GEOS RR 18

GEOS CIRCULAR ON RR TYPE VARIABLE
January 2002

GEOS
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VW CVn : A VERY IRREGULAR RR LYRAE STAR

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SUMMARY

VW CVn is an RR Lyrae pulsating star probably of the RRc type. It varies between mag. 11.61 and 12.07 (V), mean B-V = 0.285, M-m = 0.41 to 0.46. Its period and the shape of its light curve are very irregular.

RESUME

VW CVn est une étoile pulsante RR Lyrae probablement du type RRc. Elle varie entre les magnitudes 11.61 et 12.07 (V), B-V moyen = 0.285, M-m = 0.41 à 0.46. Sa période et la forme de sa courbe de lumière sont très irrégulières.

RIASSUNTO

VW CVn è probabilmente una variabile tipo RRc. Il periodo e la forma della curva di luce variano in modo molto irregolare. Le sue caratteristiche fotometriche sono : 11.61-12.07 V, B-V medio +0.285, M-m variabile da 0.41 a 0.46.

RESUMEN

VW CVn es una estrella pulsante RR Lyrae probablemente de tipo RRc. Varía entre las magnitudes 11.61 y 12.07 (V), medio B-V = 0.285, M-m = 0.41 a 0.46. Su período y la forma de su curva de luz son muy irregular.

RESÜMEE

VW CVn ist ein pulsierender RR Lyrae-Stern wahrscheinlich vom RRc-Typ. Er verändert zwischen mag. 11.61 und 12.07 (V), mittlere B-V = 0.285, M-m = 0.41 zu 0.46. Seine Periode und die Form seiner Lichtkurve sind sehr unregelmässig.

1. INTRODUCTION

The variability of VW CVn (GSC 2003 722) (13h 29min 42sec; 28° 52,8'; 2000) was discovered on photographic plates by Kurochkin (1961) who thought it was an EW or a β Lyr star ranging from 11.4 to 12.6 mag (p). He calculated a first ephemeris valid from JD 2427900 to 2436000 :

$$\text{Min} = \text{JD } 2435923.246 + 0.8499757 \times E \quad (1)$$

and a second one valid after JD 2436360 :

$$\text{Min} = \text{JD } 2435923.246 + 0.850012 \times E \quad (2)$$

It is this second ephemeris that is listed in the GCVS 85 which classifies it as an EW binary.

The variable remained almost unobserved, excepted by Diethelm (1976 and 1980) and German (1982) when Vandenbroere (1994) gave remarks on the problems concerning her visual observations. She gave a corrected finder chart along with photoelectric V magnitudes of selected comparison stars in the field of the variable (see Table 1). In addition, she questioned the validity of the period elements given in the GCVS 85.

Table 1 : Photoelectric magnitudes of the stars in the field of VW CVn

Numbers GSC	Magnitudes V	$(B-V)_G$ indices
2003 049	10.95	- 0.78
2003 081	11.19	- 0.26
2003 196	12.13	- 0.05
2003 427	12.33 to 12.39	+0.07 to 0.15
2003 077	14.37	- 0.18

Reading that, Diethelm (1994) made visual estimates of the brightness of VW CVn on 904 photographic plates of the Sonneberg Sky Survey. He subdivided his data into 23 observing seasons going from 1971 to 1993.

Giving equal weight to each seasonal light curve, he derived the following new mean elements by a simple linear regression :

Min = HJD 240981.134 + 0.8499507 x E (3)

Furthermore, Diethelm pointed out that the O-C diagram suggests the existence of a cyclical superposition on the mean O-C values with an amplitude of about ± 0.02 day and a period of close to 5000 epochs (11.65 years) and that this might be due to a third component in the system.

Agerer and Berthold (1994) wrote about their measurements made with an ST6 CCD-camera without filter together with their investigations of VW CVn on 443 plates of the Sonneberg Sky Survey from 1956 to 1994. From their measurements, they realised that VW CVn is actually of the RR Lyr type and that it is varying between 11.96 and 12.43 mag (p) with M-m = 0.46. They pointed out that the period did not remain constant in the studied time interval and that it changed probably around JD 2440000. They calculated two ephemerides :

Max = HJD 2438387.169 + 0.4249932 x E (4)

valid between JD 2435861 and JD 2440000, and

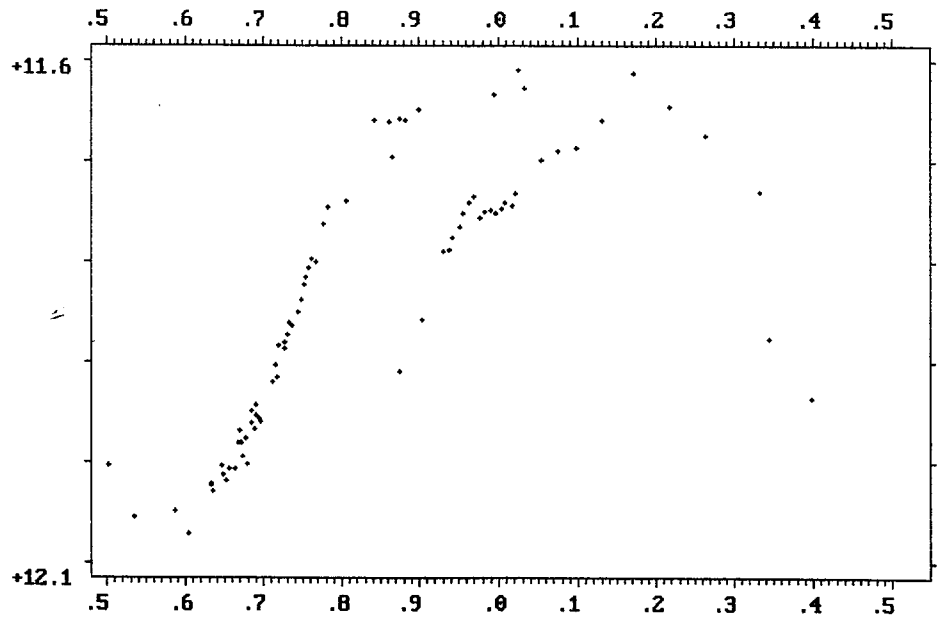
Max = HJD 244966.428 + 0.4249786 x E (5)

valid after JD 2440000.

2. NEW OBSERVATIONS

80 photoelectric measurements in the B and V filters of the Geneva system were obtained at Jungfraujoch observatory by several GEOS teams between 1993 and 1997. These measurements confirm the RR Lyr type of VW CVn without any doubt (see Fig. 1).

We can see immediately that ephemeris (5) does not allow surimposing the photoelectric measurements. Nevertheless, we can infer that VW CVn varies generally between magnitudes 11.61 to 12.07 (V) with a colour index $(B\text{-}V)_G$ going from – 0.69 to – 0.54 which corresponds to $(B\text{-}V)_J$ going from 0.22 to 0.35. The B-V corresponding to the Johnson and Morgan system were calculated from the transformation formulae described by Meylan and Hauck (1981) using the star's class III.



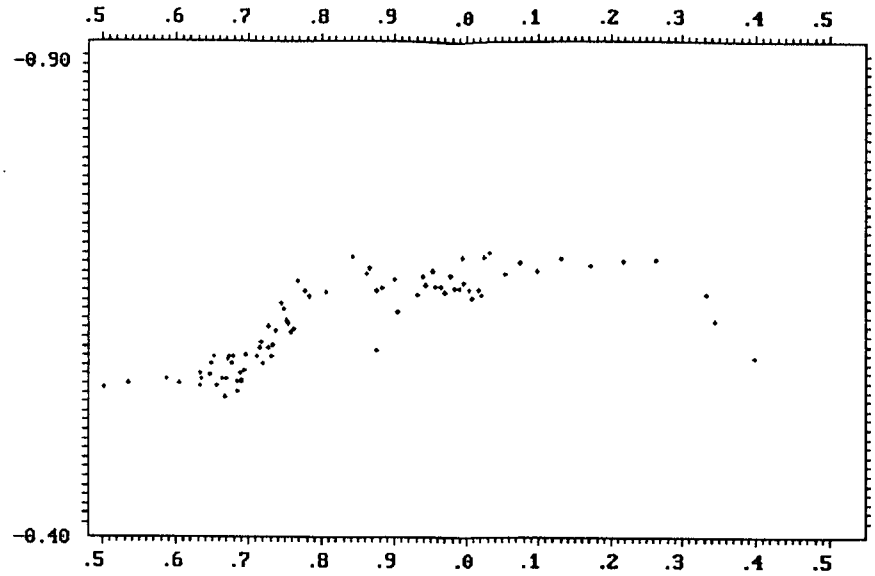


Fig. 1 : 80 V measurements and 80 B-V indices of VW CVn fitted with ephemeris (5)

50 measurements of VW CVn (J132942.14+285248.2) were also obtained by the Rotse1 (Robotic Optical Transient Search Experiment 1) survey from March to June 1999. The measurements were listed with an assigned period of 0.42518499 day and a RRc type. They are from magnitude 11.975 to 12.393 (V?) systematically 0.3 mag fainter that the Jungfraujoch measurements.

3. THE LONG PERIOD EVOLUTION OF VW CVn : THE INSTANTS OF MAXIMUM

Each period search on a different set of data has given different results and all the fitted light curves are very scattered. So, as a first step, we decided to gather all the times of maximum light in order to obtain the long term evolution of the O-Cs.

Table 1 : Instants of maximum of VCVn

OBSERVER	MODE	HDJ	E (6)	(O-C) (6)
BER	phot	19486.555	1	- 0.141
BER	phot	28300.432	20740	- 0.048
BER	phot	33711.414	33472	+0.013
BER	phot	34459.397	35232	+0.021
BER	phot	35000.377	36505	- 0.007
BER	phot	35522.259	37733	- 0.007
BER	phot	35932.379	38698	+0.001
BER	phot	36557.562	40169	+0.030
BER	phot	36632.372	40345	+0.042
BER	phot	38387.167	44474	+0.070
BER	phot	39352.330	46745	+0.090
BER	phot	40291.988	48956	+0.104
BER	phot	41393.545	51548	+0.097
BER	phot	42840.186	54952	+0.086
BER	phot	44492.729	58370	+0.027
BER	phot	45486.055	61178	- 0.007
BER	phot	46914.822	64540	- 0.043
BER	phot	48761.379	68885	- 0.050
AGE	CCD	49466.435	70544	- 0.046
AGE	CCD	49471.528	70556	- 0.053
AGE	CCD	49472.382	70558	- 0.049

OBSERVER	MODE	HJD	E (6)	(O-C) (6)
AGE	CCD	49474.517	70563	- 0.039
AGE	CCD	49480.464	70577	- 0.041
AGE	CCD	49511.487	70650	- 0.042
VBR	p. e.	49722.701	71147	- 0.046
AGE	CCD	49734.610	71175	- 0.037
AGE	CCD	49786.464	71297	- 0.031
SOB		49863.447	71478	+0.029
BRT		49863.449	71478	+0.031
AGE	CCD	50114.612	72069	+0.027
VBR	p. e.	50462.654	72888	+0.006
AGE	CCD	50502.620	72982	+0.023
AGE	CCD	50519.616	73022	+0.020
AGE	CCD	51271.373	74791	- 0.023
ROT	CCD	51292.214	74840	- 0.007

BER = T. Berthold, AGE = F. Agerer, VBR = J. Vandenbroere, SOB = P Sobotka
BRT = BrtL ROT = Rotse1

With these 35 instants of maximum, we obtained, by linear regression, the following ephemeris :

HDJ 2419486.271 (± 0.018) + 0.4249860 (± 0.0000010) d x E (6)

and the corresponding graph of the O-Cs can be seen in Fig. 2.

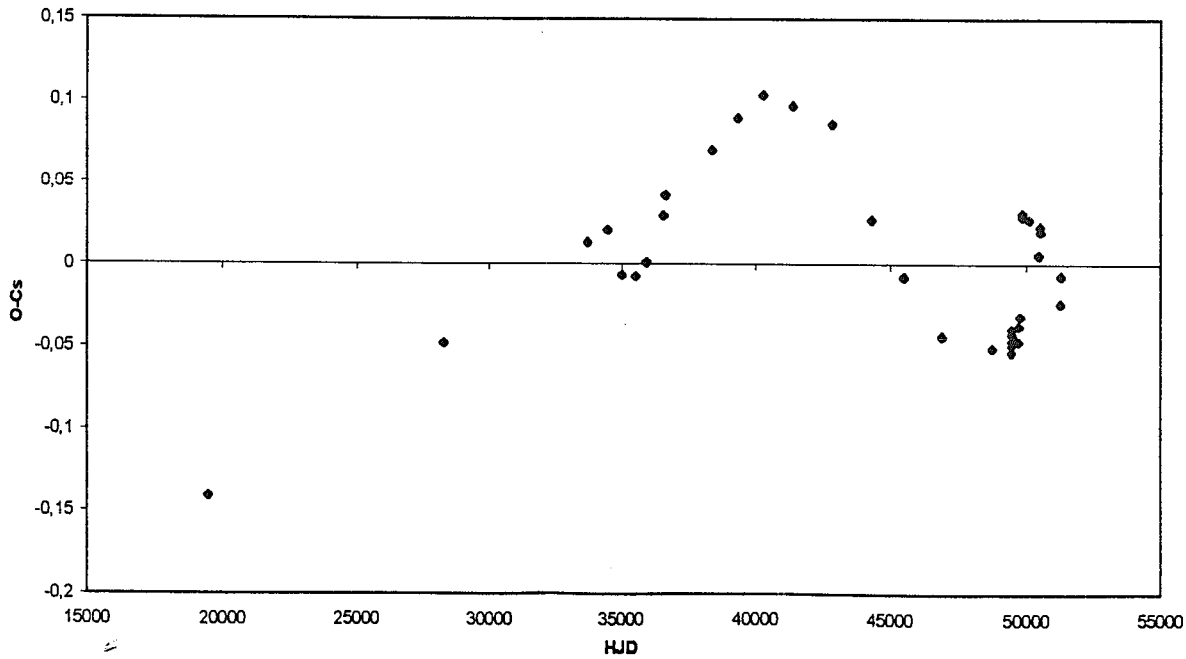


Figure 2 : O-Cs of the 35 instants of maximum of VW CVn with ephemeris (6)

The O-Cs light curve shows that since 1912 its period has been decreasing on the whole. But it must be kept in mind that till JD 2449000, the instants have been determined by mean light curves. This procedure makes the long time trend more easily discernible. The other more recent instants are based on one cycle light curves (except for the last one) and they are affected by rapid changes. The two marked facts are an abrupt period change around JD 2441000 and a bump between JD 2449800 and 2451280.

4. WHAT TYPE OF RR LYRAE STAR IS VW CVn ?

It is undeniable that the pulsating period of VW CVn is neither constant nor monoperodic. So, in a second step, we decided to search after multiple periodicities.

The only large number of measurements are the CCD observations of F. Agerer. We began to use all his 2612 measurements to make period searches with the Period98 programme (Sperl, 1998). First, we found the frequency F_1 = 2.35293761, corresponding to the main variation of the star, with a whole amplitude of 0.357 mag. ; then after prewhitening the signal bound up with that variation, we found an apparent variation with a whole amplitude of 0.0674 mag. at frequency 2.94570428. It is manifest that these searches did not show a second period with a P_1/P_0 around 0.745 typical of RRd stars. But the failure is perhaps due to an abrupt change of period during the lapse of time of the observations, or to the poor accuracy of some of the measurements.

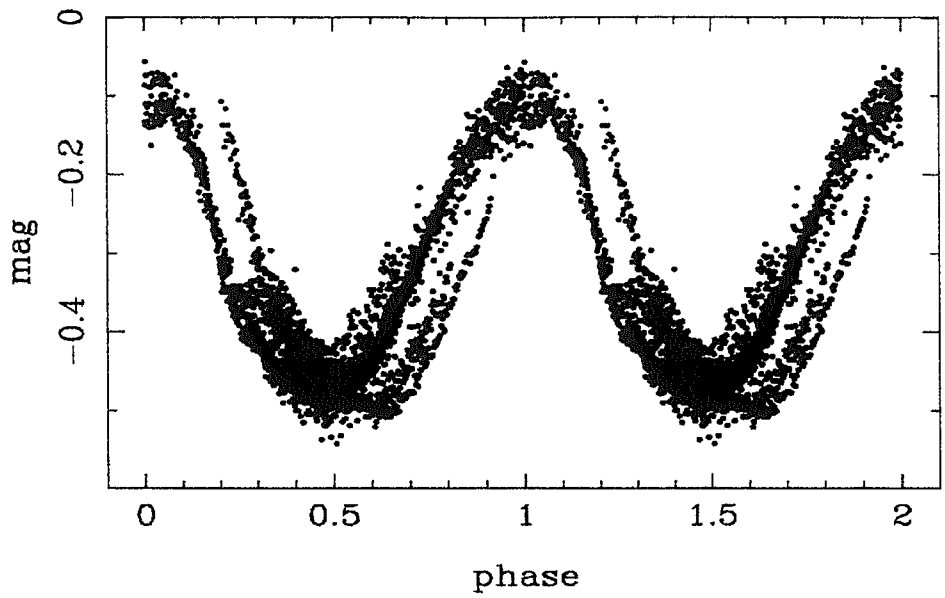


Figure 3 : The 2612 CCD measurements fitted with a period of 0.425 day = $1/F_1$

Hoping to avoid these problems, we scrutinised all the nightly sets of measurements and we rejected the visually bad measurements. We selected 1272 measurements from six good nights going from April 1994 to January 1995. The maximum nightly scatter of the measurements is of 0.052 mag. A search with the Period98 programme on these 1272 measurements displayed a highest amplitude at 3.3527135 which is obviously an alias (F+1) of the first frequency. We did not take it into account and found afterwards the highest amplitude (0.3636 mag) at frequency 2.35292016 (F_1). After prewhitening of F_1, we found F_2 = 0.164115968 with an amplitude of 0.0516 mag. The adjusted two periods are the following :

FREQUENCY	AMPLITUDE 1/2	PHASE	PERIOD
F_1 = 2.35291097	0.182015641	0.636811	0.4250055
F_2 = 0.164115968	0.0257583293	0.277516	6.0932523

Zeropoint = - 0.29029641 ; residuals = 0.0214826425 ; iterations = 8

The same searches were performed with the 80 V photoelectric measurements and the 50 CCD measurements from the Rotse1 survey. All gave somewhat different first periods and completely different second periods.

VW CVn is pulsating in a very complicated way or possibly in a totally erratic way. The solution to find the different modes of pulsation would be to have numerous high accuracy measurements from a short laps of time, and even so it is not sure to obtain positive results.

What are the other particularities of VW CVn that we can infer from our data ?

1. VW CVn is pulsating with a period around 0.425 day with a brightness amplitude of ± 0.46 mag.
2. Its $(B-V)_J$ indices are going from 0.22 to 0.35 mag. At its galactic position of l = 46.88 and b = 81.37, the reddening is not strong : 0.017 mag using the Blanco law (Blanco, 1992). Its mean deredded B-V index is therefore 0.27 mag.
3. The ascending branch of its light curve is 0.46 period (Agerer and Berthold, 1994). It is also in agreement with the light curve of the set of 1272 measurements fitted with the first period for that set with Period98 (see Fig. 4), whereas M-m = 0.41 period in the best fitted light curve from the Rotse1 survey (see Fig. 5).

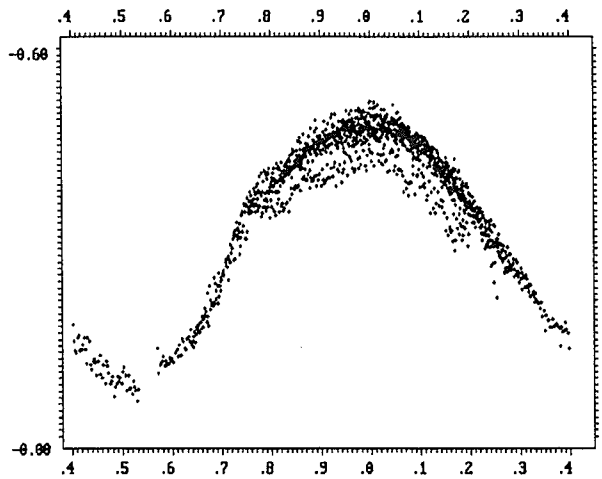


Figure 4 : 1272 CCD measurements fitted with a period of 0.4250038 day = $1/F_1$

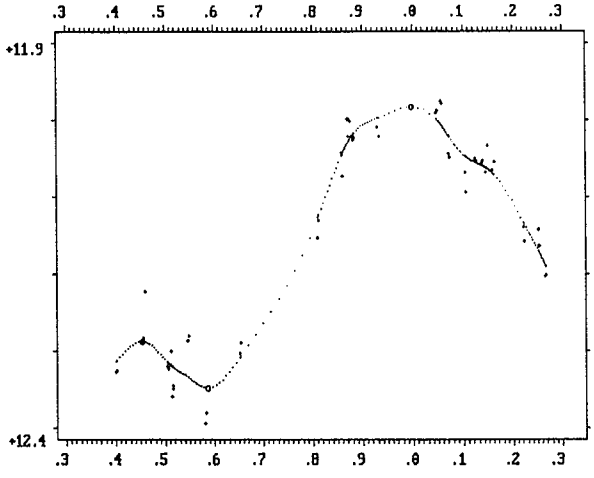


Figure 5 : 50 Rotse1 measurements fitted with a period of 0.4250875 day = $1/F_1$

From all these particularities and from the results of the period investigations described above, we can deduce that VW CVn is a RRab, a RRc or a RRd Lyrae star. The RRd type is not very probable because we never found the P_1/P_0 ratio of these stars. On the other hand, the period amplitude relation put VW CVn among the RRc Lyrae stars (Smith, 1995, p. 23). The M-m value ranging periodically from 0.41 to 0.46 and the rounded shape of maxima are also typical of the RRc type. So, VW CVn is very probably an RRc Lyrae star. Some of the irregularities in its light curves could result from a Blazhko effect, but we do not find neither periodicity in the long time O-Cs diagram (see Fig. 2), nor the triplet structure in the power spectra, in which the primary pulsation frequency ± the frequency of the Blazhko period (Kovacs, 1995).

5. CONCLUSION

VW CVn is very probably an RRc Lyrae star pulsating irregularly in a very complicated way. It is worth studying in the future with very accurate photometry and spectroscopy.

6. BIBLIOGRAPHY

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