Photometric Analysis of Eclipsing Binary Stars

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ABSTRCT

In this paper, photometric analysis of two eclipsing binaries systems CG Cyg and XY UMa is presented. New physical and geometric parameters were obtained by performing two computer modeling. The first model is software package PHOEBE based on the Wilson–Devinney method, and the second is Binary Maker 3 (BM3).Our results are in good agreement with those obtained using the same modeling

Keywords: Eclipsing binaries, Photometric, PHOEBE package, and Binary Maker 3

1. INTRODUCTION

The study of binary stars is vitally important in astronomy because it is only by carefully measuring the interactions between stars that we can accurately determine their absolute characteristics such as mass, luminosity, and radius. In this paper, we will be discussed two computer modeling PHOEBE and Binary Maker 3(BM3) for analysis the light curves of eclipsing binaries systems CG Cyg and XY UMa of the short period group RS CVn binaries.

The eclipses of the star CG Cyg were discovered by Williams [1]. The observations since that time [2,3,4,5,6]) have shown that the light curve of CG Cyg is variable (with different depths of the eclipses and different slopes in both quadratures). Small-scale “bumps” are observed sometimes on the shoulders of the light curve [4].

CG Cyg (BD +34º4217) belongs to a group of short-period, eclipsing chromospherically active stars of the type RS CVn The system consists of two components lying on the main sequence: a G9 primary and a K3 secondary. The period of this system is substantially less than a day (0d.6311) and the data were phased according to the ephemeris [7]:

$$HJD\ (MinI) = 2439425.1176 + 0.631143114 * E$$

In this paper, we used this observation for analysis the light curve. Figure 1 shows the Light curve of this binary [8].

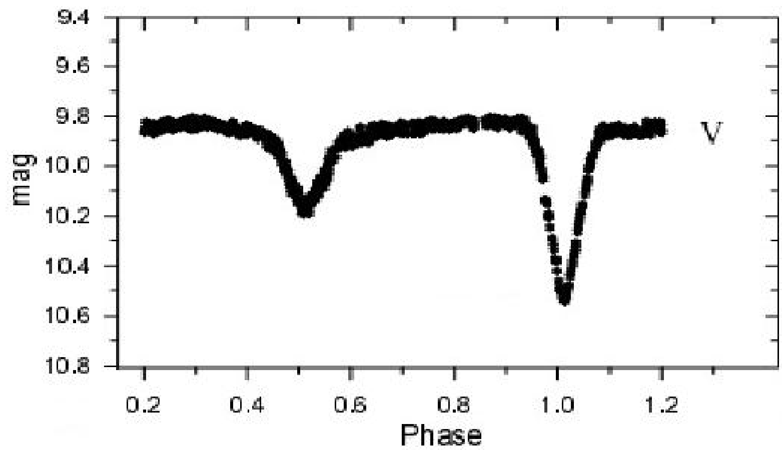


Figure 1: Light curve of CG Cyg

XY UMa (=HD 27143 = BD +55_ 1317 = BV31) was firstly noted by E.H.Geyer in 1955 as an eclipsing binary with a period of P = $0^d.4799$. After which Geyer began a prolonged series of photometric observations, the results of which he reported in 1976, 1977, and 1980 [9]. He found that the revolution period of $0^d.478995$ was constant during 20 years. The star was classified as a cool short period RS CVn star by Baliunas and Vaughan [10]. Indeed, XY UMa, in terms of its chromospheric surface flux, may well be the most active of such systems [11].The spectral data were phased according to the ephemeris [12]:

$$HJD\ (MinI) =2435216.4980+0.47899597* E$$

In this paper, we used this observation for analysis the light curve. Figure (2) shows the Light curve of this binary [13].

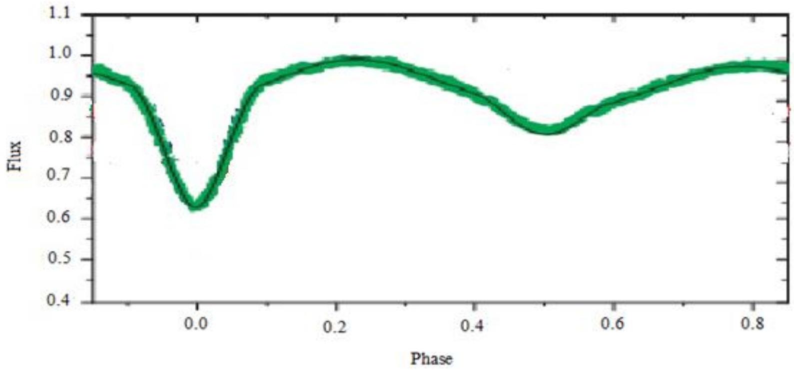


Figure 2: light curve of XY UMa.

This paper is organized as follows. We analyzed photometric data in section 2. Section 2 .1 analyzed the light curves using PHOEBE and the physical parameters for the systems are calculated. Section 2 .2 analyzed the light curves using Binary maker 3 .Section 3 is devoted to conclusions

2. Data Analysis

In order to modeling the Light curves of eclipsing binaries CG Cyg and XY UMa, we applied two different models: the first is PHOEBE (Prša and Zwitter 2005)[14] which is released under the GNU public license., it is modeling software for eclipsing binaries which uses the Wilson- Devinney code. The second is BM3 (Binary maker 3)**.**

2.1 Analysis with PHOEBE

In order to analysis the light curves of these eclipsing binaries using PHOEBE, we added the experimental data in arrange consists of two columns the first column represents the independent variables, in this cause is phase**,** Then we plotted the synthetic and the experimental light curves of CG Cyg and XY UMa as shown in figure 3 and figure 4, respectively.

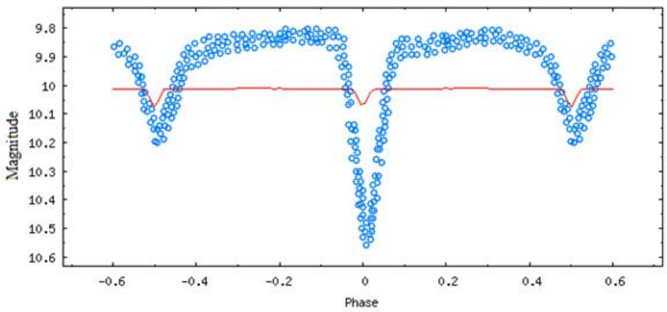


Figure 3: Synthetic and plotted light curves of eclipsing binary CG Cyg.

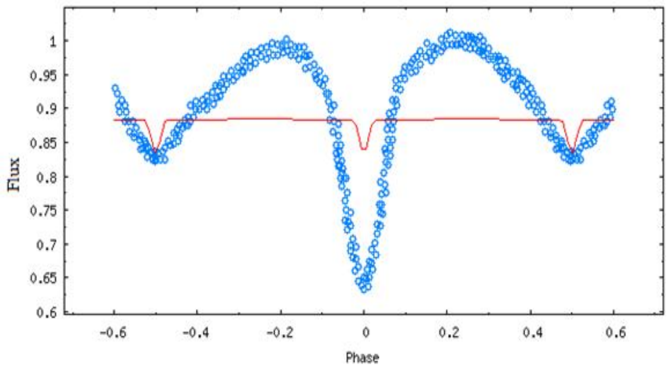


Figure 4: Synthetic and plotted light curves of eclipsing binary XY UMa.

In this paper, we concentrated on the specific parameters identified in table 1.

Table 1: List of geometric and physical parameters in PHOEBE

Parameters	Description
q	Mass ratio
i	Inclination of orbit
g1, g2	Gravity darkening coefficients
TAVH	*Temperature effect* of primary star in *K*
TAVC	*Temperature effect* of secondary star in *K*
PHSV	Surface potential of primary star
PCSV	Surface potential of secondary star
Log(g)1	Surface gravity of primary star
Log(g)2	Surface gravity of secondary star

In order to obtain the physical and geometric parameters of the binary components, we adjusted a numerical eclipsing binary model to the observations; the mass-ratio of CG Cyg and XY UMa were fixed at the values of 0.82 and 0.61, respectively. This model and for a given q has the following adjustable parameters: the orbital inclination i, the non-dimensional potentials Ω_1 *and* Ω_2, the effective temperature of the secondary component T_2, and the relative luminosity of the primary L_1. For a fixed value of the mass ratio *q*, the potentials Ω_1 *and* Ω_2 directly determine the relative radii of the components. The temperature of the primary component of CG Cyg and XY UMa were adopted to be T_1= 5200 k and 5310k, respectively. Table 2 shows two spot parameters on the primary star for eclipsing binary CG Cyg which are taken from [8] while table 3 shows two spot parameters on the primary star for eclipsing binary XY UMa which are taken from [13].

After some iteration we get the best match between the synthetic and the experimental light curve as shown in figure 5 for binary CG Cyg and in figure 6 for binary XY UMa. The light curves residuals windows plot the difference between experimental and synthetic light curves verses the phase; Figure 7 and figure 8 show the residuals of both binaries and figure 9 and figure10 show the shape of both binaries at different phases. Table 4 presents the physical parameters of CG Cyg and XY UMa from using PHOEBE model.

Table (2): Two spot parameters on the primary star of CG Cyg[8] .

Parameters	$Spot_1$	$Spot_2$
Colatitude	90.0	38.0
Longitude	80.0	200.0
Radius	15.0	25.0
temperature Factor	0.81	0.81

Table (3): Two Spot Parameters on the primary star of XY UMa [13].

Parameters	$Spot_1$	$Spot_2$
Colatitude	82.3	81.6

Longitude	192.6	139.2
Radius	10.9	11.4
temperature Factor	0.759	0.765

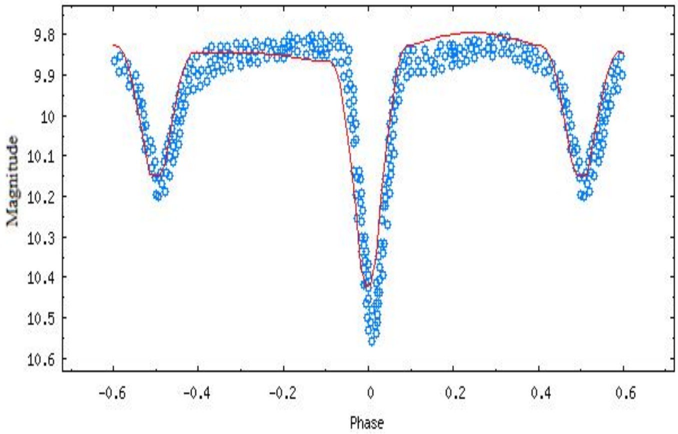


Figure 5: The best match between the synthetic and the experimental light curves of binary CG Cyg.

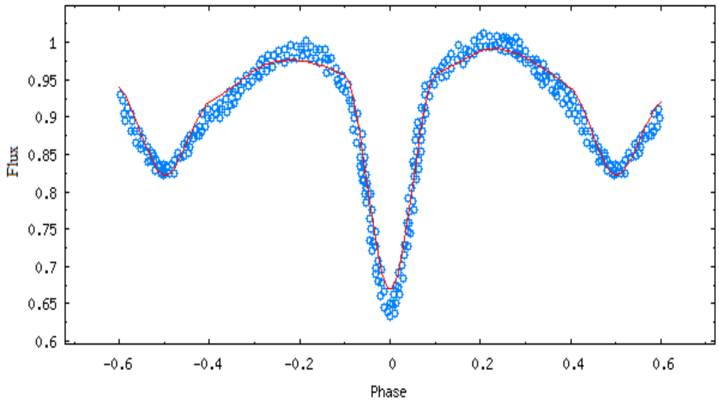


Figure 6: The best match between the synthetic light curve and the experimental light curve of binary XY UMa.

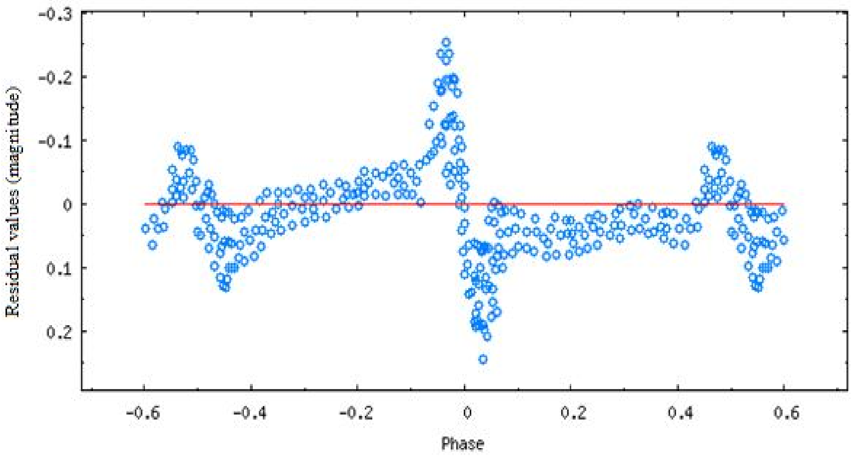


Figure 7: Residuals obtained from fitting routine of eclipsing binary CG Cyg.

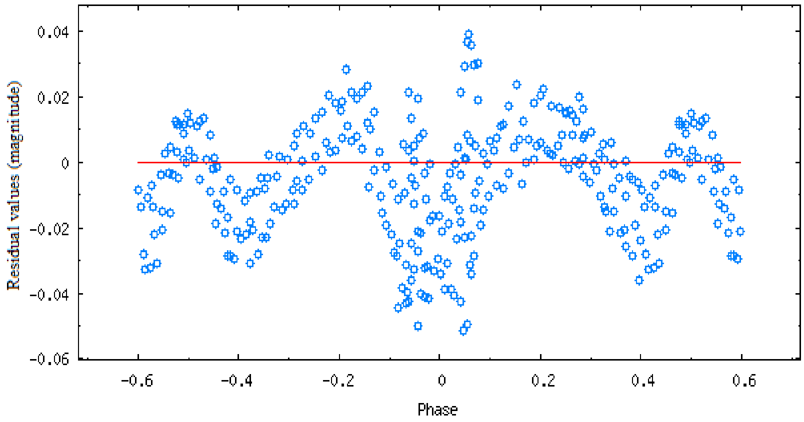


Figure 8: Residuals obtained from fitting routine of eclipsing binary XY UMa.

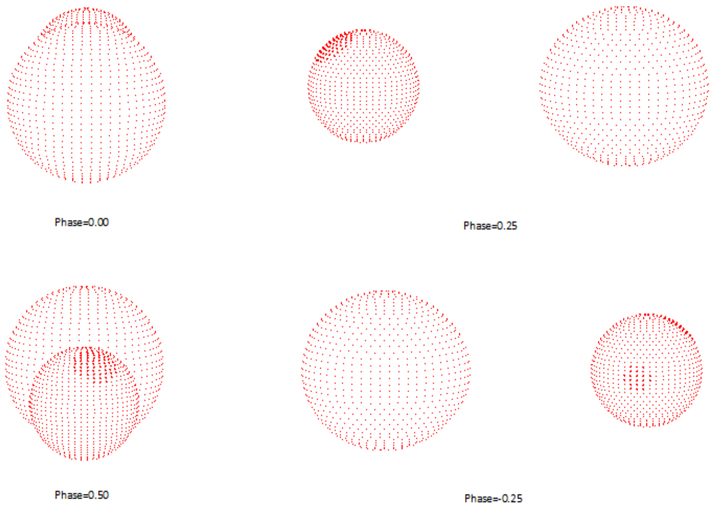


Figure 9: The shape of CG Cyg binary star at different phases.

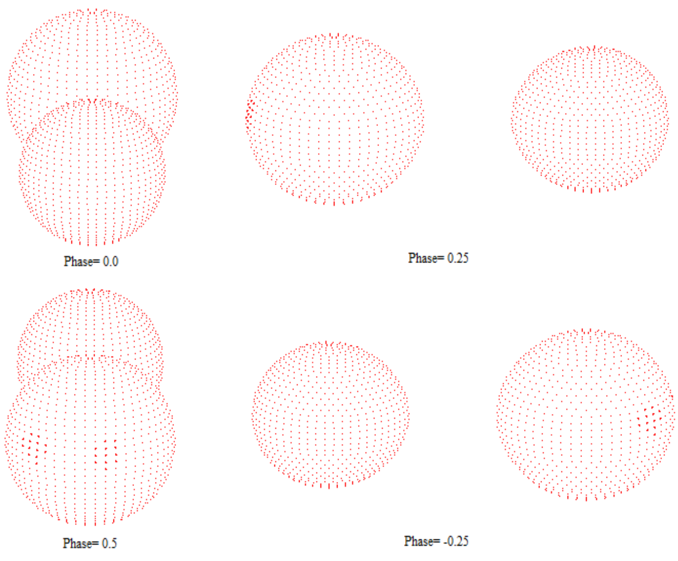


Figure 10: The shape of XY UMa binary star at different phases.

Table 4: The physical parameters of CG Cyg and XY UMa Using PHOEBE

parameters	CG Cyg	Kozhevnikova [15]	XY UMa	Dryomova [16]
Mass $_1$	0.9713	0.93	1.096	1.10
Mass $_2$	0.7965	0.81	0.668	0.66
TAVH	5200	5200	5310	
TAVC	4736	4400	4244	
R_1	1.11155	1.01	1.033	1.13
R_2	0.7965	0.82	0.89	0.66
$\Omega(L_1)$	3.451		3.0817	
$\Omega(L_2)$	2.991		2.7255	
$M_{bol\ 1}$	6.150	5.08	5.0817	4.42
$M_{bol\ 2}$	5.006	6.01	63.378	7.36
$Log(g)_1$	4.330		4.449	
$Log(g)_2$	4.539		4.362	
Surf.Bright.$_1$	3.643		2.632	
Surf Bright.$_2$	2.092		0.674	
Inclination	86.73°	84	73°	81°
PHSV	4.230		3.68224	
PCSV	4.980		3.37095	
$\frac{L_1}{L_1+L_2}$	0.479566		0.392542	
$\frac{L_2}{L_1+L_2}$	0.520433		0.607457	
Temperature Factor spot$_1$	0.650		0.6433	
Temperature Factor spot$_2$	0.9830		0.6316	

2.2 Analysis with Binary Maker 3

After providing experimental light curve data to the Binary Maker 3 we added input parameters to construct meaningful binary models. Binary Maker 3 was used to determine a preliminary solution to the light curves. Table 5 shows the light curve fit parameters for eclipsing binary CG Cyg which are taken from [8] while Table 6 shows the light curve fit parameters for eclipsing binary XY UMa which are taken from [13].

Table 5: The light curve fit parameters for CG Cyg.

Parameter	**Star$_1$**	**Star$_2$**
Mass Ratio (M_2/M_1)	0.82	
Surface Potential Ω [17]	4.86	4.09
Temperature [18]	5260 K	4720 K
Gravity Darkening	0.32	0.32
Limb Darkening	0.604	0.64
Reflection	0.5	0.5
Inclination	83°	

Table 6: The light curve fit parameters for XY UMa.

Parameter	Star1	Star2
Mass Ratio (M2/M1)	0.61	
Radii ($r_{(back)}$)	0.3935	0.2068
Temperature	5310K	3889K
Gravity Darkening	0.32	0.32
Limb Darkening	0.666	0.92
Reflection	0.5	0.5
Inclination	81°	

To create the synthetic light curves of eclipsing binaries CG Cyg and XY UMa, we pressed the Render button at the bottom of the User Input dialog and the light curves are plotted in the light curve window as shown in figures 11 and 12, respectively. The residual produced by the application of model are shown in figures 13 and 14.Figures 15 and 16 show the shape of the eclipsing binaries at different phases. Tables 7 and 8 show the output from Binary Maker3 for eclipsing binaries CG Cyg and XY UMa, respectively.

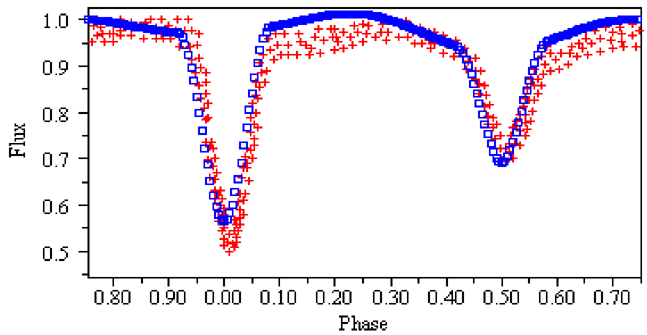


Figure 11: The synthetic light curve (**square**) and the experimental light curve (+) of Eclipsing binary CG Cyg.

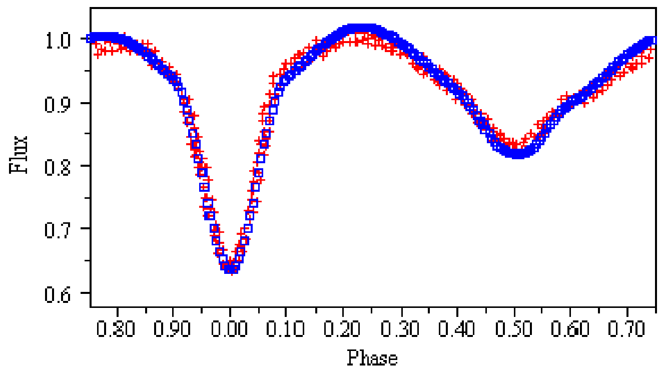


Figure 12: The synthetic light curve (square) and the experimental light curve (+) off Eclipsing binary XY UMa.

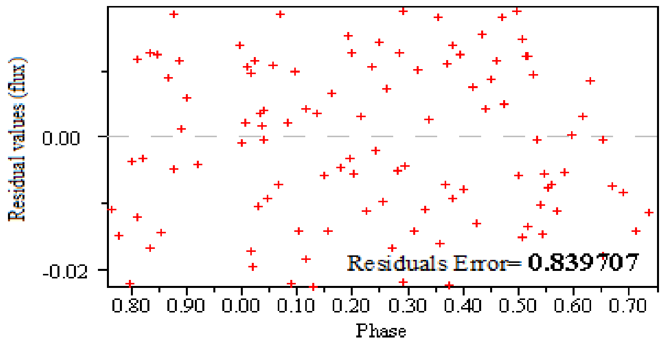


Figure 13: Residuals values generated from the synthetic and experimental data CG Cyg, the number in the bottom right hand corner is the sum of squares of the residuals.

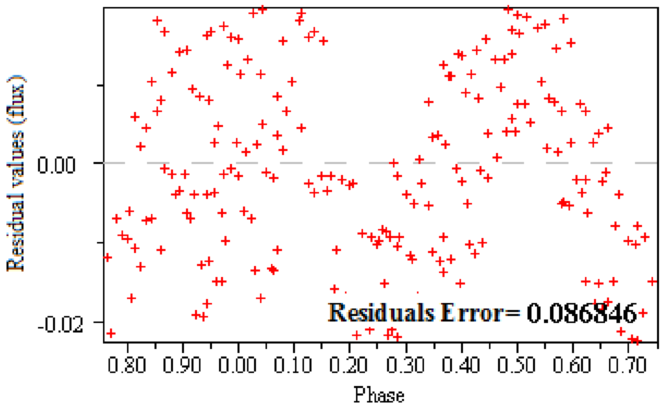


Figure 14: Residuals values generated from the synthetic and experimental data for spotted model of XY UMa using Binary Maker 3, the number in the bottom right hand corner is the sum of squares of the residuals.

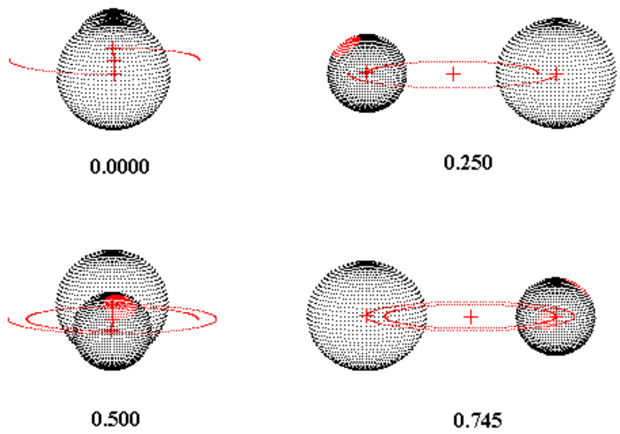
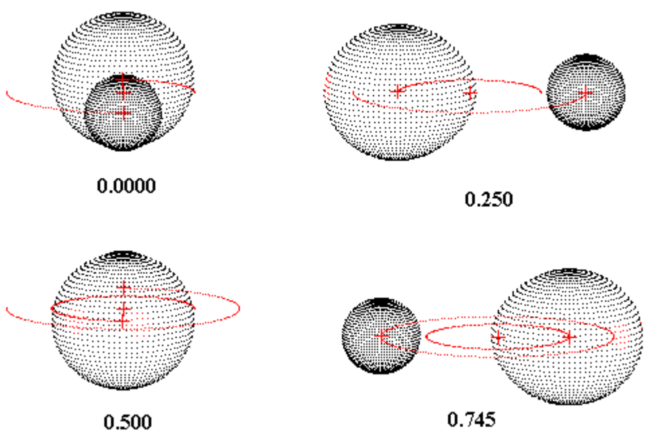


Figure 15: The shape of CG Cyg binary star at different phases.



.**Figure 16:** the shape of XY UMa binary star at different phases.

Table 4: The output from Binary Maker 3 of CG Cyg.

Ω_1 = 5.711840	Ω_2= 3.907470
Ω_{inner} = 3.451072	Ω_{outer} = 2.991107
C_1 = 6.479742	C_2 = 4.496918
C inner = 3.995381	C outer = 3.489925
f_1 = -0.383404	f_2 = -0.111529
Lagrangian L_1 = 0.520414	Lagrangian L_2 = 1.665598
$a_g = r_{1(back)}$ = 0.207317	$a_s = r_{2(back)}$ = 0.308486
$b_g = r_{1(side)}$ = 0.205329	$b_s = r_{2(side)}$ = 0.295057
$c_g = r_{1(pole)}$ = 0.203735	$c_s = r_{2(pole)}$ = 0.287085
$d_g = r_{1(point)}$ = 0.208001	$d_s = r_{2(point)}$ = 0.318227
Surface area 1 = 0.530936	Surface area 2 = 1.111835
Mean radius 1 = 0.205460	Mean radius 2 = 0.296876

Table6: The output from Binary Maker 3 of XY UMa**.**

Ω_1 = 3.3437	Ω_2 = 4.214
Ω_{inner} = 3.0817	Ω_{outer} =2.7255
Potential C_1 = 4.297248	Potential C_2 =5.379048
C inner = 3.971805	C outer = 3.529308
$Fillout_1$ = -0.075733	$Fillout_2$ =-0.261616
Lagrangian L_1= 0.550664	Lagrangian L_2 = 1.615827
$r1_{(back)}$ = 0.393500	$r2_{(back)}$ = 0.206800
$r1_{(side)}$ = 0.376095	$r2_{(side)}$= 0.202900
$r1_{(pole)}$ = 0.361015	$r2_{(pole)}$ = 0.200715
r1(point) = 0.413532	r2(point) = 0.208195
Surface area 1 = 1.793315	Surface area 2 = 0.520994
Mean radius 1 = 0.376870	mean radius 2 = 0.203472

3. Conclusions

The analysis of photometric data of the eclipsing binaries CG Cyg and XY UMa using PHOEBE and BM3 models has allowed us to determine the physical and geometric parameters of the component stars such mass, radii, Luminosity, inclination angle, and temperatures. PHOEBE and BM3 create synthetic from light curves input data. By iterative adjustment parameters best fitting to experimental data are established. Both programs PHOEBE and BM3 plotted shape at different phases for system.

According to the results obtained of fillout factor (f), both eclipsing binaries are detached system, and the secondary star effective temperature in both systems have a higher value than its initial value after complete fitting with PHOEBE model. From the results we found that the effective temperature for the primary star of both binaries are ranged between 5200k - 5310k which means that these binaries have a (G) spectral type, and the secondary star effective temperature ranged between 4244k - 4736k which means these binaries also have a (G) spectral type. Also, we found that the radius ranged between R=0.796 RΘ and R= 1.11 RΘ, and the masses ranged between M= 0.668 M and M =1.096 MΘ, and that means the selected stars representing main sequence stars.

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