J. Astron. Space Sci., Vol. 6, No. 2, 109-117(1989)

EXAMINATION OF ORBITAL PERIOD OF ZZ CANCRI*

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(Received October 11, 1989; Accepted November 20, 1989)

Abstract

A total of 266 photoelectric observations(91 in *V*, 93 in *B*, and 82 in *U*) for an eclipsing binary, ZZ Cnc, has been secured by using the 61-cm reflector and an uncooled 1P21 photomultiplier phototube of Yonsei University Observatory during 4 years from March 1984 to May 1988.

One time of minimum light, JD 2446887.534 is obtained. Although Kim *et al.*(1988) suggested the possibility of the period change, the present study shows that the orbital period of ZZ Cnc should be constant. According to a reasonable interpretation of the eclipse light curves,

$$\text{Min I} = \text{JD Hel } 2446887.574 + 25\overset{d}{.}5944\,E$$
$$\pm 2 \qquad\qquad \pm 2$$

may be useful as new light elements for future observations.

I. Introduction

The accurate determinations of the orbital periods of eclipsing binaries are based on the continuous observations of the times of minimum lights in a long time span. The accuracy of the orbital period of a long period star can not, however, be superior than that of a relatively short period star because the number of orbital cycles of a long period star is much less than that of

*Yonsei University Observatory Contribution No. 80.

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short period star during a same time base. Moreover, the observation for one time of minimum light of a long period star requires more observing time comparing to short period stars. For these reasons, the light elements of long period eclipsing binary stars have been determined less accurately. Recently, however, the orbital period variations of some long period eclipsing binaries, especially W Serpentis stars, have had attracted the binary astronomers for their interest because these stars are probably on very early evolutionary stage. If it is true to be believed, the study on the period variations of long period binaries could play important role to understand the binary evolution.

ZZ Cancri(BD+11°1722, P=25ᵈ.6) is one of long period eclipsing binaries poorly studied. A photographic light curve was made by Strohmeier(1961), and the light elements are given by him,

$$\text{Min I} = \text{JD Hel } 2426770.350 + 25^{d}.595\,E. \qquad \cdots\cdots (1)$$

Naftilan(1975) classified the spectral type of the primary star as A8 IV-V, despite A3 in HD catalog, and the secondary as K0 III with small metal deficiency. Strohmeier's light curve of the star shows a typical Algol type; deep primary minimum light with no light variation for the possible secondary eclipse and constant light at the outside eclipse. Kim *et al.*(1988) claimed the orbital period variation of ZZ Cnc with the data available by the end of 1986 season. If the period variation were existing, it should mean that the secondary component, K0 III star, filled it's critical Roche lobe. Since the emission lines detected by Naftilan(1975) possibly indicate that the system would have mass transfer between the eclipsing pair, and thus the orbital period change could be expected as a consequence. Additional observations have been made since then, and thus it becomes our main purpose of this study to find out whether there is any clear evidence of the orbital period variation in the ZZ Cnc system.

There are unexpected observations made on 19 April 1988(JD 2447271), whose light level is comparable to that of the outside-eclipse part of the light curve but located in the primary eclipse phase, 0ᵖ.964. If one include this observation as a part of the outside-eclipse, then the duration of the primary eclipse may apparently be reduced, and the shape of the light curve will be different accordingly. We are, therefore, faced on the difficulty how to treat this night's observation. This will be discussed in Section III in detail.

Ⅱ. Observations and Light Curves

A total of 266(91 in *V*, 93 in *B*, 82 in *U*) differential photoelectric observations was made during five years from March 1984 to May 1988 with the 61cm reflector, uncooled 1P21 photomultiplier, and the Johnson's *UBV* system at Yonsei University Observatory(YUO). The employed comparison

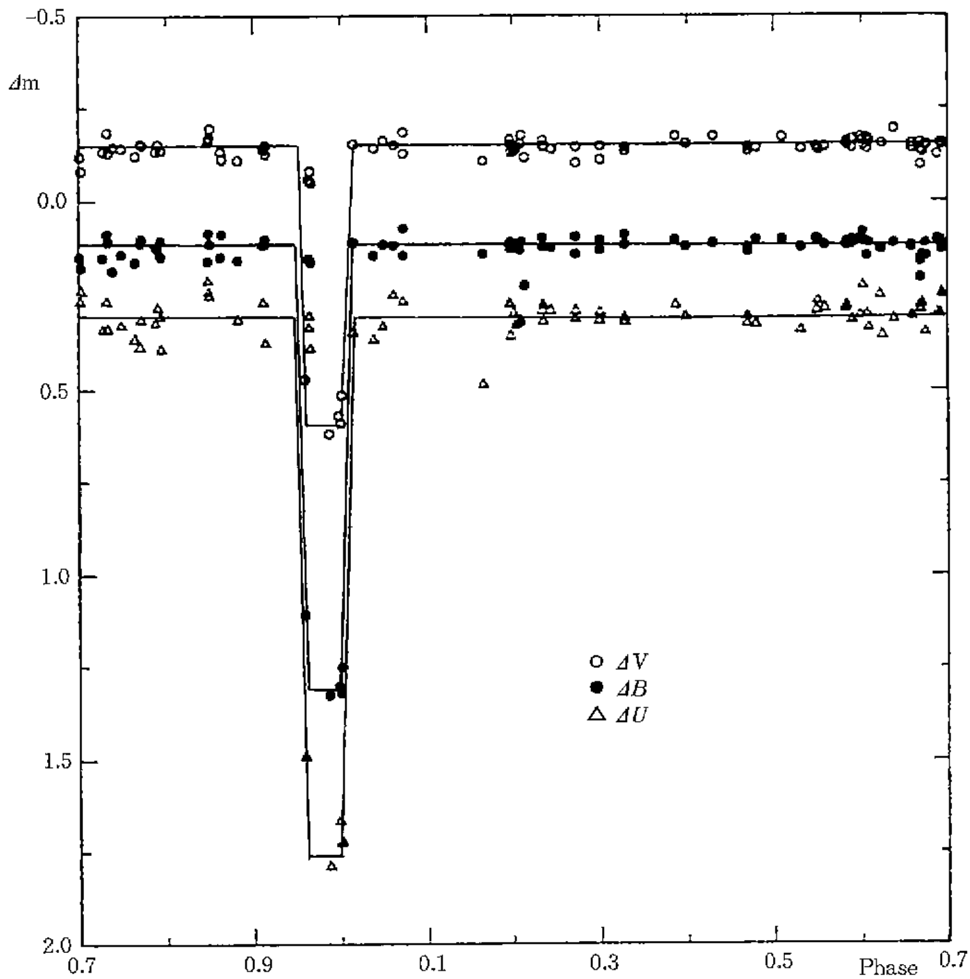


Fig. 1. *UBV* light curves of ZZ Cnc. Different symbols denote different passband as explained in the figure. The solid lines are free-hand light curves.

Table 1. Standardized *UBV* Observations of ZZ Cnc

JD Hel 2440000.+	ΔV	ΔB	ΔU	JD Hel 2440000.+	ΔV	ΔB	ΔU
5766.0752	-0.106	0.142	0.484	6901.0374	-0.170	0.105	
5766.9821	-0.132	0.118	0.295	6902.0574	-0.145	0.101	0.289
5767.0475	-0.140	0.129	0.328	6919.0570	-0.116	0.225	
5767.1501	-0.152	0.131	0.322	7177.2305	-0.109	0.130	0.315
5767.1835	-0.175	0.110	0.315	7177.2431	-0.148	0.104	0.293
5768.0666	-0.139	0.126	0.289	7200.1827	-0.164	0.116	0.271
5778.9955	-0.130	0.146	0.272	7200.1918	-0.149	0.111	0.273
5779.0820	-0.150	0.115	0.348	7200.2014	-0.131	0.128	0.355
5781.0018	-0.141	0.144	0.328	7201.1362	-0.145	0.122	0.289
5781.9972	-0.133	0.123	0.320	7201.1502	-0.162	0.099	0.274
5782.0645	-0.153	0.127	0.280	7201.1639	-0.148	0.122	0.318
5782.1467	-0.136	0.104	0.305	7202.1105	-0.101	0.144	0.310
5810.0130	-0.109	0.156	0.312	7202.1196	-0.144	0.097	0.289
5814.0141	-0.143	0.145	0.365	7207.1715	-0.134	0.138	0.325
6053.2613	-0.173	0.104	0.274	7207.1826	-0.144	0.124	0.305
6109.9888	-0.163	0.085	0.225	7210.0780	-0.151	0.120	0.285
6110.1113	-0.166	0.112		7210.0889	-0.159	0.111	0.277
6110.1589	-0.158	0.113	0.336	7212.0058	-0.152	0.119	0.304
6119.1178	0.472	1.106	1.487	7212.0152	-0.142	0.124	0.304
6136.0788		0.128	0.249	7213.1111	-0.120	0.150	0.263
6136.1427	-0.154	0.130	0.355	7213.1236	-0.082	0.178	0.235
6146.1423	-0.152	0.111	0.346	7229.1516	-0.144	0.117	0.307
6147.0248	-0.161	0.116	0.331	7229.1638	-0.132	0.092	0.318
6463.0871	-0.153	0.122	0.305	7244.0824	-0.139	0.116	0.267
6465.1750	-0.142	0.106	0.326	7244.1346	-0.149	0.113	0.373
6467.1918	-0.146	0.119	0.283	7244.1487	-0.127	0.102	0.372
6417.2455	-0.139	0.149	0.299	7264.0662	-0.151	0.115	0.248
6473.2232		0.148	0.390	7264.0712	-0.155	0.132	0.243
6478.1685	0.620	1.325	1.784	7265.0923	-0.184	0.088	0.265
6492.0792	-0.140	0.126	0.342	7265.1242	-0.130	0.109	0.338
6496.0777	-0.125	0.103	0.297	7266.0607	-0.154	0.110	0.383
6805.1884	-0.123	0.162	0.363	7266.0892	-0.149	0.103	0.313
6813.1004	-0.184	0.073	0.265	7268.0479	-0.161	0.160	0.210
6813.1037	-0.127	0.146		7268.0737	-0.169	0.086	0.239
6830.1443	-0.145	0.187		7268.0947	-0.196	0.114	0.250
6852.1786	-0.170	0.101	0.302	*7271.0206	-0.059	0.154	0.333
6852.2531	-0.148	0.107		*7271.0295	-0.080	0.156	0.302
6853.1407	-0.193	0.115	0.312	*7271.0661	-0.050	0.162	0.388
6854.1214	-0.151	0.147		7286.0224	-0.136	0.106	0.265
6863.9872	-0.151	0.121	0.248	7287.0355	-0.143	0.104	0.314
6880.1055	-0.157	0.106	0.298	7287.0453	-0.165	0.116	
6881.0497	-0.133	0.151	0.339	7289.0298	-0.155	0.155	0.276
6887.9793	0.571	1.303	1.663	7289.0432	-0.096	0.207	0.283
6888.0127	0.590	1.320	1.723	7289.0487	-0.135	0.162	0.287
6888.0577	0.517	1.250	1.719	7294.0124	-0.133	0.148	
6899.0173	-0.172	0.114		7294.0455	-0.113	0.089	

star, BD+11°1723, which is very close to the program star with almost same visual magnitude (m_v=9.27) and spectral type A2 to the variable. The atmospheric extinction coefficients were determined for each night and properly corrected. All the observations obtained were transformed into the standard *UBV* system. The standardized observations are listed in Table 1.

The observations are distributed on a whole phase homogeneously lacking only phase interval of $0^p.1-0^p.2$ region as shown in Figure 1. The phases of the light curves of Figure 1 are calculated with the light elements given by Eq. (1). The light curves show a constant light level outside-eclipse and no clear secondary minimum light in any of passbands appeared. The primary eclipse is obviously occultation and total. The depths of the primary eclipse in *V*, *B*, and *U* are $0^m.78$, $1^m.20$, and $1^m.47$, respectively.

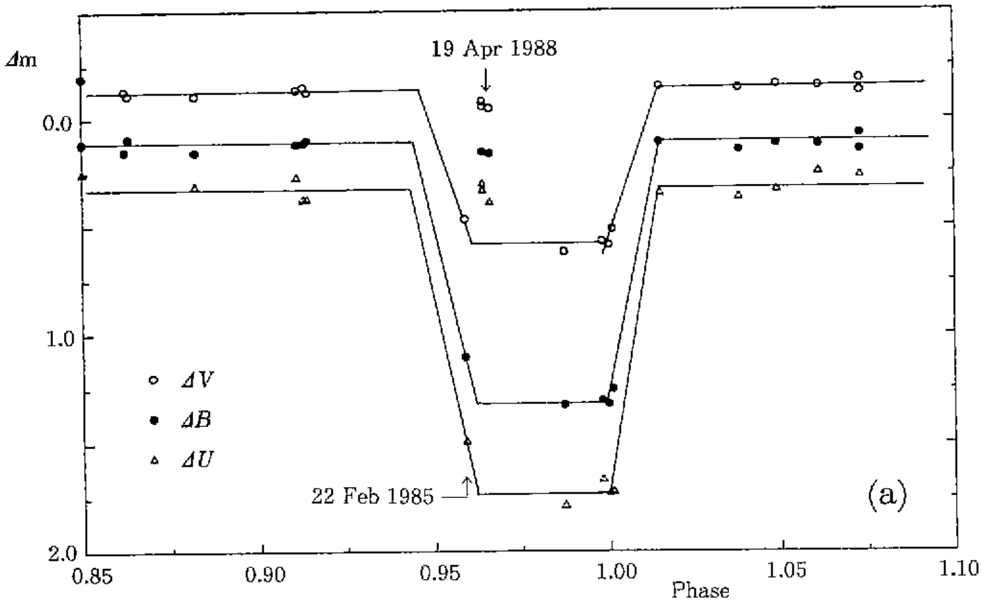
Table 2. Magnitudes and Colors of ZZ Cnc and Comparison Star

star	*V*	*B−V*	*U−B*	
comparison (BD+11°1723)	9.27	+0.30	+0.25	
ZZ Cnc (BD+11°1722)	9.12	+0.57	+0.43	at maximum
	9.89	+1.01	+0.71	at minimum
	9.86	+0.26	+0.32	primary comp.

The colors, *B−V* and *U−B*, of comparison star and ZZ Cnc are tabulated in Table 2. Since only the secondary component of ZZ Cnc is seen at the primary mid-eclipse, the colors at the primary eclipse are the value of the secondary component itself, and these are listed in Table 2. The colors of the primary component are possible to be determined using the colors at primary eclipse and at the outside-eclipse, and these values are also included in the table.

Ⅲ. Period Determination and Discussions

The orbital period of ZZ Cnc was determined by Strohmeier about 30 years ago. The orbital period of this star is relatively long (25.6 days) and the time span for this period by him was not long enough to deduce an exact period at that time. Since the present observation has been made after about 30 years from the most recent observation, there would be necessity of the improvement of the period by Strohmeier in order to make the observations of 19 April 1988 in order.



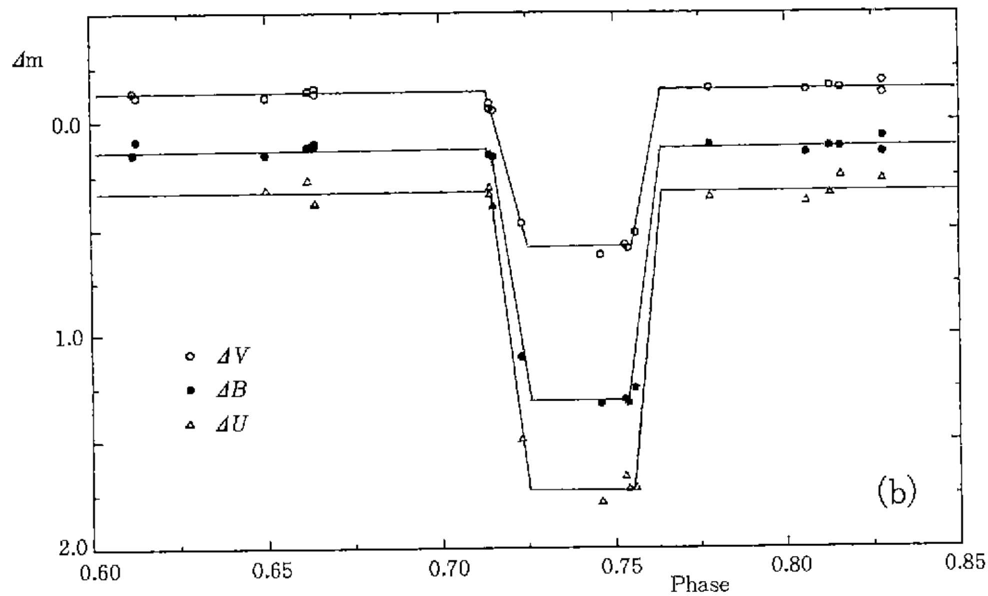


Fig. 2. *UBV* light curves around the primary eclipse. Different symbols denote different passband as explained in the figure. (a) represents the phases by Eq. (1) and (b) by Eq. (3).

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New light curves in a larger scale centered at the primary eclipse are made with the light elements by Strohmeier as shown in Figure 2. As we see in this figure, the observations on 19 April 1988 mentioned are located in a phase of the beginning of the totality, but the brightnesses of these observations are those of outside level. There could be four possible interpretations for these observations; the first is that the observation on 22 February 1985 (0^{p}959) may be wrong. The second possibility is that the observer made a misidentification of the object, the third is that the record of the observed date was wrong, and the last is that the orbital period given by Strohmeier may be wrong which needs a large revision.

First, according to the ratios of the light levels of the observations at 0^{p}959 to primary depths in *UBV*, the observations on 22 February 1985 could be regarded as correct. Otherwise, the *V* light level of the observations on 19 April 1988 is a little lower than that of normal outside-eclipse.

Second, the observer for the night was one of the most participated ones for the observing season, and she observed ZZ Cnc many times for this program. So the possibility of mis-finding the object is very weak. In addition, there are no stars in the vicinity of ZZ Cnc, whose spectral type and magnitude are almost same.

Third possibility could be checked by two different records; one by the Central Meteorological Observatory (CMO) and the other by our observatory (YUO) log books. This, of course, should not be exact checking because of different concepts for the record *clear* between meteorologist and astronomer, separated in two different places about 27km apart. According to the check for several nights before and after the observed date (19 April 1988) recorded on log book of YUO,

Table 3. *O-C* Values of Collected Times of Minimum Light of ZZ Cnc

JD Hel 2400000.+	$(O-C)_1$	$(O-C)_2$	$(O-C)_3$	Ref.
26770.350	0.000	-0.026	0.000	1
27538.326	0.126	0.118	-0.114	1
27896.334	-0.196	-0.195	-0.548	1
37315.495	0.005	0.227	-3.291	1
46478.065	-0.435	0.001	-6.595	2
46887.534	-0.486	-0.040	-6.774	3
$\Sigma(O-C)^2$	0.480	0.106	100.525	

1. Strohmeier(1961) 2. Kim *et al.*(1988). 3. This study

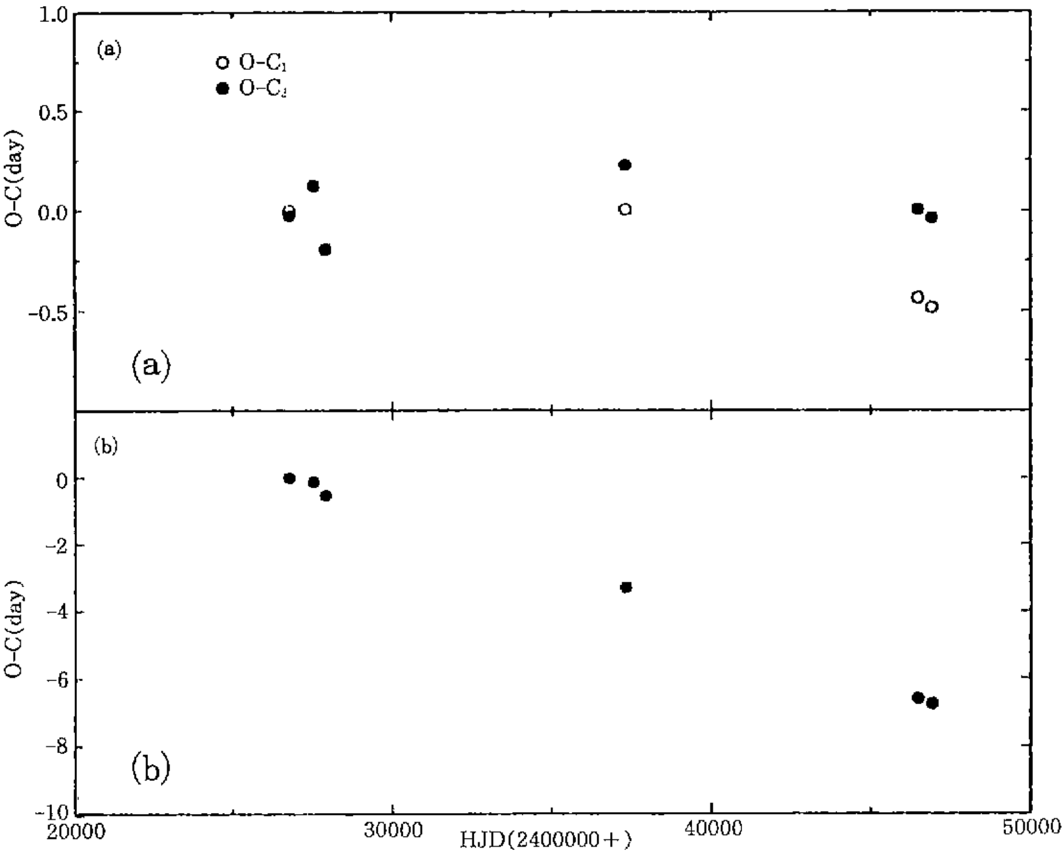

Fig. 3. O–C diagrams. (a) is made with $(O\text{-}C)_1$ and $(O\text{-}C)_2$ and (b) with $(O\text{-}C)_3$ Open and filled circles in (a) denote $(O\text{-}C)_1$ and $(O\text{-}C)_2$, respectively.

however, there was one different night. In spite of *cloudy* on YUO log book for 18 April 1988, just one night before the problem date, CMO's record was *clear* with cloud amount 0.0. If the CMO's were true, and the observed date recorded in YUO log book may be wrong by one day, then the phases of the problem observations are around 0^{p}925 just before the primary eclipse predicted by Eq. (1). Eliminating these observations from the eclipse, a time of minimum light is deduced as JD 2446887.534, whose $(O\text{-}C)_1$ then is -0.486 days. Using this and collected times of minimum light tabulated at Table 3, we made $(O\text{-}C)_1$ diagram as shown in Figure 3. According to Figure 3, the orbital period of ZZ Cnc can be regarded as constant, but needs minor corrections. The improved light elements are

$$\text{Min I} = \text{JD Hel } \underset{\pm 2}{2446887.574} + \underset{\pm 2}{25^{d}.5944}\,E. \qquad \cdots\cdots (2)$$

The $(O\text{-}C)_1$'s by Strohmeier's light elements, and $(O\text{-}C)_2$'s by new light elements are given in Table 3.

If the third possibility were correct, *i. e.*, the orbital period of ZZ Cnc by Strohmeier was ill-determined, then the light curves must be corrected with a completely different period. By the trials and errors, we found that $P=25^{d}.603$ fits the observations including those of 19 April 1988 most satisfactorily. This new attempt conceives an alternative time of minimum light 2446887.632. Using the epoch in Eq. (1) with a new period. $P=25^{d}.603$, third light elements become

$$\text{Min I} = \text{JD Hel } 2426770.350 \pm 25^{d}.603\,E. \qquad \cdots\cdots (3)$$

The values of $(O\text{-}C)_3$ by Eq. (3) are calculated for all available times minima, and are plotted in the lower part of Figure 3 as (b). The $(O\text{-}C)_3$ diagram shown in this figure indicates that the period, $25^{d}.603$, is not reliable. The slop, $(O\text{-}C)_3/E=-0.0086$, means that the orbital period adopted in Eq. (3) changed by 0.0086 days each revolution. Therefore, the period seems to changed to $25^{d}.5944$ $(=25^{d}.603-0^{d}.0086)$, which is the same as the period in Eq. (2). This obviously indicates that the problem observations on 19 April 1988 are not caused by the wrong period on the discussion.

The present analyses on the orbital period of ZZ Cnc show that the period determined by Strohmeier is correct but needs a minor revision. And, thus, at this moment Eq. (2) may be accepted as a representative one. However, more realistic orbital period of this difficult system ZZ Cnc could, of course, be warranted by more observations of times of minimum light in future.

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