XZ CYGNI: RECENT PERIOD STUDY, AGAIN

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Abstract

This paper analyzes the behavior of the RR Lyrae type variable star XZ Cygni over the past nine years.

One hundred visual light curves were analyzed, and forty selected, from which primary and secondary (Blazhko) periods were computed.

Findings indicate that the primary period of XZ Cygni has remained almost equal to that derived by Baldwin (1973), or $0^{d}.466474$, at least through 1974. The secondary period was calculated to be $58^{d}.318$, through 1973. This result, although considered only an average, also approximates Baldwin's determination.

In addition, times of maxima reveal a relationship of O-C residuals and maximum magnitude with secondary phase position.

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After the interesting behavior of the RR Lyrae variable star XZ Cygni (193056) was reported by Marvin Baldwin (1971, 1973) and Horace Smith (1975), among others, it was decided to analyze the behavior of the star over the past nine years.

Eighty-eight visual maxima timings, in the form of light curves covering the period May 1965 to July 1974, were obtained from Marvin E. Baldwin, Chairman of the RR Lyrae Committee of the American Association of Variable Star Observers. Twelve of the author's own timings, made during the fall of 1974, were also used. In addition, nineteen photoelectrically recorded maxima (Kunchev, 1974) were obtained courtesy of the Director of the AAVSO, Janet A. Mattei. These latter observations tend to confirm some of the visual times of maxima and show the definite decline in primary period previously attributed to XZ Cygni by Baldwin and Smith.

From the visual light curves forty were selected that attained an $8^{m}.9$ or brighter maximum, with a steep rise to this maximum. These requirements were set for two reasons; first, because one can determine reasonably accurate times of maxima with this shape of curve using the Pogson Method, and secondly, a rough correlation is apparent between maximum magnitude and O-C residuals in XZ Cygni (in general, the brighter the maximum, the less the O-C value).

The Pogson Method was then used to determine actual times of maxima, and heliocentric corrections were added (Table I).

In the revision of the primary period, calculated times of maxima were computed from the elements listed in the <u>General Catalog of Variable Stars</u> (1969), (Max. hel. = JD 2436933.981 + $0^{d}.466579$E). Next, an O-C diagram was constructed (Figure 1). Lines of regression were drawn using the method of least-squares, and initial epochs were selected by choosing an observation lying on the line. At this point it was found that times of maxima would be better satisfied if a two-step change (suggested by Smith, 1975) was formulated: step one commencing at about JD 2438800 (February, 1965), and step two occurring approximately JD 2440350 (May, 1969).

These two sets of primary period elements, designated P_1 and P_2, are listed below.

$$P_1: \text{Max. hel.} = \text{JD } 2438882.875 + 0\overset{d}{.}466552E \quad (1)$$

$$P_2: \text{Max. hel.} = \text{JD } 2440876.368 + 0\overset{d}{.}466474E \quad (2)$$

The value for the second step (P_2) was seen to agree closely with Baldwin's (1973) result (Max. hel. = JD 2440981.326 + $0\overset{d}{.}466471$E), and would confirm that periodicity through 1974.

After these elements were determined, the resulting O-C residuals were compared with those from elements listed in the 2nd Supplement to the GCVS (1974) (Max. hel. = JD 2440445.789 + $0\overset{d}{.}466497$E) and residuals computed using Baldwin's (1973) elements (Table II). Comparisons resulted in an $(O-C)^2$ total of .000621 (days) for the new elements after date of latest initial epoch, and an almost identical .000777 total using the elements of Baldwin. The total for the 2nd Supplement amounting to .044384 with steadily increasing O-C values, is seen to be unsatisfacory for purposes of prediction.

The elements for the secondary, or Blazhko (Blazhko 1922), period were then determined. This was carried out in a manner similar to the primary period revision, with the following exceptions: only ten timings of maxima were used that attained $8\overset{m}{.}8$ or brighter. (This requirement was appropriate as the secondary period is believed to be the result of a "beat" cycle, where two or more maxima of different period occur together, resulting in "bright" maxima at regular intervals.) In addition, two sets of elements formed the basis for calculations. The first set consisted of those secondary elements cited by Baldwin (1973) (JD 2438883.9 + 58.316E). The Julian Day of "Magnitude Maxima" (JD 2417030) corresponding to zero cycles from Smith (1975), and the secondary period ($57\overset{d}{.}410$) of Klepikova (1958), made up the second set of elements. Results from the two cases were identical, as they should be, and show a value almost exactly that of Baldwin (1973), or $58\overset{d}{.}318$. This period should be regarded only as a good average over the entire range of observations (1965-1973), rather than as an exact value for any one time span.

Finally, Figures 2 and 3 show primary period O-C residuals (using the new elements) and maximum magnitudes as functions of secondary phase position. Seventy and ninety maxima, respectively, were used in these figures. In Figures 2 and 3 the O-C curve is displaced with respect to the maximum magnitude curve by .18 of a secondary cycle. Apparently, the O-C cycle commences approximately 10.7 days earlier than the magnitude cycle. Maximum negative O-C values (shown in Figure 2 at the .5 phase position) occurred at the .32 phase position of the magnitude cycle. Zero or positive O-C residuals are approximately near the 0.0 and 0.7 phase positions of the O-C cycle before the given displacement, but the effect (because of considerable scatter) was less clear here. The following elements for these phenomena were computed:

$$\text{Time of least O-C residual (secondary)} = \text{JD } 2438990.67 + 58\overset{d}{.}318E \quad (3)$$

$$\text{Magnitude max. (secondary)} = \text{JD } 2439001.37 + 58\overset{d}{.}318E \quad (4)$$

Although derived independently, some of the findings listed in this paper agree closely with those cited in a recent (1975) analysis by V. Pop, based on photoelectric observation of XZ Cygni.

I would like to thank Marvin E. Baldwin for the eighty-eight times of visual maxima, Horace A. Smith for his paper "The Blazhko Effect in Observations of XZ Cygni", from which many ideas and data were obtained, and Janet Akyüz Mattei for the forwarding of observational data as well as valuable advice on the preparation of certain parts of this paper.

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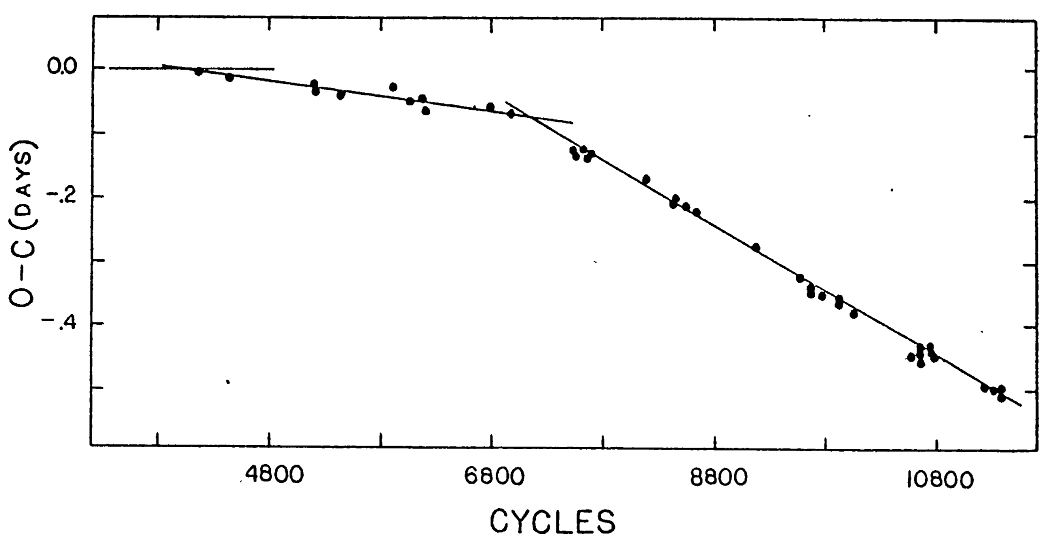

Figure 1. Deviations of selected heliocentric times of maxima from the predicted times of maxima calculated using elements listed in the 1969 General Catalog of Variable Stars.

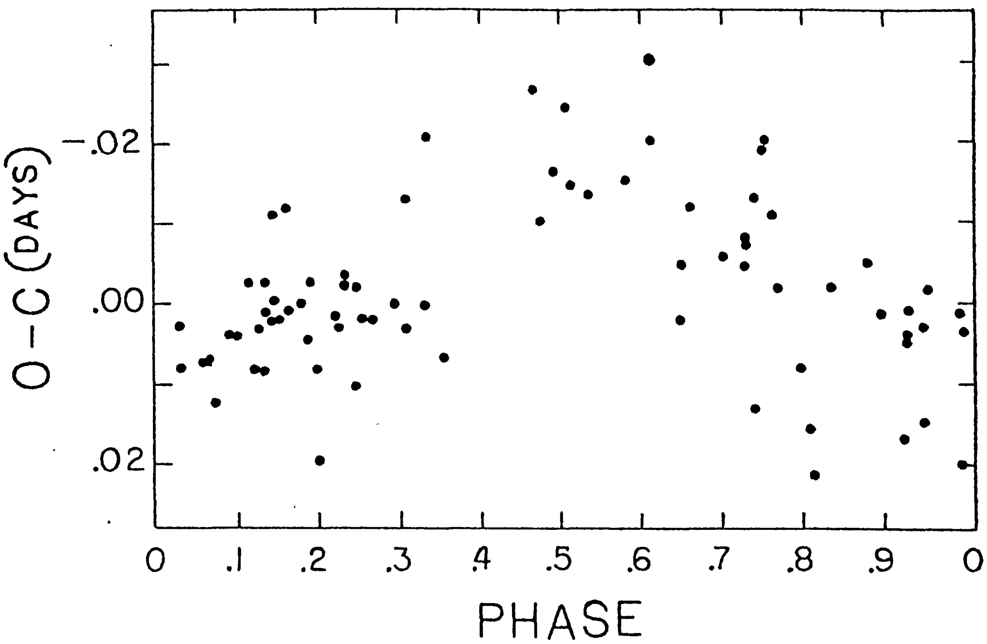

Figure 2. The relationship of primary period residuals using the new elements, with phase position in the secondary cycle of 58ᵈ.318.

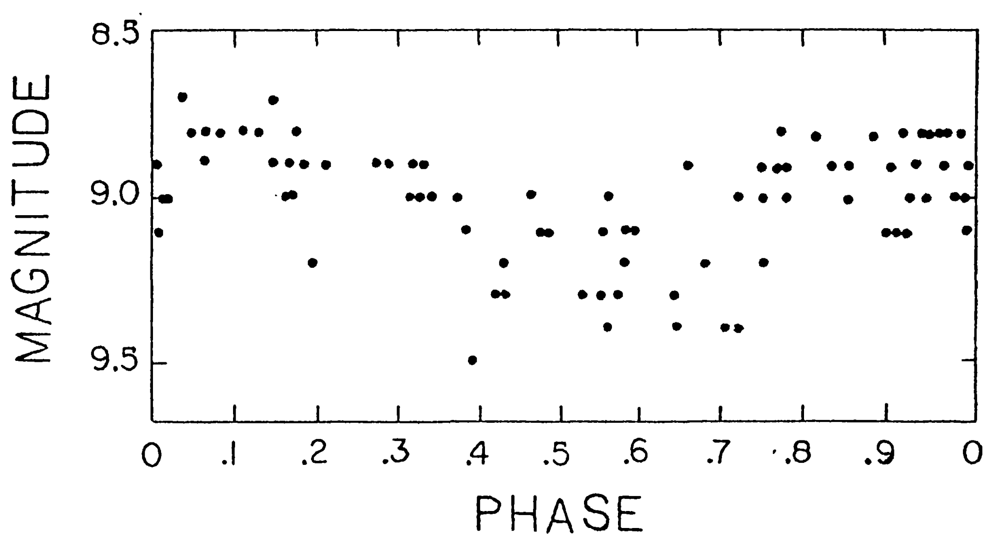

Figure 3. Maximum magnitudes are shown relative to their phase position in the 58ᵈ.318 cycle. The fainter maxima are seen to occur near .55 phase position.

TABLE I

XZ Cygni, May 1965-August 1974

Forty Selected Maxima, Magnitude 8.9 or brighter

(O-C residuals computed using GCVS Elements
JD 2436933.981 + $0^{d}.466579E$)

Max. Hel JD 2400000 + O	O-C	E
38882.875	-.006	4177
39001.843	-.016	4432
39337.777	-.019	5152
39358.761	-.031	5197
39471.662	-.042	5439
39679.760	-.038	5885
39757.662	-.055	6052
39821.588	-.050	6189
39826.689	-.081	6200
40098.712	-.074	6783
40211.615	-.083	7025
40453.731	-.121	7544
40467.720	-.130	7574
40524.647	-.125	7696
40529.767	-.138	7707
40566.628	-.137	7786
40742.495	-.170	8163
40876.368	-.205	8450
40877.309	-.197	8452
40917.426	-.206	8538
40981.326	-.227	8675
41210.370	-.274	9166
41394.623	-.319	9561
41448.734	-.331	9677
41449.666	-.333	9679
41505.649	-.339	9799
41564.414	-.363	9925
41565.350	-.360	9927
41683.368	-.387	10180
41914.728	-.450	10676
41917.543	-.434	10682
41923.602	-.441	10695
41936.649	-.458	10723
41978.643	-.456	10813
41980.514	-.452	10817
41992.629	-.468	10843
42208.618	-.505	11306
42228.676	-.510	11349
42267.858	-.520	11433
42269.729	-.516	11437

TABLE II

Least-Squares Solutions

Max. hel. J.D. 244...	New Elements $(O-C)^2$	Baldwin (1973) $(O-C)^2$	2nd Supplement $(O-C)^2$
0981.326	.000001	.000000	.000004
1210.370	.000049	.000049	.000064
1394.623	.000004	.000016	.000441
1448.734	.000004	.000016	.000576
1449.666	.000001	.000009	.000625
1505.649	.000064	.000100	.000441
1564.414	.000009	.000001	.001225
1565.350	.000000	.000004	.001024
1683.368	.000000	.000009	.001444
1914.728	.000121	.000036	.003600
1917.543	.000025	.000100	.001936
1923.602	.000000	.000025	.002500
1936.649	.000196	.000100	.004096
1978.643	.000009	.000004	.003025
1980.514	.000004	.000049	.002500
1992.629	.000121	.000036	.004096
2208.618	.000000	.000049	.003969
2228.676	.000000	.000049	.004225
2267.858	.000004	.000025	.004624
2269.729	.000009	.000100	.003969
$\Sigma (O-C)^2$	.000621	.000777	.044384

New elements Max.hel. = 2440876.368 + $0^d.466474 \cdot E$

Baldwin (1973) Max.hel. = 2440981.326 + $0^d.466471 \cdot E$

GCVS - 2nd Supplement Max.hel. = 2440445.789 + $0^d.466497 \cdot E$