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PERIOD VARIATION STUDY OF THE A-TYPE W UMA ECLIPSING BINARY V839 OPH

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ABSTRACT

We present an analysis of the measurements of mid-eclipse times of V839 Oph, collected from literature sources. Our analysis indicates a period increase of 3.2×10^{-7} day/yr. This period increase of V839 Oph can be interpreted in terms of mass transfer of rate $1.76 \times 10^{-7} M_{\odot}$/yr, from the less to the more massive component. The $O - C$ diagram shows a damping sine wave covering two different complete cycles of 36.73 yr and 19.93 yr with amplitudes approximately equal to 0.0080 and 0.0043 day, respectively. The third cycle has to be expected to cover about 13.5 years with lower amplitude than those of the former two cycles. These unequal duration cycles show a non periodicity which may be explained as resulting from either the presence of a tertiary component to the system or cyclic magnetic activity variations due to star spots. For the later mechanism, the obtained characteristics are consistent when applying Applegate (1992) mechanism.

Key words : binaries: close — binaries: eclipsing — stars: individual (V839 Oph) — stars: late A-class W UMa Type — period variation: magnetic activity.

1. INTRODUCTION

V839 Oph [BD+09°3584; HD 166231; GSC 1009.264; HIP 88946; $\alpha_{2000} = 18^h\, 9^m 21^s.4$, $\delta_{2000} = 9^\circ\, 9'\, 4''.3$; Sp. F8V; V_{max}=8.7; $(M_v)_{Hipp} = 3.08$] is a low temperature contact binary star system that has been discovered as a variable star by Rigollet (1947) who has given one minimum time out of 131 visual estimates. The system has been observed photoelectrically in 1958 and 1959 by Binnendijk (1960) who presented the first photoelectric yellow and blue light curves. He has recorded one secondary and two primary minima. About two years later, in 1961, Wilson & O'Toole (1965) have observed another photoelectric secondary minimum. Later on, light curves have been observed in 1982-1983 by Lafta and Grainger (1985) with the 74-inch telescope of the Kottamia Observatory station of the Helwan Observatory, Egypt. Other photoelectric light curves have been obtained by Niarchos (1989), Akalin & Derman (1997) and Pazhouhesh & Adalati (2002). Besides, many observations of minima have been collected and listed in Tables 6 and 7 of the Appendix.

The first radial velocity observations of the system have been obtained by Rucinski and Lu (1999). They have determined a spectral type of F7V and obtained the spectroscopic mass ratio $q_{sp} = 0.305$, which substantially differs from Akalin and Derman's (1997) photoelectric mass ratio of $q_{ph} = 0.40$. Pashouhesh and Edalati (2002) have observed the system photoelectrically in the B and V bands and obtained two light curves. They have used their photoelectric observations together with the spectroscopic observations by Rucinski and Lu (1999), to determine the geometric and physical elements of the system via Wilson's (2001) program. They have confirmed Rucinski and Lu's (1999) mass ratio with $M_1 = 1.64\, M_{\odot}$ and $M_2 = 0.5\, M_{\odot}$. Al-Naimiy et al. (1989) have developed a method of Fourier analysis of the light changes in the frequency-domain. They have obtained geometrical and physical elements of several eclipsing binaries and have calculated a theoretical mass ratio $q_{th} = 0.68$ with $M_1 = 1.19\, M_{\odot}$ and $M_2 = 0.81\, M_{\odot}$. They have reported that their method is suitable for analysis of detached and most of semidetached systems, while for contact binaries and β-Lyrae-type stars it has some difficulties. Akalin and Derman (1997) have used Al-Naimiy et al.'s (1989) theoretical inaccurate mass ratio and obtained a high rate of mass transfer which is more than three times our deduced value and that given by Senavci et al.'s (2006).

Binnendijk (1970) has classified the W UMa systems into two categories, A-type and W-type, according to the spectral type groups A9-F8 and F7-M5, respectively. It is obvious that there is no certain limit between the two subgroups. V839 Oph has been recognized as G0, F8V or F7V according to the HD Catalogue (1922), GCVS (1985) and Rucinski & Lu (1999), respectively. So, it is clear that the spectral type of V839 Oph lays in the critical position between the two subcategories. Binnendijk (1970), Akalin & Derman (1997) (from their light curves analysis) and Rucinski & Lu (1999) have reported that V839 Oph is of late A-type W UMa system. However, the system is not the only late A-type W UMa (Twigg 1979).

Table 1.
The ephemerides of V839 Oph found by different authors

JD.+240000	Period	Quadratic term	Periodic term	Reference
36361.73170	0.40899460	-	-	Binnendijk (1960)
40448.41290	0.40833532	-	-	Khlopov (1985)
40448.40190	0.40899634	1.73×10^{-10}	-	Wolf et al.(1996)
49536.39151	0.40900516	-	-	Akalin &Derman (1997)
49536.38555	0.40900419	1.7524×10^{-10}	-	Akalin &Derman (1997)
49536.38555	0.40900419	-	$a\,\sin(b\,E\,+\,c)^*$	Akalin &Derman (1997)
49536.39150	0.40900516	-	-	SAC (2001)
49536.38579	0.40900408	1.7524×10^{-10}	-	Senavci (2006)
51390.41230	0.40900560	-	-	Pribulla et al.(2003)
40448.41610	0.40899893	-	-	Kreiner et al. (2004)
52500.44470	0.40900491	-	-	Gazeas et al. (2006)
40448.21110	0.40900769	-	-	Present Work
40448.40230	0.40899636	1.68×10^{-10}	-	Present Work
40448.40230	0.40899636	1.68×10^{-10}	$a\,\sin(b\,E\,+\,c)^{\dagger,\ddagger}$	Present Work

* $a = 0^d.0065$, $b = 0^o.0003586$ and $c = 0.769619$. † $a = 0^d.0080$, $b = 0^o.011$ and $c = 354^o.90$ (for 1^{st} cycle). ‡ $a = 0^d.0065$, $b = 0^o.0043$ and $c = 165^o.80$ (for 2^{nd} cycle).

2. DATA AND LINE ELEMENTS

2.1 The Data

To analyze the period changes of V839 Oph, all the available photoelectric (phe), CCD, photographic (pg) and visual (vis) times of minima have been carefully collected from literature. In the present study a mean value of the observed time of minima for different filter bands, e.g., U, B and V has been considered. Due to the scatter of visual observations only 11 visual (out of 147) and one pg minima, have been used in the present study. The first (visual) minimum time that has been observed by Rigollet (1947), the discoverer, who has observed it with a good accuracy out of 131 visual estimates with weight, $w = 10$ and the other 11 visual minima ($w = 1$) have been used in order to fill the second gap shown as red dots in Fig. 1. The other visual minima have been neglected ($w = 0$). The photoelectric and CCD minima have been listed in Table 6 of the Appendix. While, all visual minima times together with the only pg minimum have been listed in Table 7 of the same Appendix. The used visual minima in the present analysis are in italic bold font while the only photographic minimum is presented as normal bold in the same Table 7.

2.2 Line Elements

Binnendijk (1960) has determined from his three observed times of minima the 1^{st} ephemeris: $Min.I\,(HJD) = 2436361.73170 + 0^d.4089946\,E$. Photoelectric light curves in U, B and V have been published by Akalin & Derman (1977) who also give, a linear ephemeris by using their last seven times of minima: $Min.I\,(HJD) = 2449536.39151 + 0^d.4089946\,E$. They have reported that due to the period variability their line elements will be valid only a few years around 1994. Due to the same reason, new line elements has been determined by using the recent published 32 photoelectric and CCD minima times:

$$JDHel.(Min.I) = 2440448.2111 + 0^d.4090079 \cdot E \quad (1)$$

However, all the line elements of the system that have been given by previous authors together with our deduced lines elements are listed in Table 1.

3. ORBITAL PERIOD VARIATION

The period variation studies of the system have been presented, for the first time, independently by Wolf et al. (1996) and Akalin & Derman (1997); later on, Senavci et al. (2006). Table 2 compares between the number of the data used in the previous three analyses studies and the present work. The linear ephemeris given by Kreiner (2004):

$$JDHel.(Min.I) = 2440448.4161 + 0^d.40899893 \cdot E, \quad (2)$$

has been used to construct the binary's $(O-C)_1$ diagram, where both the primary and the secondary minima follow the same trend. As it can be seen, from the $(O-C)_1$ diagram of Fig. 1a, that the orbital period of V839 Oph is changing as follows: There is a long-term period increase (caused by the mass transfer between the two components) and a periodic (LITE term due to

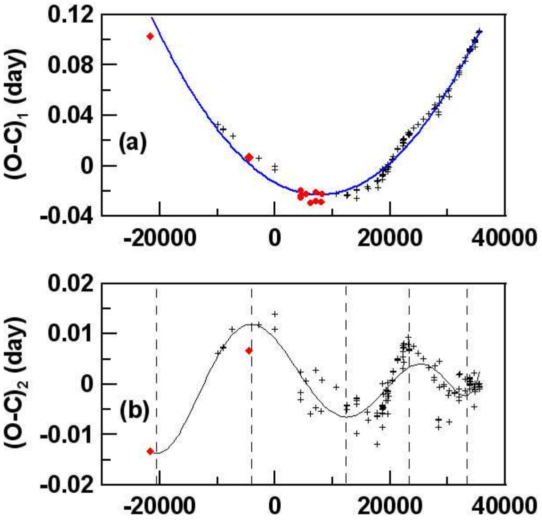

Fig. 1.— Top (a): The $(O-C)_1$ diagram of V839 Oph constructed with the line elements of Kreiner et al. (2004) $[Min.I(HJD) = 2440448.4161 + 0^d.40899893\,E]$. The solid line is its description by a quadratic fit. The crosses and dots correspond to phe&ccd and vis minima, respectively. The 1^{st} and 2^{nd} squares are the first visual and the only pg minima, respectively. The bottom panel (b) represents the residuals from the quadratic ephemerides (i.e., after subtracting the effect of mass transfer). The solid line represents the 7^{th} order polynomial fitting with $SD = 0.0034$ and $r = 0.7379$. The vertical dashed lines illustrate the durations of increasing and decreasing intervals.

the existence of a low-mass third body), or cyclic term (due to the influence of the spot activity) superimposed on the parabolic term.

The three previous orbital period variation studies by Wolf et al. (1996), Akalin & Derman (1997) and Senavci et al. (2006) have suggested and explained the $(O-C)$ variation with a sinusoidal term superimposed on a parabolic term, while the parabolic term clearly indicates that the orbital period of V839 Oph is increasing (Senavci et al. 2006). Table 3 summarizes the results they have obtained in their analysis. Also the table includes some results, for comparison, of the present work.

As it has been displayed in Fig. 1a, the general trend of the $(O-C)_1$ diagram may show a parabolic variation indicating a long-time increase in the orbital period. A second-order least-squares solution of the $(O-C)_1$ values, assuming mass transfer between the components, yields the following ephemeris:

$$\begin{aligned} JDHel.(Min.I) \quad = \quad & 2440448.4023 + 0^d.40899636 \cdot E \\ & +1.6807604 \times 10^{-8} \cdot E^2 \qquad (3) \end{aligned}$$

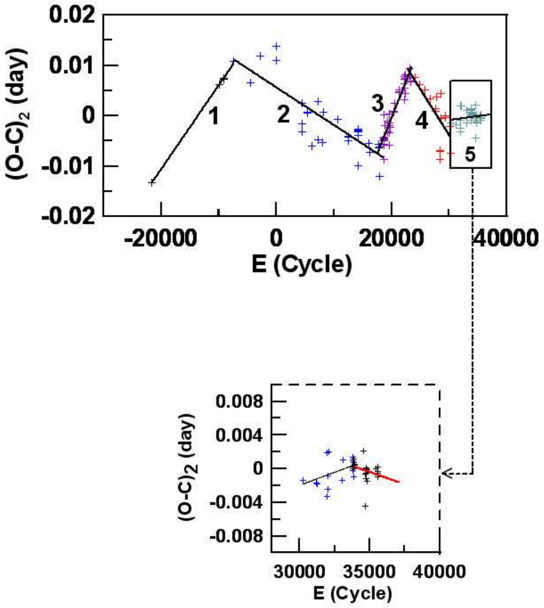

Fig. 2.— The Figure shows the $(O-C)_2$ residuals of V839 Oph from the quadratic ephemeris, after subtracting the effect of mass transfer and their description by several linear ephemerides. The window describes the real behavior of the last portion (no. 5) in the upper panel.

and a rate of increase in the period: $dP/dt = 3.24 \times 10^{-7}$ days yr^{-1} (2.8 s/century), associated with the transfer of mass ΔM from the secondary to the primary component. If the period increase is indeed caused by conservative mass transfer, then one can estimate the mass transfer between the components. Using the formula derived by Kreiner & Ziolkowski (1978):

$$\frac{\Delta P}{P} = 3 \cdot [\frac{M_2}{M_1} - 1] \times \frac{\Delta M_2}{\Delta M_1} \qquad (4)$$

and the derived masses by Pazhouhesh and Edalati (2002), $M_1 = 1.64\,\mathrm{M}_\odot$ and $M_2 = 0.5\,\mathrm{M}_\odot$, the rate of mass transfer, 1.76×10^{-7} $\mathrm{M}_\odot$ yr^{-1}, has been obtained, which is comparable to the value 1.86×10^{-7} $\mathrm{M}_\odot$ yr^{-1} of Senavci et al. (2006).

Subtracting the effect of mass transfer or lost, from the system, the $(O-C)_2$ residual plot can be obtained in Fig. 1b which shows a significant quasi-sinusoidal variation. A 7^{th} order polynomial best fit with standard deviation $SD = 0.0034$ and correlation coefficient $r = 0.7379$ is presented as solid curve in the figure. In spite of using such high degree polynomial fitting, it fits the fundamental harmonic better than the 1^{st} and 2^{nd} harmonics. Consequently, more details in studying such behavior have to be considered.

The $(O-C)_2$ residuals from the quadratic ephemeris are displayed in Fig. 2 and clearly suggest a non-continuous variation. Four obvious jumps (or more)

Table 2.
Comparison between numbers of data used in the previous and present studies

	Visual	Photog.	Phe.	CCD	Total
Wolf et al. (1996)	1	-	51	-	52
Akalin&Derman (1997)	24	$3^{\dagger}$	44	-	71
Senavci et al. (2006)	81	-	64	6	151
Present work	$11^{\ddagger}$	1	119		131

† The three minima time that have been listed in Akalin & Derman's (1997) table as pg are misprinted. They are phe minima as given in the original sources. Only one pg minimum (2438585.433) has been observed by Oburka (1965) of the BAICz, 16, 212.

‡ In the present work, a total of 11 vis (out of 147) and the only pg minima have been used to fill the 2^{nd} gap of Fig. 1.

Table 3.
Summary of previous studies and the present work

	Wolf et al. (1996)	Akalin&Derman (1997)	Senavci et al. (2006)	Present work
Parabolic behavior related				
dP/dE (d/cycle) ($\times 10^{-10}$)	3.46	3.5048	3.526	3.36
ΔM_2 ($M_{\odot}$/yr)	-	6.4×10^{-7}	1.86×10^{-7}	1.76×10^{-7}
$\Delta P/P$	8.46×10^{-10}	8.49×10^{-10}	-	8.22×10^{-10}
3^{rd}body related				
P_3 (period in yrs.)	30	19.62	16.99 ± 0.15	-
a (semi-amplit., in days)	-	0.0065	0.0075 ± 0.0003	-
e_3 (eccentricity)	-	-	0.28 ± 0.06	-
ω_3 long. preias. pass.	-	-	$29^{\circ} \pm 4^{\circ}$	-
$f(M_3)$ ($M_{\odot}$)	-	0.00376	0.0083 ± 0.001	-
M_3 ($M_{\odot}$)	-	0.077	0.378 ± 0.022	-
a_3 (semi-major axis, AU)	-	31	-	-
$a \sin i$ (projection of semi-major axis, AU)	-	-	1.34 ± 0.06	-
Magnetic activity related				
ΔJ (g cm^2 s^{-1})	-	1.9×10^{47}	3.7×10^{47}	†
$\Delta\Omega/\Omega$	-	-	9.0×10^{-4}	†
L_{RMS} ($L_{\odot}$)	-	-	0.14	†
B (kG)	-	8.21	11.1	†
P_{cycle} (yr.)	30	19.62	-	1^{st}cycle$\simeq$ 36.7 2^{nd}cycle$\simeq$ 19.9 3^{rd}cycle$\simeq 13.5^{\ddagger}$

†See Table 5, ‡expected value.

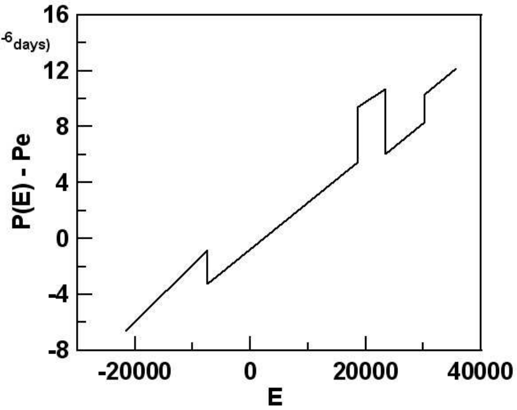

Fig. 3.— In the orbital period of V839 Oph. Several jumps in the orbital period are clearly presented.

have taken place in the period within a time interval of about 64 years between the middle of May 1945 (or $JD = 31587.7617$) and the middle of June 2009 (or $JD = 54998.4554$). Between these jumps the period is assumed to have undergone a steady increase. With the method of least squares, a linear function in each portion is used to get the best fit to the $(O-C)_2$ values:

$$(O-C)_2 = \Delta T + \Delta P \times E. \tag{5}$$

The values ΔT and ΔP in each portion are listed in Table 4. The period at any cycle E has been computed with the following equation:

$$P_{Re}(E) = P_{Eph} + \Delta P + \frac{dP}{dE} \times E, \tag{6}$$

and the results are shown in Fig. 3, where we have plotted the difference between the real period $P_{Re.}(E)$ and the ephemeris period $P_{Eph.}$ ($0^d.40899893$), in units of 10^{-6} day, as a function of time.

Another investigation to clarify such a quasi-sinusoidal behavior of the $(O-C)_2$ diagram, in order to obtain a reasonable best fit, is to divide it into separate cycles as shown in Fig. 4. The two data sets of the figure have been fitted by two 4^{th} order polynomials with $SD = 0.0027$, and $r = 0.8935$ for the 1^{st} cycle; and $SD = 0.0030$, $r = 0.7434$ for the 2^{nd} cycle. However, one has to notice that, the second cycle has a better 4^{th} order polynomial fit than that of the 7^{th} order polynomial fit of Fig. 1b. But still not fit the data well. This indeed might be due to the fact, that the data in the lower panel covers more than one duration cycle. A convenient expected behavior is to consider the 3^{rd} cycle as has been shown in Fig. 5. Such an investigation of the existence of a 3^{rd} cycle is strongly confirms the data behavior as it is shown in the window of Fig. 2.

However, highly accurate measurements of minima

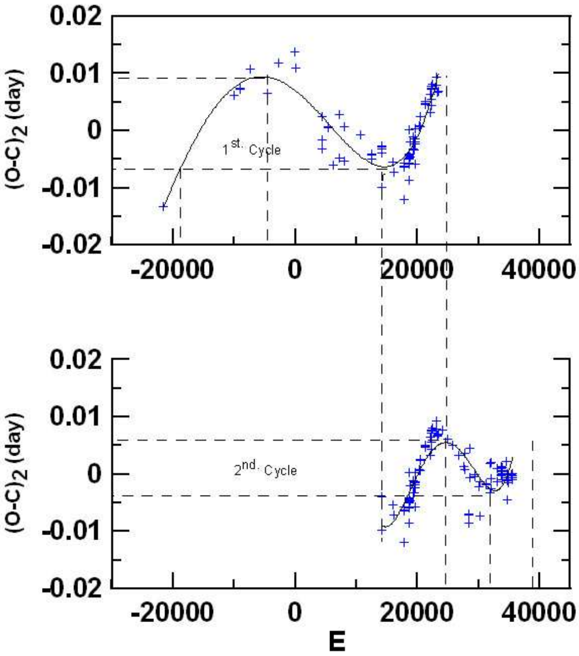

Fig. 4.— The same $(O-C)_2$ curve as in Fig. 1b, but separating the two cycles into the upper and lower panels. The solid curves in each, represents the best polynomial fit of the 4^{th} degree.

of this eclipsing binary are necessary, in the future, to cover the third cycle completely. The two first cycles are of 36.73 and 19.93 years with amplitudes $\simeq 0.0080$ and $\simeq 0.0043$ day, respectively. The duration of the other expected cycle might be of about 13.50 years with smaller amplitude than both of the former two cycles.

A more reasonable fit, to the times of minimum light, can be obtained by adding a sinusoidal term to the quadratic ephemeris to get a good fit to the observations:

$$C = T_\circ + PE + 0.5 \times (\frac{dP}{dE})E^2 + a_i \cdot \sin(b_i E + c_i)$$
$$i = 1, 2, ..., n, \tag{7}$$

where, i is the cycle number. For the first and second complete cycles (i=1 & i=2) in Fig. 5, the following two terms can be obtained: (i) for the 36.7 year cycle (1^{st} cycle): $(O-C)_2 = 0.0080 \times \sin(0^\circ.011 \cdot E + 354^\circ.9)$, (ii) for the 19.9 year cycle (2^{nd} cycle): $(O-C)_2 = 0.0043 \times \sin(0^\circ.020 \cdot E + 165^\circ.8)$.

4. CYCLIC MAGNETIC ACTIVITY VARIATION

As it is well known apsidal motion is not an acceptable explanation for such period changes for W UMa

Table 4.
The five linear fit sections, the intervals, and the rates of change of the period of V839 Oph.

	t_o to t_1	t_1 to t_2	t_2 to t_3	t_3 to t_4	t_4 to t_5
Interval (in cycles)	-21664 to -7393	-7393 to 18628	18628 to 23386	23386 to 30237	30237 to 35575
Interval (in JD:2400000+)	31587.7617 to 37424.9153	37424.9153 to 48067.4454	48067.4454 to 50013.2907	50013.2907 to 52815.37779	52815.37779 to 54998.4554
Epoch	40448.43884	40448.42158	40448.3584	40448.46685	40448.41061
Period (days)	0.4090006	0.4089982	0.4090018	0.4089971	0.4089991
SD, Stand. Div.	0.00034	0.00335	0.00173	0.00365	0.00140
r Corr. Coef.	0.9995	0.8387	0.9377	0.7253	0.1522
Res. sum of sq.($\times 10^{-4}$)	0.003476	4.0407	1.2601	2.1271	0.66686
ΔT (day)	0.0227	0.0055	-0.0577	0.0507	-0.0055
ΔP (day) $\times 10^{-6}$	1.6648411	-0.7634360	2.8589641	-1.8173647	0.1534867
$\Delta P/P$ ($\times 10^{-6}$)	4.0705102	-1.8666001	6.9901017	-4.443466	0.3752740
$\Delta P/\Delta E$ (d/cycle) ($\times 10^{-10}$)	1.1665086	-0.2933923	6.0087552	-2.652699898	0.2875359

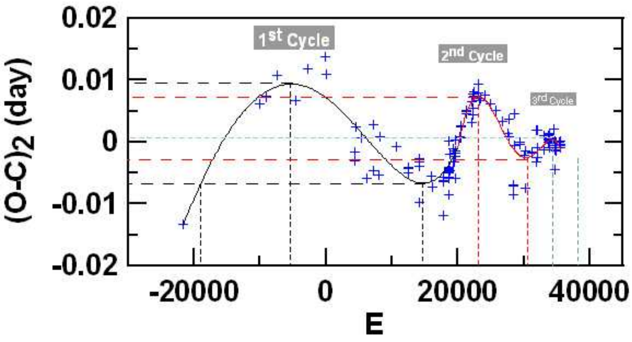

Fig. 5.— The same $(O-C)_2$ curve as in Fig. 4. The solid curves, the vertical and horizontal dashed lines represent fits of 4^{th} degree for each cycle individually, duration of each cycle and its amplitude, respectively.

type because circular orbits are believed to be the expected property in these systems where the two components are close enough for tidal interaction and/or mass transfer to rapidly damp out any eccentricity. On the other hand, explaining the orbital period modulation, for V839 Oph, to be due to LITE of a third body, as it has been explained by the previous authors, is not preferable and still questionable for the following two reasons: (i) Generally, if the third body possesses an orbit around the binary, the waveform contains the fundamental and first harmonic terms with equal durations which is not the present case (see Fig. 2). (ii) There is a discrepancy between the two solutions obtained by Akalin & Derman (1997) and Senaveci (2006) as it is shown in Table 3. However, Lanza & Rodono (1999) have pointed the difficulties confronting the assumption of the presence of a third body. They have mentioned case examples of many Algols and RS CVn systems. Many authors, e.g., Hall (1991), Simon (1996), Zavala (2002), and Hanna (2006) have studied such magnetic activity cycling affecting the $O-C$ behavior by applying the Applegate (1992) mechanism.

Many scientists (e.g., Matese & Whitmire 1983; Aplegate & Patterson 1987; Warner 1988; Applegate 1992; Lanza et al. 1998) have proposed and suggested, by several physical mechanisms, the cyclic but not strictly periodic modulation of the $O-C$ variation. In the following we are going to apply the Applegate (1992) mechanism to the W UMa binary V839 Oph.

Applegate (1992) has proposed a model which explains the period changes of alternating sign as a consequence of magnetic activity in one of the stars in binary. These orbital period modulations can be explained by the gravitational coupling of the orbit, due to the rotational oblateness, to variations in the shape of a magnetically active star in the system. By analogy to the sun, magnetic activity should be expected to produce regular, but not strictly periodic, changes in an active star, and several cycles of different durations may be present (Baliunas & Vaughan 1985; Applegate 1992). Applegate's (1992) mechanism requires the active star to be variable, and the period of luminosity variation to be the same as that of the orbital period modulation.

The present $(O-C)_2$ residual diagram for V839 Oph contains two complete cycles of 36.73 and 19.93 years and another incomplete cycle in which it is expected to be of 13.66 years. Assuming these three long periods P_1, P_2 and P_3 to be the modulation periods, P_{mod}, of the stellar magnetic activity of the convective secondary star, with semi amplitudes $O-C =$

Table 5.
Magnetic circulation elements by applying the Applegate mechanism

	1^{st}Cycle	2^{nd}Cycle	3^{rd}Cycle (expected)
$\Delta P/P$	3.7510^{-6}	3.7110^{-6}	1.6510^{-6}
$\Delta P\,$(Sec.)	0.1325	0.1312	0.0583
ΔJ $(\mathrm{g\,cm^2\,s^{-1}})$	8.7110^{46}	8.6310^{46}	3.8310^{46}
$I_{shell}\,(\mathrm{g\,cm^2})$	2.4910^{53}	2.4910^{53}	2.4910^{53}
$\Delta\Omega/\Omega$	13.1×10^{-4}	13×10^{-4}	5.8×10^{-4}
ΔE (ergs)	6.09810^{40}	5.98410^{40}	1.18210^{40}
$\Delta L_{RMS}(\mathrm{ergs\,s^{-1}})$	1.65310^{32}	2.9910^{32}	0.86210^{32}
$\Delta L_{RMS}/L$	0.037	0.067	0.019
B (kG) (the mean sub-surface field)	7.8	10.6	8.5

0.008, 0.004 and 0.001 days, respectively; and accepting the parameters given by Pazhouhesh & Edalati (2002) [$M_2 = 0.5\,\mathrm{M}_\odot$, $R_2 = 0.88\,\mathrm{R}_\odot$, $L_2 = 1.14\,\mathrm{L}_\odot$ and the orbital semi-major axis $a = 2.982\,\mathrm{R}_\odot$] one can follow the Applegate procedure (see Applegate 1992).

The observed amplitude of the period modulation of the 1^{st} cycle, $\Delta P/P = 2\pi(O-C)/P_{mod} = 3.75 \times 10^{-6}$ gives the variation of the orbital period $\Delta P = 0.13$ second. The angular momentum transfer is $\Delta J = 8.71 \times 10^{46}$ g cm^2 s^{-1}. If the mass of the shell is $M_{shell} = 0.1\,\mathrm{M}_2$, the moment of inertia of the shell is $I_{shell} = 2.49 \times 10^{53}\mathrm{g\,cm^2}$, and the variable part of the differential rotation of the active star is $\Delta\Omega/\Omega = 0.00131$. The energy budget needed to transfer the ΔJ is $\Delta E = 6.098 \times 10^{40}$ ergs. The luminosity change is $\Delta L_{RMS} = 3 \times 10^{33}$, where the angular velocity of differential rotation $\Omega_{dr} = \Delta\Omega = 0.0013\,\Omega$ has been assumed. This luminosity variation is $\Delta L_{RMS}/L = 0.037 \simeq 4\%$ of the luminosity of the active star. In addition, the mean subsurface field of 7.8 kG can be deduced. These quantities are consistent and similar to those derived by Applegate (1992) model for similar chromospherically active stars. The same calculations have been applied to the other two cycles and the results have been listed in Table 5.

5. DISCUSSIONS AND CONCLUSIONS

For V839 Oph the $(O-C)_1$ curve displayed in Fig. 1 suggests that the change of the orbital period may be continuous and that its variation is also very complex. It shows almost a sine-like variation superimposed on an upward parabola. A sine-like variation, in the $O-C$ curve, suggests either the light-time effect via the presence of a tertiary component or the magnetic activity cycling due to star spots.

By the analysis of the $(O-C)$ diagrams, Kreiner (1977) has shown that all W UMa-type contacts possesses a discontinuous variation in the orbital period with subsequent stabilization over 10^4 P_{orb}. The amplitudes of the orbital variations cannot, in most cases, be explained by the effect of a distant third body, but can be described in terms of a mass transfer process, both within the confines of the contact system and out of the system, and a process where the total angular momentum stored in the system is lost (Dryomova & Svechnikov 2006).

By the analysis of the *O-C* curve of V839 Oph, series of cycles with different durations and amplitudes are found to be superimposed on a long-term period increase with rate $dP/dt = 3.2 \times 10^{-7}$days/yr = 2.8 sec/century. A period oscillation superimposed on a secular term is usually encountered for W UMa type binary stars. Other examples are V 502 Oph (Derman & Demircan 1992), AB And (Borkovits & Hegedüs 1996), YY Eri (Kim et al. 1997), SW Lac (Pribulla et al. 1999), V566 Oph (Qian 2001), CK Boo (Qian & Liu 2000), RW Com (Qian 2002), V700 Cyg (Qian 2003), AK Her (Awadalla et al. 2004). These periodic variations are usually explained either by the light-time effect via the presence of a third body or by magnetic activity cycles in both components, because they are fast-rotating solar-type stars.

Senavci et al. (2006) have suggested an orbital period of the third body to be $\simeq 17$ years with an orbital eccentricity of $e_3 = 0.28$ and a hypothetical small third body $M_3 = 0.378\,\mathrm{M}_\odot$. Using the Hipparcos distance d of 123.61 pc, the angular separation of the third body in a coplanar orbit with the system can be calculated to be $0''.073$. Because of its extremely low angular distance and low mass indicating that it may be a white dwarf, it is difficult to find direct evidence of the supposed third body. And since the required variation of the quadrupole moment obtained is consistent and similar to those derived by Applegate (1992) model for similar chromospherically active stars. Therefore, for the late binary V839 Oph, cyclic magnetic activity for one or both component(s) may be reasonable.

On the other hand, if the third body possesses an orbit around the eclipsing binary V839 Oph, the wave form contains both fundamental and first harmonic terms with equal durations. That is to say, if the third body period of, e.g., 36.7 yr (from $E \simeq -20255$ to $E \simeq 12545$) forms the fundamental cycle we search for its 1^{st} harmonic at twice the value of the fundamental frequency. Looking at Fig. 2 or 4, one can conclude that the expected first harmonic does not behave as the fundamental. In other words, the residuals do not appear to be strictly periodic and it may be concluded that the third-body hypothesis fails to explain the observed $O-C$ curve for V839 Oph.

Regarding the magnetic activity, and assuming that only the secondary component is capable of sustaining each activity cycles, we give an estimate of the corresponding elements (Table 5).

Further precise photometric and CCD observations for minima timings with brightness determinations are needed to cover the third cycle to confirm the present solution.

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APPENDIX A. TIMES OF MINIMA

Table 6.
Photoelectric and CCD times of minima

HJD. (+2400000)	E	$(O-C)$	Type	Ref.
36361.7317	-9992	0.03291	phe	[1]
36734.73473	-9080	0.02891	phe	[1]
36735.75738	-9077.5	0.02907	phe	[1]
37424.9153	-7392.5	0.02379	phe	[2]
39313.4498	-2775	0.00573	phe	[3]
40421.422	-66	-0.00017	phe	[4]
40448.4129	0	-0.00320	phe	[4]
44815.48	10678	-0.02218	phe	[5]
45579.2837	12545	-0.02398	phe	[6]
45580.307	12548	-0.02317	phe	[6]
45581.3296	12550	-0.02307	phe	[6]
46228.5744	14133	-0.01908	phe	[7]
46229.3928	14135	-0.01868	phe	[7]
46230.4152	14137	-0.01877	phe	[7]
46231.4379	14140	-0.01857	phe	[7]
46233.4817	14145	-0.01977	phe	[7]
46270.4904	14235	-0.02547	phe	[8]
47006.4932	16035	-0.01624	phe	[9]
47062.3199	16171	-0.01790	phe	[9]
47703.4323	17739	-0.01132	phe	[10]
47717.3387	17773	-0.01088	phe	[10]
47734.3116	17814	-0.01144	phe	[10]
47736.3506	17819	-0.01743	phe	[10]
48067.4454	18629	-0.00727	phe	[11]
48069.4906	18634	-0.00706	phe	[12]
48069.4909	18634	-0.00676	phe	[12]
48072.3529	18641	-0.00775	phe	[10]
48073.372	18643	-0.01115	phe	[10]
48089.3263	18682	-0.00781	phe	[10]
48090.355	18685	-0.00161	phe	[10]
48091.3727	18687	-0.00640	phe	[10]
48092.3961	18690	-0.00550	phe	[10]
48120.4113	18758	-0.00673	phe	[11]
48129.412	18780	-0.00401	phe	[11]
48362.5423	19350	-0.00310	phe	[12]
48362.5444	19350	-0.00100	phe	[12]
48439.4353	19538	-0.00189	phe	[10]
48440.4588	19541	-0.00089	phe	[10]
48455.3877	19577	-0.00045	phe	[13]
48455.3895	19577	0.00135	phe	[13]
48456.4087	19580	-0.00195	phe	[10]
48474.4055	19624	-0.00110	phe	[14]
48480.3365	19638	-0.00059	phe	[13]
48480.337	19638	-0.00009	phe	[13]
48500.3773	19687	-0.00073	phe	[15]
48778.5023	20367	0.00499	phe	[16]
48778.5024	20367	0.00509	phe	[16]
48805.4972	20433	0.00596	phe	[15]
48829.4269	20492	0.00923	phe	[10]
48835.3565	20506	0.00834	phe	[10]
49151.313	21279	0.01317	phe	[10]
49151.5186	21279	0.01427	phe	[10]
49169.5139	21323	0.01362	phe	[17]
49169.5139	21323	0.01362	phe	[17]
49515.3267	22169	0.01782	phe	[10]
49522.4856	22186	0.01924	phe	[10]
49536.3913	22220	0.01898	phe	[10]
49556.4335	22269	0.02023	phe	[18]
49556.434	22269	0.02073	phe	[18]
49590.388	22352	0.02782	phe	[19]
49596.3117	22367	0.02103	phe	[19]
49598.3573	22372	0.02164	phe	[19]
49912.4721	23140	0.02526	phe	[20]
49919.4266	23157	0.02678	CCD	[21]
49954.3939	23242	0.02467	phe	[22]
49995.2942	23342	0.02508	phe	[22]
50013.2907	23386	0.02562	phe	[22]
50284.4612	24049	0.02983	CCD	[23]
50637.4307	24912	0.03326	CCD	[24]
50985.4927	25763	0.03717	phe	[25]
51390.406	26753	0.04153	phe	[26]
51745.4208	27621	0.04525	phe	[27]
51783.2533	27714	0.04535	phe	[27]
51787.3462	27724	0.04826	phe	[28]
52091.42968	28467	0.04107	phe	[29]
52091.43113	28467	0.04249	phe	[29]
52091.43135	28467	0.04271	phe	[29]
52143.3865	28594	0.05500	CCD	[30]
52150.3345	28611	0.05001	CCD	[30]
52444.4104	29330	0.05568	CCD	[31]
52454.43066	29355	0.05547	CCD	[31]

Table 6. — continued

HJD (+2400000)	E	$(O-C)$	Type	Ref.
52771.4088	30130	0.05944	CCD	[32]
52813.3267	30232	0.05495	CCD	[32]
52815.37779	30237	0.06104	CCD+C	[31]
53207.4103	31196	0.06808	phe	[33]
53223.3614	31235	0.06822	CCD+R	[31]
53512.533	31942	0.07758	phe	[34]
53520.5035	31961	0.07260	phe	[35]
53533.3896	31993	0.07523	phe	[36]
53538.5006	32005	0.07375	phe	[34]
53569.38508	32081	0.07881	CCD+R	[31]
53959.37013	33034	0.08338	CCD+R	[31]
53983.2994	33093	0.08621	CCD	[37]
54262.446	33775	0.09104	CCD	[38]
54263.4695	33778	0.09204	CCD	[38]
54268.378	33790	0.09255	CCD	[38]
54269.3989	33792	0.09096	CCD	[38]
54287.3945	33836	0.09060	CCD	[38]
54288.4192	33839	0.09281	CCD	[38]
54299.4619	33866	0.09254	CCD	[38]
54300.4837	33868	0.09184	CCD	[38]
54300.48391	33868	0.09205	CCD+I	[31]
54315.4129	33905	0.09258	CCD	[38]
54316.4355	33907	0.09268	CCD	[38]
54576.5661	34543	0.09996	phe	[39]
54625.4398	34663	0.09829	phe	[39]
54628.5035	34670	0.09450	phe	[39]
54654.4801	34734	0.09966	CCD	[38]
54655.5019	34736	0.09897	CCD	[38]
54655.5025	34736	0.09957	phe	[39]
54666.3412	34763	0.09980	CCD	[38]
54667.3625	34765	0.09860	CCD	[38]
54685.3586	34809	0.09875	CCD	[38]
54686.3825	34812	0.10015	CCD	[38]
54938.536	35428	0.10581	CCD	[40]
54985.3669	35543	0.10633	CCD	[38]
54993.3433	35562	0.10725	CCD	[41]
54997.4323	35572	0.10626	CCD	[38]
54998.4554	35575	0.10686	CCD	[38]

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Table 7.
Visual and photographic times of minima

HJD (+2400000)	E	$(O-C)_1$	Ref.
31587.7617	-21664.5	0.10292	[1]
38585.433	-4555	0.00703	[2]
40344.525	-254	-0.00537	*
40353.520	-232	-0.00835	*
40354.550	-229.5	-0.00085	*
40731.438	692	-0.00536	*
40753.513	746	-0.01630	*
42241.444	4384	-0.02341	[3]
42251.463	4408.5	-0.02488	[3]
42267.406	4447.5	-0.03284	[4]
42267.706	4448	0.06266	*
42272.548	4460	-0.00333	[4]
42275.395	4467	-0.01932	[4]
42620.383	5310.5	-0.02192	[5]
42621.396	5313	-0.03142	[5]
42633.471	5342.5	-0.02188	[5]
42990.520	6215.5	-0.02895	[6]
43369.466	7142	-0.02046	[7]
43370.481	7144.5	-0.02796	[7]
43717.506	7993	-0.03855	[8]
43749.418	8071	-0.02846	[8]
43756.363	8088	-0.03645	[9]
43765.375	8110	-0.02242	[9]
44059.429	8829	-0.03865	[10]
44486.428	9873	-0.03454	[11]
45107.503	11391.5	-0.02441	[12]
45115.475	11411	-0.02789	[12]
45204.421	11628.5	-0.03916	[12]
45558.424	12494	-0.02473	[13]
45925.435	13391.5	-0.09027	[14]
45932.434	13408.5	-0.04425	[14]
45933.459	13411	-0.04175	[14]
46143.497	13924.5	-0.02470	[15]
46216.510	14103	-0.01801	[16]
46216.512	14103	-0.01601	[16]
46217.536	14105.5	-0.01451	[16]
46218.549	14108	-0.02400	[16]
46253.513	14193.5	-0.02941	[16]
46259.452	14208	-0.02090	[15]
46286.456	14274	-0.01083	[16]
46613.461	15073.5	-0.00047	[17]
46615.499	15078.5	-0.00747	[17]
46623.470	15098	-0.01195	[18]
46623.472	15098	-0.00995	[18]
46643.493	15147	-0.02989	[17]
46659.442	15186	-0.03185	[17]
46667.424	15205.5	-0.02533	[17]
46677.451	15230	-0.01880	[17]
46684.404	15247	-0.01879	[17]
46957.410	15914.5	-0.01957	[19]
46958.438	15917	-0.01407	[19]
46960.291	15921.5	-0.00156	[19]
46960.471	15922	-0.02606	[19]
46997.495	16012.5	-0.01647	[20]

Table 7. — continued

HJD (+2400000)	E	$(O-C)$	Ref.
46997.501	16012.5	-0.01047	[20]
46997.502	16012.5	-0.00947	[20]
47002.615	16025	-0.00895	[20]
47003.623	16027.5	-0.02345	[20]
47006.483	16034.5	-0.02644	[20]
47006.484	16034.5	-0.02544	[20]
47290.547	16729	-0.01220	[20]
47662.534	17638.5	-0.00973	[21]
47670.492	17658	-0.02721	[21]
47724.495	17790	-0.01206	[21]
48088.504	18680	-0.01211	[22]
48095.465	18697	-0.00409	[22]
48108.550	18729	-0.00706	[23]
48120.411	18758	-0.00703	[22]
48122.449	18763	-0.01402	[22]
48122.454	18763	-0.00902	[22]
48467.456	19606.5	0.00238	[22]
48476.464	19628.5	0.01240	[22]
48476.467	19628.5	0.01540	[22]
48477.474	19631	-0.00009	[22]
48832.497	20499	0.01183	[22]
49193.431	21381.5	0.00428	[22]
49211.433	21425.5	0.01033	[22]
49212.451	21428	0.00583	[22]
49486.518	22098	0.04355	[24]
49536.393	22220	0.02068	[24]
49539.464	22227.5	0.02418	[24]
49549.478	22252	0.01771	[22]
49576.480	22318	0.02578	[24]
49600.399	22376.5	0.01834	[24]
49612.266	22405.5	0.02437	[24]
49624.325	22435	0.01791	[24]
49783.632	22824.5	0.01982	[24]
49830.469	22939	0.02645	[24]
49840.486	22963.5	0.02297	[24]
49842.531	22968.5	0.02298	[24]
49843.549	22971	0.01848	[24]
49853.572	22995.5	0.02101	[24]
49866.457	23027	0.02254	[24]
49872.382	23041.5	0.01705	[24]
49889.563	23083.5	0.02010	[24]
49895.506	23098	0.03262	[25]
49896.520	23100.5	0.02412	[24]
49897.544	23103	0.02562	[24]
49898.369	23105	0.03262	[24]
49898.561	23105.5	0.02012	[24]
49899.389	23107.5	0.03012	[24]
49900.404	23110	0.02263	[24]
49906.540	23125	0.02364	[24]
49907.560	23127.5	0.02115	[24]
49909.409	23132	0.02965	[24]
49915.542	23147	0.02767	[24]
49918.411	23154	0.03368	[24]
49920.451	23159	0.02868	[24]
49923.515	23166.5	0.02519	[24]
49924.538	23169	0.02569	[24]
49925.359	23171	0.02869	[24]
49925.569	23171.5	0.03419	[24]
49932.522	23188.5	0.03421	[24]
49934.356	23193	0.02772	[24]
49935.375	23195.5	0.02422	[24]
49936.400	23198	0.02672	[24]
49939.463	23205.5	0.02223	[24]
49941.505	23210.5	0.01924	[24]
49942.528	23213	0.01974	[24]
49948.455	23227.5	0.01625	[24]
49953.361	23239.5	0.01427	[24]
49962.351	23261.5	0.00629	[26]
49977.297	23298	0.02383	[24]
49978.322	23300.5	0.02633	[24]
49989.354	23327.5	0.01536	[26]
49990.374	23330	0.01286	[26]
49995.296	23342	0.02688	[24]
50002.247	23359	0.02489	[24]
50013.290	23386	0.02492	[24]
50180.569	23795	0.02336	[24]
50181.591	23797.5	0.02286	[24]
50189.564	23817	0.02038	[24]
50191.613	23822	0.02439	[24]
50195.501	23831.5	0.02690	[24]
50197.541	23836.5	0.02191	[24]
50242.536	23946.5	0.02702	[24]
50243.555	23949	0.02353	[24]
50244.377	23951	0.02753	[24]
50245.4000	23953.5	0.02803	[24]
50246.4210	23956	0.02653	[24]
50248.4690	23961	0.02954	[24]
50249.4880	23963.5	0.02604	[24]
52054.42856	28376.5	0.05432	[27]
52437.47070	29313	0.06897	[27]
52490.43928	29442.5	0.07218	[27]
52490.43997	29442.5	0.07287	[27]
52492.48362	29447.5	0.07153	[27]
53235.39890	31264	0.04025	[27]

* Are six visual minima times listed in the "Crakow Eclipsing Binaries Minima Database" but not presented in their mentioned sources.

Ref.: [1] Rigollet, A. (1960): Astronomy 61, 54, [2] Oburka, O. (1965): BAICz 16, 212, [3] BBSAG Bull. 16, [4] BBSAG Bull. 17, [5] BBSAG Bull. 23, [6] BBSAG Bull. 29, [7] GEOS EB 13, [8] Braune, E. and Hubscher, M. (1981): AN 302, 53, [9] BBSAG Bull. 39, [10] BBSAG Bull. 44, [11] BAV-M 32, [12] BRNO 26, [13] BAV-M 38, [14] BAAVSS 61, [15] BBSAG Bull. 77, [16] BAAVSS 64, [17] BAAVSS 67, [18] BRNO 28, [19] BAAVSS 70, [20] BRNO 30, [21] BAV-M 56, [22] BRNO 31, [23] BBSAG Bull. 96, [24] OEJV (2007), [25] BAV-M 113, [26] BBSAG Bull. 113, [27] B.R.N.O. Contr., 34.