Photometric analysis of eclipsing binary stars

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Abstract

In this paper, photometric analysis of two short period group of the eclipsing binaries (RS CVn); RT And and BH Vir 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.

Key words

Eclipsing binaries, Photometric, PHOEBE package, BM3.

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تحليل ضوئي لنجوم ثنائية كسوفية

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الخلاصة

في هذا البحث تم دراسة وتحليل نجميين ثنائية كسوفية من مجموعة (RS CVn) قصيرة المدة المدارية هما RT وBH Vir . تم ايجاد معاملات هندسية وفيزيائية لهذيين الثنائيين باستخدام نموذجين حاسوبية. النموذج الأول هو PHOEBE الذي يعني فيزياء الثنائيات الكسوفية ويستخدم طريقة ويلسون ديفني، والثاني هو Binary Maker 3 (BM3). اظهرت نتائجنا تقاربا مع نتائج باحثيين اخريين استخدموا هذين الموديلين.

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 (Physics of Eclipsing BinariEs) and Binary Maker 3(BM3) for analysis the light curves of RT And and BH Vir eclipsing binaries of the short period group RS CVn binaries.

The active star RT And is a short-period eclipsing binary. It has been extensively observed since the beginning of the 20th century due to the variability of the light curve (LC). In 1981 Milano analyzed all available photoelectric LCs of RT and obtained up to 1978 and proposed that the photometric distortion waves were caused by the spots [1]. in 1989 Zeilik successfully explained the photometric distortion waves in the LCs by using dark circular star spots at middle-high latitudes on the primary with the temperature roughly 1100−1200 K below that of the photosphere[2]. The data were phased by the ephemeris of [3]:

JHD(MinI)=2447803.5094+ 0.6289294* *E*

In this paper, we used this observation for analysis the light curve. Fig.1 shows the Light curve of this binary[4].

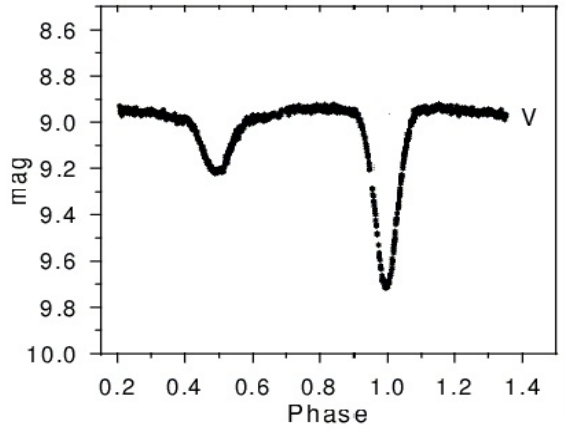

Fig.1: Light curve of RT And.

BH Vir is a double-line eclipsing binary classified as a short period RS CVn system [5]. It is a close detached binary containing main-sequence stars with rapid rotation. The observations in different spectral ranges (from X-ray to radio) indicate chromospheric-coronal radiation from these stars [6].

The light curves and the photoelectric observations in B and V obtained in 1967 by Koch have been analyzed by using the Wilson-Devinney program [7].

The spectral data were phased according to the ephemeris [8]:

HJD(MinI)=2 443 230.6077+0.816871312 * E.

In this work, we used this observation for analysis the light curve. Fig.2 shows the Light curve of this binary [9].

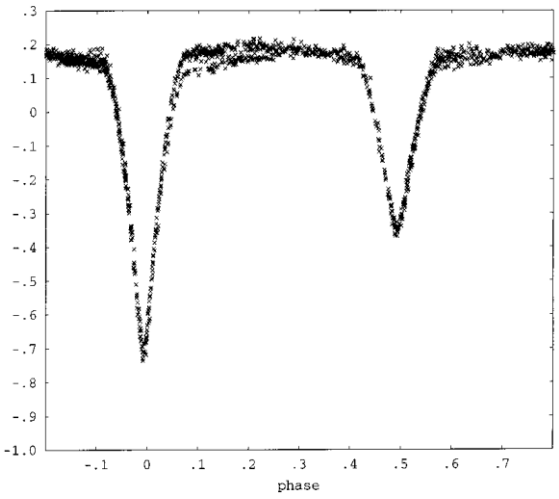

Fig.2: BH Vir light curve.

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. Section2.2 analyzed the light curves using Binary maker 3.Section 3 is devoted to conclusions.

Data Analysis

In order to modeling the Light curves of eclipsing binaries RT And and BH Vir, we applied two different models: the first is PHOEBE (Prˇsa & Zwitter 2005)[10] 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)**.**

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 case is phase and the second column contains dependent in this case is flux. Then we plotted the synthetic and the experimental light curves of RT And and BH Vir as shown in Fig.3 and Fig.4, respectively.

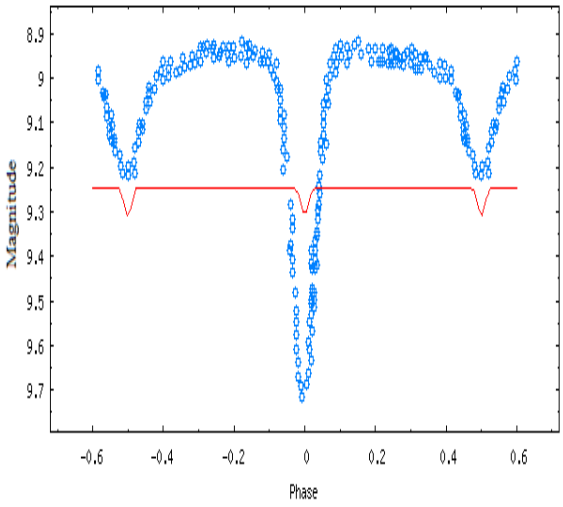

Fig.3: Synthetic and plotted light curves of eclipsing binary RT And.

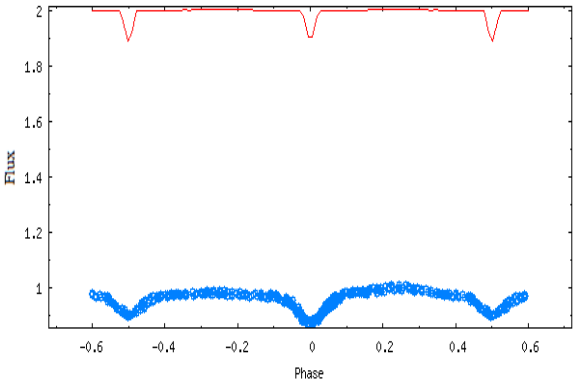

Fig.4: Synthetic and plotted light curves of eclipsing binary BH Vir.

In this paper, we concentrate on the specific parameters identified in Table 1.

Table1: 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 RT And and BH Vir were fixed at the values of 0.74, 0.967, 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 RT And and BH Vir were adopted to be T_1= 6100 k and 6000k, respectively. After some iteration we get the best match between the synthetic and the experimental light curve as shown in Figs. 5 for binary RT And and in Fig.6 for binary BH Vir. The light curves residuals windows plot the difference between experimental and synthetic light curves verses the phase; Fig.7 and Fig.8 show the residuals of both binaries and Fig.9 and Fig.10 show the shape of both binaries at different phases.
Table 2 presents the physical parameters of RT And and BH Vir from using PHOEBE model.

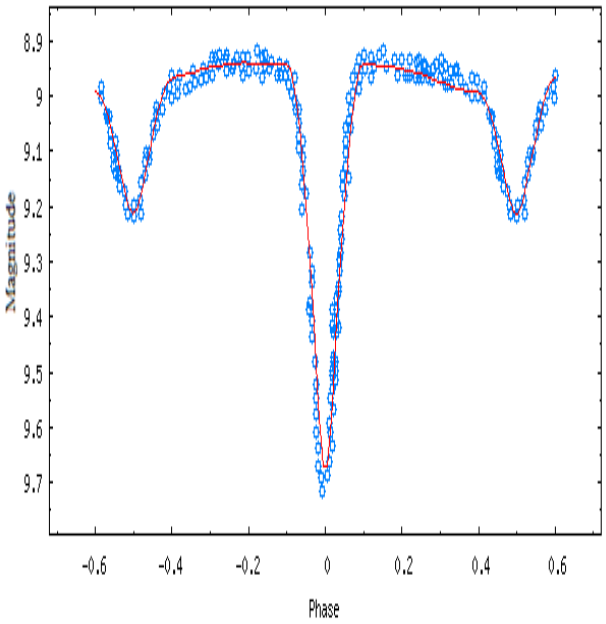

Fig.5: The best match between the synthetic and the experimental light curves of binary RT And.

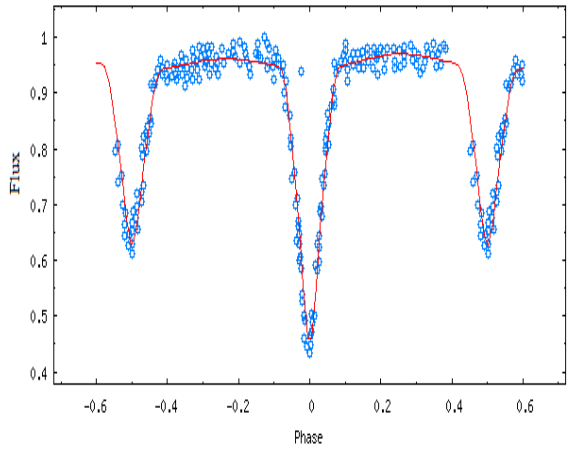

Fig.6: The best match between the synthetic light curve and the experimental light curve of binary BH Vir.

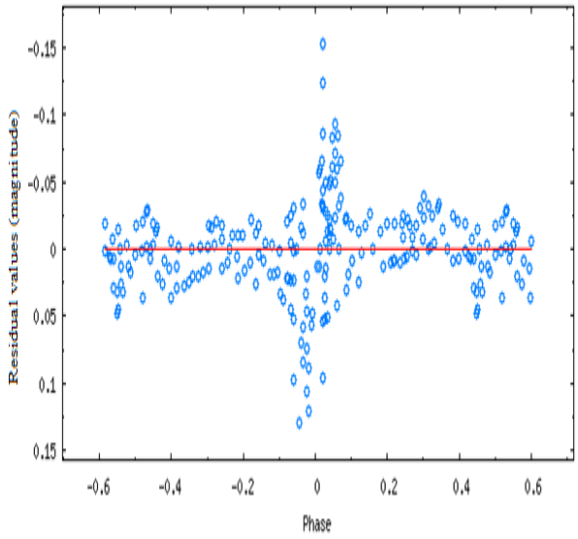

Fig.7: Residuals obtained from fitting routine of eclipsing binary RT And.

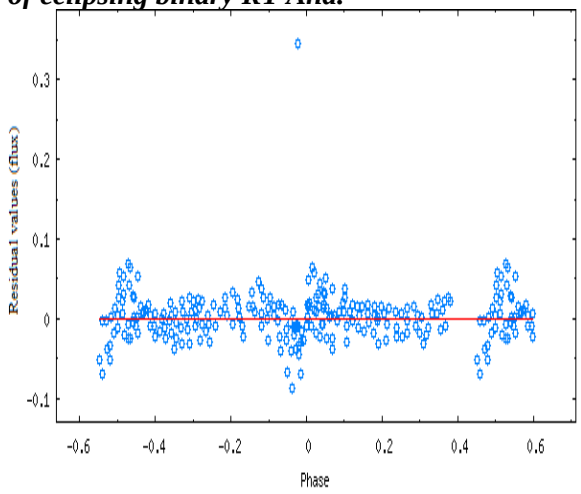

Fig.8: Residuals obtained from fitting routine of eclipsing binary BH Vir.

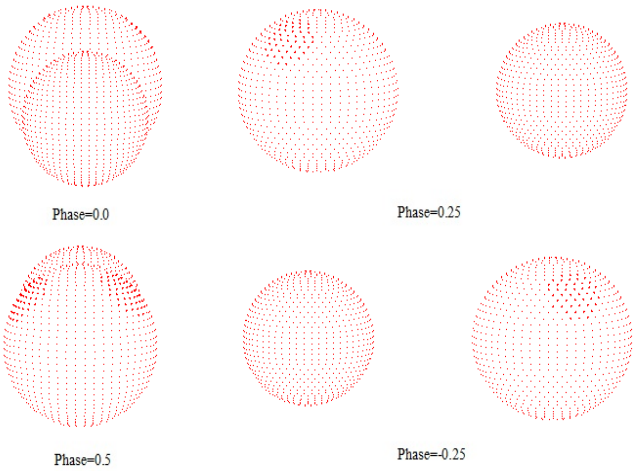

Fig. 9: The shape of RT And binary star at different phases.

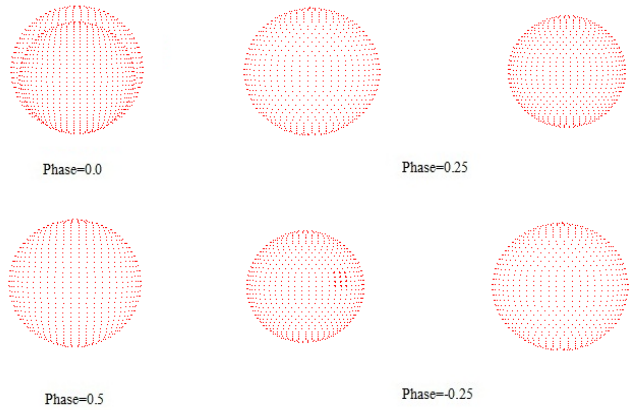

Fig.10: The shape of BH Vir binary star at different phases.

2. Analysis with Binary maker 3

After providing experimental light curve data to the Binary Maker 3 we have to add input parameters to construct meaningful binary models. Binary Maker 3 was used to determine a preliminary solution to the light curves. Table 3 shows the light curve fit parameters for eclipsing binary RT And which are taken from [12] while Table 4 shows the light curve fit parameters for eclipsing binary BH Vir which are taken from [13].

Table 2: The physical parameters of RT And and BH Vir Using PHOEBE

parameters	RT And	Kjurkchieva [4]	BH Vir	F.Y. Xiang [11]
Mass $_1$	1.233	1.23	1.127	
Mass $_2$	0.912	0.91	1.089	
TAVH	6100	6150	6000	5945
TAVC	4811	4920	5432	5500
R_1	1.249	1.26	1.244	
R_2	1.027	1.06	1.084	
$\Omega(L_1)$	3.313		3.696	4.858
$\Omega(L_2)$	2.892		3.1678	5.151
$M_{bol\,1}$	5.522		4.879	
$M_{bol\,2}$	4.067		4.147	
$Log(g)_1$	4.33		4.299	
$Log(g)_2$	4.37		4.405	
Surf.Bright.$_1$	8.08		3.309	
Surf Bright.$_2$	2.522		2.10	
Inclination	83.27°	82	88.1°	87.44°
PHSV	3.98657		4.86129	
PCSV	4.03737		5.323	
$\frac{L_1}{L_1+L_2}$	0.6949377		0.392542	
$\frac{L_2}{L_1+L_2}$	0.305062		0.607457	
Temperature Factor spot$_1$	0.8165		0.6700	0.65
Temperature Factor spot$_2$	0.638			

Table3: the light curve fit parameters for RT And.

Parameter	Star$_1$	Star$_2$
Mass Ratio (M_2/M_1)	0.74	
fractional stellar radius r (back)	0.32	0.224
Temperature	6100 K	4900 K
Gravity Darkening	0.32	0.32
Limb Darkening	0.5	0.5
Reflection	0.5	0.5
Inclination	87.6°	

Table 4: The light curve fit parameters for BH Vir.

Parameter	Star1	Star2
Mass Ratio (M2/M1)	0.967	
potentials Ω	4.85	5.151
Temperature	5945 K	5500 K
Gravity Darkening	0.32	0.32
Limb Darkening	0.5	0.5
Reflection	0.5	0.5
Inclination	86.5°	

We added these fit parameters to create the synthetic light curves of eclipsing binaries RT And and BH Vir, as shown in Figs. 11 and 12, respectively. The residual values generated by the difference between the experimental and synthetic light curves. The residual produced by the application of model are shown in Figs. 13 and 14.Figs. 15 and 16 show the shape of the eclipsing binaries at different phases. Tables 5 and 6 show the output from Binary Maker3 for eclipsing binaries RT And and BH Vir, respectively.

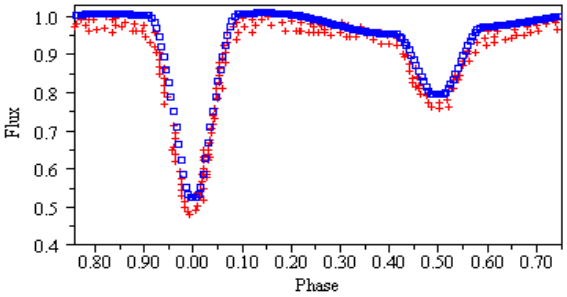

Fig.11: The synthetic light curve (square) and the experimental light curve (+) of unspotted Model of Eclipsing binary RT And.

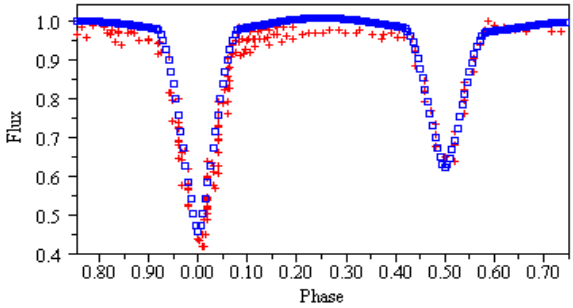

Fig.12: The synthetic light curve (square) and the experimental light curve (+) of spotted Model of Eclipsing binary BH Vir.

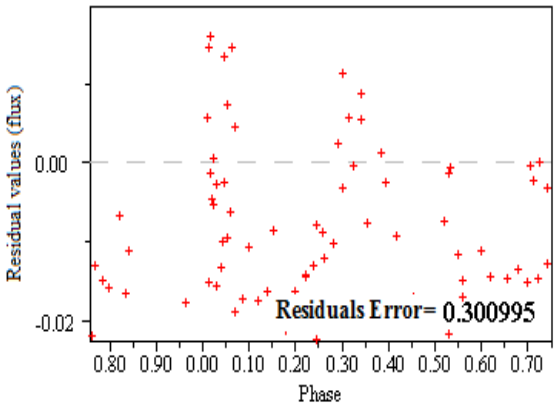

Fig.13: Residuals values generated from the synthetic and experimental data RT6 And, the number in the bottom right hand corner is the sum of squares of the residuals.

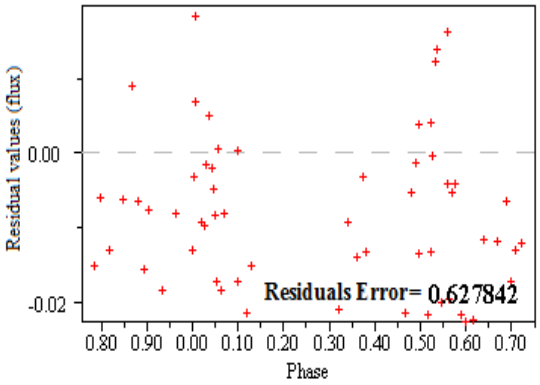

Fig.14: Residuals values generated from the synthetic and experimental data for spotted model of BH Vir using Binary Maker 3, the number in the bottom right hand corner is the sum of squares of the residuals.

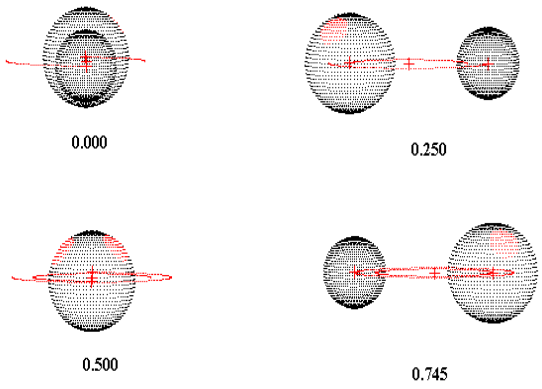

Fig.15: The shape of the spotted Model of RT And binary star at different phases.

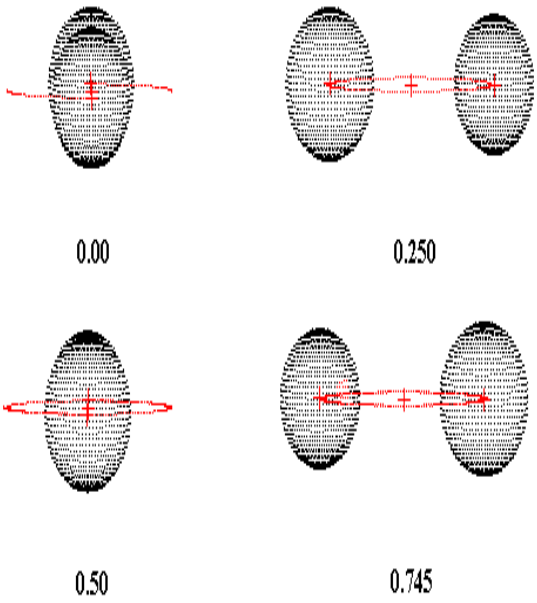

Fig.16: The shape of the spotted Model of BH Vir binary star at different phases.

Table 5: The output from Binary Maker 3 of binary RT And.

Ω_1 = 4.011494	Ω_2 = 4.518218
Ω_{inner} = 3.313430	Ω_{outer} = 2.892087
Potential C $_1$ = 5.168747	Potential C $_2$ = 5.077645
C inner = 3.989410	C outer = 3.505108
Fillout$_1$ = -0.167448	Fillout$_2$ = -0.257677
Lagrangian L_1 = 0.530946	Lagrangian L_2 = 1.648392
$r1_{(back)}$ = 0.320000	$r2_{(back)}$ = 0.224000
$r1_{(side)}$ = 0.310471	$r2_{(side)}$ = 0.219615
r1(pole) = 0.302733	r2(pole) = 0.216948
r1(point) = 0.326647	r2(point) = 0.225743
Surface area 1 = 1.219222	Surface area 2 = 0.610184
Mean radius 1 = 0.311068	Mean radius 2 = 0.220188

Table6: The output from Binary Maker 3 of binary BH Vir.

Ω_1 = 4.85	Ω_2 = 5.1510
Ω_{inner} = 3.696176	Ω_{outer} =3.696176
Potential C $_1$ = 5.173050	Potential C $_2$= 5.479099
C inner = 3.999868	C outer = 3.462704
Fillout$_1$ = -0.226787	Fillout$_2$ = -0.269977
Lagrangian L_1 = 0.503454	Lagrangian L_2 = 1.692914
$r1_{(back)}$ = 0.266002	$r2_{(back)}$ = 0.239860
$r1_{(side)}$ = 0.259898	$r2_{(side)}$= 0.235475
$r1_{(pole)}$ = 0.255551	$r2_{(pole)}$ = 0.232426
r1(point) = 0.269109	r2(point) = 0.241754
Surface area 1 = 0.854293	Surface area 2 = 0.700480
Mean radius 1 = 0.260484	mean radius 2 = 0.235921

Conclusions

The analysis of photometric data of the eclipsing binaries RT And and BH Vir 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 fitted to experimental data are established.

The data processing for PHOEBE is in essence easier than for BM3 despite the fact that is a far more sophisticated model. 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 of the secondary star effective temperature in both systems after complete fitting with PHOEBE model have a higher value than its initial value.

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