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*Research article*

# Light Curve and Period Change Behavior of a Binary Star V392 Orionis

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**Abstract:** This study investigates the period change of the eclipsing binary system V392 Orionis (V392 Ori), which is classified as an Algol-type binary star. The research utilized data from the TESS Eclipsing Binary Catalog obtained via the Transiting Exoplanet Survey Satellite (TESS). Light curves were generated through photometric analysis to determine the times of minimum light. The historical and current observational data were used to construct the O–C diagram. The O–C diagram derived from PE and CCD observations exhibits a downward parabolic trend, indicating a decreasing orbital period at a rate of $5.76\times10^{-3}$ seconds per year.

**Keywords:** V392 Ori; Period Change; O-C Diagram

## 1. Introduction

Binary systems are stellar systems composed of two stars orbiting a common center of mass under mutual gravitational attraction [1]. The study of binary star systems allows astronomers to determine the physical properties of stars and understand stellar evolution [2]. The binary star systems can be classified into two major types: visual binary systems, where individual stars can be distinguished through a telescope, and close binary systems, where the components are so close that they appear as a single star and can only be identified as binaries through other analytical methods. The type of a binary system is typically classified by constructing a light curve, which plots the variation in brightness over time. A dip in the light curve indicates an eclipse event where one star blocks the other along the observer's line of sight. In a whole orbital period of a binary system, two eclipses typically occur, corresponding to the primary and secondary eclipses. The time it takes for the system to complete one full orbit is referred to as the orbital period.

V392 Orionis (V392 Ori) is an Algol-type close eclipsing binary star with a spectral type of A5V. Its celestial coordinates are RA 06h 11m 25.17s and Dec +18° 32′ 59.60″. [3] The orbital period is 0.659284 days [4] and decreasing. [5] This study aims to analyze the period change of V392 Ori through its O–C diagram, contributing to a better understanding of the system's long-term behavior and evolution.

## 2. Materials and Methods

The study of the light variation of the binary star V392 Ori involved data collected from the TESS Eclipsing Binary Catalog, which contains observations

from the Transiting Exoplanet Survey Satellite (TESS). The TESS, operated by NASA, is accessible via the website http://tessebs.villanova.edu [6]. The TESS conducts observations of exoplanets, variable stars, and binary star systems, collecting data within the wavelength range of 600–1,000 nanometers, which corresponds to portions of the R to I bands in the Johnson UBV photometric system, as illustrated in Figure 1. [7]

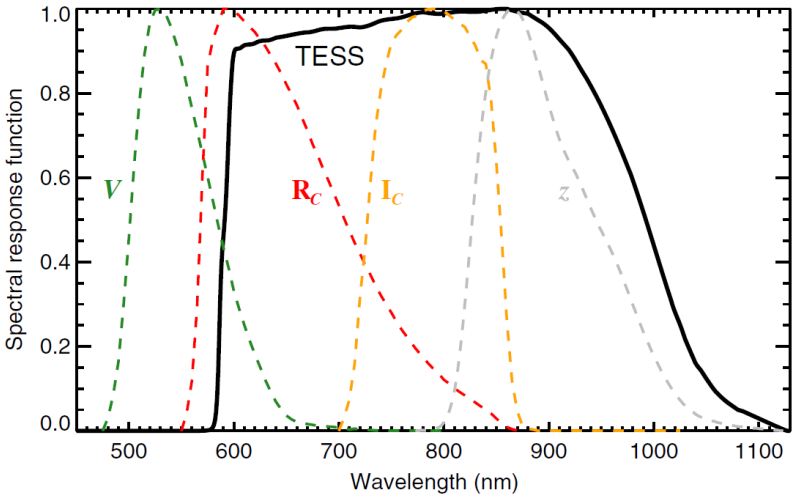


**Figure 1.** The black line is the wavelength bandwidth of the TESS observation.

This work uses Python code to download the data of V392 Ori, including the BJD time of observation and flux. The data at the latest time were used to plot the light curve as illustrated in Figure 2.

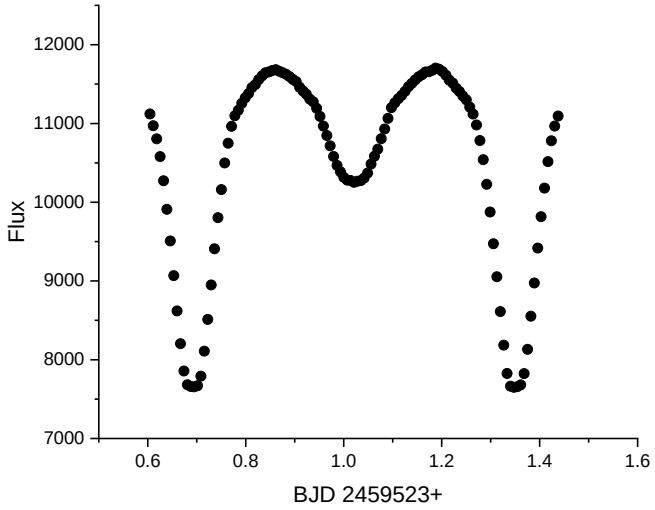


**Figure 2.** The light curve of V392 Ori, plotted from TESS observational data.

## 3. Results and Discussion

In Figure 2, the vertical axis represents the flux, and the horizontal axis represents time in Barycentric Julian Date (BJD), a time standard that accounts for the motion of light and other relevant factors by referencing the barycenter of the solar system. From this light curve, the times of minimum light were determined by fitting parabolic curves to the regions around the minima. The minimum time obtained in this study is BJD 2459523.691. The period change analysis was conducted following the procedure described by

Bob Nelson [8], as referenced by the American Association of Variable Star Observers (AAVSO), where the Heliocentric Julian Date (HJD) is converted to Barycentric Julian Date (BJD). The linear ephemeris used in this study is:

$$\text{Min. I} = \text{BJD } 2425506.620 + 0.659284\ E \quad (1)$$

Where: Min. I = BJD time of primary minimum
E = Epoch (number of orbital cycles since the initial reference time)

The O–C values of the eclipsing binary system V392 Ori, based on the times of minimum compiled by Bob Nelson [8], were computed from equation (1) as shown in Table 1.

**Table 1.** O–C values for the eclipsing binary system V392 Ori

| Time of Minimum BJD | Epoch | O-C | Photograph | Source |
|---|---|---|---|---|
| 2425506.62 | 0 | 0 | pg | GCVS 4 |
| 2425506.624 | 0 | 0.004 | pg | MVS 3.199 |
| 2426224.583 | 1089 | 0.002724 | pg | MVS 3.199 |
| 2426743.425 | 1876 | -0.011784 | pg | MVS 3.199 |
| 2428453.629 | 4470 | 0.00952 | pg | VSS 2.56 |
| 2428494.467 | 4532 | -0.028088 | pg | VSS 2.56 |
| 2428547.276 | 4612 | 0.038192 | pg | VSS 2.56 |
| 2428809.597 | 5010 | -0.03584 | pg | VSS 2.56 |
| 2429167.598 | 5553 | -0.026052 | pg | VSS 2.56 |
| 2429229.567 | 5647 | -0.029748 | pg | VSS 2.56 |
| 2429231.59 | 5650 | 0.0154 | pg | VSS 2.56 |
| 2429251.35 | 5680 | -0.00312 | pg | VSS 2.56 |
| 2429340.354 | 5815 | -0.00246 | pg | VSS 2.56 |
| 2429630.469 | 6255 | 0.02758 | pg | VSS 2.56 |
| 2429641.317 | 6271.5 | -0.002606 | pg | VSS 2.56 |
| 2429729.328 | 6405 | -0.00602 | pg | VSS 2.56 |
| 2429943.596 | 6730 | -0.00532 | pg | VSS 2.56 |
| 2429957.471 | 6751 | 0.024716 | pg | VSS 2.56 |
| 2430326.609 | 7311 | -0.036324 | pg | VSS 2.56 |
| 2430375.422 | 7385 | -0.01034 | pg | VSS 2.56 |
| 2430778.27 | 7996 | 0.015136 | pg | MVS 3.199 |
| 2432118.601 | 10029 | 0.021764 | pg | MVS 3.199 |
| 2432908.4 | 11227 | -0.001468 | pg | MVS 3.199 |
| 2433186.588 | 11649 | -0.031316 | pg | MVS 3.199 |
| 2433357.358 | 11908 | -0.015872 | pg | VSS 2.56 |
| 2433361.332 | 11914 | 0.002424 | pg | MVS 3.199 |
| 2433378.15 | 11939.5 | 0.008682 | pg | AC 151.26 |
| 2433597.32 | 12272 | -0.033248 | pg | AC 151.26 |
| 2433630.3 | 12322 | -0.017448 | pg | AC 151.26 |
| 2433659.29 | 12366 | -0.035944 | pg | AC 151.26 |
| 2434088.15 | 13016.5 | -0.040186 | pg | AC 151.26 |
| 2434420.12 | 13520 | -0.01968 | pg | AC 151.26 |
| 2434653.544 | 13874 | 0.017784 | pg | MVS 3.199 |
| 2435135.41 | 14605 | -0.05282 | pg | MVS 3.199 |
| 2435164.446 | 14649 | -0.025316 | pg | MVS 3.199 |
| 2435892.339 | 15753 | 0.018148 | pg | MVS 3.199 |

| | | | | |
|---|---|---|---|---|
| 2435921.352 | 15797 | 0.022652 | pg | MVS 3.199 |
| 2436604.322 | 16833 | -0.025572 | pg | MVS 3.199 |
| 2436608.28 | 16839 | -0.023276 | pg | MVS 3.199 |
| 2436896.412 | 17276 | 0.001616 | pg | HABZ 98 |
| 2437312.418 | 17907 | -0.000588 | pg | MVS 644 |
| 2437345.369 | 17957 | -0.013788 | pg | HABZ 98 |
| 2437349.36 | 17963 | 0.021508 | pg | HABZ 98 |
| 2437917.624 | 18825 | -0.0173 | pg | MVS 3.199 |
| 2438088.397 | 19084 | 0.001144 | pg | HABZ 98 |
| 2438372.526 | 19515 | -0.02126 | pg | MVS 3.199 |
| 2438411.458 | 19574 | 0.012984 | pg | MVS 3.199 |
| 2438440.458 | 19618 | 0.004488 | pg | HABZ 98 |
| 2438670.58 | 19967 | 0.036372 | pg | MVS 3.199 |
| 2439024.547 | 20504 | -0.032136 | pg | MVS 3.199 |
| 2439055.556 | 20551 | -0.009484 | pg | MVS 3.199 |
| 2439057.581 | 20554 | 0.037664 | pg | MVS 3.199 |
| 2439059.517 | 20557 | -0.004188 | pg | HABZ 98 |
| 2439088.545 | 20601 | 0.015316 | pg | MVS 3.199 |
| 2439528.276 | 21268 | 0.003888 | pg | HABZ 98 |
| 2440981.332 | 23472 | -0.002048 | pg | HABZ 98 |
| 2441329.444 | 24000 | 0.007 | pg | HABZ 98 |
| 2441331.416 | 24003 | 0.001148 | pg | HABZ 98 |
| 2441333.394 | 24006 | 0.001296 | pg | HABZ 98 |
| 2442404.725 | 25631 | -0.004204 | pg | BBS 19 |
| 2442417.28 | 25650 | 0.0244 | pg | BBS 20 |
| 2442475.28 | 25738 | 0.007408 | pg | HABZ 98 |
| 2443212.368 | 26856 | 0.015896 | pg | BBS 33 |
| 2445052.421 | 29647 | 0.007252 | pg | VSSC 60.22 |
| 2445054.398 | 29650 | 0.0064 | pg | VSSC 60.22 |
| 2447231.361 | 32952 | 0.013632 | vis | BBS 88 |
| 2447233.331 | 32955 | 0.00578 | vis | BBS 88 |
| 2447554.39 | 33442 | -0.006528 | vis | BBS 91 |
| 2447564.282 | 33457 | -0.003788 | vis | BBS 91 |
| 2447566.28 | 33460 | 0.01636 | vis | BAVM 52 |
| 2447587.367 | 33492 | 0.006272 | vis | BBS 91 |
| 2447914.367 | 33988 | 0.001408 | vis | BBS 94 |
| 2447922.308 | 34000 | 0.031 | vis | BBS 94 |
| 2447941.423 | 34029 | 0.026764 | vis | BBS 94 |
| 2447943.419 | 34032 | 0.044912 | vis | BBS 94 |
| 2448272.361 | 34531 | 0.004296 | vis | IBVS 4097 |
| 2448272.364 | 34531 | 0.006996 | vis | IBVS 4097 |
| 2448307.308 | 34584 | 0.009144 | vis | BBS 97 |
| 2448332.352 | 34622 | 0.000352 | vis | BBS 97 |
| 2448688.365 | 35162 | -8E-06 | vis | BBS 101 |
| 2450390.627 | 37744 | -0.009296 | vis | BBS 116 |
| 2450483.597 | 37885 | 0.00126 | PE | BBS 114 |
| 2451925.451 | 40072 | 0.001652 | PE | IBVS 5296 |
| 2452647.368 | 41167 | 0.002772 | PE | IBVS 5643 |
| 2452654.622 | 41178 | 0.004348 | CCD | IBVS 5502 |
| 2452655.278 | 41179 | 0.000964 | CCD | IBVS 5438 |

| | | | | |
|---|---|---|---|---|
| 2452715.274 | 41270 | 0.00182 | CCD | IBVS 5676 |
| 2452998.766 | 41700 | 0.002 | CCD | IBVS 5493 |
| 2453354.121 | 42239 | 0.002724 | CCD | VSB 43 |
| 2453450.376 | 42385 | 0.00286 | CCD | IBVS 5741 |
| 2453671.897 | 42721 | 0.003936 | CCD | IBVS 5677 |
| 2453674.535 | 42725 | 0.0048 | CCD | IBVS 5741 |
| 2453696.291 | 42758 | 0.004228 | CCD | VSB 44 |
| 2453700.246 | 42764 | 0.003924 | CCD | VSB 44 |
| 2453715.41 | 42787 | 0.004592 | CCD | IBVS 5741 |
| 2453758.261 | 42852 | 0.001632 | PE | IBVS 5802 |
| 2454068.788 | 43323 | 0.006268 | CCD | IBVS 5760 |
| 2454091.534 | 43357.5 | 0.00667 | PE | IBVS 5761 |
| 2454476.553 | 43941.5 | 0.003614 | PE | IBVS 5874 |
| 2454521.382 | 44009.5 | 0.001652 | CCD | OEJV 0094 |
| 2454809.161 | 44446 | 0.003436 | CCD | VSB 48 |
| 2454829.599 | 44477 | 0.003232 | PE | IBVS 5918 |
| 2454881.684 | 44556 | 0.004996 | CCD | IBVS 5894 |
| 2455135.177 | 44940.5 | 0.003798 | CCD | VSB 50 |
| 2455136.165 | 44942 | 0.002172 | CCD | VSB 50 |
| 2455158.913 | 44976.5 | 0.004974 | CCD | IBVS 5920 |
| 2455163.854 | 44984 | 0.001544 | CCD | IBVS 5929 |
| 2455244.287 | 45106 | 0.001796 | PE | IBVS 5959 |
| 2455591.73 | 45633 | 0.002128 | CCD | IBVS 5992 |
| 2455602.278 | 45649 | 0.001684 | PE | IBVS 6070 |
| 2455838.629 | 46007.5 | -0.00063 | CCD | OEJV 0142 |
| 2456256.945 | 46642 | -0.000828 | CCD | IBVS 6042 |
| 2457042.487 | 47833.5 | 0.004586 | PE | IBVS 6152 |
| 2457296.632 | 48219 | -0.004196 | CCD | IBVS 6230 |
| 2457414.308 | 48397.5 | -0.01029 | CCD | IBVS 6196 |
| 2457702.091 | 48834 | -0.004556 | CCD | VSB-063 |
| 2458058.105 | 49374 | -0.004416 | CCD | VSB-64 |
| 2458219.63 | 49619 | -0.004178 | CCD | JAVSO 49, 106 |
| 2458785.954 | 50478 | -0.005088528 | CCD | RHN 2019 |
| 2459523.691 | 51597 | -0.0052129 | CCD | This Study |
| 2459938.063 | 52225.5 | 0.005658 | CCD | VSB, 108 |

Note:

pg (photographic): Refers to observations derived from astronomical photographic plates or films, which were commonly used in early stellar photometry.

vis (visual): Refers to visually estimated observations, obtained either with the unaided eye or through a telescope. The timing of events is subject to the observer's judgment and experience.

PE (photoelectric): Refers to measurements acquired using a photoelectric photometer, a method prevalent before the development of CCD technology. This technique provided improved accuracy over visual methods.

CCD (Charge-Coupled Device): Refers to observations obtained using CCD sensors, a modern and highly precise technique in photometric measurements that has become the standard in contemporary astronomical research. The O–C values derived from the observed times of minimum light (O) and the predicted times (C) were plotted against the corresponding epochs to produce the O–C diagram. This study considers the period change in three solutions: the first is computed from all data, the second calculates from vis to present, and the last one analyzes especially PE and CCD. The first solution is the O-C diagram of V392 Ori, as shown in Figure 3.

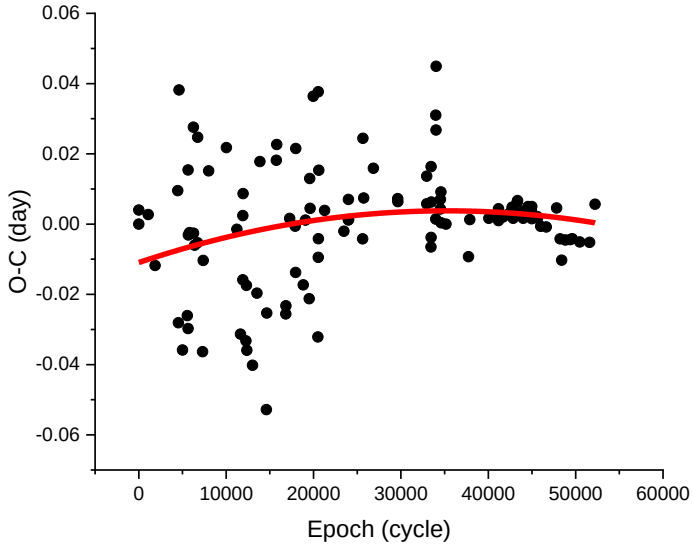


**Figure 3.** The O-C diagram for V392 Ori, based on all available data.

The parabolic nature of the O–C diagram indicates a trend of increasing orbital period. A second-order polynomial fit was applied using the Quadratic Polynomial Fitting Method, resulting in the following equation:

$$O\text{-}C = -0.01094 + 8.35174 \times 10^{-7}\ Epoch - 1.18474 \times 10^{-11}\ Epoch^2 \quad (2)$$

From this, the rate of orbital period change (dP/dE) can be calculated as:

$$\begin{aligned} dP/dE &= 2(-1.18474 \times 10^{-11}) \\ &= -2.3694 \times 10^{-11}\ \text{day/cycle} \\ &= -1.134 \times 10^{-3}\ \text{sec/year} \end{aligned}$$

This negative value of dP/dE indicates that the orbital period of the binary system V392 Ori is decreasing. This suggests that the distance between the two stellar components is decreasing, consistent with the Angular Momentum Loss (AML) theory [9]. The loss of angular momentum in a binary star system drives orbital evolution, which may ultimately result in the merger of the two components into a single, rapidly rotating star. The second solution, the O-C diagram of V392 Ori, was computed from data except for pg, as shown in Figure 4.

The O-C diagram from Figure 4 shows that there is a periodic pattern (blue line) on the second-order polynomial line (red line). The second-order polynomial and sinusoidal fit to the O–C data yielded the following equation:

$$\begin{aligned} O\text{-}C = {} & 0.05561 - 1.7805 \times 10^{-6}\ Epoch + 1.2656 \times 10^{-11}\ Epoch^2 \\ & + -0.00145 + 0.00349 \sin(\pi((Epoch - 1447.9893)/ 4972.98766)) \end{aligned} \quad (3)$$

So,

$$\begin{aligned} dP/dE &= 2 \times 1.2656 \times 10^{-11} \\ &= 2.5312 \times 10^{-11} \quad \text{day/cycle} \\ &= 1.21 \times 10^{-3} \quad \text{sec/year} \end{aligned}$$

The positive rate of change of the period ($1.21 \times 10^{-3}$ seconds/year) suggests that the orbital separation between the two stars is increasing. This supports the Thermal Relaxation Oscillation (TRO) theory [10], which

suggests that variations in the internal structure and energy balance of the components, combined with mass transfer between them, can drive cyclic changes between contact and semi-detached configurations, thereby influencing the orbital evolution of the system. This periodic variation indicates the likely presence of a third body in the system. The light-time effect gives an orbital radius of approximately 0.67 AU for the third body, with an orbital period of about 17.95 years. The third solution, the O-C diagram of the V392 Ori, was calculated from PE and CCD data as shown in Figure 5.

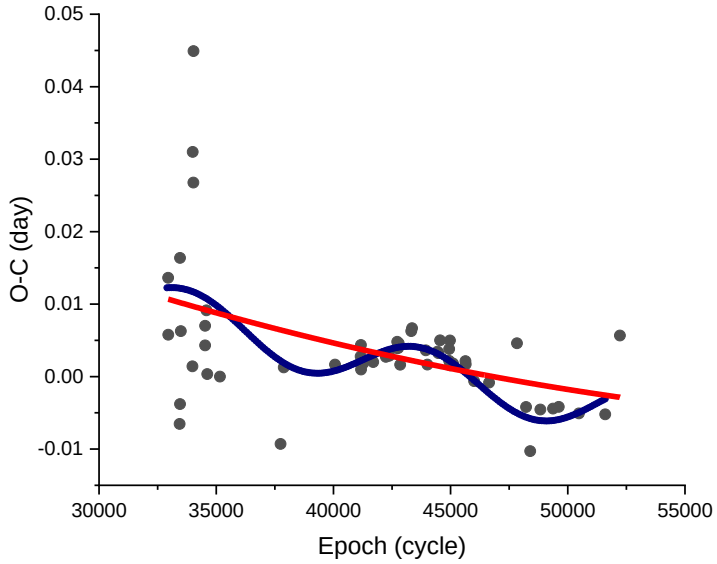


**Figure 4.** The O-C diagram for the V392 Ori from vis to present data.

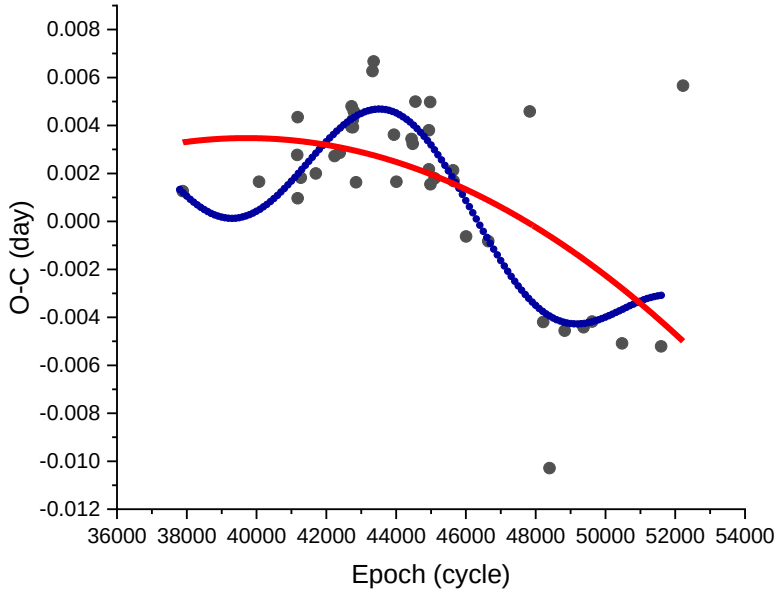


**Figure 5.** The O-C diagram for V392 Ori, based on PE and CCD data.

The O-C diagram from Figure 5 exhibits a similar pattern to that in Figure 3, which is a periodic pattern (blue line) on the second-order polynomial line (red line). Therefore, the O–C data yielded the following equation:

$$\begin{aligned} O\text{-}C &= -0.08178 + 4.29419 \times 10^{-6}\ \text{Epoch} - 5.40715 \times 10^{-11}\ \text{Epoch}^2 \\ &\quad -0.000642856 + 0.0027 \sin(\pi((\text{Epoch} - 23541.55743)/ 4510.50998)) \end{aligned} \quad (4)$$

So,

$$dP/dE = -5.176 \times 10^{-3} \quad \text{sec/year}$$

The negative rate of change of the period (-5.176 $x10^{-3}$ seconds/year) is consistent with the evolution of AML theory. The sinusoidal variation may indicate the presence of a third body in this system, which is positioned approximately 0.47 AU from the primary body and has an approximate orbital period of 16.28 years.

## 4. Conclusions

This study of the eclipsing binary system V392 Ori used data from the TESS Eclipsing Binary Catalog, obtained via the TESS satellite. A light curve was constructed and analyzed to determine the times of minimum light, which were then used to build an O–C diagram. The analysis using the Quadratic Polynomial Fitting Method revealed three solutions for the orbital period of V392 Ori. The second condition was calculated from the previous data to the present data. The orbital period was found to be increasing at a rate of $1.21 \times 10^{-3}$ seconds/year, suggesting ongoing mass transfer and cyclical structural changes in the binary system, as predicted by the TRO theory. Furthermore, periodic variations in the O–C diagram indicate the potential presence of a third body with an orbital radius of about 0.67 AU and a period of approximately 17.95 years. On the other hand, the first condition was computed from all data, while the last solution was computed from data excluding pg and vis. The period change is decreasing at rates of $1.134 \times 10^{-3}$ and $5.176 \times 10^{-3}$ seconds/year, respectively. The evolution corresponds to the AML theory. Furthermore, the last solution presented for the third body's behavior is at a distance of 0.47 AU, with an orbital period of around 16.28 years. When considering the observations in modern astronomy, which includes modern instrumental photography, the third condition may show a trustworthy solution. However, this binary should be observed further to study its evolution.

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