VZ Cnc

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RESUME : De nouvelles observations visuelles de VZ Cnc effectuées depuis l'année 2001 par F. Gobet (GBF) et M. Dumont (DMT) permettent de préciser la période principale de cette étoile et d'étudier le phénomène de battement.

ABSTRACT: New visual observations of VZ Cnc from 2001 to 2020 by F. Gobet (GBF) and M. Dumont (DMT) allow to specify the primary period and to study the beat phenomenon.

1. INTRODUCTION

VZ Cnc is a delta Scuti (DSCT/HADS) variable star. The stars of this type have a period less than 0.3 day and an amplitude less than a magnitude, generally 0.2 mag. VZ Cnc is one of the few stars with an amplitude approaching one magnitude.
The 1985 version of GCVS (Kholopov et al., 1985, the present version is Samus, 2017) gives the elements:
Max 2 439 897.4246 + 0.1783 6370 4 E (1) Spectrum A7- F2 III
We denote P_1 = 0.1783 6370 4 day.
The GCVS gives also a beat period P_0 = 0.7162 92 days due to a second oscillation.

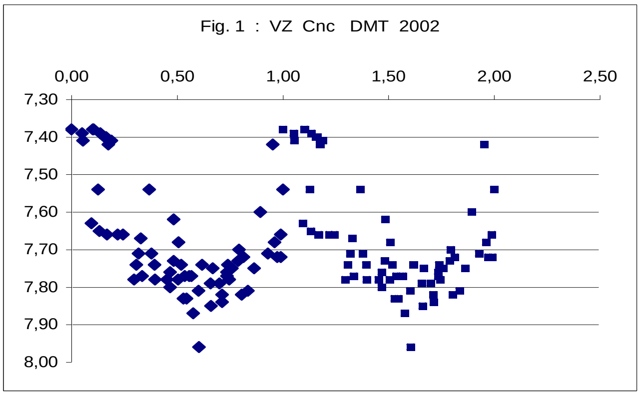
Our observations show a slow drift of the maximum times relative to ephemeris (1). In the present paper we also demonstrate we have observed visually the known beat phenomenon (Fitch, 1955).

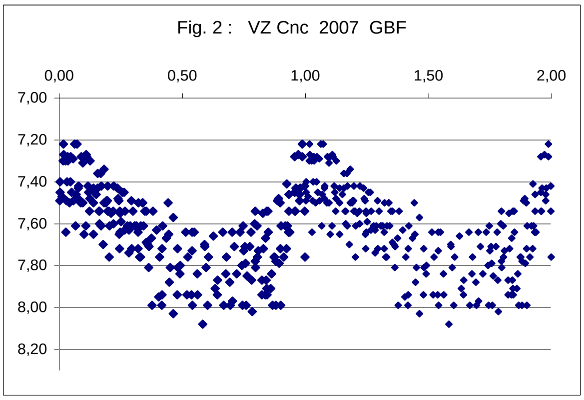
Two pulsations with the periods P_1 and P_2 generate a beat period P_0 such that:

$$\frac{1}{P0} = \frac{1}{P2} - \frac{1}{P1} \qquad \text{(i.e.) } P_2 = \frac{P1P0}{p1+P0}$$

2. OBSERVATIONS

From 2001 to 2020, we collected 442 observations by GBF and 2158 by DMT.
Figure 1 gives folded light curve using the estimates of DMT in 2002 and figure 2 using the estimates of GBF in 2007. Both use the ephemeris (1) to calculate the phase.





From the observations, we extract 7 maxima observed by GBF and 36 by DMT. Figure 3 shows the light curve of the maximum simultaneously observed by GBF and DMT on April 21, 2007.

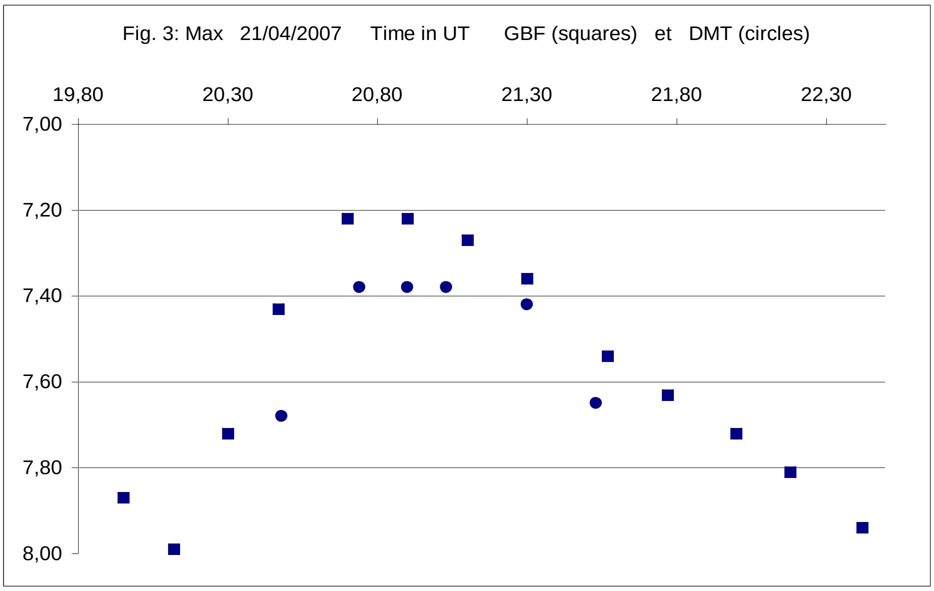


Table 1 gives the list of the observed heliocentric times of maximum.

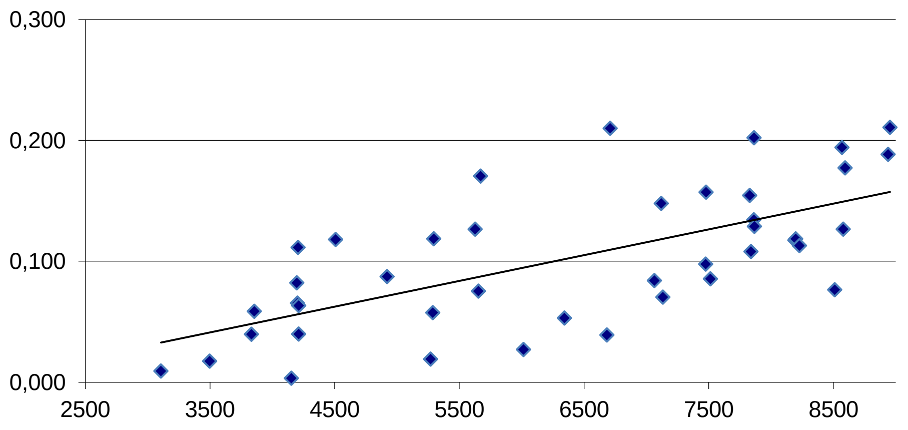
Column 1: Calendar date
Column 2: Time in UT
Column 3: HJD: 24…
Column 4: Probable error
Column 5: Number of observations
Column 6: Phase according to (1)
Column 7: Magnitude of the star at maximum
Column 8: Observer.

Table 1

1	2	3	4	5	6	7	8
11/04/2004	21h 32	53 107,3989	0,007	8	0,00928	7,44	DMT
07/05/2005	20h 59	53 498,3736	0,004	6	0,01747	7,02	DMT
07/04/2006	20h 13	53 833,3446	0,014	6	0,03969	7,07	GBF
30/04/2006	20h 34	53 856,3569	0,010	11	0,05865	7,01	GBF
21/02/2007	19h 37	54 153,3226	0,008	13	0,00333	7,40	GBF
06/04/2007	21h 22	54 197,3925	0,009	13	0,08219	7,30	GBF
11/04/2007	21h 10	54 202,3837	0,014	13	0,06546	7,28	GBF
16/04/2007	21h 14	54 207,3861	0,007	9	0,11152	7,36	DMT
19/04/2007	21h 29	54 210,3962	0,006	14	0,98772	7,22	GBF
21/04/2007	20h 48	54 212,3675	0,006	16	0,03985	7,22	GBF
21/04/2007	20h 54	54 212,3717	0,008	6	0,06340	7,38	DMT
11/02/2008	23h 02	54 508,4652	0,007	7	0,11807	7,42	DMT
30/03/2009	20h 50	54 921,3717	0,010	8	0,08738	7,40	DMT
14/03/2010	21h 55	55 270,4173	0,005	7	0,01915	7,29	DMT
31/03/2010	20h 47	55 287,3687	0,007	9	0,05755	7,38	DMT
08/04/2010	21h 40	55 295,4049	0,004	7	0,11268	7,15	DMT
07/03/2011	0h 23	55 627,5206	0,004	11	0,12660	7,42	DMT
01/04/2011	20h 55	55 653,3742	0,004	7	0,07537	7,40	DMT
19/04/2011	21h 43	55 671,4059	0,009	6	0,17049	7,01	DMT
28/03/2012	22h 35	56 015,4439	0,004	11	0,02705	7,49	DMT
19/02/2013	22h 54	56 343,4594	0,010	8	0,05311	7,39	DMT
26/01/2014	23h 35	56 684,4883	0,010	11	0,03908	7,39	DMT
21/02/2014	21h 02	56 710,3816	0,017	8	0,21004	7,40	DMT
11/02/2015	23h 25	57 065,4812	0,010	11	0,08409	7,38	DMT
07/04/2015	22h 14	57 120,4286	0,004	7	0,14789	6,88	DMT
20/04/2015	22h 27	57 133,4364	0,006	9	0,07640	6,97	DMT
28/03/2016	22h20	57 476,4336	0,004	12	0,09769	7,22	DMT
31/03/2016	23h 22	57 479,4764	0,006	11	0,15722	7,40	DMT
05/05/2016	22h 10	57 514,4229	0,007	11	0,08553	7,22	DMT
16/03/2017	22h 07	57 829,4255	0,007	14	0,15450	6,94	DMT
26/03/2017	21h 39,5	57 839,4056	0,004	9	0,10810	7,02	DMT
18/04/2017	22h 02	57 862,4192	0,004	8	0,13440	6,76	DMT
20/04/2017	21h 25	57 864,3933	0,004	7	0,20220	7,38	DMT
23/04/2017	21h 53	57 867,4124	0,004	11	0,12890	6,56	DMT
13/03/2018	23h 50	58 191,4972	0,006	13	0,11740	7,42	DMT
20/03/2018	22h 48	58 198,4536	0,004	10	0,11860	6,51	DMT
19/04/2018	22h 00	58 228,4177	0,007	14	0,11300	6,94	DMT
27/01/2019	23h 15	58 511,4744	0,007	7	0,07650	7,02	DMT
26/03/2019	23h 03	58 569,4636	0,004	6	0,19420	7,06	DMT
05/04/2019	22h 30	58 579,4399	0,007	8	0,12660	6,67	DMT
20/04/2019	22h 20	58 594,4315	0,010	8	0,17730	6,93	DMT
30/03/2020	21h 16	58 939,3889	0,010	8	0,18850	7,39	DMT
14/04/2020	21h 00	58 954,3765	0,007	5	0,21680	7,45	DMT

Figure 4 shows the evolution of the moment of the maximum according to (1), with in abscissa HJD-245000 and in ordinate the O-C in days.

Fig. 4 : Evolution of the time of the maximum



We note a slight delay which increases slowly and linearly. It means that the period is constant, but P_1 is a little too short. The equation of the fitting line is:

$$y = \frac{2}{10^5}x - 0.036$$

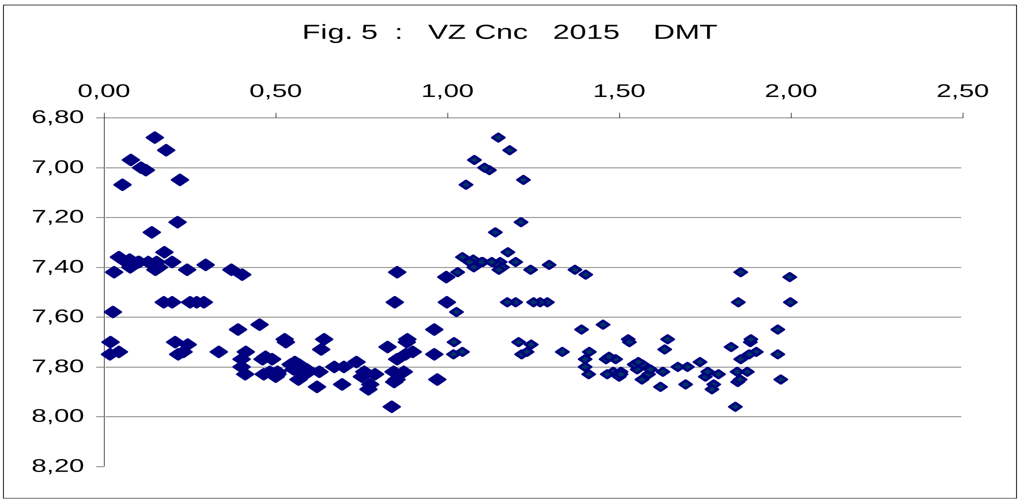
Since the date (245)3100 until (245) 8950, the phase of the maximum according with (1) moved from 0.026 to 0.143 in 5850 days that is 32798 cycles. Then every cycle is longer than P_1 by 3,56729 .10^{-6} P_1 or 6,362751 .10^{-7} day. The new period is then:

$P'_1 = P_1$ + 0,000 000 636 day = 0,178 364 34 day.

3. THE BEAT PERIOD

But, VZ Cnc has many oscillations with different periods P_1, P_2, … and surely others as J.N. Fu and S.Y. Jiang (1999) have shown. The first mention and measure of a beat period is due to Fitch (1955).

When the maxima of two pulsations occur at the same time, we observe an exceptionally bright maximum, but if the maximum of the first pulsation falls at the minimum of the second pulsation, the maximum is less pronounced. We can observe this situation in figure 5 in the observations of DMT in 2015, showing a great dispersion of the estimates at the maximum. The time interval between two exceptionally bright maxima is the beat period.



To calculate this period, we consider the magnitudes observed during the maxima as the magnitudes of a "variable" star, so we have to determine the period of this "variable". We computed this period by two different methods:

a) The PDM method.

Figure 6 shows a periodogram drawn by this method (Stellingwerf, 1978), searching periods between 0.2 and 0.9 days with a step of 0.005 days (7 minutes).

The periods are in abscissa; in ordinate appear the sums of quadratic residuals, which are low in the vicinity of a possible period.

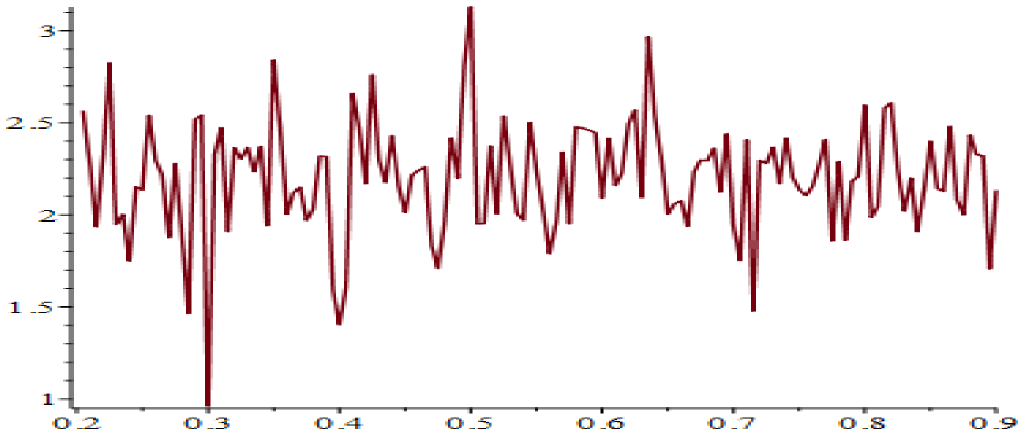


Figure 6: PDM periodogram from 0.2 to 0.9 day

We then observe, on this periodogram, downward peaks. Such peaks appear for the periods 0.3 d, 0.4 d, 0.48 d, 0.57 d, 0.72 d and 0.9 d.

b) The Fourier method.

The method consists in representing the observations by a fitted sine curve :

$$y = a \sin(2kt + \varphi) + d$$

Where d is the mean magnitude, a the semi-amplitude and φ is the parameter to be fitted.

The figure 7 shows the periodogram obtained with this method.

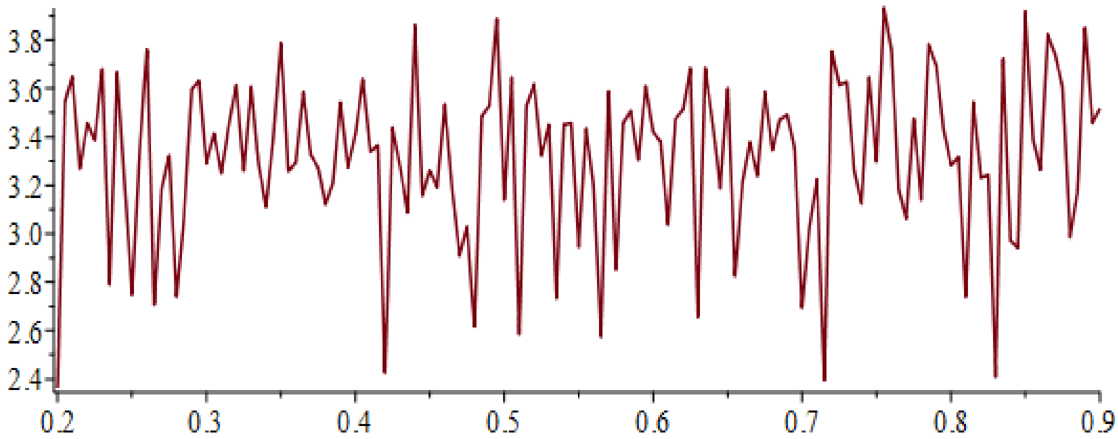


Figure 7: Fourier periodogram from 0.2 to 0.9 day.

Peaks appear for 0.42 d, 0.48 d, 0.51 d, 0.57 d, 0.63 d, 0.72 d and 0.83 d.

Some periods appear only on one periodogram, because visual observations are not very accurate (in time and in magnitude of the maximum). We plotted also more detailed periodograms (step of 0.0001 day or 9 seconds) but we find nothing new.

4. ANALYSIS OF THE OBSERVATIONS

J.N. Fu and S.Y. Jiang (1999) found the following frequencies (cycles per day) in their measurements of VZ Cnc :

f_1 = 5.6066	f_4 = 16.8188
f_2 = 11.2128	f_5 = 12.6095
f_3 = 7.0022	f_6 = 1.3957

f_1 is the main frequency corresponding to the period of 0.178 days (P_1).

f_3 corresponds to a period of 0.143 days. The other ones, f_2, f_4 and f_5 are aliases of f_1 and f3. The frequencies f_2, f_5 and f_4 are out of our search range (0.2- 0.9 days). We think we cannot find high frequencies visually because we have not a high precision on the time of the maxima; furthermore our search used only the estimates around the maxima and all our 2500 observations would be necessary to rediscover these frequencies.

a) **The 0.72 day period**

The 0.72 d period is the deepest peak in figure 7. A higher time resolution gives 0.719 days; 1/0.719 = 1.391, almost Fu and Jiang f_6. And 0.719 days ≈ 4 P'_1(P'_1 is the main period). But 4 P'_1 = 0.713466 days. If the beat period P_0 is a multiple of the main period, then it exists a second period P_2 which is an integer divisor of the beat period: $P_0 = 4P'_1 \rightarrow P_0 = 5\ P_2$ $P_2 = 0.1438$ day $1/P_2 = 6.954 \approx f_3$ ($f_3 = 7.002$).

The main period is P'_1 (1/ f_1) . The other period is P_2 = 0.1438 days = 1/f_3. These two periods generate a beat period P_0 = 0.719 days (1/f6).

b) **Other periods**

Other periods appear in our periodograms. Table 2 gathers our results (Periods in days).

Table 2

Period	PDM	Fourier	Frequency	P'n	1/P'n
0.30	*		3.33	0.112	8.94
0.40	*		2.50	0.123	8.11
0.423		*	2.36	0.125	7.97
0.48	*	*	2.08	0.13	7.69
0.576	*	*	1.736	0.136	7.34
0.719	*	*	1.391	0.1438	6.954
0.83		*	1.205	0.147	6.81
0.90	*		1.11	0.149	6.71

We note the periods 0.423 d and 0.83 d on the figure 7 and the periods 0.4, 0.9 and particularly the period 0.30 days which is the deepest peak on figure 6!
Are they artefact? May be future observations would show it!

5. CONCLUSION

Observing VZ Cnc, we did not expect it was possible to determine visually the second period. We will carry on the observations of this star and try to improve the precision of our estimates (time and magnitude) and, may be, motivate CCD observers.

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