Periodic variation of the (O-C) values for the cepheid CK Cam ?

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Abstract:
This study presents 16 new maximum timings of the bright cepheid CK Cam. These data, obtained visually, as well as those already published verify the ephemeris of the IBVS 4375. However, the residual values of (O-C) could present cyclic variations with period around 1350 days.

Résumé:
Cette étude présente 16 nouvelles dates de maxima de la céphéide CK Cam. Ces dates ainsi que celles déjà publiées vérifient l'éphéméride de l'IBVS 4375. Cependant les valeurs résiduelles de (O-C) pourraient présenter des variations cycliques avec une période d'environ 1350 jours.

I) Introduction :

CK Cam (HD32456, spectral type G5) was recently discovered to be variable in the course of the data reductions for the Tycho experiment on the Hipparchos satellite (V.Makarov et al., 1994). U.Bastian *et al.* showed that CK Cam is a bright cepheid (V magnitude between 7.2 and 7.8) with the elements:

JD(max): 2450015.46 + 3.2942 E   (IBVS 4306).

Independently, F.Campos-Cucurella *et al.* derived the following ephemeris using additional photometric measurements:

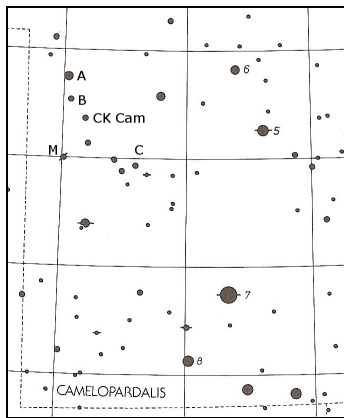JD (max) = 2450117.597 + 3.2951 E   (IBVS 4317).

The ephemeris has been improved by L.N.Berdinhov *et al.* using all the published data, some photographic archival plates and new photoelectric measurements:

JD (max) = 2433442.959 + 3.2947470 E   (IBVS 4375).

It is now well-established that cepheids undergo changes in pulsation period, more or less rapidly and regularly (D.G.Turner, 1998). Being a bright Cepheid of wide amplitude, CK Cam is therefore an interesting target for amateur observers to test the ephemeris and to check possible modifications in the period. In this study we present 16 additional times of maximum light obtained from visual estimates made by GEOS (Michel DUMONT (DMT) and Franck GOBET (GBF)) and BAV members that confirm the last ephemeris. However, the last decades (O-C) measurements seem to exhibit sinusoidal trend that could hint at more complex behaviour.

II) Visual estimates by GEOS members

CK Cam is easily observable using binoculars from August to May (from France latitudes).
The figure 1 shows the chart and the comparison stars used by DMT and GBF.

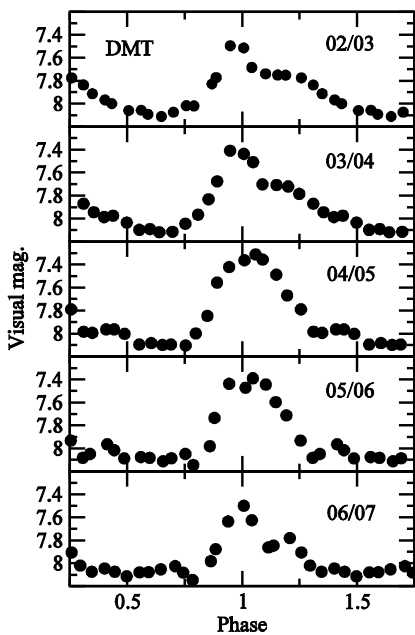| Comparison star	Identifier	V Mag.	Spectral type
A	HD32629	6.92	K0
B	HD32606	7.39	F8
M	HD32652	8.08	B9
C	HD32016	8.16	G0

(source: Simbad database, CDS, Strasbourg, France)

Fig.1: CK Cam and its comparison stars (source: Uranometria 2000 chart)

A total of 463 visual estimates were obtained from September 2002 to May 2007 by these both observers:

	2002	2003	2004	2005	2006	2007	Total
DMT	26	87	62	70	53	42	340
GBF					76	47	123

The Figure 2 reports on the folding of these data per steps of two seasons using the elements of the IBVS 4375. A similar light curve shape is obtained by the both observers during the seasons 2006/ 2007: i) the amplitude is close to 0.6 – 0.8 mag, ii) the maximum light curve is slightly in advance iii) a hump is observed in both curves around the phase φ=0.2. Furthermore, the folded light curves deduced from DMT estimates exhibit a variation of the maximum phase with time: the star seems to be in advance in 2002- 2004 whereas a small delay is observed in the 2004 -2006 light curves.

The phases of each maximum have been measured using a 3rd order polynomial fit (J.M.Roney et al, 1983). The instants of the maxima are calculated considering the closest light maximum timings from the mean times of the estimates. The times of the maxima are not reduced to the sun: the heliocentric corrections are 10 to 100 smaller than the errors on the maximum time measurements.
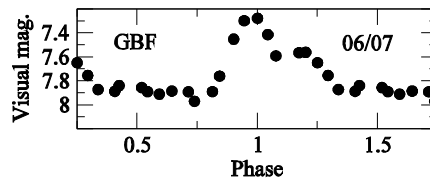
Fig.2: Folded light curves of CK Cam for the mentioned visual observations between 2002 and 2007.

III) Analysis and discussion

The times of light maximum are reported on the Table 1 with those published in the different IBVS. Furthermore, 11 other times obtained from visual estimates made by BAV members have been also considered.

source	JD max	± (day)	O-C (day)
IBVS4375	2416567.2012	0.0766	-0.0637
IBVS4375	2417522.7952	0.0667	0.0537
IBVS4375	2428260.2223	0.0654	-0.0997
IBVS4375	2433442.959	0.031	0.00
IBVS4375	2436839.7696	0.078	-0.074
IBVS4375	2436839.8578	0.0899	0.0146
IBVS4375	2448216.6518	0.0681	0.0473
IBVS 4306	2448276.14	0.15	0.23
Tycho *	2448361.50	?	-0.07
IBVS 4306	2448503.21	0.05	-0.04
Born *	2450015.42	?	-0.12
IBVS 4306	2450015.46	0.02	-0.08
Born *	2450081.33	?	-0.10
Baule *	2450088.01	?	-0.01
Kriebel *	2450107.75	?	-0.04
IBVS 4317	2450117.597	0.004	-0.077
Born *	2450137.30	?	-0.14
Nn *	2450140.75	?	0.01
Groebel *	2450150.552	?	-0.069
Groebel *	2450150.560	?	-0.061
IBVS4375	2450318.5951	0.0029	-0.0580
IBVS4375	2450318.6230	0.0042	-0.0301
Reinhard *	2451293.87	?	-0.03
DMT	2452763.276	0.033	-0.079
DMT	2452964.246	0.076	-0.089
DMT	2453376.29	0.215	0.112
Meyer, 2006	2453501.38	0.04	0.00
DMT	2453692.586	0.211	0.112
DMT	2453998.829	0.063	-0.057
GBF	2454018.555	0.128	-0.099

Table 1: available times of maximum light for CK Cam. Some times have been measured in this study (DMT, GBF) or have been published elsewhere (the three IBVS and Meyer, 2006). The data libelled with a star have been obtained by BAV observers and communicated by R. Meyer. The (O-C) values are calculated with the elements of IBVS 4375.

The (O-C) values calculated with the ephemeris of the three IBVS are reported on the Figure 3. These figures exhibit clear linear trends with more or less strong slope. The top figure indicates the validity of the IBVS 4375 ephemeris. There was no rapid and strong change of the pulsation period during the 15 last years. However, fluctuations of the O-C values with amplitude around 0.3 day are observed. This amplitude is larger than the errors on the timing measures.

The linear trend has been removed to the O-C data calculated with the elements of the IBVS 4375. The 30 values of the (O-C) residual are scattered around a null value and have been used to search for a periodicity using a phase-dispersion-minimization (PDM) method (Stellingwerf, 1978). The periodogram is shown in figure 4. Despite the small number of the data, the PDM calculation gives a well-defined minimum at a period P = 1350 ± 50 days. A second minimum around 2600 days could be correlated to the first harmonic.
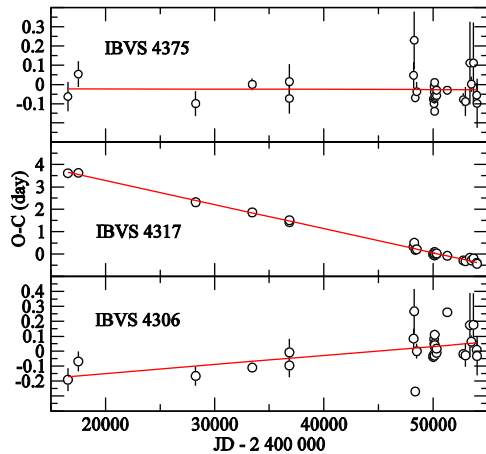
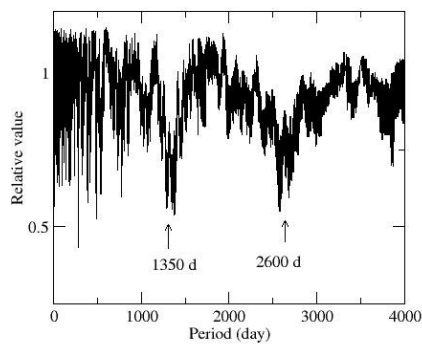Fig. 3: O-C data for CK Cam considering the ephemeris given by different IBVS.

Fig. 4: Periodogram of the (O-C) residual values calculated with a PDM program. The main minimum in this curve is situated at P=1350d.

The behaviour of CK Cam within this period can be shown clearly, presenting a diagram in which the 30 values of the (O-C) residuals are plotted versus a phase φp determined by:

$$\varphi p = (JDmax/P) - E (JDmax/P)$$

where E(x) is the integer portion of the real number x.
This diagram reported in figure 5 seems to show variations of the (O-C) residual data with a sinusoidal shape. A least squares fit of a sine wave to the data gives an amplitude of 0.058 ± 0.011 day.
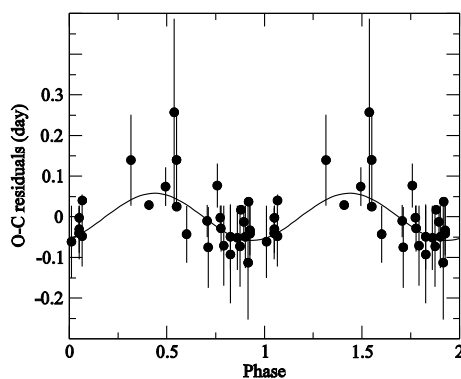

Fig.5: Phased (O-C) data residuals for a period P=1350 days. Sine wave fit to the data has been reported.

The data are rather sparse around φp =0.15 – 0.50, i.e. in the rising part of the curve. The true situation will only be established in the future by further monitoring of this interesting star. However, the sinusoidal trend of the O-C data residuals is a feature observed in a few other

cepheids. In some cases such trends arise from random fluctuations in pulsation for the star. The Cepheid SV Vul is an example of such a situation (Turner & Berdnikov, 2004). In other cases the trend may arise from light travel time effects in a binary system, as shown in the bright Cepheid RT Aur (D.G.Turner et al, 2007). Additional data as radial velocity observations or statistical analysis (as Eddington and Plakidis procedure) may clarify the sine behaviour of CK Cam if it really exists.

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