 1 of IBVS n° 2191 (Zhukov, 1982). In fact, there is a very little difference in the depth of the two minima and this favours the numbering of E according to ephemeris (5).

3. UNDERSTANDING OF THE STARS SYSTEM AND PHOTOELECTRICALLY KNOWN ELEMENTS

From the previous works, we know that BI CVn is a W UMa eclipsing star of the W subclass. The period of the star was approximately known but all the photoelectric measurements were in relative differential magnitudes. From the 43 new measurements in the B and V filters of the Geneva system, we found that BI CVn varied from magnitude 10.22 to 10.67 (V) with a (B−V)G going from − 0.29 to − 0.24 which correspond to a (B−V)J of + 0.55 to + 0.59. Minimum II = 10.63 (V) at phase 0.5.

The photoelectric measurements of BI CVn by Zhukov are of 1980 and their composite light curve in V (fig 4) shows very little difference between the depth of primary and secondary minima whereas the composite light curve of the colour indices shows a reddening occurring clearly before the minima.

The BI CVn photoelectric measurements by Demircan are from April 1985 and seem to show a reddening nearly in phase with the V minimum if not somewhat in advance (Demircan, 1987).

From fig 3, we see that in 1994−95, BI CVn is redder during the primary as well as during the secondary minima. But the B−V light curve does not mimic perfectly the V light curve, the reddening occurring a little after the mid eclipses.

As BI CVn is a W UMa eclipsing star of the W subclass, the two components of the system are in overcontact with energy exchanges between them. That explains why the two components, although not of the same mass, can have the same colour (Wilson, 1994). And it is understandable that the mass exchange causes period variations or that period variations originate mass exchanges. The reddenings may be understood if each component has a hot region near the contact point. Cool spots are another explanation but, with rotation synchronized with orbital motion, spot migration is hard to admit.

All this seems to prove that the V light curve of BI CVn is changing with time, more particularly when we consider the depth of primary and secondary minima. The B−V indices light curves are showing, for their part, a reddening during the eclipses, but not always exactly at the same phase. New photoelectric measurements in B and V would be very interesting in order to follow the changes.

4. THE PERIOD CHANGES OF BI CVN

Supposing that the period of ephemeris (5) (0.384210198 day) gives the accurate O−C without any shift of the cycles numbers (E), it is obvious that the period is not constant. An O−C > 0.03 day is too much for photographic minima and all the photoelectric minima have obviously too large O−Cs (− 0.0107 to + 0.0375). It is only after JD 2448000 that the minima are regularly observed and since this time the period seems to keep the constant value of 0.384203608 day.

The greater change seems to have occurred a few time before 1980 and the Zhukov measurements. But it is too hazardous to make more suppositions. The solution should come from the study of other ancient photographic plates and by the future monitoring of the star.

5. CONCLUSION

BI CVn is a W UMa eclipsing binary varying from magnitude 10.22 to 10.67 (V) ; minimum II is now 10.63 (V) and B−V colour index ranges from 0.55 to 0.59. Its period is not constant, but its elements correspond approximatively to the linear formula (5) JD hel 33064.05743 + 0.384210198 d x E.

The evolution of its period and of the shape of its light curve should be very interesting to survey in the next years.

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