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EVALUATION OF PERIOD VARIATION OF V338 HERCULIS ALGOL BINARY STARS

AVEN M. HAMEDAMEN

Ph.D. Astrophysics, Assistant Lecture, Physics Department, College of Education, Salahaddin University- Erbil, 44001, Erbil, Iraq. Corresponding Author Email: aven.hamadamen@su.edu

ISMAIL MUSA MURAD

Ph.D. Astrophysics, Assistant professor, Physics Department, College of Education, Salahaddin University, Department of Physics, Faculty of Education, Tishk International University, Erbil, Kurdistan Region, Iraq. Email: ismail.murad@su.edu.krd

Abstract

Aims: *We intend to derive the absolute parameters of the V338 her component, interpret the variations in their orbital periods, and discuss their evolutionary status.* ***Methods:*** *We have obtained new and comprehensive multi-filter light curves of the eclipsing binary V338 Her.* ***Analyzed with modern methods****: Moreover, we acquired new photometric observations during the secondary eclipses of V338 Her.* ***Results****: We derive reliable photometric data for V338 Her's principal stars. In the case of V338 her, statistical tests of orbital period analysis for all systems are extremely reassuring. By incorporating a third light option into photometric analyses, the light-Time Effect (LITE) results are verified. Light curve solutions provide the means for calculating the absolute parameters of the system's components and estimating their current evolutionary status with reliability.* ***Conclusions:*** *Star is confirmed as classical Algol with a relatively low mass in configurations of a similar nature. V338 her continues to transmit matter between its components, sparking interest in the predictability of Algols' evolutionary histories.*

Keywords: *Eclipsing stars; Individual (V338 Herculis); star spots; Third body*

1. INTRODUCTION

The primary objective of this investigation is to derive new physical elements for V338 Her based on new photometric data and to analyze their orbital period data using modern analysis tools. The studied systems were selected for two primary reasons: (1) they have known irregularities in their "observed-calculated" times of minima (henceforth O-C), and (2) their light curves in the literature are either incomplete or not multi-filtered. New light curves were sought: (a) to photometrically search for additional companions of the eclipsing binary (hereafter EB) and (b) to attempt to detect the potential pulsational behavior of its components. The O-C diagram analysis prompts us to consider the physical mechanisms influencing the behavior of an EB refer to (Budding & Demircan, 2007). These may be due to the presence of a third body, variations in the quadrupole moment, mass transfer between the components, or mass loss in the system. Moreover, parameters derived from the light curve (LC) analysis permit a valuable specification of the evolutionary status of EB stars (e.g., semi-detached, detached, or contact configurations). Brancewicz & Dworak (1980) generated absolute elements for the binary components investigated in this article, including photometric parallaxes. In the compendium of Soydugan et al. (2006), the system V338 she was identified as a candidate for containing Sct-type components. V338 her was included in our observing program due to the lack of period change and light curve analyses. By 2022, our group hopes to analyze the period variations and evolutionary status of Algols using a number of small telescopes in Rome. V338 her was included in

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our observing program due to the lack of period change and light curve analyses. Hoffmeister (1949) discovered the Algol-type eclipsing binary V338 Herculis (AN29.1907; J 2000.0 = 17h53^{m}12^{s}.7357, J 2000.0 =+4346 23.158). This star's visible light amplitude ranges from 10 m.07 to 11 m.15. Whitney (1959) determined a period of 1.30572 days, which has since been enhanced to 1.3057406 days (Kreiner 1971), 1.3057515 days (Mallama 1980), and 1.305758 days (Kreiner 2004), indicating that the period of V338 Her may be increasing continuously. Vetesn'k (1968) published the first photoelectric observations in BV bands and derived the spectral types A9+K0 for both components. Kreiner et al. (2001) determined the F0V-F2V spectral type with a color index of B V = +0.21. However, Malkov et al. (2006) changed the spectral type to F1V. In addition, Walter (1969) observed this binary system and obtained dispersed V-band observations from 1964 to 1968. Mezzetti et al. (1980) revised the photometric elements of V388 Her with a mass ratio of qph = 0.16 based on these observations.

2. OBSERVATION

The new measurements were taken at the Astronomic Galati observatory, which is located on the Romanian campus of Maldives. The 40-centimeter telescope is outfitted with an SBIG ST-8XMEI CCD camera and Bessell UBVRI photometric filters. All observations were obtained beginning in December 2022. The exposure durations vary from 25 to 80 seconds based on the individual systems and observing conditions.

2.1: Analysis of O-C for V338 Herculis

Analyzing the photometric solution for V338 Her, BD+43 2835, and HIP 87556 780 observations again in the B band and 962 observations in the V band were used (Vetesn'k, 1968). Kreiner et al. (2001) calculated phases for 1,370574535 days. The effective temperatures were deduced to be 7820 K and 7150 K based on the spectral type of F1V and the color index B V = +0.21 for V338 Her. This results in a mean value of 7485 (335) K, which was assumed to be the effective mean temperature for Star 1, T1. Star 1 was assigned the linear limb-darkening coefficients x1B = 0.551 and x1V = 0.469. To investigate the changes in the orbital period of V338 Her, a total of 132 light minimum times, including seven plates, 104 visual, six photographic, three photoelectric, and 12 CCD measurements, were gathered. With the Kreiner et al. (2001) linear ephemeris formula,

$$\text{Min.I} = \text{HJD}2433771.3365 + 1.30574535 \times E \quad (1)$$

the (O − C) values, shown in Fig (1), were calculated. The corresponding (O − C) curve is displayed in the upper panel of Figure 2, where the open circles represent plate, visual, or photographic observations, and the solid ones represent photoelectric or CCD data. In calculating, we assigned a weight of 1 to plate, visual, and photographic data and a weight of 10 to photoelectric and CCD observations. The (O − C) curve can be described by an upward parabolic curve superimposed with a cyclic variation. A weighted nonlinear least-squares fitting method gave the equation,

$$\mathbf{O - C = 0.0019(\pm0.0029) - 2.13(\pm0.83) \times 10{-}6E + 2.57(\pm0.43) \times 10{-}10E2 + 0.0116(\pm0.0015) \times \sin [7.73(\pm0.01) \times 10{-}4E + 2.6193(\pm0.1326)]} \quad \mathbf{(2)}$$

Figure 1 bottom panel depicts the corresponding residuals. Continuous and dashed curves represent equation (2) and its parabolic component. Using the coefficient of the quadratic term of the equation, a continuous period growth rate, dP /dt = +1.44(0.24) 107 days yr1 (i.e., +1.24(0.21) s/century, has been calculated. The sinusoidal term in Equation (2) reveals a cyclic oscillation with an amplitude of A = 0.0116(0.0015) days and a period of P3 = 29.07(0.04) years. Furthermore, many parameters can be calculated as shown in Table 1.

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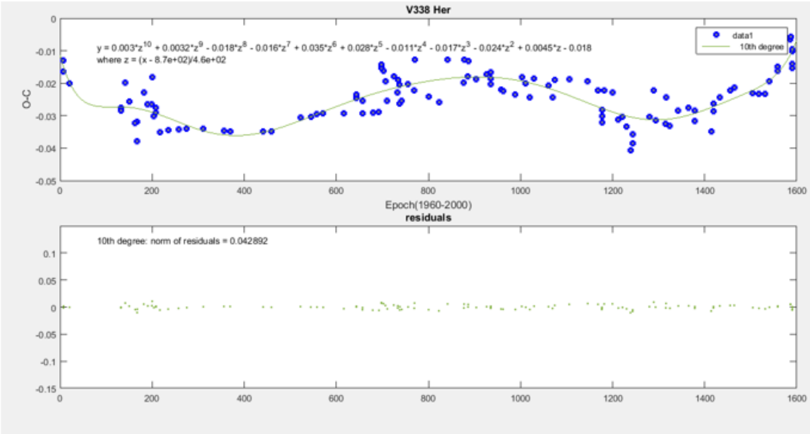

Figure 1: The sinusoidal fit is presented from (1960-2000)

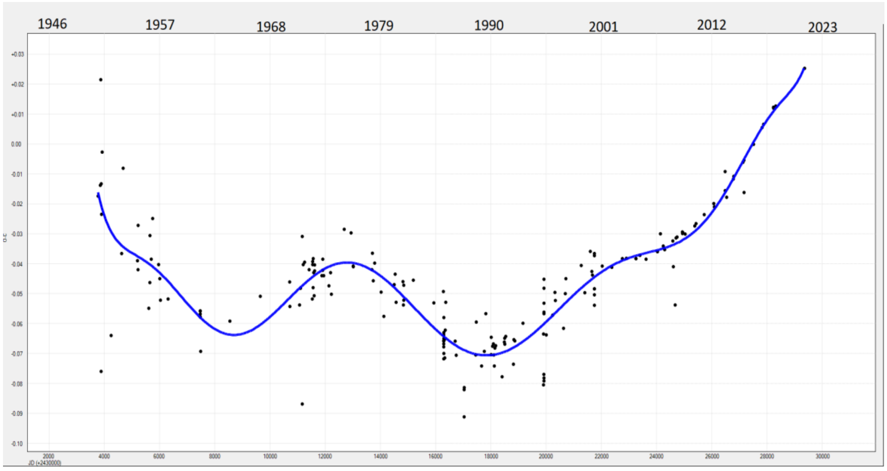

Figure 2: The sinusoidal fit is presented from (1946-2022)

Table 1: Shows the results from the O-C analysis

Parameter	Value
T_o(HJD)	2424791.485
P(day)	1.07000000
a12,3sini3(AU)	+2.3/-0.91
e3	0.5
ω3	196
P3(years)	30 Yr
A3 (days)	0.005 d
FM3(MΘ)	0.001
M3(MΘ)	0.01
porb	0.3795

The data in Figure 1 show a periodic change in the O-C data, pointing to the possible existence of a third body around the eclipsing binary. In the data from 1999 to the end of 2021, two orbits of the presumed third body have taken place. The period analysis was done in the Peranso program using the DCDFT algorithm with the following parameters: start: 500 d, end: 15000 d, range: 25000. The

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resulting period is 4399 +/- 574 days.

2.2. Modeling Light Curves

Photometric solutions of V338 Her were (re)deduced using the 2003 version of the W–D program (Wilson & van Hamme 2003). During the calculation, we adopted the following fixed parameters: the temperature for Star $_1$ of T_1, the linear limb-darkening coefficients of x_1 and x_2 for various bands (Van Hamme 1993), the gravity darkening exponents of g_1 = 1.0 and g_2 = 0.32 (Lucy 1967), and the bolometric albedo coefficients of A_1 = 1 and A_2 = 0.5 (Rucinski 1973). The commonly adjustable parameters employed are the orbital inclination, I, the mean temperature of Star $_2$, T_2, the potential of the primary, Ω_1, and the monochromatic luminosity of Star 1, L_1. The reflection effect was computed with the detailed model of Wilson (1990). The relative brightness of Star 2 was calculated by the stellar atmosphere model (Kurucz 1993). However, we calculate the spot of V338 Her and the shape of the spots, shown in Fig (6) and Table (2).

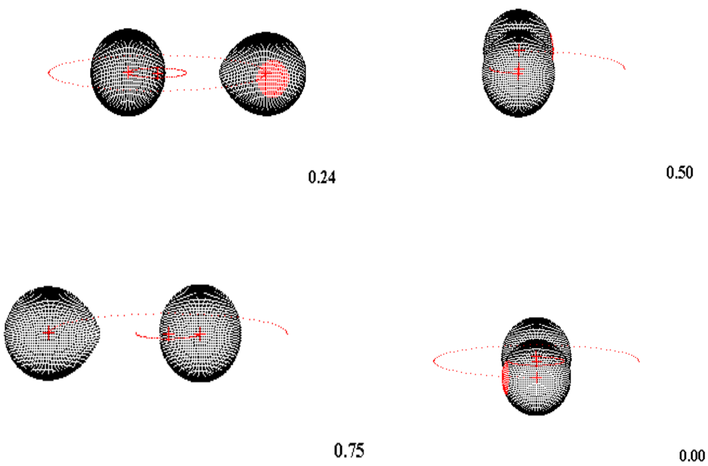

Figure 3: Shows the shape of the spotted model of v338 her binary star at different phases

Table 2: Spot parameters solution for the primary stars

Parameters	V338 Her
Colatitude	89.000
Longitude	105.000
Radius	26.000
temperature Factor	0.900

To determine the absolute parameters for V338 Her, it was decided to apply for the Matlab Programme. The bolometric parameters were evaluated using the relationship Allen gave (1976). The mirrored image coefficients were evaluated using the subsequent equations (Budding E, 1980). This was reinforced using the method of Barrado et al. (1994). The quick duration binary structures from the well-known mass-luminosity relation and the outcomes are provided in Table (3). The first touch angle (θ1) may be derived from the subsequent equation (Kopal Z, 1979). Also, we calculated the Empirical Relationship among CI, Mbol and Tef; the age and mass may be decided. As a result, using the method of Barrado et al. (1994). All the parameters we calculated were gathered in one place for comparison with earlier authors.

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Table 3: Absolute parameter (in solar units) for the v338 her binary system

Parameter	Present work	A. Liakos(2014)	Y.-G. Yang(2010)
R1	1.0328	2.3	1.75
R2	1.1012	2.4	1.52
M1	0.7874	1.5	1.56
M2	0.2126	0.41	0.31
L1	3.348	6	-
L2	3.6246	0.7	-
L3	3	3	-
q	0.2700	0.27	0.200(±0.002)
RL	0.1182	-	-
VL	0.0069	-	-
Mbol1	8.26288	3	-
Mbol2	8.27449	5	-
g1(B,V,R)	0.1145, 0.0855, 0.0681	-	-
g2(B,V,R)	0.1427 , 0.1178 , 0.1024	-	-
E1(B,V,R)	1.1870 , 1.2720, 1.2555	-	-
E2(B,V,R)	9.5288 , 9.2314 , 8.3435	-	-
log Age1	2.0004	-	-
log Age2	2.0064	-	-
t1/tsun*10^76	1.1699	-	-
t2/tsun *10^77	1.6855	-	-
θ_I	1.3003	-	-
a	0.4840	-	-
C_o	0.4281	-	-
Mv1	-1.9691	-	-
Mv2	-1.5472	-	-
(B-V)1	0.2785	−0.21	-
(B-V)2	1.2190	−0.19	-
BC1	1.9692	0.00	-
BC2	- 1.5472	-0.68	-

3. METALLICITY ANALYSIS

3.1 Mass Fraction

Stellar composition is often simply defined by the parameters X, Y and Z. Here, X is hydrogen's mass fraction, Y is helium's mass fraction, and Z is the mass fraction of all the remaining chemical elements (Asplund, Martin (2009). Thus

$$X+ Y + Z =1 \tag{9}$$

X+Y+Z=1In most stars, nebulae, H II regions, and other astronomical sources, hydrogen and helium are the two dominant elements. The hydrogen mass fraction is generally expressed as , where M is the total mass of the system, and mh is the mass of the hydrogen it contains. Similarly, the helium mass fraction is denoted as Y= mhe. The remainder of the elements are collectively referred to as "metals", and the metallicity i.e. the mass fraction of elements heavier than helium - can be calculated as

$$\mathbf{Z} = \sum_{i>H} \left(\frac{mi}{M}\right) = \mathbf{1} - \boldsymbol{X} - \boldsymbol{Y} \tag{10}$$

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For the surface of the Sun, these parameters are measured to have the following values (Asplund, Martin,2009)

Table 4: Show The metalicity of the solar value for V338 Her

Description	Solar value
Hydrogen mass fraction	Xsun=0.7381
Helium mass fraction	Ysun=0.2485
Metallicity	Zsun=0.0134

So by applying the equation (9, 10), we evaluate the numerical value of metalicity for the v338 her as X= 1.0078 and Y= 4.0026 and Z = 0.024 where mh = 0.70, mhe = 0.292.

4.5 Third Light

The third light of a third source—typically a far-off third star—established a gravitationally confined triple system. The presence of a third star diminishes both the primary and secondary eclipse depths. The problem of third light arises when a binary is a component of multiple large systems. Her binary is an illustration of such a system as V338. Sometimes, the additional component (responsible for the "third light") may be brighter than the individual components. The data for V338 Her has been collected, and the binary maker 3.0 program has been applied in two distinct ways, one with the third light and the other without it, to demonstrate the effect of the third body on the light curve, as depicted in Figures (4). Where the red line represents the curves of stars with a third light, the blue line represents the curves of stars without a third light.

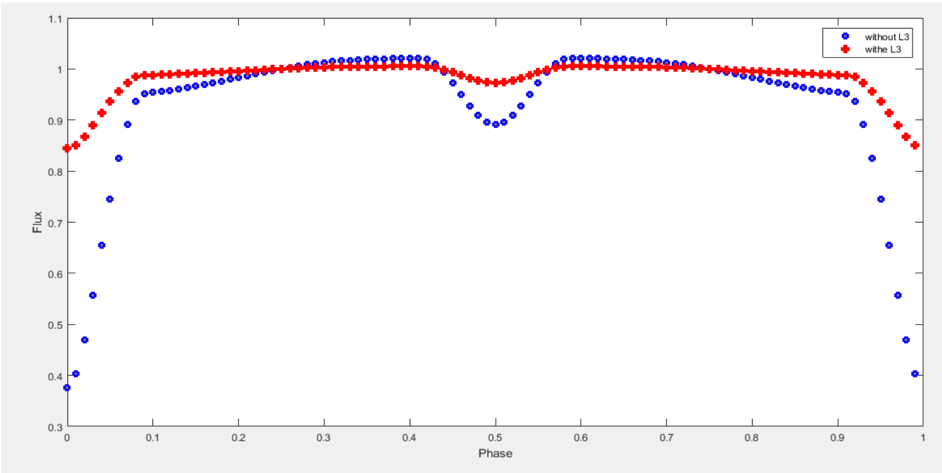

Figure 4: The comparison of V filter analysis with third light component for V338 Her

6. CONCLUSION

By modeling the light curves of V338 Her, we could deduce photometric solutions indicating that these two stars are Algol-type binaries with low mass ratios, qph =0.220 for V338 Her. The O-C curves suggest that their orbital periods exhibit long-term period changes with cyclic variations. The absolute parameters of V338 Her cannot be determined directly due to the absence of published spectroscopic elements. The spectral type was used to estimate the mass of the more substantial component. A mass error can be approximated, assuming an uncertainty of less than 1 spectral subclass. Therefore, M1 = 1.56 (0.04) M_{Sun} was adopted as the mass of the more substantial components for V338 Her (Cox, 2000). Then, other parameters listed in Table 6 can be readily derived.

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In our paper on selected Algol-type binaries, photometric observations of V338 Her are analyzed and discussed. Following is a summary of the findings.

1. Using a modified version of the Wilson-Devinney code, photometric solutions for V338 Her were deduced from our new observations of Vetesn'k's (1968) data. The third LED in VR bands accounts for 0.1%. The mass ratio and fill-out factor for the primary of V338 Her are qph = 0.200 (0.002) and f = 54.2%, respectively. Mezzetti et al. (1980) determined the mass ratio be 0.16; the derived value is greater.
2. For V338 Her, there is a continuous period increase along with a cyclic variation whose period and amplitude are 29.07 (0.04) years and 0.0116 (0.0015) days, respectively. The second component's cyclic magnetic activity or a third body's light-time effect could cause cyclic oscillation. dP / dt = +1.44 (0.24) 107 days per year indicates that the secular period is increasing. This indicated that mass is transferred from the less massive element to the more massive element. With the mass transfer, this type of binary with a secular period increase can transition from a semidetached configuration to a contact one.

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