

RESEARCH PAPER

Photometric Analysis of CN Andromeda Short Period Binary Star

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ABSTRACT:

In this work, the short period binary system named (CN Andromeda) have been chosen to be analyze with B,V light curves using the PyWD2015-Qt5 program .The physical and geometrical parameters have been gained and contrasted with previous results of workers. Also, the absolute parameters have been established with results that are acceptable with the results of other workers. With good accuracy, the bolometric magnitude and Roche lobe radius have been calculated. .The present result shows that the selected system is over contact. Spot solution parameters for the analysed binary system have been evaluated. The observed light curves exhibit asymmetries and oddities caused by the system.

KEY WORDS: W Ursae Majoris, light curve, CN And, binary star

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1. INTRODUCTION

The over-contact eclipsing binary systems known as EW stars, or W UMa-type variable stars, have orbital periods between 0.2 and 1 day. That each item is an A to K spectral type main sequence star that burns hydrogen in its core. An EW star's spectral class and colour remain constant throughout the orbital cycle. This indicates that the temperature and optical thickness of the shared boundary are both high. That is essentially constant. Between the two components, there are only a few hundred Kelvin worth of temperature changes. The early-type eclipsing binary Beta Lyrae experiences a large-scale energy transfer from the bigger, more massive component to the smaller one, less massive one, roughly balancing surface temperatures throughout the entire system. The Roche model was first used to describe eclipsing binary stars, more especially the W UMa stars, by (Lucy, 1968).

The Roche lobes are being touched or blocked by both stars in this dumbbell-shaped binary over the short period. One of its distinctive features of contact binaries of the W UMa-type, the equality of the effective temperatures of both components was initially one of the most challenging properties is to explain and result in the development of the successful "contact model" (Lucy, 1968). In general, the two components of these systems have masses in the order of a solar mass or less, making the study of W UMa one of the most crucial jobs in eclipsing binary research. According to observational characteristics, (Binnendijk, 1970) separated the W UMa binaries into the A- and W-type systems, with the division as follows: Type A class: Systems often have components with a lower mass ratio, a greater mass, a higher brightness, and an earlier spectral type (usually from A to G). The light curves of W UMa stars can be recognized by their continuous brightness change and roughly equal minima. The light curves variation varies between a few tenths and a few magnitudes. Because of the larger, more massive, and hotter element's passing eclipse. Wilson (1978) provided a list of eight A-type systems with known properties .All showed main sequence radii over zero, indicating that were

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actually all experienced progression. There is really increased communication and a sizable shared boundary. (Van Hamme, 1982). Despite the fact that W UMa stars are believed to be contact binaries, the origin, structure, and evolution of the class have not yet been satisfactorily explained. According to certain hypotheses, massive exchange could lead to the evolution of W-type systems into A-type ones. Yet, Kuiper and Kopal appeared to have had slightly different interpretations of what the phrase "contact binary" meant. Although contact binaries are believed to exist in W UMa stars, a satisfying the system's theory of genesis, organization, and progression is incomplete-type: Most W-type systems consist of stars with later spectrum classes (from F to K). The wider primary minima in W-type W UMa stars relates to eclipse of the smaller, less massive component. In comparison to A-type system, stars in W-type structures are typically nearer to ZAMS stars (celestial object zero age main sequence, or stars that have just started burning hydrogen in their cores). The secondary elements of W-type systems have radii which are bigger as compared to typical ZAMS (celestial object zero age main sequence, or stars that have just started burning hydrogen in their cores). Which has begun burning hydrogen in its core in comparison with the A-type classification. The secondary elements of the W-type systems have radii that really are bigger than those found in typical ZAMS (celestial object zero age main sequence, a star that has just started burning hydrogen in its core) of stars with the same masses. It is typical to believe that A- and W-type systems Hofmeister (1949) first identified it as a binary star of the W UMa class. constitute slightly different stages of progression.

1.1 A description of CN Andromeda

CN And (BD +3959, AG+39 30, CSV 38) Mergentaler (1950) conducted that star's first in-depth investigation and conducted a statistical analysis of the asymmetry of the light curves. Hofmeister 1949 first who identified it as a binary star of the W UMa class (1949). The orbital period, the depth of the eclipses, the relative diameters of the component stars, and the densities of their atmospheres are only a few of the variables that (O'Connell, 1951) investigated for connections with the degree of the asymmetry. He discovered that at shorter optical wavelengths, the extent of the imbalance tended to be greater.

Researchers have frequently discussed and looked into it (Michaels et al., 1984). To study this system UBV filters were used by (Van Hamme and Wilson, 1984) to study this system, and for the first time addressed its light contours. The initial spectroscopic studies on CN And were carried out by (Rucinski et al., 2000). It was projected that the components' spectral types would fall between F5 and G5. The mass transfer that caused the orbital period to decrease at a rate of 4.82, according to (Siwak et al., 2010), the candidate. The secondary star should be less than 1% under filled, the parent star should fill its Roche lobe, and the system should be semi-detached. The O'Connell effect and the system's period fluctuation has been the subjected to additional study (Koju and Beaky, 2015). (Yildirim et al., 2019) were planned for the system to demonstrate that the W UMa binary is an A-subtype of the CN And was being a tight-knit binary semi-detached. Several explanations for the phenomenon have been proposed, including the existence of star spots and circumstellar materials. There is no evidence that the amount of the imbalance in the maxima and the orbital periods of the systems are connected. The aforementioned star is an active binary of the solar type with spectral elements in the F5 to G5 range. The system's change in orbital period has been ascribed to magnetic mass transfer from primary to the secondary section disintegration brought upon with strong system activity, or even both.

2. Photometric analysis of CN And with PyWD2015-Qt5 program

Short period binary star's light curve photometric analysis has CN And. Moreover, I've been utilizing PyWD2015-Qt5. After inputting data from light/velocity curves inside the inputs window, this software then started by entering the identification of a binary star, choosing the operation mode, the phase in the time variable, and the input device. The parameters have been input for the short period binary star CN And artificial light curve in the system tab. Also, the physical characteristics of the binary star were shown in the LC 2015 tab. The primary star effective temperature (T_1), the mass ratio (q), the gravity brightening coefficient for primary and secondary components, the primary and secondary stars' surface albedo ($Albd_1$, $Albd_2$), and the gravity brightening coefficient for primary and

secondary stars (g_1, g_2) were all fixed before the secondary star effective temperature (T_2) and the inclination in d were adjusted. One looked for solutions in order to derive a photometric solution for this system at the first time. The values of the non-dimensional potentials $_1$ and $_2$ were discovered to be too less than the inner Roche potential with q values as stated in Table after numerous runs. It suggests that for any assumed value of q , the result immediately converged to a solution and that CN And is an overcontact eclipsing binary system of W UMa type. Table (1) lists the weighted square deviations as a function of q 's various fixed mass ratios. Choosing the mass ratio for which the sum of the weight squares of the variations was the least of the initial objective. A light curve or radial velocity curve, for example, would be an observed quantity. A calculated quantity would be a synthetic light curve or radial velocity curve. Weights, O-C: residuals, $(O-C)^2$: squares of the residuals, $W(O-C)^2$: weighted squares of the residuals, $\sum W(O-C)^2$: weighted sum of squares of the residuals from Fig.(11) Sum of the residuals vs mass ratio each solid point represent a solution one can see that smallest value of q is equal to the smallest to the sum of residuals. The variable q as a second adjustable parameter is added, carried out computation, and found that $q=0.62$ is the optimal value for CN And. For B and V filters the synthetic and observed light curve have been shown in Figs. (1 and 6) the synthetic and observed light curve of B,V filter CN And have been shown in Figs.(2 and 7) third light is set as free parameter because third Light's input to the study it because it is not significant, and mode 3, a contact binary system analysis method, is adopted. And after a few rounds, the Best match between synthetic observed light curve outcome has been discovered, as shown in the Figs. (3 and 8). Table (3) Represent the output parameters of the unspotted model of B,V filters, and the best fit parameters are shown in Table (8) for B,V filters (2). The light curve following the addition of the spot parameters is given in Figs. We add the spot parameters to the primary star as described in Table (6). For (BV) filters Synthetic and observed light curve after adding spot parameters have been shown in Figs. (4 and 9) respectively. The output parameters of CN And are displayed following adjustment of the temperature factor for the principal spot, which permitted varying the output parameters. In the Table (5), the best match

between the synthetic and observed light curve of CN And is obtained after deleting the temperature factor and maintaining adjustments to other parameters, as shown in Figs. (5 and 10) for B and V filters and the best fitting parameters for the spotted model are presented in Table (4). Using the PyWD2015-Qt5 program, the unspotted and spotted models of CN And are displayed in Figs. (12 and 13), respectively. As illustrated in figs. (15 and 16), these two light curves are used to examine the candidate star's light curve which the light curve of fig.(16) is getting from this source(Seeds and Abernethy, 1982).

2.1 Spot analysis

Star spots are the astrophysical analogues of sun spots on other stars. Have the sizes of Sun spots which are extremely difficult to discover on stars because they are too small to create perceptible variations in luminosity. The identified star spots are often larger than those of the sun and can cover up to 30% of the stellar exterior. They are also 100 times larger than those on the sun. Table (1) provides a representation of the modelled places. Not all of the bands of the light curve's initial portion are matched because spot adjustments are entered in the spot tab (cool spot), but the second half of the light curve had good matching.

2.2 Absolute parameters

Equation (1) to (6) are applied in the MATLAB program to get the absolute parameters. By applying equation (6), the bolometric magnitude and roche lobe radius are estimated using the references from two studies (Gürol et al., 2015).

$$A^3 = 74.5. p^2. (M_1 + M_2) \quad (1)$$

Equation (2) is Kepler's third law. P : The orbital period in days. M_1 and M_2 are the masses of the components in solar mass

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

Equation (3) is mass of each component of binary star system. M_1 and M_2 : Are the masses of the components in solar system. M : The solar mass, q : mass ration of the components of binary star system.

$$R_1 = A. r_1, R_2 = A.r_2 \quad (3)$$

Equation is the absolute radii and the relative radii of the components.

A: Separation between components expressed in solar radii R_1 and R_2 : The absolute radii in solar radii

$$Q = \frac{M_2}{M_1} \quad (4)$$

Mass ratio between secondary and primary component.

$$L_1 = R_1^2 \cdot T_1^4, \quad L_2 = R_2^2 \cdot T_2^4 \quad (5)$$

Equation of luminosity and radius relation

L_1 : The luminosity of primary component L_2 :

The luminosity of secondary component

R_1 : The absolute radius of primary component

R_2 : The absolute radius of secondary component

T_1 : The effective temperature of primary component

T_2 : The effective temperature of secondary component.

$$M_{bol1,2} = 4.75 - 5 \log\left(\frac{R_{1,2}}{R_\odot}\right) - 10 \log\left(\frac{T_{1,2}}{T_\odot}\right) \quad (6)$$

Equation is bolometric magnitude.

$$r_1/A = 0.38 + 0.2 \log(M_1/M_2) \quad \text{For } 0.3 < M_1/M_2 < 2 \quad (7)$$

Equation is roche lobe radius

3.2.1 Reflection coefficient, Gravity darkening coefficient

Theses parameters gravity darkening coefficient and reflection coefficient are determined using equations (8-10) for this purpose Matlab program have been used to determine this parameters .

$$g_{1,2} = \frac{c_2}{4\lambda T_{1,2} [1 - \exp(-\frac{c_2}{\lambda T_{1,2}})]} \quad (8)$$

$$c_2 = \frac{1.43883}{(\lambda T_{1,2})_{eff}}$$

λ : Effective wavelength of the filters.

T_1 : The effective temperature of primary component.

T_2 : The effective temperature of secondary component.

$$E_{eff1} = t_1 \left[\frac{T_2}{T_1}\right]^4 \frac{e(\frac{c_2}{\lambda T_2 - 1})}{e(\frac{c_2}{\lambda T_1 - 1})} \quad (9)$$

$$E_{eff2} = t_2 \left[\frac{T_1}{T_2}\right]^4 \frac{e(\frac{c_2}{\lambda T_1 - 1})}{e(\frac{c_2}{\lambda T_2 - 1})} \quad (10)$$

3.3 Empirical Relationship between CI, M_{bol} and T_{eff}

Formula (11), which shows the Empirical Connection among CI, M_{bol} , and T_{eff} , the bolometric correction have been shown in equation (13). The Matlab application is utilized for all of this. The primary and secondary components of the short-period double star CN And are shown in the Table (8) as the most recent experiment findings by Reed [1998]

$$M_{sun} = 4.83, \quad BC = M_v - M_{bol} \quad \text{for } \leq 0$$

$$B.C. \text{ sun} = -0.07$$

$$B-V = -3.684 \cdot \log(T) + 14.551 \quad \text{for } \log(T) < 3.96 \quad (11)$$

$$B-V = 0.344 \cdot [\log(T)]^2 - 3.402 \cdot \log(T) + 8.037 \quad \text{for } \log(T) > 3.961 \quad (12)$$

$$BC = -8.499[\log(T)^4] + 13.421 \cdot [\log(T)]^3 - 8.131 \cdot [\log(T)]^2 - 3.901 \cdot [\log(T)] - 0.4 \quad (13)$$

3.4 Mean density of the components

Mean density of the components can be determined using equations (14) and the table (15) represent the mean density of the component

$$\rho_1 = \frac{0.0189}{r_{1mean}^3 \cdot P^2 \cdot (1+q)} \quad (14)$$

$$\rho_2 = \frac{0.0189 \cdot q}{r_{2mean}^3 \cdot P^2 \cdot (1+q)} \quad (15)$$

3.Results

The outcome of the detected model's output parameters for binary star CN And has been demonstrated in Table 5 that the output parameter results correspond to those of other workers. Table (4) displays the spotted model's best-fitting parameters. Equations (4) to (8) are used to calculate the absolute values for the Roche lobe radius and bolometric magnitude, which are roughly close to the values from other workers. The results for output parameters for unspotted model have been shown in Table (3), best fit parameters have been presented in Table (2) for two filters, and they are close to one another. The

spotted and unspotted models' output parameters have very good agreement with one another. Unspotted models are shown in Fig. (13) Whereas spotted models are displayed in Fig.(12).

4. Discussion

CN And its photometric analysis as discovered using PyWD2015-Qt5. The system can be categorized as a near contact binary or a marginal contact binary due to its short orbital period, late spectral type, and low fill-out factor. A binary system with little contact means that CN And is a shallow contact binary. Mass transfer takes place between low mass stars and high massive stars, as opposed to energy flow that is driven by third light and magnetic activity The output parameters are very similar to the gravity brightening output parameters of other earlier publications. The values of the primary and secondary surface albedo coefficients and primary and secondary component coefficients are same (Yildirim et al., 2019) CN And its photometric solution were discovered using PyWD2015-Qt5. The system can be categorized as a near contact binary or a marginal contact binary due to its short orbital period, late spectral type, and low fillout factor.. In contrast to energy flow that is influenced by magnetic activity and third light, mass transfer occurs from low mass star to high massive star. The output parameters are very similar to the gravity brightening output parameters of other earlier publications. The values of the primary and secondary surface albedo coefficients and primary and secondary component coefficients are same (Yildirim et al., 2019). CN And binary system's potential and are depicted in Fig (14).

5. Conclusion

Getting these assignments is done primarily for the authors to gain experience with actual research. One should therefore share some of the lessons that acquired from their experience.

Through the current study, it was found that:

1. The answer demonstrates that the binary system (CN And) is an A-type system due to its bigger physical size as well as its hotter and more massive star. There is some difference between physical parameters of spot and unspotted models.
2. There is clear correlation seen between chosen short period binary star systems' absolute properties, physical dimensions, and geometrical parameters.
3. The fill-out factor value indicated the type of system near contact or overcontact system
4. Authors using observe the configuration for a particular binary star system in the PyWD2015-Qt5 software.

Acknowledgment

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Conflict of Interest

According to the authors, there is no conflicts of interest.

Table 1 Sum of weighted squares deviations corresponding to different mass ratio for CN And

$q = \frac{M_2}{M_1}$	$\sum w(o - c)^2$
0.39	0.01998
0.42	0.01914
0.44	0.019154
0.46	0.019152
0.48	0.019138
0.5	0.19204
0.52	0.019055
0.56	0.019025

Table 2 Best fit parameters of unspotted model of CN And for B, V filters

Parameters	CN And(B) filter	CN And(V) filter
I	74.956	74.956
T_2K	4608	4687
L1	13.96	15.152
Ω_1	2.809	2.488

Table 3 Output parameters of unspotted model of CN And for B, V filters.

Parameters	CN And (B) filter	CN And(V)filter
q	0.56	0.56
T_1	4690	4182
$*T_2$	4480	4756.31
$*i$	74	74
$*\Omega_1$	2.634	2.50
L1	13.069	15.034
$R_{pole}(\text{primary})$	0.464858	0.464858
$R_{pole}(\text{secondary})$	0.290257	0.290257
$R_{side}(\text{primary})$	0.505213	0.505213
$R_{side}(\text{secondary})$	0.303973	0.303973
$R_{back}(\text{primary})$	0.545597	0.545597
$R_{back}(\text{secondary})$	0.344005	0.344005
ALB_1	0.50	0.50
ALB_2	0.50	0.50
GR1	0.32	0.32
GR2	0.32	0.32
Ω_{in}	2.658	2.658
Ω_{out}	2.419	2.419
$\sum w(o - c)^2$	0.019025	0.019023

Note: *adjusted parameters

i-Inclination in arc degrees, T_1 -Temperature effect of primary star in, T_2 -Temperature effect of secondary star, Ω_1 -Surface potential of primary star, X_2 -Limb darkening for secondary star, X_1 -Limb darkening for primary, ALB_1 -Primary star surface albedo, ALB_2 -Secondary star surface albedo, q-Mass ratio, GR1-Gravity brightening of primary component, GR2-Gravity brightening of secondary component, Ω_{in} -inner surface potential, Ω_{out} -Outer surface potential, L1-Relative luminosity of primary star. $\sum w(o - c)^2$ -Sum of residuals

Table 4 Best fit parameters of spotted model for CN And for B, V

Parameters	CN And (B)filter	(Yildirim et al., 2019)	CN And (V)filter	(Yildirim et al., 2019)
*As ₁	1.02	0.650	0.756	0.650
Q	0.56	0.3935	0.56	0.387
*i	74.512	68.02	73.51	67.802
T ₁	6500	6500	6500	6350
*T ₂	5947	5947	5100	5732
*Ω ₁	2.554	2.667	2.533	2.651
*L ₁	11.283		14.66	
ALB ₁	0.50	0.50	0.50	0.50
ALB ₂	0.50	0.50	0.50	0.50
X ₂	0.837		0.837	
GR1	0.32		0.32	
GR2	0.32		0.32	

Table 5 Output parameters of spotted model for CN And for B, V filters

Parameters	CN And(B) filter	CN And(V)filter
I	72.577	72.82
T ₂ K	4828.96	5142.65
L1	8.70	10.624
Ω ₁	2.504	2.483

Note:*adjusted parameters

i-Inclination in arc degrees, T₁-Temperature effect of primary star in, T₂-Temperature effect of secondary star, Ω₁-Surface potential of primary star, X₂-Limb darkening for secondary star, X₁-Limb darkening for primary star, ALB₁-Primary star surface albedo, ALB₂- Secondary star surface albedo, q-Mass ratio, GR1-Gravity brightening of primary star, GR2-Gravity brightening of secondary star, As1-Temperature factor for spot. R_{pole}(Primary) – Primary relative radii at pole, R_{pole}(secondary) -Secondary relative radii at pole, R_{back}(primary)-Primary relative radii at back, R_{back}(secondary)-Secondary relative radii at back, R_{side}(primary) -Primary relative radii at side, R_{side}(secondary)-Secondary relative radii at side, L1 -Relative luminosity of primary star

Table 6 Spot parameters solution of CN And

Primary spot of CN And	Parameter (Yildirim et al., 2019)
ϕ_{s_1}	15
λ_{s_1}	22
θ_{s_1}	35
As_1K	0.650

As_1 , θ_{s_1} , λ_{s_1} and ϕ_{s_1} – spots' temperature factor, radius of spot and longitude and latitude (in arc degrees)

Table 7 Reflection coefficient, gravity darkening coefficient of short period binary star CN And

Name of star	g_1	g_2	E_1	E_2
CN And	0.2731	0.173	0.336	2.72
B filter	0.173	0.1724	0.3351	2.71
V filter				

Table 8 Empirical results of three short period binary stars.

Name of star	Component	$BC=M_{bol} - M_v(\text{mag})$	$CI=B-V$	$M_{bol}(\text{mag})$	$M_v(\text{mag})$
CN And	Primary	-0.7701	7.784	3.446	4.216
CN And	Secondary	-0.0824	8.614	4.358	4.441

Table 9 Mean component density of three binary stars with short periods.

Name of stars	ρ_1	ρ_2
CN And	0.579	0.286

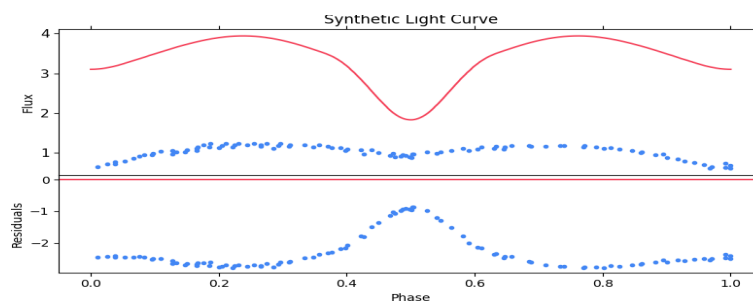


Fig.1: Synthetic light curve of unspotted model for CN And of B filter

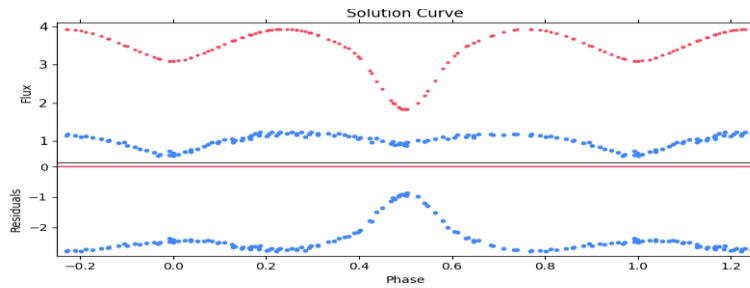


Fig.2: Synthetic and observed light curve of unspotted model for CN And of B filter

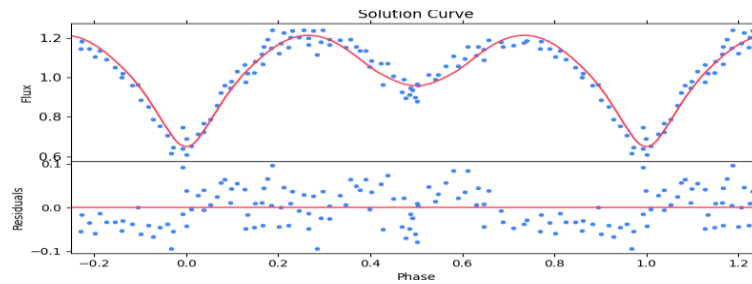


Fig.3: The unspotted model's light curve's best match between observed and synthesized light curve is for the CN And B filter.

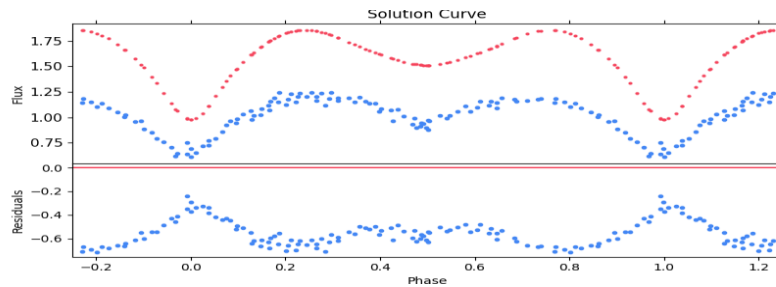


Fig.4: After adding spot parameters for the CN and in the B filter, the light curves, for both synthetic and observed.

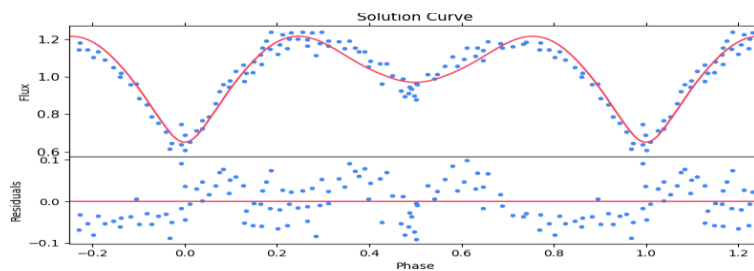


Fig.5: Best match between synthetic and observed light curve for CN And of B filter.

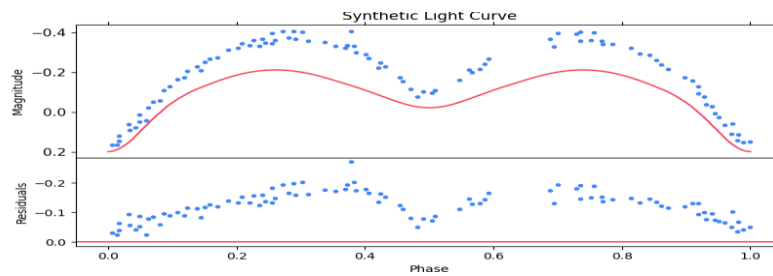


Fig.6: Unspotted model's synthetic light curve for the CN And and V filter.

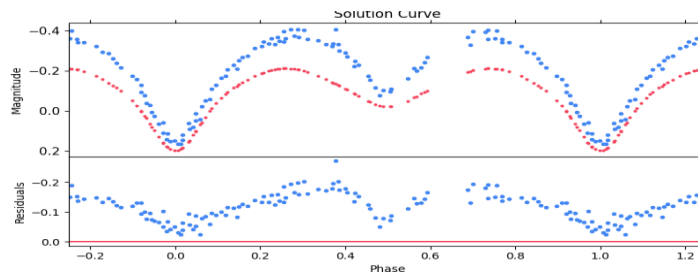


Fig.7:Synthetic and observed light curve of unspotted model for CN And V filter.

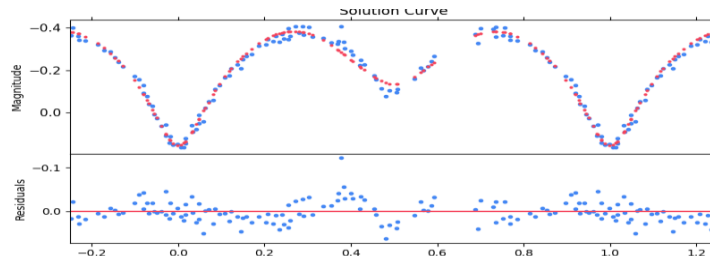


Fig.8: The unspotted model's light curve's best match between observed and synthetic light curve is for the CN and V filters.

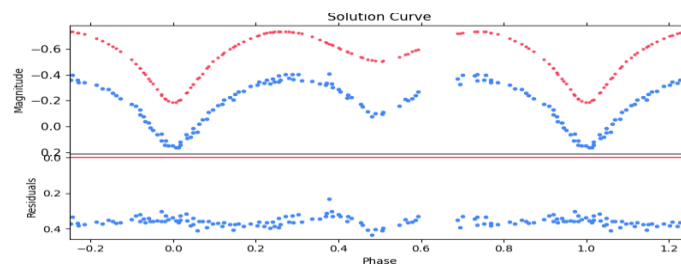


Fig.9: Synthetic and observed light curve after adding spot of CN And.

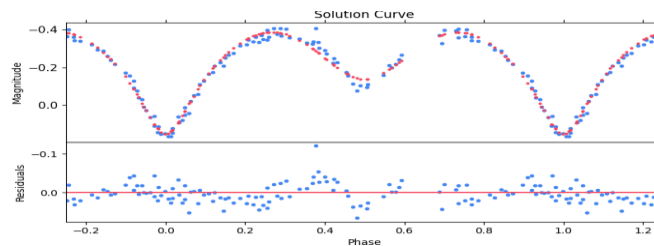


Fig.10: Best match between synthetic and observed light curve of spotted model for CN And.

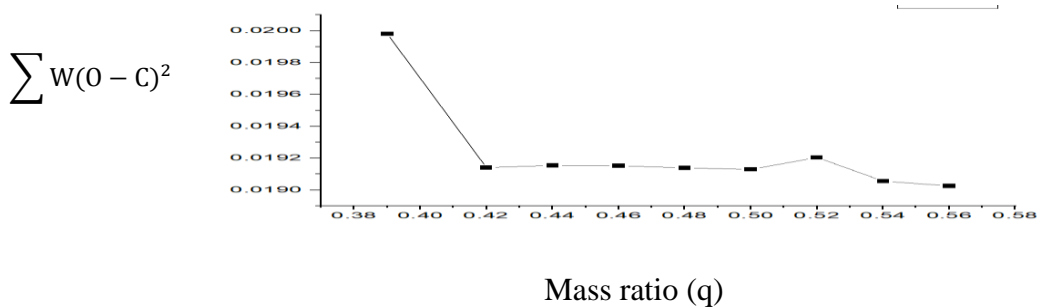


Fig.11: Sum of the residuals vs. mass ratio for CN And each solid point represent a solution.

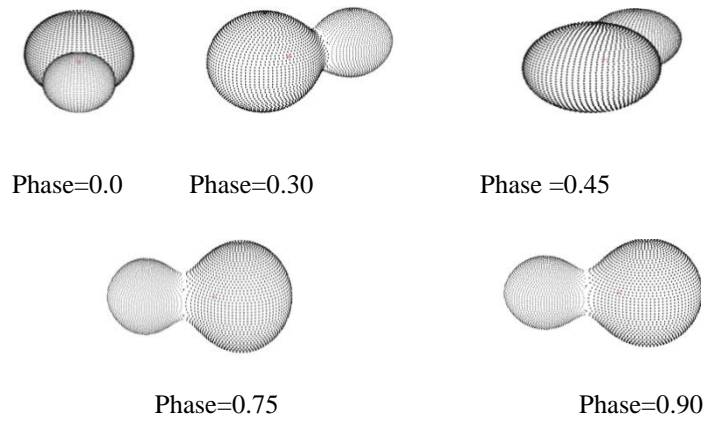


Fig.12: Spotted model of CN And by using PyWD2015-Qt5 program.

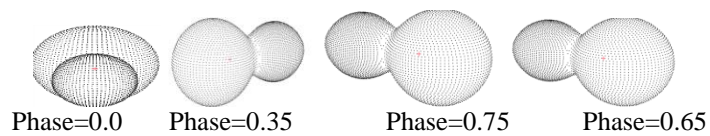


Fig.13: Unspotted model of CN And by using PyWD2015 -Qt5 program.

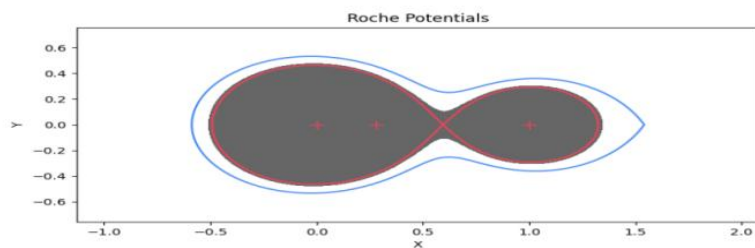


Fig.14: Roche potential of binary star system CN And.

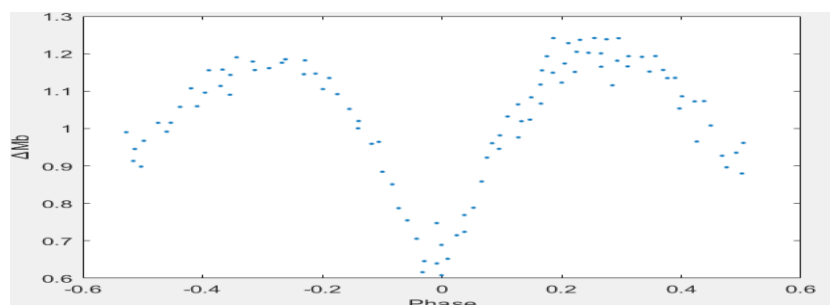
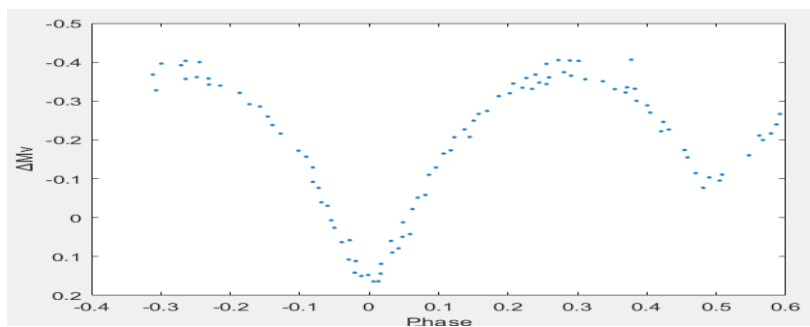


Fig.15: Plot os CN And B filter(Michaels et al., 1984).



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