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ON THE O-C DIAGRAM AND PERIOD BEHAVIOUR OF CY Aqr
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The observational material on CY Aquarii, an ultra-short period dwarf cepheid discovered 50 years ago by Hoffmeister (1934) was recently reviewed by Mahdy and Szeidl (1980). They found strong evidence of a sudden period change ($\Delta P = -0.0016$) in 1952, whereas the period appeared constant before and after this date, apart from small yet notable fluctuations. It could not be decided whether these resulted from systematic differences between different observers (e.g., in time resolution, or in the method of determining times of maximum light) or, possibly, from the cumulative character of period noise (cf. Balázs-Detre and Detre 1965). Some authors also noticed apparent phase shifts of 0.003 d around 1944 and 1972 (Ashbrook 1954, Bohusz and Udalski 1980).

Close examination of the rather dense observational series established by Sanwal (1962) and Zissell (times of maximum light as quoted by Fitch (1973)) revealed further significant phase jumps ($\Delta\phi = 0.001$) between groups of observations only some weeks apart from each other. This fact prompted us to look for a correlation between phase shifts of maximum light and amplitude of individual cycles. Such a correlation was indeed found in photoelectric data of different observers, and its typical effect amounts to a phase lag of about half a minute per 0.005 decrease in amplitude.

In this context, it should be recalled that in contrast to other results Zissell (1968) stated that the period of CY Aqr had been essentially constant, at least between 1953 and 1966 ($P = 0.0610383405 \pm 22$). Zissell's conclusion was based on the study of epochs of the critical magnitude on the rising branch, at which the rising and descending branches were separated by 0.220 period. The light curve passes through this point at the time of its steepest rise, approximately. — It is well known that the epochs obtained in such a way are more accurately determined than those of maximum light (Oosterhoff, 1930). Moreover, Fig.2 of Zissell's paper demonstrated that the light curve is more stable at this point than near maximum light.

Unfortunately, later investigators didn't follow this procedure, thus introduced apparent and fictitious scattering in the O-C diagram which may obscure real variations in the star's period. We therefore decided to carry on the work of Zissell (1968), who already provided a homogeneous set of 77 epochs of critical magnitude over an interval of 33 yr (see Tab.III of his paper). From available photographic and photoelectric observations we graphically derived further 80 epochs by using the method described above. Results of determinations in different colours have been averaged (their difference being less than $0^d.0003$ and of unsystematic nature). These times are given in Table I below, extending Zissell's compilation until 1984. Cycle numbers and O-C(1) refer to the ephemeris given by Wesselink (1941):

$$\text{phase} = 16.3831079 \text{ (JD hel - 2428725.4177)} \quad (1)$$

(phase reckoned from the critical point). They may be compared directly to the values given in Zissell's Table 3. In constructing the O-C diagram, we used the ephemeris chosen for the same purpose by Mahdy and Szeidl (1980):

$$C = \text{HJD } 2434\,308.4310 + 0^d.061038395 \text{ (E- 91467)} \quad (2)$$

which leaves the residuals O-C(2) of Table I. In order to allow for comparison, we have given in Column 2 the values $\Delta\text{JD}_{\text{max}}$ of the difference between the published moment of maximum light and the moment of steepest rise given in this paper. For the latest photoelectric series reported by Peña et al.(1985) we can only give a preliminary normal epoch derived from the published maxima.

Unfortunately, the extensive photoelectric series established by Sanwal (1962) and Karetnikov and Medvedev (1966) could not be included in this study because neither the individual observations nor light curves were accessible. Nevertheless, it is possible to draw some interesting conclusions. Figure 1 shows the O-C diagram for the present data (including Zissell's). Residuals calculated for the quoted times of maximum light and the corresponding moments of steepest rise are displayed in the same diagram. When both representations are compared, it becomes obvious that Oosterhoff's procedure succeeded in reducing the internal variance (within groups) by about 60% and also yielded much better external agreement (between different groups of observations). One should note in particular the disappearance of (spurious) phase shifts at JD 37000, 39400 or 42100. Also, the O-C diagram for moments of steepest rise does not support the reality of the questionable $0^d.003$ phase shift around 1944 suggested by Ashbrook (1954). On the other hand, our O-C diagram

Table I

JD _{crit.} hel.	Δ JD _{max}	Epoch(1)	O-C(1)	O-C(2)	O-C(3)	Type	W	Ref.
2427658.4040	0.0056	- 17481	0.0000	-0.0159		vN	1	Je
27671.5273	0.0044	- 17266	0.0000	-0.0159		pg	1	BD
27688.4965	0.0045	- 16988	+0.0005	-0.0154		pg	1	BD
27690.3889	0.0051	- 16957	+0.0007	-0.0152		pg	1	BD
27692.6460	0.0060	- 16920	-0.0006	-0.0165		pg	1	Ga
27695.4549	0.0051	- 16874	+0.0005	-0.0153		pg	1	BD
27712.3019	0.0050	- 16598	+0.0009	-0.0149		pg	1	BD
27744.2861	0.0048	- 16074	+0.0009	-0.0149		pg	1	BD
28045.3879	0.0045	- 11141	-0.0001	-0.0155		pg	1	MS
28046.3028	0.0043	- 11126	-0.0008	-0.0161		pg	1	Ku
28046.4857	0.0044	- 11123	-0.0010	-0.0164		pg	1	Ku
28047.2796	0.0030	- 11110	-0.0006	-0.0160		pg	1	Ku
28047.3408	0.0056	- 11109	-0.0004	-0.0158		pg	1	Ku
28047.4622	0.0046	- 11107	-0.0011	-0.0165		pg	1	Ku
28048.3790	0.0043	- 11092	-0.0009	-0.0162		pg	1	Ku
28074.3820	0.0040	- 10666	+0.0007	-0.0146		pg	1	MS
28090.3149	0.0040	- 10405	+0.0026	-0.0127		pg	(1)	Sc
28090.3765	0.0035	- 10404	+0.0031	-0.0122		pg	(1)	Sc
28094.2828	0.0032	- 10340	+0.0030	-0.0123		pg	(1)	Sc
28397.5199	0.0034	- 5372	+0.0009	-0.0140		pg	1	MS
30592.3426	0.0051	+ 30586	+0.0020	-0.0099		vs	.2	Ts
30592.4642	0.0048	+ 30588	+0.0015	-0.0104		vs	.2	Ts
30601.2536	0.0021	+ 30732	+0.0013	-0.0105		vs	.2	Ts
30601.3139	0.0029	+ 30733	+0.0006	-0.0112		vs	.2	Ts
30601.4358	0.0031	+ 30735	+0.0004	-0.0114		vs	.2	Ts
31742.4298	0.0059	+ 49428	+0.0021	-0.0081		pg	1	Mi
32091.3854	0.0060	+ 55145	+0.0007	-0.0090		pg	1	LM
32091.4490:	0.0042	+ 55146	+0.0033	-0.0065		pg	.5	LM
32092.3640:	0.0040	+ 55161	+0.0027	-0.0070		pg	.5	LM
32092.4241	0.0034	+ 55162	+0.0018	-0.0080		pg	1	LM
32093.4015	0.0041	+ 55178	+0.0026	-0.0072		pg	1	MS
32440.4654	0.0046	+ 60864	+0.0017	-0.0076		pg	1	MS
32445.7153	0.0045	+ 60950	+0.0023	-0.0070		vN	1	As
33860.5261	0.0049	+ 84129	+0.0021	-0.0052		pg	1	MS
33861.5637	0.0042	+ 84146	+0.0021	-0.0052		pg	1	MS
37524.5381	0.0044	+ 144157	-0.0037	-0.0059		pe	2	PO
38680.7257	0.0043	+ 163099	-0.0070	-0.0076		pe	2	Fi
38680.7867	0.0043	+ 163100	-0.0070	-0.0076		pe	2	Fi
40779.7745	0.0038	+ 197488	-0.0105	-0.0082	+0.0034	pe	(3)	El
40779.8352	0.0038	+ 197489	-0.0108	-0.0085	+0.0031	pe	(3)	El
40779.8966	0.0039	+ 197490	-0.0105	-0.0082	+0.0034	pe	(3)	El
40894.6463	0.0044	+ 199370	-0.0131	-0.0106	+0.0011	pe	3	NW
41126.5914	0.0046	+ 203170	-0.0142	-0.0114	+0.0006	pe	2	Lu
41623.2602	0.0045	+ 211307	-0.0156	-0.0121	+0.0006	pe	3	MS
41623.3214	0.0037	+ 211308	-0.0154	-0.0119	+0.0008	pe	3	MS
41959.3370	0.0035	+ 216813	-0.0166	-0.0127	+0.0004	pe	3	GH
41959.3976	0.0042	+ 216814	-0.0171	-0.0131	-0.0000	pe	3	GH
41959.4592	0.0042	+ 216815	-0.0165	-0.0125	+0.0005	pe	3	GH
41959.5204	0.0030	+ 216816	-0.0163	-0.0124	+0.0007	pe	3	GH

Table I (cont'd)

JD _{crit.} hel.	Δ JD _{max}	Epoch(1)	O-C(1)	O-C(2)	O-C(3)	Type	W	Ref.
42302.5562	0.0045	+ 222436	-0.0168	-0.0124	+0.0012	pe	1	FR
42303.4703	0.0075	+ 222451	-0.0183	-0.0138	-0.0003	pe	1	FR
42304.4476	0.0057	+ 222467	-0.0176	-0.0131	+0.0004	pe	1	FR
42304.5085	0.0041	+ 222468	-0.0177	-0.0133	+0.0002	pe	1	FR
43401.3660	0.0046	+ 240438	-0.0217	-0.0157	-0.0008	pe	1	FR
43401.4280	0.0047	+ 240439	-0.0207	-0.0148	+0.0001	pe	1	FR
43401.4882	0.0055	+ 240440	-0.0216	-0.0156	-0.0007	pe	1	FR
43402.3441	0.0037	+ 240454	-0.0202	-0.0143	+0.0006	pe	1	FR
43402.4044	0.0042	+ 240455	-0.0210	-0.0150	-0.0001	pe	1	FR
43402.4653	0.0046	+ 240456	-0.0211	-0.0151	-0.0002	pe	1	FR
43402.5264	0.0047	+ 240457	-0.0210	-0.0151	-0.0002	pe	1	FR
43425.4159	0.0048	+ 240832	-0.0210	-0.0150	-0.0000	pe	3	BU
43425.4766	0.0048	+ 240833	-0.0213	-0.0153	-0.0004	pe	3	BU
43482.2424	0.0030	+ 241763	-0.0213	-0.0152	-0.0002	pg	1	Pp*
43490.2388	0.0046	+ 241894	-0.0209	-0.0148	+0.0002	pe	3	BU
43490.2996	0.0042	+ 241895	-0.0212	-0.0151	-0.0001	pe	3	BU
43815.3286	0.0039	+ 247220	-0.0221	-0.0155	-0.0001	pe	3	BU
43815.3898	0.0049	+ 247221	-0.0219	-0.0154	+0.0000	pe	3	BU
44158.3029	0.0040	+ 252839	-0.0230	-0.0160	-0.0001	pe	3	MS
45621.3307	0.0044	+ 276808	-0.0265	-0.0175	+0.0002	pe	2	PS
45629.3263	0.0038	+ 276939	-0.0269	-0.0179	-0.0002	pe	2	PS
45631.2796	0.0047	+ 276971	-0.0269	-0.0178	-0.0001	pe	2	PS
45631.3406	0.0047	+ 276972	-0.0269	-0.0179	-0.0002	pe	2	PS
45635.3081	0.0041	+ 277037	-0.0269	-0.0179	-0.0001	pe	3	PS
45635.3693	0.0039	+ 277038	-0.0268	-0.0177	+0.0000	pe	3	PS
45641.2900	0.0040	+ 277135	-0.0268	-0.0177	0.0000	pe	3	PS
45641.3508	0.0042	+ 277136	-0.0270	-0.0180	-0.0002	pe	3	PS
45645.2575	0.0046	+ 277200	-0.0268	-0.0177	+0.0000	pe	3	PS
45645.3186	0.0039	+ 277201	-0.0267	-0.0177	+0.0001	pe	3	PS
45661.2496	0.0036	+ 277462	-0.0268	-0.0177	+0.0001	pe	2	PS
45662.2873	0.0047	+ 277479	-0.0267	-0.0176	+0.0001	pe	2	PS
46062.5764	(0.0042)	+ 284037	-0.0280	-0.0183	-0.0001	peN	3	Pe

*) Present paper, determined from a multiple exposure plate taken with the large double refractor at the Hoher List Observatory, Daun (F.R.G.).

gives some evidence for a further period change around 1966 and possibly also in 1977, period changes hitherto not noticed by other investigators.

We divided the whole data into three segments whose borderlines were marked by the abrupt period changes in 1953 and 1966, computed best linear approximations over these intervals (using weighted Least Squares) and investigated the residuals for the influence of cumulative and noncumulative random errors according to a method described by Sterne (1934). Our results indicate the presence of random fluctuations in pulsation frequency characterized by a rms value of $\sigma \approx 0.0056\%$. This is very small compared to mean σ -values quoted

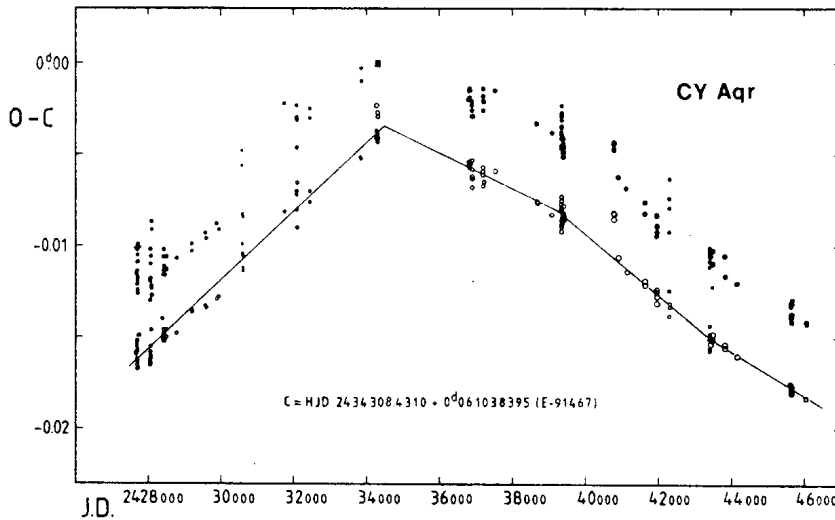


Figure 1: O-C diagram for CY Aqr, constructed with times of maximum light (filled circles) and moments of steepest rise (open circles).

for other types of pulsating variables (Miras 1.6 %, W Virginis stars 1.6 %, δ Cepheids 0.3 ... 0.08 %, RR Lyrae stars 0.11 ... 0.04 %, after Balázs-Detre and Detre, 1965). From our data we derived the following mean periods:

1934 - 1953 :	$\bar{P} = 0.061038509 \pm 11$	$\Delta\bar{P} = -0.00149 \pm 18$
1953 - 1966 :	$\bar{P} = 0.061038336 \pm 18$	$\Delta\bar{P} = -0.0037 \pm 20$
1970 - 1977 :	$\bar{P} = 0.061038293 \pm 19$	$\Delta\bar{P} = +0.0023 \pm 23$
1977 - 1984 :	$\bar{P} = 0.061038320 \pm 18$	

The main contribution to the estimated mean error of these quantities comes from the intrinsic noise process. The column "O-C(3)" of Table I refers to the instantaneous elements computed for the last interval, with $E_0 = 2445641.2900$. Since random superposition of small steps can lead to data which display apparent slope discontinuities, the last "period change" cannot be regarded as statistically significant and might as well be part of the noise.

As the mean period of CY Aqr has remained constant within ± 0.003 s since 1953, the parabolic representation of the O-C diagram suggested by some authors seems to be inadequate. Thus, a simple evolutionary interpretation of the observed period changes is not possible. But it is interesting to note, that CY Aqr is a member of the small subgroup of low mass metal poor Pop. II

dwarf cepheids (Frolov and Irkaev, 1984). The explanation of abrupt period changes in RR Lyrae stars through random mixing events in the semiconvective zone proposed by Sweigart and Renzini (1979) might apply here, too.

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