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A CCD Photometric Study and Search for Pulsations in RZ Dra and EG Cep

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Abstract. This paper presents CCD observations of the Algol-type eclipsing binaries RZ Dra and EG Cep. The light curves have been analyzed with the PHOEBE software and Wilson-Devinney code (2003 version). A detailed photometric analysis, based on these observations, is presented for both binarity and pulsation. The results indicate semidetached systems where the secondary component fills its Roche lobe. After the subtraction of the theoretical light curve, a frequency analysis was performed in order to check for pulsations of the primary component of each system. Moreover, a period analysis was performed for each case in order to search for additional components around the eclipsing pairs.

1. Introduction

Eclipsing Binaries are important astrophysical objects and several of them are known to contain a pulsating component. It is interesting to study such systems, since extra information can be extracted from both their pulsation and eclipsing properties, leading to a more reliable determination of system parameters.
EG Cep and RZ Dra are referred as candidate systems for including pulsating components (Soydugan et al. 2006) and therefore have been selected for observations and study.

2. Observations

The photometric observations were carried out at the Gerostathopoulion Observatory of the University of Athens during 12 nights from May to August 2007, using the 0.4m Cassegrain telescope equipped with the ST-8XMEI CCD camera and BVRI Bessell photometric filters. The comparison and check stars used for each system are presented in Table 1 and the calculated times of minima obtained from our observations, using the method of Kwee & van Woerden (1956), are given in Table 2.

Table 1. The photometric observations log

System	Nights spent	Filters used	Comparison Star	Check Star
EG Cep	7	BVRI	GSC 4589:2757	GSC 4589:2842
RZ Dra	5	RI	GSC 3916:1889	GSC 3916:1825

Table 2. The times of minima derived from our observations

System	HJD-2400000.0	Filters
EG Cep	54264.5537 (1)	RI
	54265.3706 (2)	RI
	54334.5376 (3)	BVRI
RZ Dra	54201.5765 (1)	R
	54229.3945 (1)	RI
	54232.4247 (2)	RI

3. O-C Analysis

In order to analyze the O-C diagram of each system, the least squares method with statistical weights has been used. The construction of the O-C diagrams of EG Cep and RZ Dra are based on a total of 258 and 91 times of minima taken from literature and from our observations (see Table 2), respectively. For both cases, the derived values of the O-C diagram solution are listed in Table 3, and in Figure 1 are shown the fits on the data points and the O-C residuals after the subtraction of the solution.

Table 3. The results of the O-C diagram analysis of EG Cep and RZ Dra

System	EG Cep	RZ Dra
Parameters of the EB		
$Min.\ I$ [HJD]	2435956.5430 (3)	2437181.4353 (2)
P [days]	0.5446213 (1)	0.5508763 (1)
$M_1 + M_2$ [$M_\odot$]	1.0 + 0.84	1.62 + 0.66
c_2 ($\times10^{-10}$) [days/cycle]	0.1307 (1)	0.0349 (1)
$\dot{P}$ ($\times10^{-8}$) [days/year]	1.753 (1)	0.463 (1)
$\dot{M}$ ($\times10^{-9}$) [$M_\odot$/years]	16.72 (1)	3.70 (1)
Parameters of the 3^{rd} body		
P_3 [yrs]	74.4 (9)	118.1 (1)
e_3	0.59 (4)	0.72 (2)
$M_{3,min}$ [$M_\odot$]	0.15 (2)	0.226 (3)
χ^2	0.1538	0.0050

4. Light Curve Analysis

The light curves (hereafter LCs) have been analysed with the Wilson Program (version 2003) (Wilson & Devinney 1971; Wilson 1979, 1990) and PHOEBE software (Prša & Zwitter 2005). We applied the code in MODE 5, which solves the LC of semi-detached eclipsing binaries, where the secondary (cooler) component fills its Roche lobe, while the primary (hotter) one is well inside its Roche lobe. For radial velocity analysis of RZ Dra, we used 64 points data given by Rucinski et al. (2000). The BVRI LCs of EG Cep, and the radial velocity and the RI LCs of RZ Dra were used simultaneously for determination of the geometric and physical elements of each system.

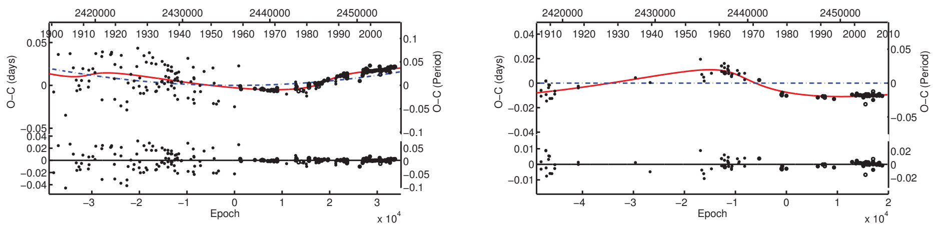

Figure 1. The O-C diagram of EG Cep (left panel) and RZ Dra (right panel) fitted by a LITE curve and a parabola (upper part) and the total residuals after the subtraction of the whole solution (lower part). The red solid line indicates the sum of the solutions, while the blue dashed line corresponds to the parabola. The bigger the symbol the bigger the weight assigned.

The LC solution is summarized in Tables 4 and 5 for EG Cep and RZ Dra, respectively, and the theoretical and observed LCs are illustrated in Figure 2.

Table 4. Physical and geometrical parameters of EG Cep

Parameter	Value	Parameter	Value
i [deg]	87.5 (2)	q (m_2/m_1)	0.449 (1)
T_1^* [K]	8500	T_2 [K]	5792 (9)
$L_{1V}/(L_1 + L_2)$	0.650 (4)	$L_{2V}/(L_1 + L_2)$	0.350 (4)
$r_{1(pole)}$	0.4092 (4)	$r_{2(pole)}$	0.2914 (2)
$r_{1(side)}$	0.4326 (5)	$r_{2(side)}$	0.3039 (2)
$r_{1(back)}$	0.4553 (6)	$r_{2(back)}$	0.3365 (2)
Ω_1	2.859 (2)	$(\sum(\mathrm{res})^2)$	0.071

**assumed*

Table 5. Physical and geometrical parameters of RZ Dra

Parameter	Value	Parameter	Value
R_1 $[R_\odot]$	1.62	R_2 $[R_\odot]$	1.13
M_1 $[M_\odot]$	1.617	M_2 $[M_\odot]$	0.656
$M_{bol,1}$	2.84	$M_{bol,2}$	3.52
α $[R_\odot]$	3.71 (2)	V_γ [km/sec]	14.9 (3)
i [deg]	87 (1)	q (m_2/m_1)	0.406(2)
T_1^* [K]	8150	T_2 $[K]$	5531 (10)
$r_{1(pole)}$	0.4157 (6)	$r_{2(pole)}$	0.2837 (3)
$r_{1(side)}$	0.4399 (7)	$r_{2(side)}$	0.2957 (3)
$r_{1(back)}$	0.4618 (3)	$r_{2(back)}$	0.3284 (3)
Ω_1	2.781 (3)	$(\sum(\mathrm{res})^2)$	0.077

**assumed*

5. Search for Pulsations

In order to reveal any possible pulsation nature of RZ Dra and EG Cep we subtracted the theoretical LCs from the observed ones in order to remove the proximity effects (reflection and eclipticity). The frequency analysis was made with PERIOD04 software

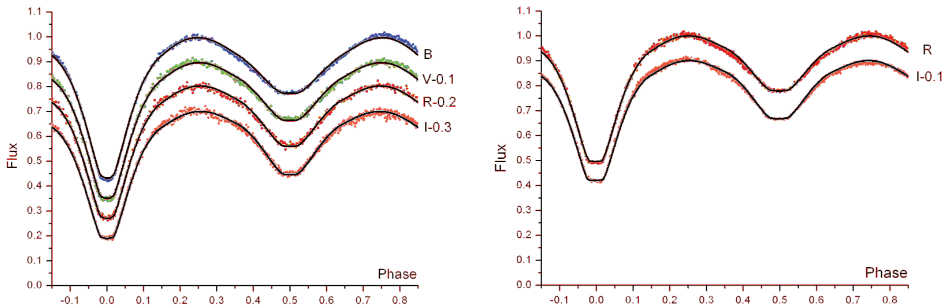

Figure 2. Observed (colored points) and theoretical (solid lines) LCs of EG Cep (left panel) and RZ Dra (right panel).

(Lenz & Breger 2005) on the LC residuals, and we found no evidence of pulsational behaviour either in EG Cep nor RZ Dra.

6. Discussion and Conclusions

The LC analysis of EG Cep and RZ Dra showed that both of them are semi-detached systems with the secondary component filling its Roche Lobe. The periodic variations of the orbital periods of these systems could be explained by adopting the existence of a tertiary component, while the steady increase of their period is probably due to the mass transfer procedure. In contrast with the O-C diagram solution, the LC analysis for both systems showed that there is not a third light contribution in the total luminosity of the system. This disagreement can be explained by taking into account the small values of mass of the third body found in each case. Finally, we could not detect any pulsation nature of the primary components of both systems. So, more accurate data (by using larger telescope and better CCD) in the future might reveal possible pulsational behaviour.

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References

Kwee, K., & van Woerden, H. 1956, BAN, 12, 327
Lenz, P., & Breger, M. 2005, CoAst, 146, 53
Prša, A., & Zwitter, T. 2005, ApJ, 628, 426
Rucinski, S. M., Lu, W., & Mochnacki, S. W. 2000, AJ, 120, 1133
Soydugan, E., Soydugan, F., Demircan, O., & İbanoğlu, C. 2006, MNRAS, 370, 2013
Wilson, R. E. 1979, ApJ, 234, 1054
Wilson, R. E. 1990, ApJ, 356, 613
Wilson, R. E., & Devinney, E. J. 1971, ApJ, 166, 605