



Computing Physical Parameters for Short Period Eclipsing Binary Star YY Eridani

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Abstract:

This research employs B and R filter observations to scrutinize and appraise the several Parameters attributes of star YY Eridani (Eri) at lower elevations. The data analysis unveils asymmetries and irregularities in the recorded light curves. The value of double star YY Eri lies in its ability to provide essential insights into the fundamental attributes of stars. Notably, binary stars are unique due to their distinct kinematic characteristics and chemical compositions. However, the recurring spectroscopic parallelism observed in the disk and the galactic corona are not entirely dissimilar. The numerical values of the parameters are tabulated for comparison with earlier studies. In this work, various physical parameters such as bolometric magnitudes, lifetimes, gravity darkening, Age, mass reflection coefficients, and empirical results of YY Eri are computed. The results align with those of previous studies.

Key words: bolometric magnitudes; gravity darkening; reflection coefficients; YY Eri.

1. Introduction

The importance of binary stars (BS) can be attributed to multiple factors. To begin, they are not interchangeable. Second, most star structures are multi- or paired star structures, even though kinematic features and chemical composition can change [1, 2]. Many or paired stars make up the majority of star frameworks. To consider the goal for singular stars, two stars are sufficiently separated by a few parts of parallel BS. Comprises two stars that, from Earth's perspective, darken each other due to their circles [4, 7]. Any sporadic long-term alteration is linked to the reallocation of an article between the stars when the frameworks precise speed changes. In contrast, if

the vas versa appears, the period increases or decreases [5, 10, 24]. Figures 1 and 2 illustrated the LC and close field map of YY Eri respectively.

First, the YY Eri binary star was introduced and found by researcher Struve in 1947. Huruata and Kitamura noted in 1953 that the YY Eri's spectral type is G5 V. Yang investigated YY Eri's photometric in 1999. In 2010, Rucinski discovered modifications to Y Eri

's periodic orbit. Maxted outlined the adaptable LC model for BS in 2016. Menon conducted research on contact binary stars in 2020. Orbital period changes YY Eri were studied by researcher YU in 2018. Gazeas in 2021 studied Physical parameters of close binary systems. Warisa researched light curve analysis for YY Eri in 2021. Hussein researched LC analysis for CN And in 2023. Studying and assessing a number of physical parameters for YY Eri and with B and R filters will help to expand these works.

2. The significant information about YY Eridani

Hoffmeister, a W UMA-type binary, was first identified as a new variable in a list compiled by YY Eri in 1933 (BD -10.858° , HD-26609, HIP-1960). He identified it as a G5 spectral type SP eclipsing binary. Struve in 1947 made the first spectroscopic observations of this object, which has spectral type G5 V and a period equal to 0.312495. He used this information to determine the mass ratio of $q \approx 0.5$ and the inclination of $i = 80.8^\circ$. Nesci in 1986 determined several parameters by performing spectroscopic observations ($M_1 = 1.54M_\odot$, $M_2 = 0.62M_\odot$, $R_1 = 1.20R_\odot$, and $R_2 = 0.77R_\odot$). Additionally, they acquired a photometric solution with a degree of overcontact of $f = 15\%$, an inclination of $i = 82.50^\circ$, and an amass ratio of $q = 0.4011$ [22,23], conducted spectroscopic and photometric analyses to gradually ascertain the binary system's physical parameters. Additionally, they seem to show an inverse O'Connell effect, with maximum II being brighter than maximum I. Additionally, they calculated an inclination of $i = 82.12^\circ$ and a mass ratio of $q = 0.4699$. The radial velocities were measured by Duerbeck and Rucinski, 2006. They identified a spectroscopic mass ratio of $q \approx 0.44$ and a spectral type of roughly G3 V [19, 21]. The primary star's effective temperature was 5533 K, while the secondary star's was 5598 K. The mass ratio is 0 point 550, and the inclination is 81point 450.

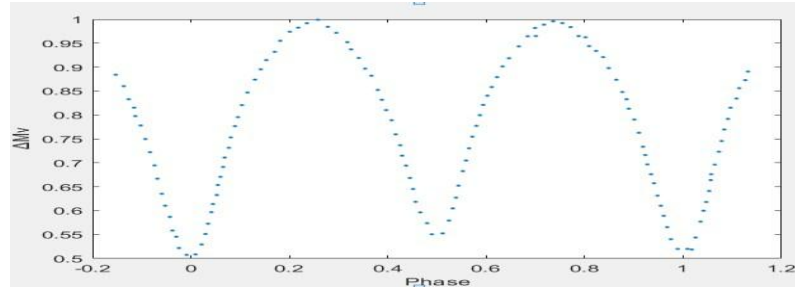


Figure 1. Shows the Light curve of YY Eri [15].

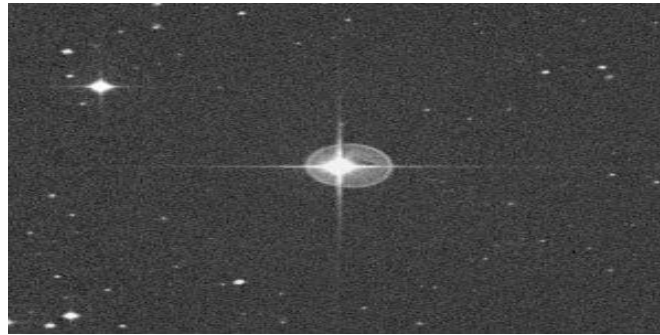


Figure 2. Represent close field map of YY Eri [17, 22].

3. Absolute Parameters

The fundamental parameters of stars' masses, radii, temperatures, and abundances dictate their properties and evolution. A star's mass and other basic characteristics can be most precisely ascertained by combining photometric and spectroscopic data from eclipsing binaries [8]. Kepler's third law has been applied to the absolute parameters of the binary system.

$$A^3 = p^2 \times 74.50 \times (M_1 + M_2) \quad (1)$$

P: The orbital period in days. M1 and M2 are the masses of the components in solar mass

$$M_1 = \frac{1}{1+q} \quad \text{and} \quad M_2 = \frac{M}{1+q} \quad (2)$$

q : mass ratio for the components of binary star system.

$$R_1 = r_1 A \quad \text{and} \quad R_2 = r_2 A \quad (3)$$

A: Separation between components expressed in solar radii R_1 and R_2 : The absolute radii in solar radii, the Stefan–Boltzmann law

$$L_1 = R_1^2 T_1^4 \quad \text{and} \quad L_2 = R_2^2 T_2^4 \quad (4)$$

L_1 : The luminosity of primary component. L_2 : The luminosity of secondary component

T_1 : The effective temperature of primary component.

T_2 : The effective temperature of secondary component. The mass ratio formula is,

$$q = \frac{M_1}{M_2} \quad (5)$$

4. Age mass relationship for YY Eri.

Equation (6), which is defined in [1, 13], is used to study the Age-Mass of YY Eri. Table (9) displays the primary and secondary log ages.

$$\text{Log}(Age) = 9.8830 - 2.9650 \log\left(\frac{M}{M_0}\right) \quad (6)$$

5. The life time

Life time (LT), which provides a wealth of information about the BS, is an important component of research B.S, utilizing equation (7) to determine life time.

$$\frac{t_1}{t_0} = \frac{1}{2.5\left(\frac{M_1}{M_0}\right)} \quad \text{and} \quad \frac{t_2}{t_0} = \frac{1}{2.5\left(\frac{M_2}{M_0}\right)} \quad (7)$$

6. Bolometric Magnitudes M_{bol1} and M_{bol2} .

Using the well-known equation (8), where T is the effective temperature of the primary and secondary components in the solar unit, the absolute parameters of M_{bol1} and M_{bol2} can be determined [9, 10].

$$M_{bol1} = 4.75 - 5 \log\left(\frac{R_1}{R_\odot}\right) - 10 \log\left(\frac{T_1}{T_\odot}\right) \quad (8)$$

$$M_{bol2} = 4.75 - 5 \log\left(\frac{R_2}{R_\odot}\right) - 10 \log\left(\frac{T_2}{T_\odot}\right)$$

7. Density of components of binary star systems.

The following relationships are used to calculate the components' mean density [10].

$$p_1 = \frac{0.0189}{r_{1mean}^3 p^2 (1+q)} \quad (9)$$

$$P_2 = \frac{0.0189}{r_{2mean}^3 p^2 (1+q)} \quad (10)$$

8. Gravity Darkening

The phenomenon known as gravity darkening, or gravity brightening, occurs when a star's oblate shape and fast rotation cause its poles to be brighter than its equator. An oblate star has a large radius at its equator compared to its poles.

9. Empirical relation between CI and M_{bol} .

These parameters are found using the following formulas in this section.

$$M_{bol} = M_{sun} + BC(T) \quad (11)$$

$$BC_{sun} = -0.0700, \quad M_{sun} = 4.8300$$

$$B - V = -0.3440 \log(T) + 14.5510 \quad (12)$$

Such that $\log(T) < 3.9611$

$$B - v = 0.3440 \times (\log(T))^2 - 3.4020 \times \log(T) + 8.0370 \quad (13)$$

for $\log(T) > 3.9610$

$$B - v = -8.4990 \times (\log(T) - 4)^4 + 13.4210 \times (\log(T) - 4)^3 - 8.1310 \times (\log(T) - 4)^2 - 3.9010 \times \log(T) - 3.5620 \quad (14)$$

$$C_1 = 2\Omega B_1 + 2B_2^2 \quad \text{and} \quad C_2 = 2\Omega B_1 - 2B_2^2 \quad (15)$$

Such that

$$B_1 = \frac{1}{1+q} \quad \text{and} \quad B_2 = \frac{q}{1+q} \quad (16)$$

Degree of Geometrical contact (fill out factor) has the form

$$F = \frac{\Omega_{in} - \Omega_{1,2}}{\Omega_{in} - \Omega_{out}} \quad (17)$$

and this is very important to find empirical relationship between BC and CI.

$$BC = M_{bol} - M_y \quad (18)$$

$$CI = B - V$$

Then the effective temperature is proportional to the fourth root of the effective gravity.

$$g_1 = \left(\frac{c^2}{4\epsilon T_1 [1 - e^{-\frac{c^2}{8T_1}}]} \right), \quad g_2 = \left(\frac{c^2}{4\epsilon T_2 [1 - e^{-\frac{c^2}{8T_2}}]} \right) \quad (19)$$

10. Reflection Coefficient.

The equations listed below were used to calculate the reflection coefficient.

$$E_{\text{eff1}} = t_1 \left(\frac{T_2}{T_1} \right)^4 \left(\frac{e^{\left(\frac{c_2}{g T_2} - 1 \right)}}{e^{\left(\frac{c_2}{g T_1} - 1 \right)}} \right) \quad (20)$$

$$\text{where } c_2 = \frac{(1.438830)}{(T_2)_{\text{eff}}}$$

$$E_{\text{eff2}} = t_2 \left(\frac{T_1}{T_2} \right)^4 \left(\frac{e^{\left(\frac{c_2}{g T_1} - 1 \right)}}{e^{\left(\frac{c_2}{g T_2} - 1 \right)}} \right) \quad (21)$$

YY Eri's absolute parameters are calculated using equations (1–5). Using equations (11–18), determine the gravity darkening coefficient and reflection coefficient for YY Eri. We utilized the Matlab program for this application.

Table 1. Shown the absolute parameters for YY Eri binary star.

| Name | R ₁ | R ₂ | M ₁ | M ₂ | T ₁ | T ₂ | L ₁ | L ₂ | q | A | References |
|--------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-------|--------|-----------------------------|
| YY Eri | 1.010 | 0.730 | 0.990 | 0.613 | 0.976 | 0.976 | 0.930 | 0.48 | 0.62 | 2.3115 | Brancewicz and Dworak, 1980 |
| | 1.153 | 0.793 | 1.456 | 0.614 | 0.966 | 0.917 | 1.155 | 0.444 | 0.62 | 2.5170 | Awadalla and Hanna, 2005 |
| | 0.631 | 0.349 | 0.368 | 0.629 | 0.972 | 0.920 | 0.350 | 0.087 | 1.294 | 1.9375 | Present work |

Table 2. Reflection coefficient, gravity darkening coefficient of YY Eri.

| Name of stars | g_1 | g_2 | E_{eff1} | E_{eff2} |
|---------------|--------|--------|-------------------|-------------------|
| B | 0.2728 | 0.2732 | 0.8709 | 1.0459 |
| R | 0.1728 | 0.1726 | 0.8569 | 1.0487 |

Table 3. Shows the Roche lobe radii and bolometric magnitude for YY Eri.

| Name of Star | Roche lobe radii $\frac{r_l}{a}$ | M_{bol1} | M_{bol2} |
|--------------|----------------------------------|-------------------|-------------------|
| YY Eri | 0.273592 | 3.43401 | 1.63119 |

Such that r is relative radii and a is semi major axis.

11. Relationship among CI , M_{bol} and T_{eff} .

Table (4) shows the current empirical results for primary and secondary data. Equations (20) and (21) can be used to determine the empirical relationship between CI and T_{eff} . The Matlab program was utilized for this purpose.

Table 4. Shows the Empirical results for YY Eri.

| Name of stars | Component | BC | CI | M_{bol} | M_y |
|---------------|-----------|---------|--------|-----------|--------|
| YY Eri | Primary | -0.3309 | 8.1368 | 3.4339 | 3.7637 |
| YY Eri | Secondary | -0.1749 | 8.3269 | 1.6309 | 1.8058 |

Table 5. Mean density of the components of YY Eri.

| Name of stars | ρ_1 | ρ_2 |
|---------------|----------|----------|
| YY Eri | 3.3368 | 2.9639 |

12. Photometric analyzing for YY Eri.

Following a series of tests, we have determined a set of parameters that are representative of the observed LC for YY Eri in figures 3 and 4. The parameters that are included in the arrangement are as follows. The initial star temperature is 6150K. Note: As demonstrated, the parameters for double star YY Eri are derived from the outcomes of the established models. Recommending a good Matlab application to determine the parameters. Table (1) shows the YY Eri BS absolute parameters as well as the results for other works. Reflection and gravity darkening coefficients were calculated using equations (20) and (21) and are displayed in table (2). YY Eri's lifetime was calculated using equation (7), and the results are displayed in table (10). Equations (9) are used to display the component densities in table (5). Figuring out the initial contact angle. This displays the solar eclipse type and current first contact angle for YY Eri. These parameters, which are bolometric magnitudes and component densities, are calculated using equations (8) through (12). The empirical relationship between BC and CI was discovered through the use of equations (13) and (14).

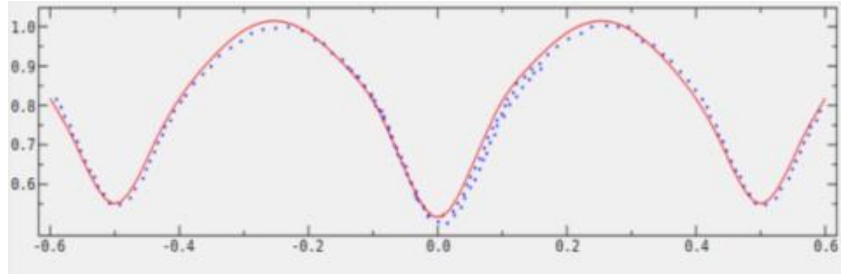


Figure 3. Best matches between synthetic and observed light curve of YY Eri (B) filter.

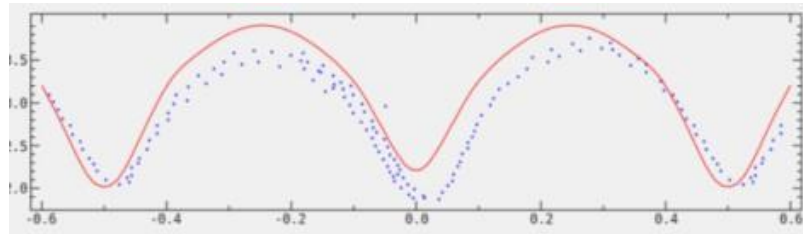


Figure 4. Synthetic and observed light curve of YY Eri after adding spot parameters.

Note: In figures 3 and 4 the red line is synthetic, and the blue points are LC.

Table 7. Output parameters of spotted model of YY Eri (B) filter.

| Parameters | YY Eri |
|------------|-----------|
| A_{s1} | 1.8378 |
| q | 0.4649 |
| I | 78.0722 |
| T_1K | 5557.9021 |
| T_2K | 5327.8003 |
| Ω_1 | 2.6409 |
| X_1 | 0.8193 |
| X_2 | 0.6688 |

Table 8. Best fit parameters for spotted model of YY Eri.

| Parameters | YY Eri |
|------------|--------|
| i | 79.119 |
| T_1K | 5452 |
| T_2K | 5591 |

11. Conclusion and discussion for YY Eri

Based on this study, YY Eri's photometric arrangements were obtained by applying a number of equations to evaluate physical parameters. A photometric arrangement is shown in tables (2) and (3), which may be W-type over-contact paired. In this research, the level of contact was found to range from 16 to 64 percent. The fill-out factor for the degree of overcontact is calculated to be 0.4967, which lies between 0 and 1. This suggests that the binary star system is classified as overcontact. The mass ratios for the B and R filters are 1.30 and 1.4, respectively, which are comparable to the obtained mass ratio of 0.4223. Because the effective temperature of the primary component exceeds that of the secondary component, the inclination angles are 78.99 degrees for the B filter and 80.02 degrees for the R filter. Thus, the following conclusions are drawn: -

- 1) When compared to earlier research, the absolute parameters, geometrical parameters, physical parameters, and relative radii for YY Eri exhibit good agreement.
- 2) Near the main sequence are the chosen stars.
- 3) The findings indicate that YY Eri are categorized as W-type since larger stars are considered to be more massive and cooler physically.
- 4) When the results for this work are compared to those for other works, they show positive results in table (1).
- 5) The binary system YY Eri is a W-type contact binary, according to the solution, with a mass ratio of 0.555879 and a degree of contact of 16.6391 percent.

Table 9. The age-mass for YY Eri.

| star | primary | secondary |
|--------|----------|-----------|
| YY Eri | 105.2370 | 106.66750 |

Table 10. Shows the life time for YY Eri.

| Star | $\frac{t_1}{t_{sun}} \times 10^{83}$ | $\frac{t_2}{t_{sun}} \times 10^{83}$ |
|--------|--------------------------------------|--------------------------------------|
| YY Eri | 3.78910 | 3.96520 |

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Recommendations

I suggest the following two things for future research:

- 1) Examining sun spot parameters for the YY Eri binary star.
- 2) Researching the CN Andromeda's minimum time.

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