VW CEP IS APPROACHING EARTH

Summary: the 29 times of minimum during the 1994/1995 season show the validity of ephemeris (5), and of its light variation period, for VW Cep. Instead, negative O-Cs, according to ephemeris (2), indicate that the variable star is approaching Earth in its revolution around a third companion. A research of an available orbital period was carried out, which provided a value of 0.2783090 day, almost the same of IBVS 3207. From 1985 to 1994 it seems that this period was very stable. The light curve shows a primary minimum deeper than secondary one of about 0.1 magnitude.

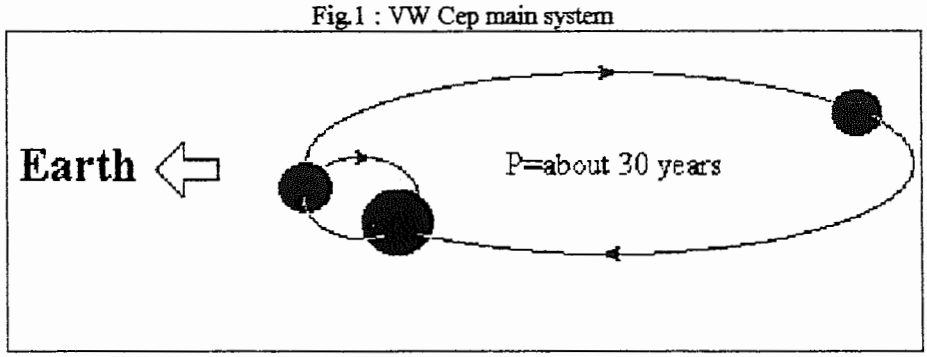
Introduction

VW Cep is one of the most observed eclipsing variable stars by GEOS members, in particular by italian observers, who from the ninety have increased their observations. Some peculiar features make this star very interesting to study. The type is EW/KW with light variation between 7.26-7.68 magnitudes (min II = 7.56), while ephemerides, concerning primary minimum, which are in literature indicate little different periods:

Min. I (GCVS 85) = 44157.4131 + 0.27831460 * E (1)
Min. I (IBVS 3207) = 46467.4000 + 0.27830940 * E (2)
Min. I (IBVS 3704) = 46822.5233 + 0.27830990 * E (3)
Min. I (SAC 62) = 47374.4129 + 0.27831015 * E (4)
Min. I (IBVS 4117) = 48862.5220 + 0.2783076 * E (5)

Binary system' s components are in contact and have exchange of matter between themselves, even if models proposed on the basis of spectroscopical and photoelectric results reveal that system oscillates between a contact and a semi-detached system in a period of about 10^7 years(1). Furthermore, in 1975, Hershey discovered astrometrically a third body orbiting around the common centre of gravity of system with a period of about 30 years(2). Visual and photoelectric observations, carried out in the past, confirm the presence of sunspots and a disk of matter around the binary system, which could justify the different height of the maxima, reported by Gaspani(3) too, and accidental asymmetry of the light curves. Acerbi, Barani and Gobet's observations(4), put in evidence a secondary minimum deeper than primary one, different O-C values of primary and secondary minima, different height of maxima and presence of double maxima in light curve after data treatment by Fourier Transform technique. At last, annual variation of O-C seems to be caused by a geometrical, not physical effect: components revolution around the centre of gravity of the main system makes relative distance among Earth-VW Cep to vary in the period of 30 years and this phenomenon causes a fluctuating of the O-Cs in the same time of about 0.02 day(5).

Fig.1 : VW Cep main system



As if this is not enough, every 20 years, the orbital period of VW Cep, perhaps owing to an increased contact, undergoes a sudden reduction of a certain quantity of time. Following I report a table that put in evidence period changes in the last 50 years(6):

Tab.1 : period change values

Years	1943	1960	1980
$\Delta P/P$	$-1.4 \cdot 10^{-5}$	$-1.6 \cdot 10^{-5}$	$-1.1 \cdot 10^{-5}$

We are waiting for an essential reduction of period at the end of this century.

Results and discussion

In 1994 and in the first month of 1995, I have carried out about 1050 visual estimates of VW Cep using chart GEOS C83. In the next table, 29 heliocentric times of minimum are reported, calculated by S.O.P. program(7), then the relative julian days, O-C values according to the former 5 ephemerides and the type of observed minimum, primary or secondary:

Tab.2 : VW Cep's minima in 1994/95

DATE	U.T.	HJD	O-C(1)	O-C(2)	O-C(3)	O-C(4)	O-C(5)	TYPE
18 Jul 94	22.41	49552.445	- 0.096	- 0.014	- 0.020	- 0.023	- 0.001	I
24 Jul 94	22.19	49558.430	- 0.095	- 0.013	- 0.019	- 0.022	0.000	II
26 Jul 94	21.16	49560.386	- 0.088	- 0.006	- 0.011	- 0.014	+ 0.008	II
27 Jul 94	23.34	49561.482	- 0.104	- 0.022	- 0.028	- 0.030	- 0.009	II
30 Jul 94	22.36	49564.442	- 0.067	+ 0.015	+ 0.009	+ 0.006	+ 0.028	I
31 Jul 94	21.32	49565.397	- 0.086	- 0.004	- 0.009	- 0.012	+ 0.009	II
1 Aug 94	20.53	49566.370	- 0.087	- 0.005	- 0.010	- 0.013	+ 0.008	I
4 Aug 94	22.15	49569.427	- 0.091	- 0.009	- 0.015	- 0.018	+ 0.004	I
10 Aug 94	21.36	49575.400	- 0.102	- 0.020	- 0.025	- 0.028	- 0.007	II
26 Aug 94	21.42	49591.404	- 0.102	- 0.019	- 0.024	- 0.027	- 0.006	I
25 Oct 94	21.14	49651.385	- 0.097	- 0.014	- 0.019	- 0.022	- 0.001	II
31 Oct 94	17.33	49657.231	- 0.096	- 0.012	- 0.018	- 0.021	+ 0.001	II
31 Oct 94	20.54	49657.371	- 0.095	- 0.011	- 0.017	- 0.020	+ 0.002	I
14 Nov 94	18.29	49671.270	- 0.112	- 0.027	- 0.033	- 0.036	- 0.014	I
14 Nov 94	22.03	49671.419	- 0.102	- 0.018	- 0.024	- 0.027	- 0.005	II
21 Nov 94	17.40	49678.236	- 0.104	- 0.020	- 0.025	- 0.029	- 0.007	I
21 Nov 94	21.04	49678.378	- 0.101	- 0.017	- 0.023	- 0.026	- 0.004	II
30 Nov 94	19.00	49687.292	- 0.093	- 0.008	- 0.014	- 0.017	+ 0.005	II
30 Nov 94	22.21	49687.431	- 0.093	- 0.009	- 0.014	- 0.018	+ 0.004	I
2 Dec 94	17.41	49689.237	- 0.096	- 0.011	- 0.017	- 0.020	+ 0.002	II
2 Dec 94	21.01	49689.376	- 0.096	- 0.011	- 0.017	- 0.020	+ 0.002	I
8 Dec 94	17.04	49695.211	- 0.106	- 0.021	- 0.027	- 0.030	- 0.007	I
12 Dec 94	17.40	49699.236	- 0.116	- 0.031	- 0.037	- 0.040	- 0.018	II
26 Dec 94	19.44	49713.322	- 0.085	0.000	- 0.006	- 0.009	+ 0.014	I
7 Jan 95	18.42	49725.279	- 0.096	- 0.011	- 0.017	- 0.020	+ 0.003	I
9 Jan 95	17.22	49727.224	- 0.099	- 0.014	- 0.020	- 0.023	0.000	I
9 Jan 95	20.47	49727.366	- 0.096	- 0.011	- 0.017	- 0.020	+ 0.003	II
20 Jan 95	20.35	49738.358	- 0.098	- 0.013	- 0.018	- 0.022	+ 0.001	I
29 Jan 95	18.03	49747.252	- 0.109	- 0.024	- 0.030	- 0.033	- 0.010	I

Mean O-C values, concerning the 5 ephemerides, are reported in the next page:

Tab.3 : mean values of O-C calculated by the 5 ephemerides

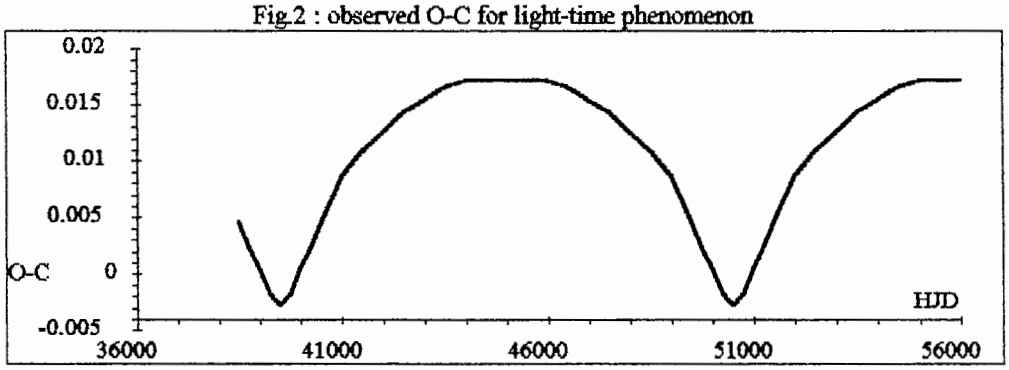
EPHEMERIS	SOURCE	$O\text{-}C_{mean}$
1	GCVS 85	- 0.097 ± 0.009
2	IBVS 3207	- 0.013 ± 0.009
3	IBVS 3704	- 0.019 ± 0.009
4	SAC 62	- 0.022 ± 0.009
5	IBVS 4117	0.000 ± 0.009

We note that nowadays the most correct ephemeris for expecting times of minima is the (5) of IBVS 4117. In order to explain the differences showed by the other ephemerides we could think that VW Cep's period is changed, but...

Light variation period and orbital period

We must remember that observed times of minima must be corrected for the time-light factor, caused by VW Cep's revolution around the centre of gravity of the main system. So there is a light variation period, depending on the VW Cep relative velocity towards Earth, and an orbital period, depending on the revolution time. The time-light correction to bring at revolution period can be illustrated in the next graph(1), which shows observed O-C in time, and that at the beginning of 1997 (HJD equal to about 50500) VW Cep will be at the lowest distance from Earth:

Fig.2 : observed O-C for light-time phenomenon

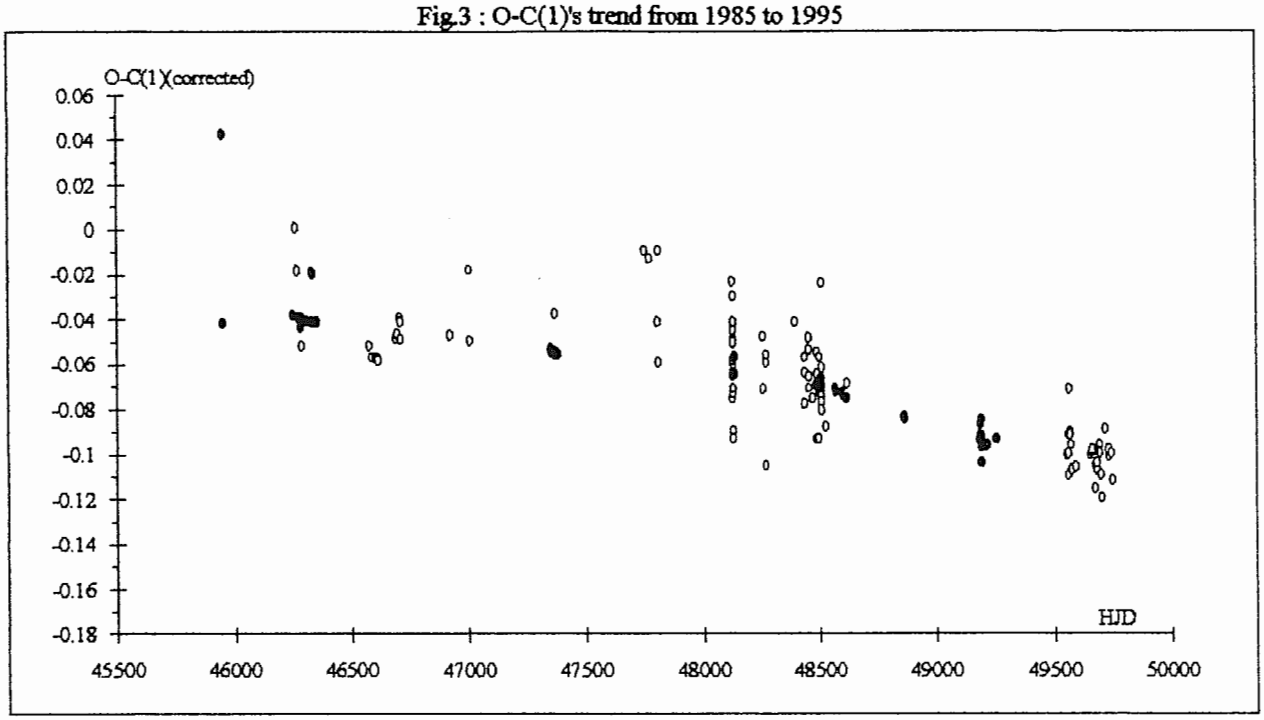


Expected O-C for 1994 is about 0.013 day less than that expected at the time indicated from ephemeris (2), so correct values of mean O-C(2) confirms validity of 0.2783094 day for the orbital period:

$$O\text{-}C(2)_{mean}(correct) = 0.000 \pm 0.009 \text{ day}$$

For verifying that the orbital period is that indicated by ephemeris (2), I collected in a graph all heliocentric minima of VW Cep from 1985 until today in my possession(3,4,5,8,9) versus O-Cs(1) calculated with the oldest ephemeris and corrected for time-light factor. In the next fig.3, filled circles indicate photoelectric minima and blank circles indicate visual minima:

Fig.3 : O-C(1)'s trend from 1985 to 1995



It seems that near HJD 48500 (year 1991) there was another discrete period change, but it need other observations for checking this behaviour. If O-C's trend is linear from 1985 until today, the orbital period of VW Cep has been almost constant in accordance with hypothesis of Karimie[6] and Lloyd et al.[5]. In this case the least squares method detects a correction of $-5.6 \cdot 10^{-6}$ days to bring at the period of ephemeris (1). So we obtain an orbital period equal to:

$$P = 0.2783090 \pm 0.0000003 \text{ day}$$

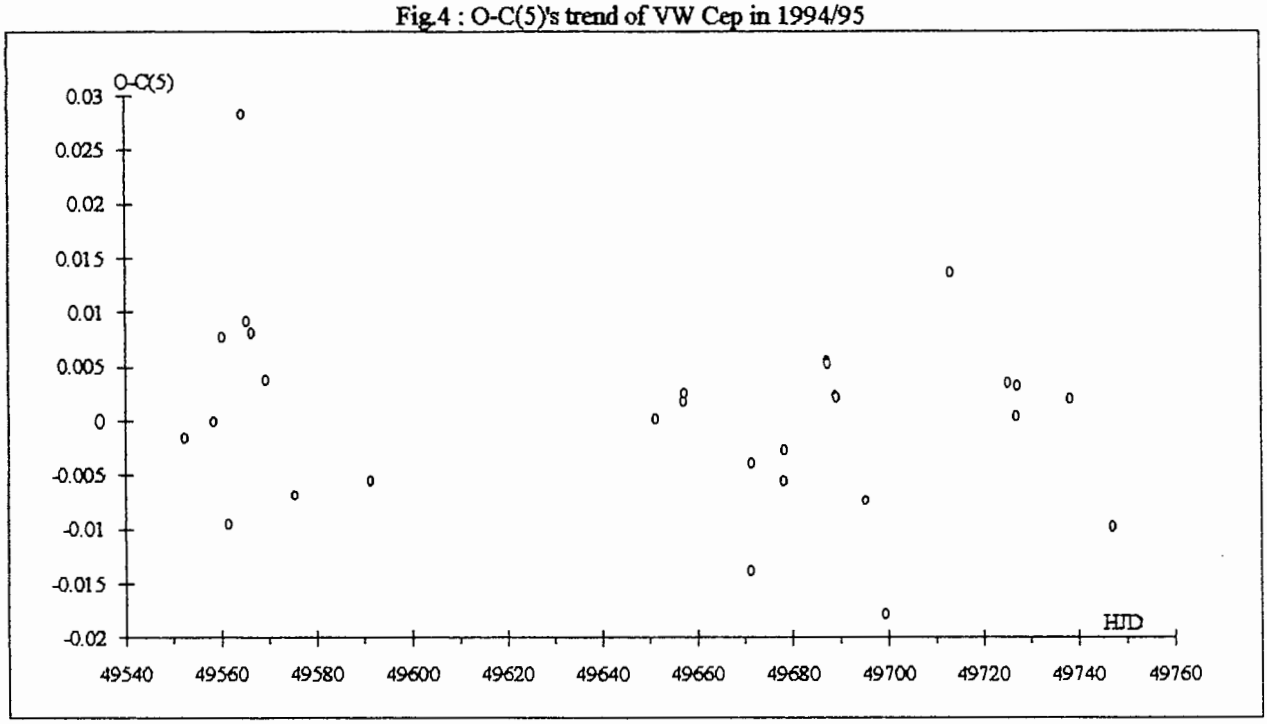
almost the same of that one provided with ephemeris (2) published in IBVS 3207. Instead, the period of ephemeris (5), which is in accordance with visual O-Cs in 1994/95, remains the best light variation period nowadays.

A different analysis of primary and secondary minima indicates an essential symmetry of mutual eclipses:

$$O\text{-}C(5)(I)_{mean} = +0.001 \pm 0.010 \text{ day}$$
$$O\text{-}C(5)(II)_{mean} = -0.002 \pm 0.007 \text{ day}$$

Instead, in previous works, it was noticed a remarkable difference between primary and secondary O-C[8].
In the following figure O-C(5), obtained in 1994/95, versus heliocentric julian day are reported:

Fig.4 : O-C(5)'s trend of VW Cep in 1994/95

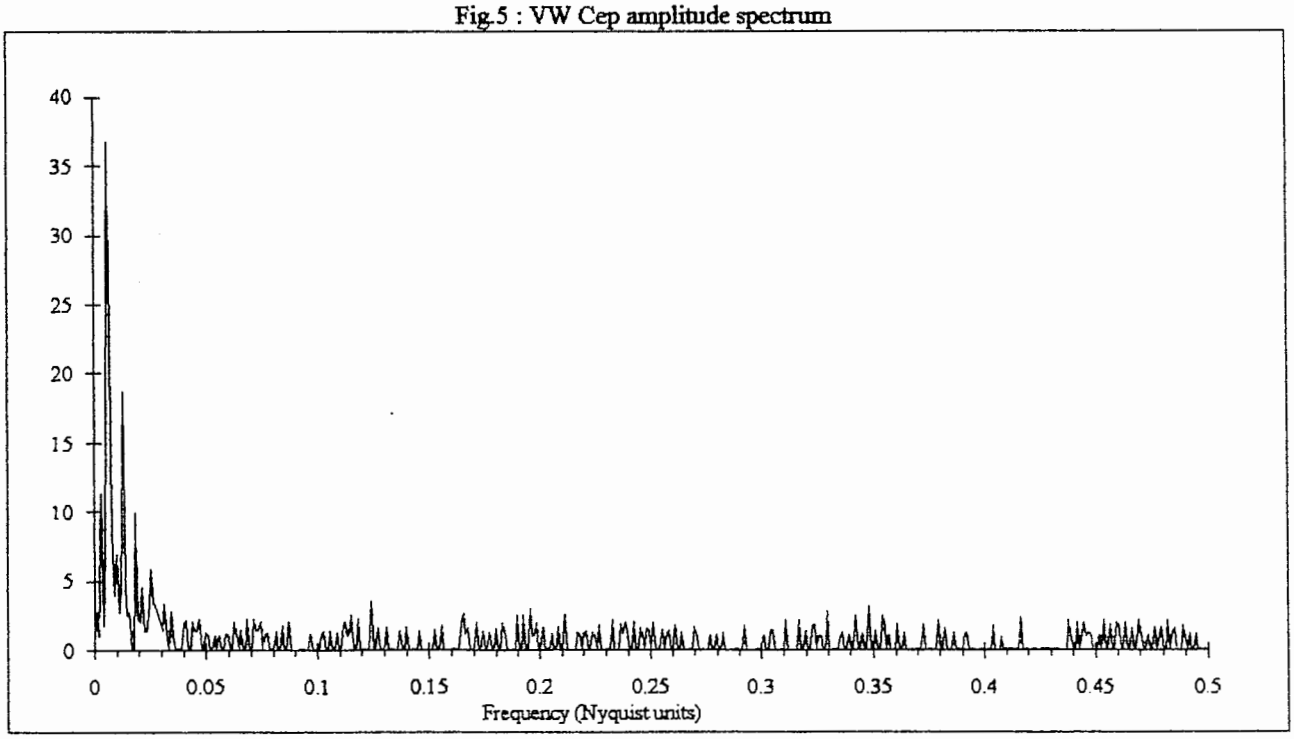


As we can see, points haven't a linear trend, on the contrary these ones seem to be very scattered around mean value. In order to explain this fact we must remember that the fig.4 put in evidence the typical dispersion of visual O-Cs, even if a small contribution could be caused by the expected physical phenomena that involve sunspots on the stars' surface and disks of matter around binary system.

Compositage and light curve

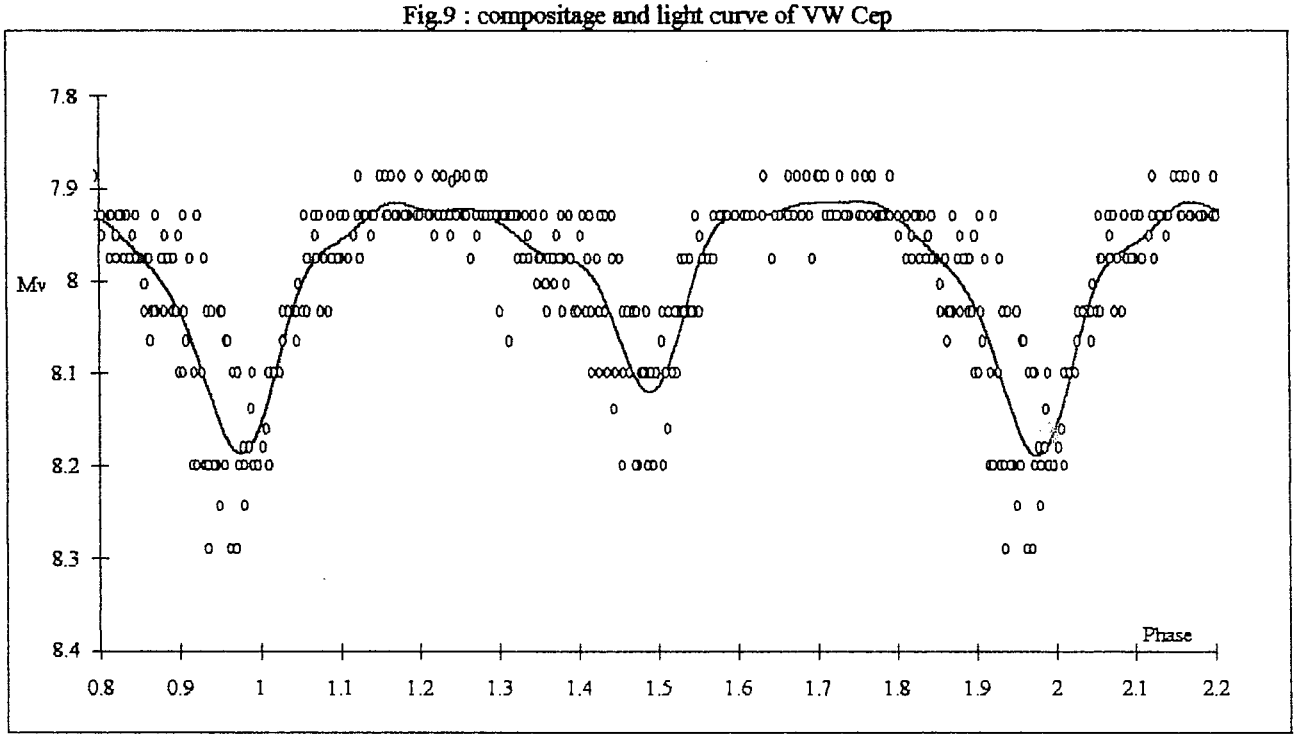
Observations of Oct 31, Nov 14, 21 and 30, equal to 322 visual estimates, have been used for generating a *compositage*. For putting in phase data, I used ephemeris (5) and, by RCFM program[10], I generate an amplitude spectrum that is represented below:

Fig.5 : VW Cep amplitude spectrum



For restoring light curve I used the FDGFP program[11], making use of a low-pass exponential filter of 10th order and 0.033 Nyquist units bandwidth. VW Cep *compositage* (blank circles), and light curve (continuous line) are presented below.

Fig.9 : compositage and light curve of VW Cep



The choice of the bandwidth is justified by the amplitude spectrum, which have the most information contained in 0 to 0.033 Nyquist units range. It is important to remark that the distorsions in light curve are caused by visual non-white noise in spectra. This is self-evident in amplitude as well as power and phase spectrum because peaks increase at the lowest frequencies.

The fig.9 shows primary minimum deeper than secondary one and height of maxima almost equal, a fact opposed to that reported by Acerbi[4] and Gaspani[3] et al.. However, in some nights, the light curve of VW Cep shows different height of maxima of about 0.1 magnitude: it is possible that *compositage*, placing above light curves of several nights, doesn't show this behaviour.

Conclusions

The best ephemeris for VW Cep in foreseeing times of minimum is that given by Gaspani et al. in IBVS 4117, that indicates a light variation period of 0.2783076 day. However the orbital period of VW Cep seems to be 0.2783094 day, like that suggested by Lloyd et al. in IBVS 3207. Furthermore, if O-C's trend is linear from 1985 to 1994, this last period seems to be very stable, confirming again that variable star undergoes discrete reductions of period about every 20 years. In this case, it will be interesting to inspect the next discrete period change, expected for about year 2000. At last VW Cep is quickly approaching Earth in its revolution around the centre of gravity of the main system. This fact is confirmed from mean O-C(2) values obtained in 1994/95. The compositage and the light curve obtained in this work don't reveal presence of multiple maxima and different height of these ones. Furthermore, contrary to other times, the depth of primary minimum seems to be greater than secondary one of about 0.1 magnitude. In any case VW Cep combines in itself many peculiarities and could be considered a variable star to follow in next years too.

Thanks

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References:

(1) J.A.ROBERTSON, P.P.EGGLETON, *Mon. Not. R. Astron. Soc.* **179** (1977), 359
(2) J.L.HERSHEY, *Astron. J.* **80** (1975), 662
(3) A.GASPANI,M.ALUIGI,G.GALLI, *Inform. Bull. Var. Stars* **4117** (1994)
(4) F.ACERBI, C.BARANI, F.GOBET, *Note Circulaire GEOS* **NC 682** (1992)
(5) C.LLOYD,J.WATSON,R.D.PICKARD, *Inform. Bull. Var. Stars* **3207** (1992)
(6) M.T.KARIMIE, *Astrophys. Space Sci.* **92** (1983), 53
(7) A.GASPANI, *Stochastic Optimization Program* (priv.comm.)
(8) F.ACERBI et al., *Note Circulaire GEOS* **NC 629** (1990)
(9) F.ACERBI et al., *Note Circulaire GEOS* **NC 620** (1990)
(10) A.GASPANI, *Recursive Fourier Transform Technique* (priv.comm.)
(11) A.GASPANI, *Freq. Domain Gen. Filtering Program, GEOS Fiche Technique* **FT 54, 55, 56**