ASEAN Journal of Scientific and Technological Reports

Research article

A Period Change Study of the Contact Binary System YY Eri

Warisa Pancharoen[1] and Wiraporn Maithong[2*]

[1] Faculty of Science and Technology, Phetchaburi Rajabhat University, Phetchaburi, 76000, Thailand; warisa.pan@mail.pbru.ac.th
[2] Faculty of Science and Technology, Chiang Mai Rajabhat University, Chiang Mai, 50300, Thailand; wiraporn_mai@cmru.ac.th
* Correspondence: wiraporn_mai@cmru.ac.th

Abstract: The W UMa type of the eclipsing binary system YY Eri was observed by using a 0.7-meter telescope with a CCD photometric system in *B*, *V*, and *R* filters at the Regional Observatory for the Public, Chachoengsao, Thailand, on 5 December 2018, from 12:30 PM to 10:00 PM, UT. The obtained data were calculated using the photometry method to construct the light curve of each wavelength band and determine the minimum time. HJD 2458458.306 and HJD 2458458.144 are the minimum time of the primary and secondary eclipse, respectively. The data were used to plot the *O-C* curve. The upward parabolic curve means the period increases at the rate of 4.57×10^{-3} seconds/year. The sinusoidal curve suggests that YY Eri might have a third body which is located at a distance of about 3.45 AU from the center of mass with an orbital period of 68.6 years.

Keywords: YY Eri; Period Change; Third body

Citation:
Pancharoen, W.; Maithong, W. A Period Change Study of the Contact Binary System YY Eri. *ASEAN J. Sci. Tech. Report.* **2022**, *25*(3), 45-50. https://doi.org/10.55164/ajstr.v25i3.246953.

Article history:
Received: June 27, 2022
Revised: September 21, 2022
Accepted: September 21, 2022
Available online: September 29, 2022

1. Introduction

Most stars in our sky are binary or multiple star systems. They are the system of the stars with one center of mass. Eclipsing binaries are one binary star whose orbital plane is inclined to the observer. Therefore, we can see the eclipse when one star moves in front of the other. They showed the difference in the brightness of the stars[1]. YY Eri is a contact binary system, which is defined to be a W UMa subtype. The spectral type of both components is about G5[2], with a magnitude of 8.4 and a period of 0.32149510 days [3]. The radial velocity of YY Eri is -15 kms^{-1}[4]. The value of masses M_h =0.567 $M_\odot$ and M_c =0.967 $M_\odot$ [5]. When M_h is the mass of a hotter star and M_c is the mass of a cooler star.

The W UMa variable had nearly identical depths in primary and secondary eclipses. They show slight color variation through eclipses. The ratio of depths is related to the brightness of component stars and corresponds to the effectiveness of the temperature T_1 and T_2. The study of the light curve synthesis model and employing Roche potentials for the equilibrium surface of the star shows that the component stars in W UMa binaries exist in a state of physical contact [6]. The period of eclipsing binary corresponds to the distribution between the stars. Using the conservative mass exchange of two stars could transfer the mass from a more massive to a low massive star. The period will be decreased [1]. For this work, we study the YY Eri binary star's period change using the differential photometry technique.

2. Materials and Methods

YY Eri (RA 04h 12m 08.849 s and Dec. -10^0 28′ 09.993′′) was observed on 5 December 2018, from 12:30 PM to 10:00 PM, UT at the Regional Observatory for the Public, Chachoengsao, Thailand. The 0.7 -meter reflecting telescope and CCD with the blue (*B*), standard visual (*V*), and red (*R*) filters of the UVB system were used. The MaxIm DL6 program was used to analyze YY Eri's photometry. We obtained 150 images in *B*, 149 in V, and 149 in R filters using 30 seconds of exposure time for each image in the clear sky. We chose the TYC 5315-986-1 (RA 04h 12m 21.364s and Dec.-10^0 26′ 03.797′′) and HD 26650 (RA 04h 12m 32.596s and Dec.- -10^0 33′ 57.865′′) for comparison star and check star. The observational light curve between flux and time of YY Eri in *B*, *V*, and *R* wavelength bandwidth is shown in Figure 1.

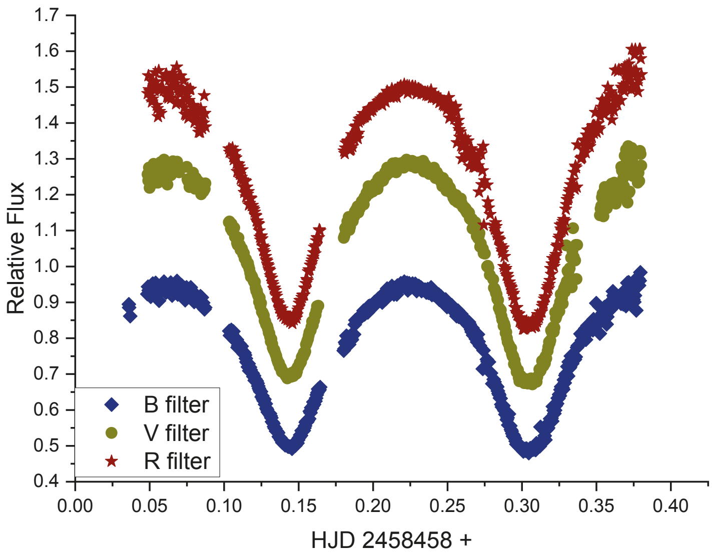

Figure 1. Light curve of the YY Eri.

3. Results and Discussion

The time of minimum light from the YY Eri light curves was determined by differential equation theory [7] and constructed in the *O-C* diagram using the Wilson-Devinney software. It is derived from the linear ephemeris equation obtained from the Database of Eclipsing Binary *O-C* Files by Bob Nelson, AAVSO [8] as follows:

$$HJD\ Min = 2441581.624 + 0.32149415E \tag{1}$$

Where *HJD Min* is the photoelectric times of the minimum light,

And *E* is the epochs of the minimum light.

In this observation, the light curves were calculated as the times of minimum light of the secondary and primary eclipses, as shown in Table 2.

Table 2. The *O-C* values of the YY Eri from this observation.

HJD Min	Type of Minimum	Epoch	*O-C*
2458458.144	secondary	52493.5	0.16685
2458458.306	primary	52494	0.16810

The *O-C* values in this research were combined with those from other astronomers in the past (979 times of minimum light) and were fitted by Quadratic Polynomial Fitting Method. The result is shown in Figure 2 [8-9].

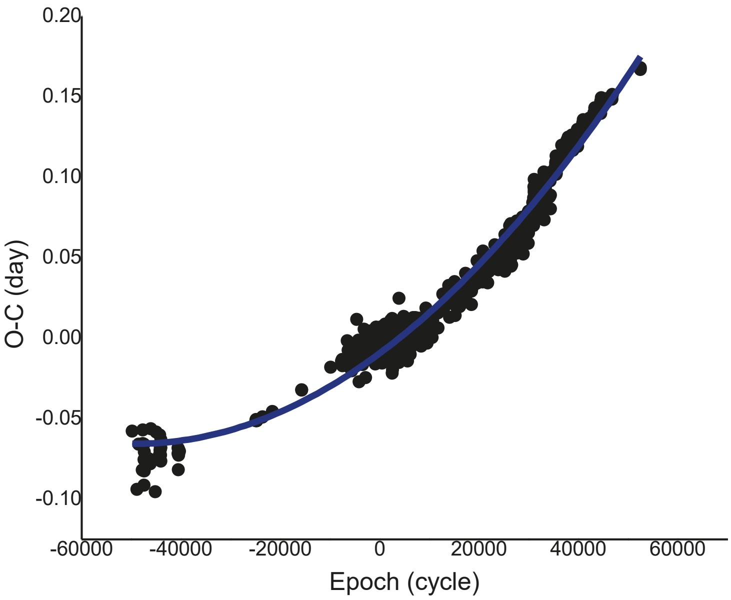

Figure 2. *O-C* Diagram of the YY Eri.

The O-C diagram, which is a plot between the observed time of minimum light (*O*) minus the calculated from ephemeris (*C*) in the y-axis with time in the x-axis, in Figure 2 shows the upward parabolic curve designated that the orbital period of YY Eri is increasing. The best solution to the quadratic ephemeris is shown as follows:

$$O\text{-}C = 2.33\times10^{-11}E^2 + 2.29\times10^{-6}E - 0.00932 \tag{2}$$

The quadratic ephemeris equation shows that the value of the period change (dP/dE) in this binary system YY Eri is $2 \times (2.33 \times 10^{-11})$ day/cycle. That means the period is increased continuously by approximately 4.57×10^{-3} seconds/year. Corresponding to the period changing rate of 5.51×10^{-3} seconds/year calculated by Ting et al. in 2018 [10]. The increase of the period showed that the distance between the stars was increased according to Thermal Relaxation Oscillation (TRO) theory. It explains the binary system evolution when the orbital period grows [11-12]. Furthermore, we present the residuals as the difference between the data (black dot) and the parabolic fitting (blue line). Besides this relation, there are periodic oscillations in the diagram, as shown in Fig 3.

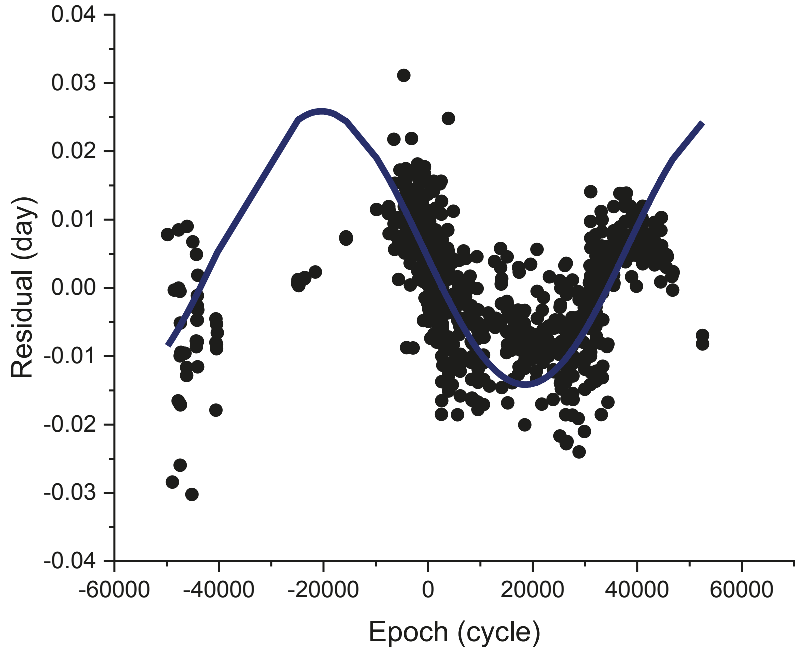

Figure 3. Residual of the YY Eri.

Figure 3 shows the sinusoidal changing of the residual. This effect may be from the apsidal motion of an elliptic orbit, the light time effect due to a third body, or cyclic changes in the magnetic activity of one of the stars[13]. However, the magnetic might be affected by the AML theory that the period change is decreasing [12]. So, the periodic residual oscillation in this study could be caused by the third body in the binary system. The best solution to the periodic oscillation is shown as follows:

$$\text{Residual} = 0.00585 + 0.02 \sin\left(\pi \frac{E - 115956.67059}{38967.43273}\right) \quad (3)$$

From the relation, we found that the YY Eri has a third body in the system. The computation method shows the distance of the third body is 3.45 AU from the center of mass and the orbital period is 68.6 years. The relation as: can calculate the mass function

$$f(m) = \frac{m_3^3}{(m_1 + m_2 + m_3)^2} \sin^3 i' = \frac{1}{P'^2}(a' \sin i')^3 \quad (4)$$

Where m_1,m_2, and m_3 are the mass of the first, the second, and the third star, respectively,

i' is the inclination,

a' is the distance of the third body from the binary system

and P' is the orbital period of the third body.

The masses of the two stars (m_1 and m_2) are 1.3 and 0.5. Solar mass in equation (4) comes from the study by Kim *et al.* in 1998 [13]. If the orbital of the third body is the circle, the calculated mass of the third body is 0.34 Solar mass, corresponding to the studies of Ting *et al.* in 2018 [10]. They calculated the range of third mass for the inclination of 30-90 degrees are 0.17 – 0.36 Solar mass.

4. Conclusions

YY Eri, the eclipsing binary system, was observed on 5 December 2018, from 12:30 PM to 10:00 PM, UT. at the Regional Observatory for the Public, Chachoengsao, Thailand. The photometric data were analyzed at the Faculty of Science and Technology, Chiang Mai Rajabhat University, Chiang Mai, and the Faculty of Science and Technology, Phetchaburi Rajabhat University, Phetchaburi, Thailand. In Figure 5, we show *O-C* Diagram with the sinusoidal and quadratic curves of the YY Eri. We derived the solution that shows in equation (5)

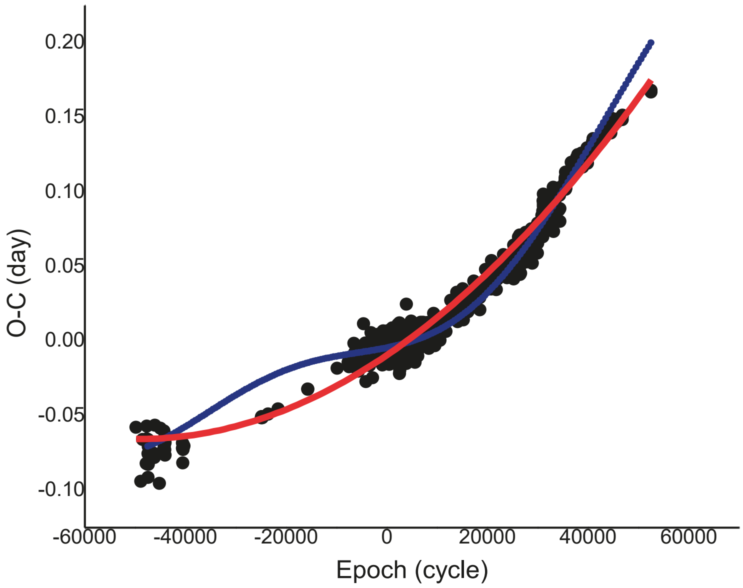

Figure 4. O-C Diagram with the sinusoidal and quadratic curves of the YY Eri.

$$\begin{aligned} O\text{-}C &= 2.33\times10^{-11}E^2 + 2.29\times10^{-6}E - 0.00932 \\ &+ 0.00585 + 0.02\sin\left(\pi\frac{E - 115956.67059}{38967.43273}\right) \end{aligned} \tag{5}$$

The *O-C* diagram and the solution show that the period of YY Eri is increasing at the rate of about 4.57×10^{-3} seconds/year. In addition, the values in this diagram are variance between near-contact binary system and contact binary system corresponding to the (TRO) theory. Moreover, the O-C residuals show that their orbital periods have a sinusoidal oscillation means that the third body in this binary system with an orbital period is about 68.6 years, and the distance from the center of mass of the binary system is about 3.45 AU. Finally, if we assume the third body is a circular orbit, we can calculate its mass is 0.34 Solar mass.

5. Acknowledgements

The author would like to acknowledge the National Astronomical Research Institute of Thailand (Public Organization) for this observation.

References

[1] Skelton, P.L.; Smits, D.P. Modeling of W UMa-type variable stars. *South African Journal of Science. 105*(3/4), March/April, 2009, 120-126.

[2] Cillié, G. G. The Photoelectric Light Curve of YY Eridani. *Harvard College Observatory Bulletin No.* 1951, *920.* 41-45.

[3] Maceroni, C.; vilhu, O.; Van't Veer, F.; Van Hamme, W. Surface imaging of late-type contact binaries I:AE Phoenicis and YY Eridani., *Astronomy and Astrophysics*. 1994, 288. 529-537.

[4] Nesci, R.; Macerini, C.; Milano, I.; Russo, G. YY Eri revisited. *Astronomy and Astrophysics*. 1986, 159. 142-146.

[5] Macerini, C.; Milano, L.; Russo, G. Determination of parameters of W UMa systems.III:CC Com, YY Eri, V502 Oph and TY Pup. *Astronomy and Astrophysics Supplement Series*. 1982, 49. 123-128.

[6] Webbink, R.F.; Contact binaries. 3D stellar evolution. ASP Conference Proceedings, University of California Davis, Livermore, California, USA, 22-26 July 2002; Edited by Sylvain Turcotte, Stefan C. Keller and Robert M. Cavallo. ISBN: 1-58381-140-0, 2003. 76.

[7] Pancharoen, W.; Maithong, W. The First Study of a Period Change of the V1851 Orion Eclipsing Binary System. *ASEAN journal of Scienctific and Technological Reports*. 2021, *24*(3). 9-14.

[8] Bob Nelson's Database of Eclipsing Binary O-C Files, AAVSO. https://www.aavso.org/bob-nelsons-o-c-files (accessed on 21 Feb 2022).

[9] SIMBAD Astronomical Database - CDS (Strasbourg) http://simbad.u-strasbg.fr/simbad/ (accessed on 21 Feb 2022).

[10] Yu, T.; Hu, K.; Yu, Y.-X.; Xiang, F.-Y. Orbital period changes of the W UMa-type binary YY Eri. *Research in Astronomy and Astrophysics.* 2018, *18*(9). 106.

[11] Lucy, L.B.; Wilson, R.E. Observational Tests of Theories of Contact Binaries. *The Astrophysical Journal*. 1979, 231. 502-513.

[12] Qian, S. Orbital Period Changes of Contact Binary Systems: Direct Evidence for Thermal Relaxation Oscillation Theory. *Monthly Notices of the Royal Astronomical Society*. 2001, 328. 914–924.

[13] Kim, C.; Jeong, J.; Demircan, O.; Muyesseroulu, Z.; Budding, E. The Period Changes of YY Eridani. *Highlights of Astronomy*. 1998, *11*(1). 370-370.