Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi
Dokuz Eylul University Faculty of Engineering Journal of Science and Engineering

Basılı/Printed ISSN: 1302-9304. Elektronik/Online ISSN: 2547-958X

Orbital Period Changes of Contact Binaries: HT Vir and V1073 Cyg

Değen Çiftlerin Yörünge Dönem Değişimleri: HT Vir ve V1073 Cyg

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Geliş Tarihi / Received: 08.04.2019
Kabul Tarihi / Accepted: 04.11.2019
Araştırma Makalesi/Research Article
DOI: 10.21205/deufmd.2020226429

Atıf şekli/ How to cite: YILDIRIM, M.F., SOYGUDAN, F. (2020). Orbital Period Changes of Contact Binaries: HT Vir and V1073 Cyg. DEUFMD 22(64), 301-307.

Abstract

In this study, we investigated changes in the orbital period of two eclipsing contact binaries HT Vir and V1073 Cyg using all published times of minima. From the analysis of *O-C* residuals, it was found that HT Vir indicates orbital period increase, whereas the period of V1073 Cyg is decreasing. The changing rates of their periods have been determined to be 1.33 and -0.43 s/century for HT Vir and V1073 Cyg, respectively. In the distribution of *O-C* graph for HT Vir and V1073 Cyg, periodic variations also exist. Periodic changes were explained as being the result of a hypothetical third companion around the eclipsing pair.
Keywords: *Stars: eclipsing binaries; close binaries; stars: individual: HT Vir, V1073 Cyg*

Öz

Bu çalışmada, iki örten değen çift yıldız HT Vir ve V1073 Cyg sistemlerinin yayınlanmış minimum zamanları kullanarak yörünge dönem değişimlerini inceledik. Sistemlerin *O-C* analizleri sonucunda, HT Vir sisteminin döneminin arttığı, buna karşın V1073 Cyg sisteminin döneminin azaldığı bulundu. Dönem değişim oranları HT Vir ve V1073 Cyg için sırasıyla 1.33 s/yüzyıl ve -0.43 s/yüzyıl olarak belirlenmiştir. Aynı zamanda her iki sistem için elde edilen *O-C* grafiklerinde periyodik değişim de görülmektedir. Periyodik değişim, çiftin etrafında olası görülmeyen üçüncü bir bileşenin ile açıklanmıştır.
Anahtar Kelimeler: *Yıldızlar: örten çift yıldızlar, yakın çift yıldızlar, yıldızlar: HT Vir, V1073 Cyg*

1. Introduction

The evolution and structure of close eclipsing binary systems is one of the major problems that cannot be solved in stellar astrophysics. Orbital period analysis studies provide us to get clues for the dynamical evolution of close binaries. Orbital period analysis for contact binaries were performed by many authors (e.g [10-11-14-20]). Contact binaries (CBs) are essential objects to investigate the evolution of binary stars. These systems indicate light variations at the all phases of the orbital period due to the proximity effects. The orbital periods of some of contact binaries show changes resulted from several reasons such as additional components around the binaries, mass transfer and loss, magnetic cycles of cool components. In this study, the changes in the periods of two contact binaries (HT Vir and V1073 Cyg) have been investigated and the sources of these variations have been discussed. The main parameters taken from the literature for the systems studied are given in Table 1.

Table 1. Basic information of target sysetems taken from literature.

System	HT Vir	V1073 Cyg
Spectral Type	F8V[6]	F0V[18]
Period(day)	0.407673[8]	0.785854[8]
T_0(HJD)	2428760.6647[8]	2438672.571[8]
M_1-M_2($M_\odot$)	1.05[21]-1.28[21]	1.81[18]-0.55[18]
R_1-R_2($R_\odot$)	1.10[21]-1.22[21]	2.54[18]-1.48[18]
a($R_\odot$)	3.10[17]	5.17[18]
References	[6,8,17,21]	[8,18]

The HT Vir (PPM 160035, HIP 67186) was determined as ADS 9019 in Atikens catalogue [1] and was found to be visual binary by Wilhelm Struve. Spectral measurements were performed by [6] and found that the system is a quadruple, which consists of SB1 type binary (HT Vir A) and SB2 type contact system (HT Vir B). In the same study, the period of the system was determined to be 0.407670 days. Light curves were obtained in *BVR* filters and analysed [21]. Recent analysis of radial velocity values of the system's components was presented by [4]. The orbital period analysis was carried out by [5] and they reported an increase for the period of the target.

V1073 Cyg (HIP 105739, TYC 2707-173-1) was first described by[15], and later photographic light curriculum was reported by [16]. Many authors presented both photometric and spectroscopic studies for the system (e.g. [2-13-19]). Radial velocity curve and its analysis were presented by [9] and they reported that period and mass ratio (q) for the system are P=0.7858506 and q=0.303, respectively. Recently, light curve solutions of V1073 Cyg was carried out by [18]. Analysis of the variations in the period of the eclipsing pair was studied out by several authors (e.g. [7-13-19]). Recently, orbital period analysis of V1073 Cyg was carried out by [18] and it was reported that the orbital period of V1073 Cyg have declined with the rate of -1.04×10^{-10} days/cycle.

2. Material and Method

For orbital period analysis of two targets, we preferred the O-C (observed minus calculated minima times) analysis. If there is a change in the O-C data versus time other than linear change, we can say that the period of eclipsing pair is varying. In this study, for distributions of O-C residuals of the studied targets, the following equation was used to calculate minima times:

$$Min\,I = T_o + E.P + Q.E^2 + \Delta t \quad (1)$$

In this equation, T_0 and P are initial time of primary minima and period of the binary, respectively. E is the number of epoch, Q is the coefficient of the parabolic term and Δt is the delay in time resulted from a third companion around the close pairs [3].

$$\Delta t = \frac{a_{12}\sin i'}{c}\left\{\frac{1-e'^2}{1+e'\cos v'}\sin(v'+w') + e'\cos w'\right\} \quad (2)$$

where a_{12}, i', e', v' and w' are the semi-major axis, inclination, eccentricity, true anomaly of the position of the binary system's mass center of orbit and the longitude of the periastron of the orbit of the eclipsing binary around the third component, respectively.
The following equation is used to describe the change in time in unit time:

$$\frac{\Delta P}{P} = \frac{2Q}{P} \quad (3)$$

If the mass transfer is conserved, using the third law of Kepler, a correlation between the period change (ΔP) and the amount of mass transferred ($\dot{m}_1$) can be obtained as follows [12]:

$$\frac{\Delta P}{P} = \frac{3\dot{m}_1(m_1 - m_2)}{m_1 m_2} = 3\frac{1-q^2}{qM}\dot{m}_1 \quad (4)$$

where the masses of the components m_1 and m_2, M represents the total mass of the system and the mass ratios of the components q (= m_2 / m_1).

We have collected all published minima times from literature for the application of *O-C* analysis.

3. Results and Conclusion

For HT Vir, we have collected all published eclipse times from the public archive of *O-C* gateway [8]. *O-C* analysis of HT Vir was performed with a total of 102 minima times collected with 11 pe. and 91 CCD from the literature. Different weights were used for the vis, pg, pe and CCD data (5 for pe. and 10 for CCD). Both parabolic and cycle variations can be noted in the diagram of *O-C* residuals for HT Vir. Therefore, we used Eq. 1 which includes the terms of parabolic and light-time effect (Δt) to represent the minima times. The resulted parameters from the analysis of *O-C* data were listed in Table 2. Using the quadratic term (Q), we have calculated the increasing rate of the orbital period to be 1.33 s century^{-1}. The mass transfer between components was calculated as 7.3×10^{-7} $M_\odot$ yr^{-1} using equation 4 for HT Vir. The *O-C* data, its theoretical representation and the residuals from the calculated fit are indicated in Fig. 1-2.

In this paper, for V1073 Cyg we have collected all published eclipse times from *O-C* gateway [8]. *O-C* analysis of V1073 Cyg was performed with a total of 264 minima times collected from the literature with 10 vis., 158 pg., 36 pe. and 60 CCD. Different weights were used for the vis, pg, pe and CCD data (1 for vis., 3 for pg., 5 for pe. and 10 for CCD). The *O-C* distribution of V1073 Cyg shows both parabolic and cycle variations. So, we used Eq. 1 to represent variations in the *O-C* residuals. From the analysis, we have found the parameters listed in Table 2. Using the quadratic term (Q), we have calculated the decreasing rate of the orbital period to be -0.43 s century^{-1}. The mass transfer between components was calculated as -1.7×10^{-8} $M_\odot$ yr^{-1} using equation 4 for V1073 Cyg. The *O-C* data, its representation and the residuals from the theoretical curves are indicated in Fig. 3-4.

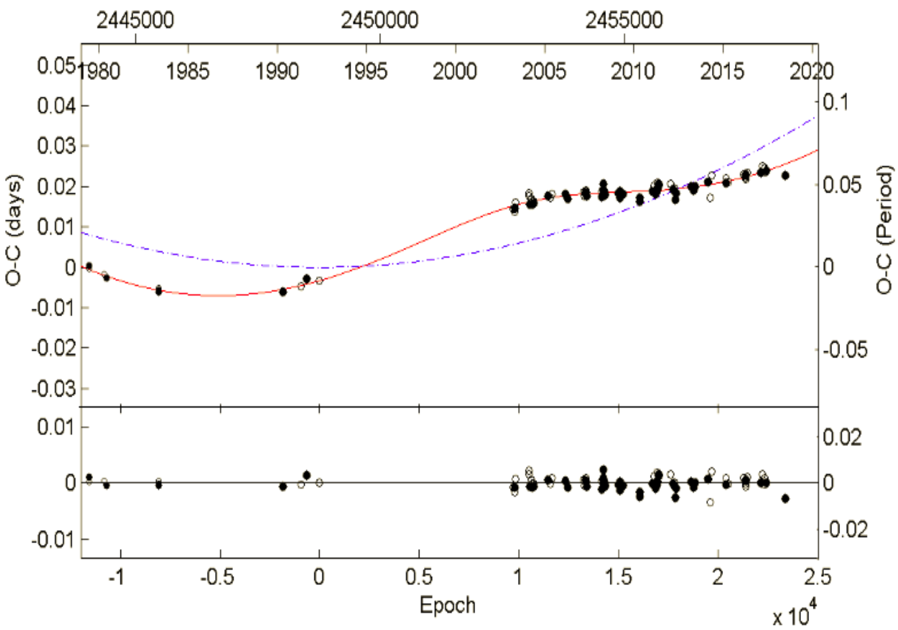

Figure 1. *O-C* distribution of HT Vir. Parabolic (dashed blue line) and parabolic together with periodic representation (continuous red line) of O-C data can be also seen in upper panel. Residuals from the best fit are presented in bottom panel.

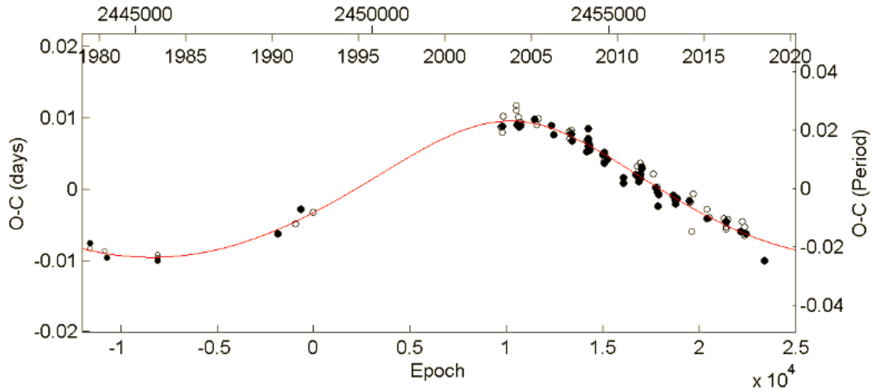

Figure 2. *O-C* diagram HT Vir and its LITE representation after subtraction of parabola.

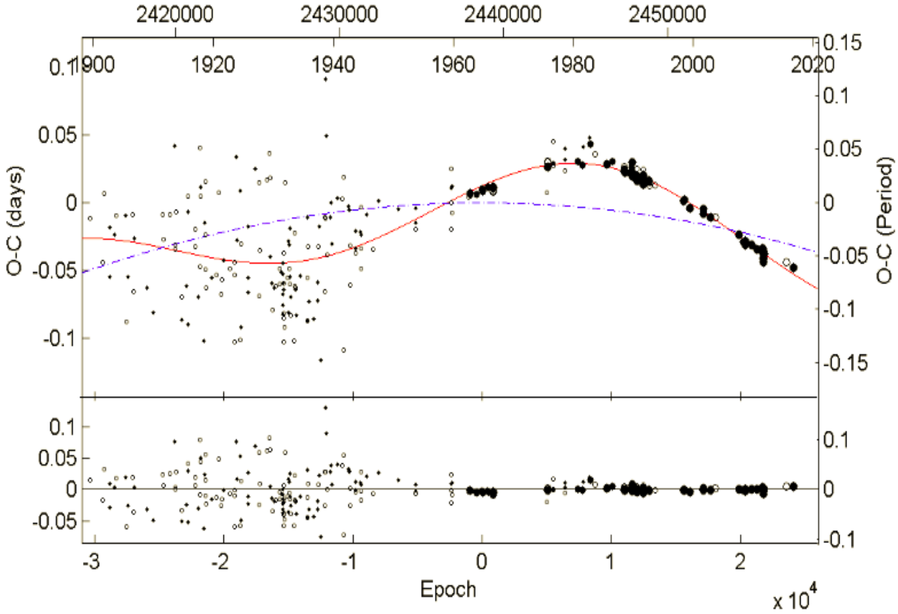

Figure 3. As seen in Fig. 1 but for V1073 Cyg.

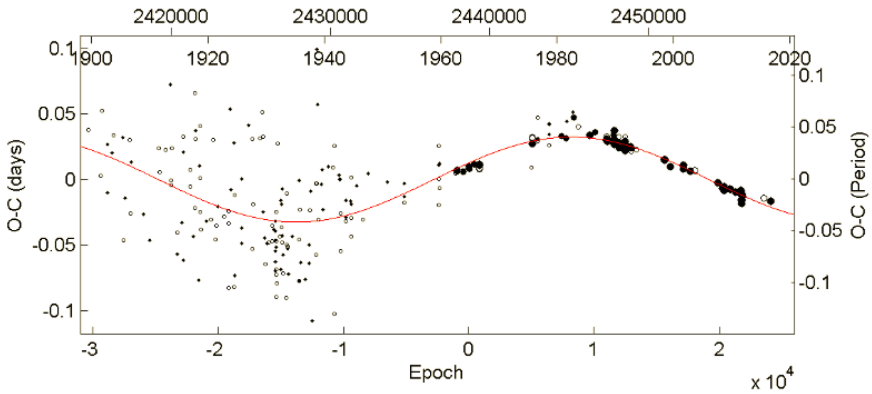

Figure 4. Distribution of *O-C* data for V1073 Cyg and its LITE representation after removing parabolic change.

In this work, variations in their periods of two selected early contact binary stars, HT Vir and V1073 Cyg were investigated. Table 1 shows the T_o and P values of the systems from the literature. Table 2 shows the values obtained from the *O-C* analysis. The orbital period change of HT Vir and V1073 Cyg were analyzed using by all times of minima.

O-C analysis was performed with 102 eclipsing times collected from the literature for HT Vir. In the O-C diagram of the close binary, both upward parabolic and cycle variations can be seen. Orbital period increase rate of the system was found as 1.5×10^{-7} days yr^{-1}. Increase in the period of the target can be interpreted by mass transfer in the system and the transfer rate was calculated to be approximately 7.3×10^{-7} $M_\odot$ yr^{-1}. We have found a period of 40.8 years for cyclic changes, although the period for these type variations of the system is estimated to be 30.5 years by [5]. Two ways to explain cyclic change are preferred. One way is by using light time effect (LITE) and the other way is via Applegate mechanism. For HT Vir, it was suggested that it is a quadruple system using the spectral data analysis and listed the parameters of the components [6]. So, we interpreted cyclic variations in the period by using the LITE resulted from a hypothetical unseen body around the pair and the minimum mass value for the third companion was calculated to be 0.4 $M_\odot$. *O-C* analysis of HT Vir showed only one cyclic change. Therefore, the fourth body was not discussed in this study.

O-C analysis of V1073 Cyg was performed with 264 minima times collected from the literature. It was found that V1073 Cyg indicates orbital period decline and this decrease rate was found to be $dP/dt = -5.0\times10^{-8}$ days yr^{-1}. For V1073 Cyg, decrease in the period can be interpreted by mass transfer between the components (from more massive to less massive one) with a rate of -1.7×10^{-8} $M_\odot$ yr^{-1}. The period of cyclic changes for the system was found to be $P_3 = 94.5\pm9.5$ years, whereas it is found to be $P_3=82.7\pm3.6$ years by [18]. Magnetic activity explanation for the cyclic changes may not be used since the modulation period is quite long for the suggested periods for the magnetic cycles. Therefore, in this study, it is focused on the existence of a possible unseen companion in the system. For V1073 Cyg, the minimum mass of the probable unseen body was calculated to be 0.5 $M_\odot$.

Table 2. Resulted parameters from *O-C* analysis.

System	HT Vir	V1073 Cyg
T_0 (HJD+2400000)	48760.6656 (5)	38672.5732 (8)
P_{orb} (day)	0.407671332 (4)	0.785855532 (5)
Q (day)	8.53 (3)×10^{-11}	-5.38 (2) ×10^{-11}
dP/dt (s/century)	1.33	-0.43
dM/dt ($M_\odot$/year)	7.3×10^{-7}	-1.7×10^{-8}
a_{12} sin i (AB)	2.27 (23)	5.61 (28)
e	0.0	0.0
ω (deg)	90	90
T' (HJD+2400000)	51377 (286)	36707 (592)
P_{12} (year)	40.8 (6.4)	94.5 (9.5)
f(m$_3$) ($M_\odot$)	0.0071 (5)	0.0198 (8)
m_3 ($M_\odot$) for i=90 deg.	0.4	0.5

Acknowledgment

The authors thank the anonymous referees for the substantial suggestions and comments that enabled us to improve the manuscript. This work was supported by the Scientific Research Fund of Çanakkale Onsekiz Mart University, Turkey (Project number: FDK-2018-2458). The study is a part of the PhD thesis of Muhammed Faruk Yildirim. In this research, VIZIER and SIMBAD databases at CDS (Strasbourg, France) were used.

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