A NEW PERIOD AND PERIOD CHANGES IN VZ HYDRAE

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Abstract. A new period ($P = 2^{\mathrm{d}}.9042997$) of the eclipsing binary system VZ Hydrae has been given, which is based on all the available times of minima. The period based on the photoelectric epochs has also been presented. The O–C diagram and detailed period study of VZ Hya have been presented for the first time, and the period changes have been estimated in different portions of the O–C diagram. Significant period changes do not appear to have occurred in VZ Hya, however, the O–C diagram suggests that the period of the system shows a slow tendency to increase. Period changes of 10^{-5} d (?) to 10^{-7} d have occurred around the years 1933, 1971, and 1975. All four period changes are noted in the time-interval 1918 to 1978. Upward trends appear stronger than the declining trends. Secondary minima show larger fluctuations than the primary minima. The fluctuations of the O–C values around the zero-line of VZ Hya demands notice for searching out the cause of period variations such as the presence of a third body.

1. Introduction

Double-lined spectroscopic and eclipsing binary VZ Hydrae (= BD − 5°2564 = HD 72257 = HV 5489) was discovered by O'Connell (1932). Lause (1949), Gaposchkin (1953) (cf. Popper, 1965), and many others gave the light elements. Struve (1945) and Popper (1965) presented the spectroscopic elements of the system. Wood (1946), Walker (1970), Wood (1971), Padalia and Srivastava (1975), Cester *et al.* (1978) presented the orbital elements. The nature of eclipses given by various authors are in disagreement. Two sets of photoelectric observations (Walker, 1970; Padalia and Srivastava, 1975) are available in the literature. Detailed period study of the VZ Hya has been lacking in the literature and is being presented in this communication.

2. Minima and Period Studies

O'Connell (1932), Wood (1946), Lause (1949), Gaposchkin (1953), Walker (1970), Locher (1974), Padalia and Srivastava (1975), Peter (1976, 1978) have presented the epochs of minima and or the periods of the system. These are listed in Table I.

O'Connell (1932) gave a period of $1^{\mathrm{d}}.4521499$, which was doubled by Struve (1945) from his spectroscopic observations. Wood's (1946) and Gaposchkin's (1953) periods were definitely short and showed decreasing tendency in the period of VZ Hya. If we use Walker's (1970) epoch, the period obtianed by Padalia and Srivastava was found to be also shorter than the others.

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TABLE I

Epoch and period of VZ Hydrae

S. No.	Author	Epoch and period
1	O'Connell (1932)	J.D. 2421925.8246 + $1^{d}_{.}4521499$ ($\pm$ 0.0008)($\pm$ $0^{d}_{.}0000003$)
2	Struve (1945)	J.D. 2421925.825 + $2^{d}_{.}9042998$ (adopted)
3	Wood (1946)	J.D. 2421925.825 + $2^{d}_{.}9042982$
4	Gaposchkin (1953) (cf. Popper, 1965)	J.D. 2426674.341 $2^{d}_{.}904291$
5	Walker (1970)	J.D. 2421925.825 $2^{d}_{.}9042998$
6	Srivastava (1986) (using photoelectric primary minima of Walker, and Padalia and Srivastava)	J.D. 2421925.8246 + $2^{d}_{.}9042998$ ($\pm$ $0^{d}_{.}0000001$)
7	Srivastava (1986) (using only Padalia and Srivastava's photoelectric primary minima)	J.D. 2440254.8607 + $2^{d}_{.}9042990$ ($\pm$ $0^{d}_{.}0000030$)
8	Srivastava (1986) (present work, using all minima)	J.D. 2421925.825 + $2^{d}_{.}9042997$ ($\pm$ $0^{d}_{.}0000001$)

3. New Period

We have collected 19 times of minima of VZ Hya, which are available in the literature. Out of these, five minima are photoelectric, five are photographic, three are visual, and six are based on the visual measurements. From all these minima, a new period of VZ Hya has been obtained after several trials, using the method of least squares. The new period comes out to be $2^{d}_{.}9042997 \pm 0^{d}_{.}0000001$.

The period from the three photoelectric epochs (Table II) of primary minima has also been obtained using O'Connell's (1932) epoch, and the period comes out to be $2^{d}_{.}9042998$, and is in agreement with the Walker's (1970) period.

The period based on Padalia and Srivastava's (1975) epochs of primary minima, using Walker's (1970) epoch has also been determined, and the period comes out to be $2^{d}_{.}9042990 \pm 0^{d}_{.}0000030$, which is slightly lesser than the Walker's (1970) period, but the error comes out to be large appearing in the sixth place. Thus, the new period based on all the epochs appears reasonable, as it fairly conforms to the total period change of 1.4×10^{-6} d, within error.

4. O–C Diagrams and Period Variations

All available primary and secondary minima of VZ Hya have been collected, which have been observed between 1918 and 1978, and O–C diagrams have been constructed from the O–C values calculated from the ephemeris (Wood, 1946)

$$\text{Primary Minimum} = \text{J.D. } 2421925.825 + 2^{d}_{.}9042982E\,.$$

Two O–C diagrams (Figures 1 and 2) have been constructed. In Figure 1, the O–C

TABLE II

Minima of VZ Hydrae

S. No.	J.D.$_{\odot}$	Type	Observation	Cycles	Mean of cycles	O–C	Mean of O–C values	Weighted mean of O–C values	Reference
1	2 421 925.8246	I	pg	0	0	$-0^{d}.0004$	$-0^{d}.0002$	$-0^{d}.0002$	O'Connell (1932)
2	.825	I	pg	0		0.000			Struve (1945) (adopted)
3	6 674.341	I	pg (?)	1635		− 0.012			Gaposchkin (1953)
4	7 840.437	II	pg (?)	2036.5	1904	+ 0.009	+ 0.0023	+ 0.0023	Lause (1949)
5	56.412	I	pg (?)	2042		+ 0.010			Lause (1949)
6	9 604.794	I	V	2644		+ 0.005			Wood (1946)
7	81.751	II	V	2670.5		− 0.002			Wood (1946)
8	700.634	I	V	2677	2710	+ 0.003	− 0.0002	− 0.0001	Wood (1946)
9	48.556	II	V	2693.5		+ 0.004			Wood (1946)
10	30 015.742	II	V	2785.5		− 0.011			Wood (1946)
11	34.626	I	V	2792		0.000			Wood (1946)
12	40 254.8607	I	pe	6311		+ 0.0098			Walker (1970)
13	654.201	II	pe	6448.5		+ 0.009			Padalia and Srivastava (1975)
14	86.154	II	pe	6459.5	6473	+ 0.015	+ 0.0108	+ 0.0108	Padalia and Srivastava (1975)
15	998.362	I	pe	6567		+ 0.011			Padalia and Srivastava (1975)
16	1 033.212	I	pe	6579		+ 0.009			Padalia and Srivastava (1975)
			pe						
17	2 354.668	I	v	7034	7119	+ 0.009	+ 0.0105	+ 0.0105	Locher (1974)
18	848.401	I	v	7204		+ 0.012			Peter (1976)
19	3 577.372	I	v	7455		+ 0.004			Peter (1978)

v = visual estimate; pg = photographic; V = visual measurement; pe = photoelectric; I = primary minimum; II = secondary minimum.

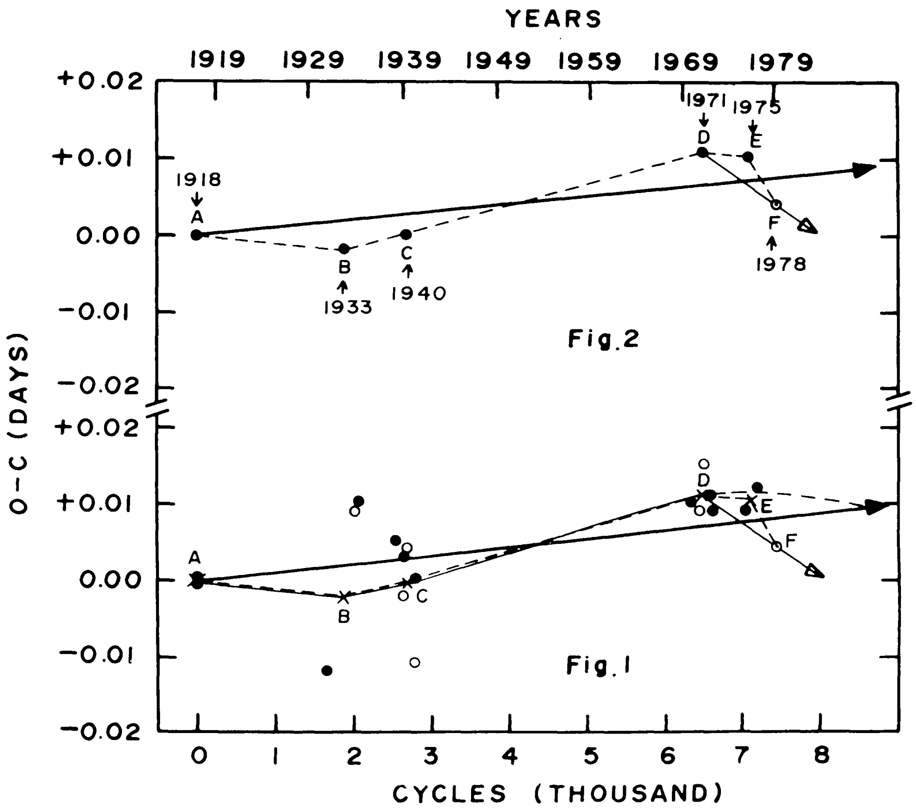

Fig. 1. O–C diagram of VZ Hya based on the individual and the mean O–C values. Filled and open circles indicate the primary and secondary minima values, respectively, while the crosses represent the mean O–C values. The thick solid line, marked by a filled arrow at one end indicate an upward tendency of the period, while the dashed lines represent the period fluctuations. The thin solid line, with an open arrow at one end, represents the incomplete changing tendency of the period. The thick solid curve indicates the suspected presence of a third body. Last point inside the circle represent the individual O–C value.

Fig. 2. O–C diagram of VZ Hya based on the weighted means of the O–C values. The solid thick line, marked by a solid arrow at one end, indicates the upward tendency of the period, while the dashed lines represent the period fluctuations. The thin solid line, with an open arrow at one end, shows the incomplete changing tendency of the period. Last point inside a circle indicates the individual O–C value.

values of all the individual points are shown. Mean O–C values at some points have also been obtained to understand the trend, and are shown by the crosses. In order to differentiate between different types of observations, arbitrary weights 1, 2, 3, and 4 are respectively, assigned to the visual estimates, the photographic, the visual measurements, and the photoelectric observations in the absence of availability of the errors and/or the quality classification of the minima. The weighted O–C values have been obtained, listed in Table II, and are plotted in Figure 2. A solid thick line with an arrow at one end in the figures indicte an upward tendency of the period, while the dashed lines indicate the period fluctuations. The thin arrow line shows the incomplete declining trend of the period. Our experience shows that O–C(s) > $0^{\mathrm{d}}.01$ are important for the period discussions. Table III shows that the O–C values hardly exceed $0^{\mathrm{d}}.01$, and,

TABLE III

Changes in period of VZ Hydrae[a]

Portion	Interval of cycles	Total change in period (days)
AB	$E = 0$ to $E = 1904$	1.21×10^{-6}
BD	$E = 1904$ to $E = 6473$	2.85×10^{-6}
DE	$E = 6473$ to $E = 7119$	4.64×10^{-7}
EF	$E = 7119$ to $E = 7455$	1.93×10^{-5} (?) (Incomplete)

[a] Results are from Figure 2.

hence, the system does not appear to have appreciable period changes. However, since Wood's (1946) period, the systematic period shows a slow upward tendency. By taking the means at some scattered points, and by taking the weighted means, we find that the epochs of period changes do not alter in both figures.

The O–C diagrams split up into four portions between points *A* to *F*. The period changes are apparent around the points *B*, *D*, and *E* falling in the years 1933, 1971, and 1975. The period changed from *A* to *B*, *D* to *E*, and *E* to *F* in one direction, and changed from point *B* to *D* in the opposite direction. There is a complete absence of minima between 1918 to 1930, and photographic minima lie in this interval (portion *AB*). Many visual measurements lie around point *C*. Because the portion *BC* conforms to the period trend *CD*, hence, the point *B* also becomes important. Although the portion *CD* is also scantily covered, but all the photoelectric minima lie at point *D*; and, hence, the point *D* is beyond doubt. Likewise the number of visual measurements lie at point *C* and, hence, the position of point *C* is not doubtful. Thus, the position *CD* is beyond question. And, since point *B* conforms to the period trend between points *C* to *D*, hence, the point *B* also becomes important, as such the portion *BD* is beyond doubt. The minima were highly scattered around points *B* and *C*, hence, their representation by their means enable them to be important. Since the visual estimates lie at points *E* and *F*, hence, their reality is doubtful. Although we are considering a period change from *B* to *D*, it is possible that it may extend up to *E*. Also, the portion *DE* gives a negligible period change and, thus it carries no importance. The largest period change of the order of 10^{-5} d occurs in the interval *EF*. This amount of the period change is doubtful on two grounds:

(a) VZ Hydrae was shown to be a simple detached system in the literature, and such period changes are too high for a simple system.

(b) All the visual observations (estimates) lie in this portion and the minima may be in errors, which are not shown.

(c) There is only a solitary (individual) observation at point *F*, and the trend appears incomplete.

The O–C values have also been determined from the newly-determined period and using the first epoch, which are listed in Table IV alongwith the mean O–C values, and are plotted in Figure 3. The following features are seen in the figure and Table IV:

(i) Up to eleventh minimum, all the mean O–C values are negative, and after eleventh minimum all the mean O–C values are positive. These indicate that the period of the system has suddenly changed (11^s yr^{-1}).

TABLE IV

O–C values from newly determined period of VZ Hydrae

Sl. No. of minima	Cycles	Mean of cycles	O–C	Mean of O–C
1	0	0	$-0^d.0004$	$-0^d.002$
2	0		0.000	
3	1635	1904	−0.014	−0.0003
4	2036.5		+0.006	
5	2042		+0.007	
6	2644	2710	+0.001	−0.0013
7	2670.5		+0.006	
8	2677		−0.001	
9	2693.5		0.000	
10	2785.5		−0.010	
11	2792		−0.004	
12	6311	6473	+0.0003	+0.0011
13	6448.5		0.000	
14	6459.5		+0.005	
15	6567		+0.001	
16	6579		−0.001	
17	7034	7119	−0.001	0.000
18	7204		+0.001	
19	7455		+0.003	

(ii) The mean O–C values are running on both sides of the zero O–C line, hence, it is expected that sinusoidal variation may be a possibility, and which may help to explain the large scatter of VZ Hya, and also difficulties in fitting the light curves.

(iii) Strong period fluctuations (smoothed dashed lines) are seen in Figure 3, which range from 5×10^{-7} d to 9×10^{-6}, the average being 3×10^{-6} d.

From these features, we infer that the period of VZ Hya shows weak period changes of the order of 10^{-6} d and 10^{-7} d. It is apparent that our results derived from Figures 1 and 2 are not considerably different to those drawn from Figure 3.

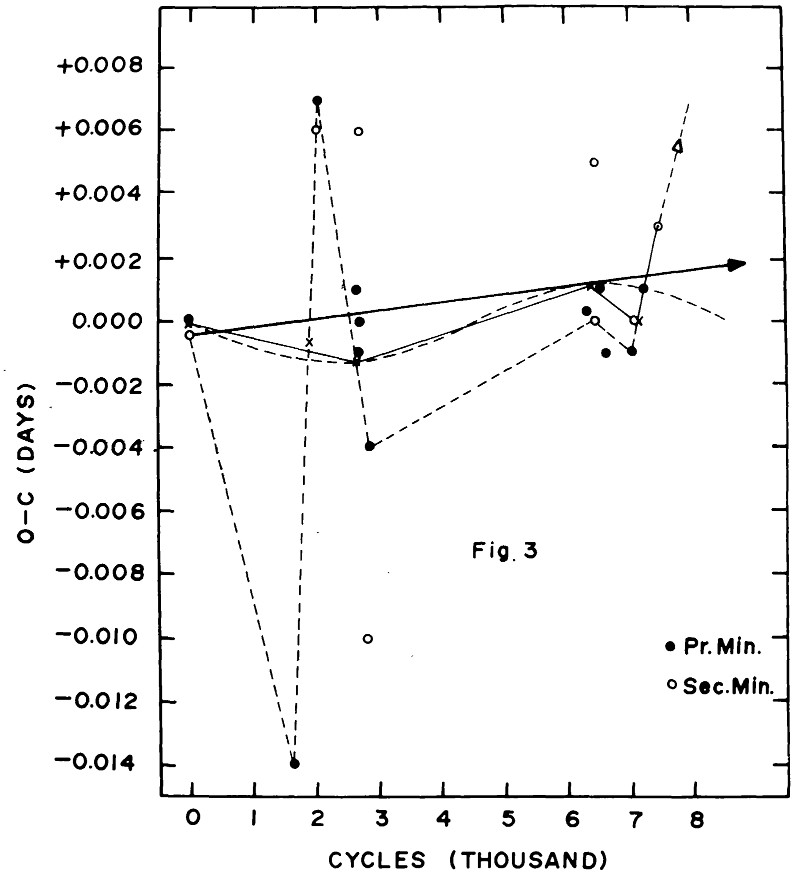

Fig. 3. O−C diagram based on the corrected period. Solid circles represent the individual O−C values, while the crosses represent the mean values. Thick solid line, marked by a filled arrow at one end, indicates the upward changing tendency of the period, while the dashed lines represent the period fluctuations. Dotted curve is indicative of the suspected presence of a third body. Last point inside a circle is the individual O−C value. The solid-dashed line, marked by an open arrow at one end, represents the incomplete period trend.

5. Presence of a Third Body

Only two photoelectric light curves by Walker (1970) and by Padalia and Srivastava (1975) are available in the literature. Padalia and Srivastava (1975) have presented *UBV* light curves, while Walker (1970) has presented only *V* light curve. From visual inspection, Padalia and Srivastava's (1975) light curves are better covered than the Walker's (1970) curve. Both photoelectric observations show large scatter, particularly in the phase of the primary. No attention has been paid to the large scatter, probably due to the faintness of the system $9^m_.1$ (max.) to $9^m_.8$ (min^{pr}). Padalia and Srivastava (1975) observed the system through the 15-inch telescope while Walker (1970) secured its observation through the 40- and 60-inch telescopes. Although, it is near to the limiting magnitude of the 15″ telescope at the time of the primary minimum, but far from the limiting magnitudes of 40- and 60-inch telescopes. These facts suggest that the consideration of the scatter present in the system is important, although it is a simple detached system.

The O–C diagram (Figure 1) shows a sinusoidal variation of the O–C values, wherein both the primary and the secondary minima lie on both sides of the thick arrow line and some of them, secondary minima particularly, which are photoelectric, lie along with the primary minima. The amplitudes of O–C along the solid thick line are nearly $\pm 0^{\mathrm{d}}.004$. All these facts apparently show the suspected presence of a third body of a nearly 68 years period, which may not be largely contributing to the O–C values due to certain unknown reasons. The point *F* does not allow us to say anything on this point, and future times of minima around 8500 cycles may throw some light in this regard.

The extent of period changes in different portions of the O–C diagram has been estimated in different intervals and are given in Table III. The portion *EF* is incomplete and, hence, doubtful. Other portions of the O–C diagram reveal period changes of the order of 10^{-7} d to 10^{-6} d, which are not significant.

It is apparent from the O–C diagram (Figure 1) that the secondary minima show larger fluctuations than the primary minima. This is true particularly for the photoelectric and the visual measurement minima. Although, the eccentricity is shown to be found, nowhere in the literature, yet it will be important to see the behaviour of the secondary minima in the future. Small sample of the minima does not allow us to express ourselves convincingly either on the suspected presence of a third body, or on the existence of the eccentricity.

6. Conclusions

The period study of the eclipsing binary system VZ Hya has been presented for the first time, which reveals that the major period changes do not appear to have occurred in the system; however, the period of the system shows an upward tendency (11^2 yr^{-1}). Sinusoidal variation of the O–C values is indicative of the suspected presence of a third body, which is yet to be confirmed. Large scatter of the secondary minima is important for future investigations. Newly determined periods of VZ Hya have been given.

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