GEOS
RR 9

GEOS CIRCULAR ON RR LYR TYPE VARIABLES

1985 December 20

GEOS
12 rue Bezout
F-75014 PARIS

ANALYSIS OF 1961 - 1982 MAXIMA OF VZ DRACONIS , AN RRc WITH A VARIABLE PERIOD

(Received 1985 January 24 ; accepted 1985 December 05)

ABSTRACT. VZ Dra is an RRc-type star for which FIGER (1982) gave a first ephemeris :
Max. = Hel.J.D. 2 443 534.7546 + 0.3210250 E (1)
The observations discussed here are composed of two series. The first series consists of brightness estimates made from plates exposed at Sonneberg Observatory (GDR) between 1961 and 1979. The second series is a batch of over 5000 visual observations made between 1980 and 1982 by 16 European observers belonging to GEOS. Both series confirm FIGER's ephemeris independently, though the O-C's are fairly important and alternately positive or negative. It follows therefore that the period of VZ Dra varies fairly rapidly.

RIASSUNTO. FIGER (1982) ha dato la prima effemeride per la RRc VZ Dra :
Max. = G.G.elioc. 2 443 534.7546 + 0.3210250 E (1)
Sono qui discusse due serie di osservazioni. La prima consiste di stime di luminosità effettuate su lastre ottenute al Sonneberg Observatory (Ger. Or.) fra il 1961 ed il 1979. La seconda è basata su oltre 5000 stime visuali effettuate fra il 1980 ed il 1982 da 16 osservatori appartenenti al GEOS. Entrambe le serie danno una conferma indipendente dell'effemeride (1), anche se gli O-C non sono trascurabili ed alternativamente positivi e negativi. Viene quindi suggerita l'ipotesi che il periodo di VZ Dra sia variabile.

RESUMEN. VZ Dra es una variable de tipo RRc cuya primera efeméride fué dada por FIGER (1982) :
Max. = D.J.Hel. 2 443 534.7546 + 0.3210250 E (1)
Las observaciones analizadas aquí constan de dos series. La primera contiene medidas de brillo realizadas a partir de placas fotográficas tomadas en el Observatorio de Sonneberg (RDA) entre 1961 y 1979. La segunda está constituida por más de 5000 observaciones visuales, efectuadas por 16 miembros europeos del GEOS entre 1980 y 1982. Estas dos series confirman independientemente la efeméride de FIGER, a pesar de los O-C relativamente importantes, tanto positivos como negativos. Parece por lo tanto que el período de VZ Dra varía de forma bastante rápida.

RESUME. VZ Dra est une variable de type RRc dont FIGER (1982) a donné la première éphéméride :
Max. = J.J.hel. 2 443 534.7546 + 0.3210250 E (1)
Les observations analysées ici sont formées de deux séries. La première contient des mesures d'éclat réalisées à partir de plaques photographiques prises à l'Observatoire de Sonneberg (RDA) entre 1961 et 1979. La seconde est constituée de plus de 5000 observations visuelles, effectuées par 16 membres européens du GEOS entre 1980 et 1982. Ces deux séries indépendantes confirment l'éphéméride de FIGER, avec néanmoins des O-C relativement importants, tantôt positifs, tantôt négatifs. Il semble donc que la période de VZ Dra est assez rapidement variable.

1. INTRODUCTION.

VZ Draconis (R.A. 16h 20mn 24s ; D. +58° 33' (1950.0)) is an RR-type star, as discovered by MEINUNGER (1961) from photographic plates. FIGER (1982) found its actual period, the real type of variation (RRc), and gave a first ephemeris :

$$\text{Max.} = \text{Hel.J.D. } 2\,443\,534.7546 \pm 33 + 0.3210250 \pm 63\ E \quad (1)$$

The observations discussed here were made on the one hand on plates exposed before 1980, and on the other hand, visually between 1980 and 1982.

2. EARLIER OBSERVATIONS.

Estimates were made on 194 sky-patrol plates exposed at Sonneberg Observatory between 1969 and 1979. Light curves were plotted from elements (1), using four sets of observations, each covering 2 or 3 years. A mean light curve was drawn on tracing paper, and O-C values were obtained for the four original light curves. Somewhat refined elements were then used to repeat this procedure with a mean light curve showing a smaller scatter (see Tab.1 and Fig.1).
Normal maxima were obtained with an accuracy of 0.005 d. from the final phase shifts of the four sets of observations (the last four dates in Tab.2).

Phase	m_{pg}	n	Phase	m_{pg}	n
.025	12.17	12	.525	12.81	4
.075	12.25	10	.575	12.81	11
.125	12.34	11	.650	12.77	20
.175	12.39	19	.725	12.65	10
.225	12.43	8	.775	12.60	13
.275	12.53	8	.825	12.45	9
.350	12.67	13	.875	12.41	8
.425	12.70	9	.925	12.22	10
.475	12.74	11	.975	12.18	8

Tab.1. Mean magnitudes of VZ Dra (194 photographic observations 1969-1979).

Hel. Max. J.D. - 2 400 000	$O-C_1$
37955.253	- .087
38092.632	- .107
38282.357	- .108
39289.444	- .076
40447.387	- .070
41088.480	- .064
42637.445	- .045
43432.346	- .002

Tab.2. Photographic maxima of VZ Dra (1961-1979).

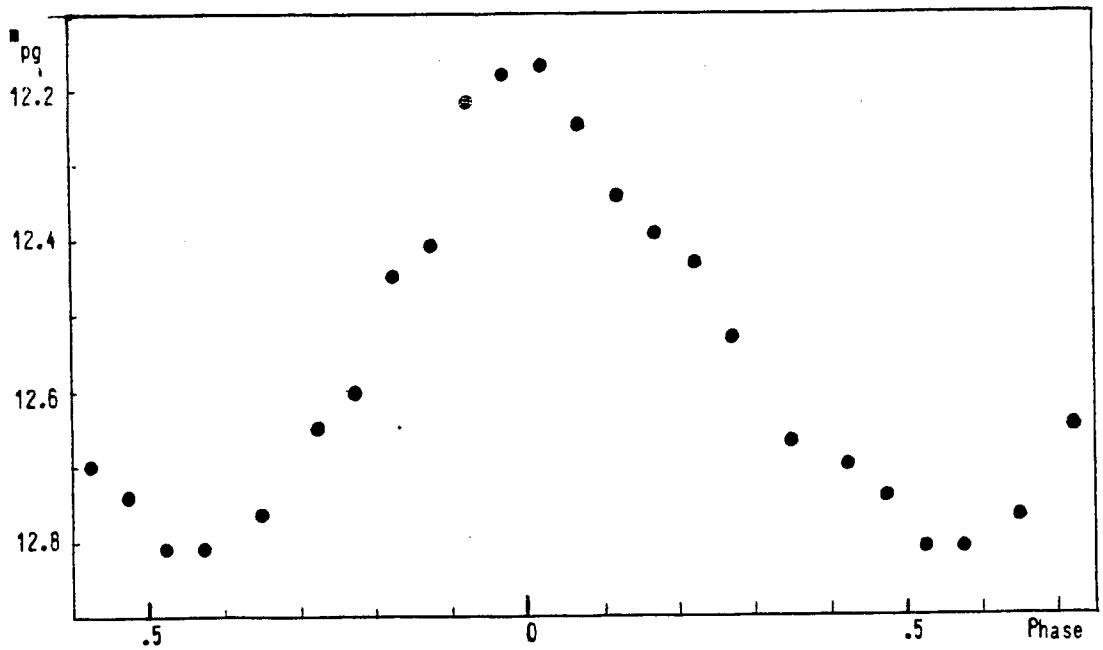

Fig.1. Mean light curve of VZ Dra (194 photographic observations 1969-1979).

In addition, older plates (1961 to 1968) were searched for bright observations. The first four times in Tab.2 are dates on which VZ Dra was found to be extremely bright on these plates. Of course, their accuracy is about three times lower than that of the normal maxima.
For comparison stars, see Fig.2. Their magnitudes are : a=11.86 m_{ph} ; b=12.20m_{ph} c=12.51 m_{ph} ; d=12.91 m_{ph}.

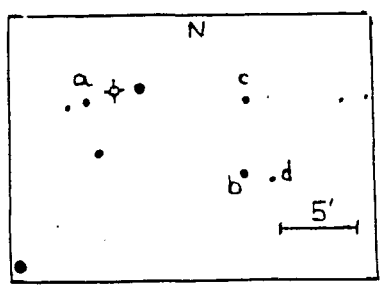

Fig.2. Comparison stars of VZ Dra.

3. LATER OBSERVATIONS.

VZ Dra was also observed visually at the GEOS camps of Casinos (Valencia, Spain) in 1980 and 1981, and Bédarieux (Hérault, France) in 1982. For these three years, more than 5000 observations were collected, made by 16 observers from Belgium, France, Italy, and Spain. Table 3 gives the list of observers and the number of their estimates. The instruments and the observing conditions were the same as for other GEOS camps, as described in an earlier paper by FIGER (1982). The observed maxima are listed in Table 4, with the O-C's referred to ephemeris (1).

Observer	Location	Number of estimates 1980	1981	1982	Total
M. Benucci	I - Firenze	155		91	246
R. Boninsegna	B - Dourbes			87	87
J. Busquets	E - Valencia	194	245	103	542
J. Fabregat	E - Valencia	158	227	94	479
S. Ferrand	F - Bougival			80	80
A. Figer	F - Paris	253	351	146	750
J. Gomez	E - Valencia	169			169
P. Graulus	B - Braine		200		200
P. Guiraudou	F - Montpellier	191	227	93	511
J.F.Le Borgne	F - Toulouse		141		141
P. Matagne	B - Bruxelles		313		313
E. Nezry	F - Toulouse	127	269		396
E. Poretti	I - Milano	190			190
P. Ralincourt	F - Nantes	222	297	101	620
J. Remis	F - Aix	180			180
L. Rivas	E - Valencia	197			197
Total		2036	2270	795	5101

Tab.3. List of observers 1980 - 1982.

4. DISCUSSION.

4.1. 1980-1982 Results.

First of all, Tab.4 shows a rather large dispersion of the O-C's. This is probably not due to an intrinsic change on a short time-scale ; on the contrary, this amplitude corresponds very well to a normal distribution in the case of visual observations. Moreover, some dispersion of the O-C's of the same order has already been obtained in studies of visual observations on stars with constant period (LE BORGNE, 1984) or slowly variable (FIGER, 1983) without altering the accuracy of the results.

We can then notice that the 1980 and 1981 observations are quite consistent with one another, except perhaps for the O-C's of 1981 July 28. These show a systematically positive trend and are therefore more questionable. In fact, on that day, the maximum occurred very early in the night and it is quite possible that the observers

Geoc. time of max. Date	Hour U.T.	Hel. time J.D. - 2 440 000	O-C$_1$	Observer
9 AUG 80	1 14	4460.551	- .040	FGR
9	1 40	4460.569	- .022	RAL
11	22 40	4463.444	- .036	FGR
11	22 47	4463.449	- .031	GUI
11	22 59	4463.457	- .023	FBG
11	23 02	4463.459	- .021	BSQ
11	23 09	4463.464	- .016	RMS
11	23 10	4463.465	- .015	RVS
11	23 14	4463.467	- .013	RAL
11	23 18	4463.470	- .010	POI
11	23 37	4463.483	+ .003	GOM
12	21 47	4464.407	- .036	BEN
12	22 07	4464.421	- .022	NZY
12	22 09	4464.422	- .021	FGR
12	22 18	4464.429	- .014	GUI
12	22 19	4464.429	- .014	RAL
12	22 20	4464.430	- .013	BSQ
12	22 25	4464.433	- .010	FBG
12	23 05	4464.461	+ .018	POI
18	1 31	4469.562	- .017	BSQ
18	1 39	4469.568	- .011	RAL
18	1 40	4469.569	- .010	BEN
18	1 47	4469.574	- .005	FGR
18	1 53	4469.578	- .001	RMS
18	1 54	4469.578	- .001	POI
18	1 56	4469.580	+ .001	GOM
18	2 10	4469.590	+ .011	FBG
24 JUL 81	23 00	4810.458	- .050	GUS
24	23 20	4810.472	- .036	MAT
24	23 30	4810.479	- .029	FLB
24	23 37	4810.484	- .024	FGR
24	23 37	4810.484	- .024	RAL
24	23 38	4810.485	- .023	BSQ
24	23 41	4810.487	- .021	GUI
24	23 44	4810.489	- .019	NZY
25	0 05	4810.503	- .005	FBG
25	22 50	4811.451	- .020	NZY
25	23 12	4811.466	- .005	FGR
25	23 13	4811.467	- .004	RAL
25	23 14	4811.468	- .003	BSQ
25	23 30	4811.479	+ .008	FBG
25	23 55	4811.496	+ .025	GUI
26	21 34	4812.398	- .036	MAT
26	21 49	4812.409	- .025	RAL
26	21 56	4812.414	- .020	GUI
26	21 59	4812.416	- .018	NZY
26	22 18	4812.429	- .005	FGR
26	22 29	4812.437	+ .003	BSQ
26	22 36	4812.441	+ .007	FBG
27	21 19	4813.388	- .009	GUI
27	21 21	4813.389	- .008	GUS
27	21 23	4813.391	- .006	MAT
27	21 27	4813.393	- .004	NZY
27	21 27	4813.393	- .004	RAL
27	21 29	4813.395	- .002	FGR
27	21 36	4813.400	+ .003	BSQ

14 MAR 1983

Geoc. time of max. Date	Hour U.T.	Hel. time J.D. - 2 440 000	O-C$_1$	Observer
28 JUL 81	20 38	4814.359	- .001	FGR
28	20 53	4814.370	+ .010	MAT
28	21 00	4814.375	+ .015	RAL
28	21 02	4814.376	+ .016	BSQ
28	21 03	4814.377	+ .017	GUI
28	21 04	4814.377	+ .017	GUS
28	21 17	4814.387	+ .027	NZY
28	21 23	4814.391	+ .031	FBG
30	3 23	4815.641	- .003	MAT
30	3 26	4815.643	- .001	FGR
30	3 32	4815.647	+ .003	RAL
31	1 38	4816.568	- .039	NZY
31	2 10	4816.590	- .017	GUI
31	2 12	4816.591	- .016	RAL
31	2 21	4816.598	- .009	FGR
2 AUG	22 54	4819.454	- .043	NZY
2	23 18	4819.470	- .027	FGR
2	23 23	4819.474	- .023	MAT
4	21 10	4821.382	- .041	GUS
4	21 12	4821.383	- .040	NZY
4	21 25	4821.392	- .031	GUI
4	21 30	4821.395	- .028	MAT
4	21 35	4821.399	- .024	BSQ
4	21 50	4821.409	- .014	RAL
4	21 51	4821.410	- .013	FGR
5	20 39	4822.360	- .026	GUS
5	20 43	4822.363	- .023	NZY
5	20 45	4822.364	- .022	FBG
5	21 00	4822.375	- .011	RAL
5	21 04	4822.377	- .009	FGR
5	21 09	4822.381	- .005	BSQ
5	21 09	4822.381	- .005	GUI
23 JUL 82	2 04	5173.586	- .001	FGR
23	2 16	5173.594	+ .007	BSQ
23	2 28	5173.603	+ .016	RAL
24	1 15	5174.552	+ .002	FND
24	1 18	5174.554	+ .004	FGR
24	1 24	5174.558	+ .008	BSQ
24	1 31	5174.563	+ .013	BEN
24	1 42	5174.571	+ .021	GUI
24	2 00	5174.583	+ .033	RAL
25	23 03	5176.460	- .016	BEN
25	23 15	5176.469	- .007	FGR
25	23 21	5176.473	- .003	FND
25	23 23	5176.474	- .002	BNN
25	23 38	5176.485	+ .011	GUI
25	23 44	5176.489	+ .013	BSQ
25	23 47	5176.491	+ .015	FBG
25	23 52	5176.494	+ .018	RAL
26	22 12	5177.425	- .015	BEN
26	22 28	5177.436	- .004	GUI
26	22 29	5177.437	- .003	FND
26	22 32	5177.439	- .001	RAL
26	22 52	5177.453	+ .013	FBG
26	22 53	5177.453	+ .013	FGR
26	23 06	5177.462	+ .022	BSQ
26	23 20	5177.470	+ .030	BNN

Tab.4. Visual maxima of VZ Dra 1980 - 1982.

were persuaded they were monitoring it while it was actually just over.

In 1982, the O-C's display a different character. They are however more in the line of the results obtained by FIGER in 1977 and 1978.

Finally, FIGER's ephemeris is confirmed within its error bars.

4.2. Mean period 1961 - 1982.

In order to ensure a better comparison with the past series, a diagram of the O-C's against J.D. may be useful. For that purpose, a mean period must be calculated. A linear regression using all the observed maxima from 1961 (MEINUNGER rediscussed by FIGER, 1982) to 1982, yielded a mean period P = 0.3210295 d. The corresponding elements are :

$$\text{Hel.J.D. } 2\,437\,543.368 + 0.3210295\ E \qquad (2)$$

It is important to emphasize the fact that these elements are not an ephemeris : it would be meaningless to use them to determine the O-C's of maxima to come. They can only be used to link series of observations made during the past twenty years.

4.3. O-C diagram.

Table 5 summarizes the O-C's of all the maxima of VZ Dra, referring to elements (2), and Fig.3 shows the corresponding O-C diagram.

As the observations made between 1978 and 1982 are numerous and as they were made every year over a short period of time, it did not seem interesting to show each maximum individually on the diagram. The choice was therefore to give in Table 5 one average maximum a year, each one being followed by its standard deviation. The error bars, on Fig.3, have been calculated at the 99 % level of confidence. On the contrary, the calculation of a standard deviation for the 6 photographic maxima of MEINUNGER would not be relevant because of their small number.

Maximum HJD or mean maximum	Reference	Number of max.	$O-C_2$ or mean $O-C_2$	Standard deviation	Error bar (99% level)
2 437 558.765	Meinunger (1961)	6	- .012		
37 955.253	Present paper	1	+ .004		
38 092.632	" "	1	- .017		
38 282.357		1	- .021		
39 289.444		1	- .003		
40 447.387		1	- .014		
41 088.480		1	- .017		
42 637.445		1	- .019		
43 379.375	Figer (1982)	44	+ .012	.013	± .006
43 432.346	Present paper	1	+ .013		
43 725.443	Figer (1982)	89	+ .010	.015	± .005
44 465.393	Present paper	27	- .013	.014	± .008
44 815.312	" "	61	- .016	.018	± .007
45 175.841		25	- .003	.013	± .008

Tab.5. Observed maxima of VZ Dra 1961 - 1982.
(Mean maxima are given when several maxima have been observed in a short time).

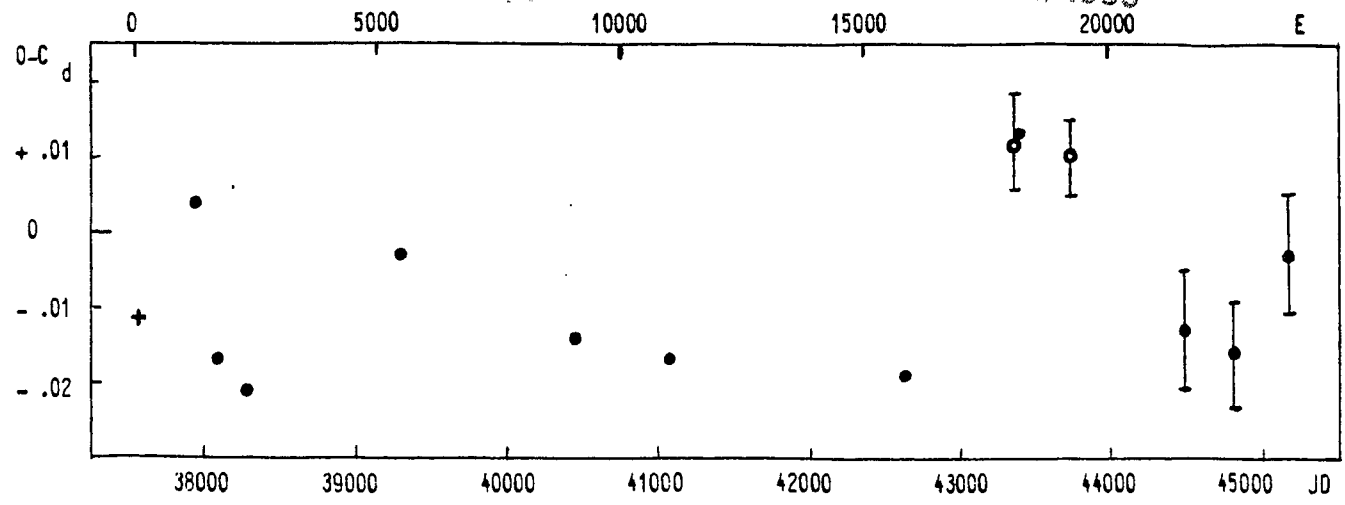

Fig.3. O-C diagram for VZ Dra.

Fig.3. clearly shows that the O-C's vary within a large range over a short interval of time. The first question which comes to mind is therefore whether the observations are reliable or not.

True enough, their individual accuracy is not very high, and they are rather scattered. For the last four years, however, one takes into account the yearly means of a great number of maxima monitored by several observers. These independant maxima were determined in similar conditions and they are quite consistent with one another, as was seen in paragraph 4.1. Hence, it appears that no observational error, whether systematic or occasional, could explain why, for instance, the difference between the averaged 89 observations of 1978 and the averaged 61 determinations of 1981 reaches 0.026 d. (or 37 minutes).

As a precaution, error bars have been calculated at the 99 % level of confidence, and it can be seen that, even in this case, the error bands of the last five years are greatly separated.

Moreover, the last photographic maximum exactly confirms the visual observations of 1977, which gives credit to the whole diagram.

It follows from this that observational errors, though they cannot be totally excluded, can probably not account for the variation of the O-C's. Such a variation must therefore have a physical explanation.

5. INTERPRETATION.

A first tentative explanation for the dispersion of the O-C's from one year to another could be the Blazhko effect. As a matter of fact, looking at the curve of O-C's one can consider that their variations are recurring, one cycle lasting about 2500 days. But this constitutes too long a period for a beat. Moreover, it can be seen from the time of the normal maximum at J.D. 2 441 088.480 and its error bar that such cyclic variations are inconsistent with the 1971/72 observations. Nevertheless, such a beat phenomenon can exist in VZ Dra, but on a short period, and the observations which have been gathered here do not allow us to go through this question. Indeed, the observations are concentrated every year on only a fortnight, which is too short a time interval.

We could put forward a second hypothesis which is more likely i.e. that VZ Dra would be a star with variable period. Its period being included between 0.3 and 0.4 day, it would be assimilated to the "non stable stars of the group P~ 0.36 d." according to the classification of TSESEVICH (1969). Besides, some RRc such as RU Psc (KANISCHCHEVA, 1971) are also known to have a period rapidly variable. VZ Dra could be in a similar case.

6. CONCLUSION.

The observations discussed here confirm on the whole the results and the ephemeris of FIGER. However, some rather important variations of the O-C's appear, and they are different from one year to the other. Such a quick evolution is difficult to interpret. It is likely that VZ Dra is a star with variable period, and further observations will lead to knowing the trend of the variation, unless it is cyclic.

ACKNOWLEDGEMENTS.

We would like to thank the C.D.S. of Strasbourg for the documentation, and Dr. W. WENZEL, Director of Sonneberg Observatory, for use of the sky-patrol plates.

T. BERTHOLD° & P. RALINCOURT

° Bruno H. Bürgel Sternwarte, DDR - 7302 HARTHA

REFERENCES.

FIGER A. 1982, GEOS Circ. RR 3 : "133 times of maximum and first ephemeris for the RRc star VZ Draconis".

FIGER A. 1983, GEOS Circ. RR 6 : "BP Pegasi : 74 times of maxima, improvement of the ephemeris and evidence of visually observed Blazhko effect".

KANISCHCHEVA R.K. 1971, VS 17, n°6, 651 : "On period of RU Piscium".

LE BORGNE J.F. 1984, GEOS Circ. RR 5 : "Improved elements for the dwarf cepheid v 567 Oph".

MEINUNGER L. 1961, MVS 599 : "VZ Draconis".

TSESEVICH V.P. 1969, "RR Lyrae stars" (ed. IPST Ltd, Jerusalem) p.21 & p.346.