The Algol-type eclipsing binary TZ Eridani : BV Photometry and search for pulsations and tertiary component

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Abstract

CCD photometric observations of the Algol-type eclipsing binary TZ Eri have been obtained in B and V filters during 26 nights from December 2007 to February 2008 at the Athens University Observatory. The light curves are analyzed with the Wilson-Devinney program and new geometric and photometric elements are derived. A time-series analysis of the observations shows that the primary component pulsates with a frequency of 18.7 c/d, while a multiperiodic behavior is also discussed. The presence of a third light in the system is considered and our results are compared with those of the O-C analysis for a third body in the system, given by Zasche et al. (2008).

1. Introduction

The system TZ Eri (= BD -06°880 = GSC 4733-1261 = SAO 131144 = AN 40.1929, α2000 = 4h 21m 40.3s, δ2000 = -06° 01´ 09.2´´) belongs to Algol-type EB's and its period is ~2.6 days. The first spectral classification of the primary component was made by Cannon (1934) as F –type, while Brancewicz & Dvorak (1980) estimated it as F8. Kaitchuck & Park (1988) and Yoon et al. (1994) classified the secondary component as K0 type, while Brancewicz & Dvorak (1980) estimated the physical parameters of the system's components. Kaitchuck & Park (1988), based on emission of H_β and Hγ lines during the eclipse, discovered the existence of an accretion disk around the more massive star of the system. Barblan et al. (1998) observed the system in seven filters and obtained its radial velocities curves. They also calculated the absolute parameters of the two components and reclassified them as A5/6V and K0/1III, respectively, based on B-V indexes. They also performed a period study of the system and confirmed a mass transfer between the two components. A new period study of the system, made by Zasche et al. (2008), showed that except the mass transfer between the components, the Light-Time effect is also present. The calculation of the minimal mass of the 3rd body resulted in 1.3 ± 0.1 $M_\odot$ with the assumption that it is a MS star ($L \sim M^{3.5}$), while its contribution to the total light of the system ($L_1+L_2+L_3$) should be ~ 10.9 %. In the present study, the light curve analysis shows that the primary component is an oscillating star and a small third light contribution to the total flux of the system exists.

2. Observations

The system was observed during 26 nights from December 2007 to February 2008 at the Athens University Observatory, using a 40-cm Cassegrain telescope equipped with the CCD camera ST-8XMEI and B and V Bessell photometric filters. Differential magnitudes were obtained, while the stars SAO 131145 and GSC 4733-1292 were used as comparison and check stars, respectively.

3. Light curve analysis

The light curves were analysed with the PHOEBE 0.29d software (Prša and Zwitter, 2007) which uses the 2003 version the Wilson-Devinney code. The MODE 5 model was applied (semi-detached system where the secondary (cooler) component fills its Roche lobe, while the primary (hotter) one is well inside its Roche lobe). Barblan et al. (1998) derived the temperatures of the components based on B-V indexes, but we can trust only the temperature of the secondary component, since the primary minimum is a total eclipse and the whole light comes only from this component. The temperature of the secondary component was used as a fixed parameter, based on the model by Barblan et al. (1998). The temperature of the primary component and the spectroscopic mass ratio of the system were set as free parameters, using Barblan's model as the initial solution. The contribution of a third light was also considered and the albedo of the secondary component A_2 was set on 1, with respect to the reflection effect due to the large temperature difference of the two components, while the albedo A_1 of the primary was set to the theoretical value. The gravity darkening coefficients g_1, g_2 of the primary and secondary components, respectively, were set to the theoretical values, while the limb darkening coefficients x_1, x_2 were supplied by van Hamme's tables. The synthetic and observed light curves are shown in Figure 1, while the derived parameters from the solution are listed in Table 1.

Table 1. Results of the simultaneous light curve solution of the system.

$Parameter$	$Value$
$i(degrees)$	87.69(7)
q	0.1773(5)
$T_1(K)$	9307(20)
$T_2(K)$	4562^a
Ω_1	6.323(12)
Ω_2	2.175
$[L_1/L_T]_B$	0.9418(14)
$[L_1/L_T]_V$	0.8892(13)
$[L_2/L_T]_B$	0.0529
$[L_2/L_T]_V$	0.0990
$[L_3/L_T]_B$	0.0053(8)
$[L_3/L_T]_V$	0.0118(9)
g_1	1.0^a
g_2	0.32^a
A_1	1.0^a
A_2	1.0^a
Fractional radii	
r_{1pole}	0.1626(3)
r_{1point}	0.1633(3)
r_{1side}	0.1631(3)
r_{1back}	0.1632(3)
r_{2pole}	0.2249(2)
r_{2point}	0.3307(12)
r_{2side}	0.2339(2)
r_{2back}	0.2661(2)
χ^2	0.499967

$^a adopted$

$L_T = L_1 + L_2 + L_3$

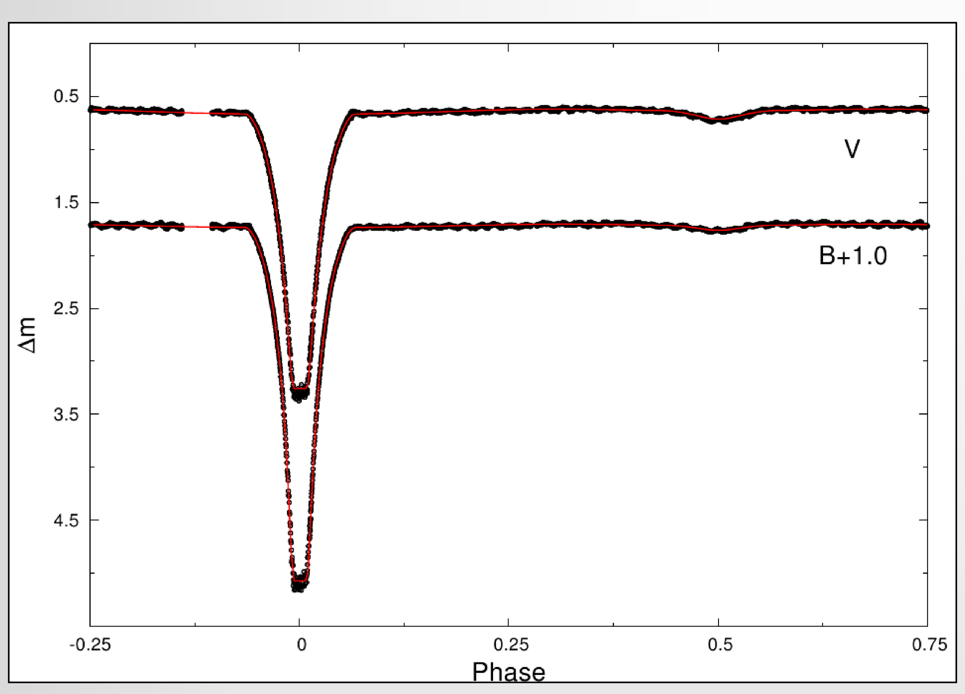

Fig. 1. The synthetic (red lines) and the observed light curves of TZ Eri in B and V filters.

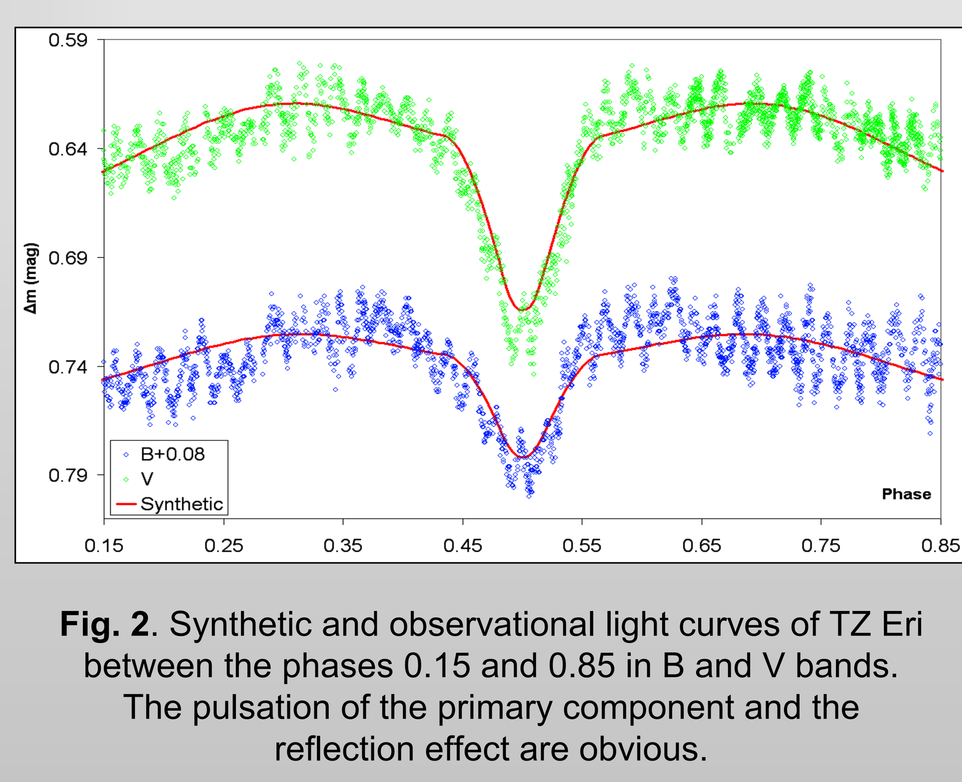

Fig. 2. Synthetic and observational light curves of TZ Eri between the phases 0.15 and 0.85 in B and V bands. The pulsation of the primary component and the reflection effect are obvious.

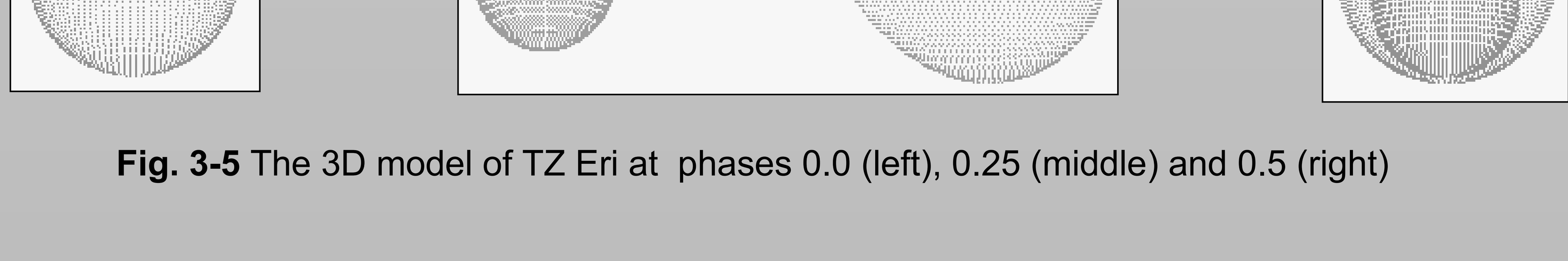

Fig. 3-5 The 3D model of TZ Eri at phases 0.0 (left), 0.25 (middle) and 0.5 (right)

4. Pulsational behaviour of the system

Frequency analysis was performed, in order to investigate possible short periodic pulsational behaviour of the components in the system, using the data points well outside the primary eclipse, which were substracted from the constructed (theoretical) light curves. For this analysis the software PERIOD04 (Lenz & Breger, 2005) was used.

The results of the frequency analysis are listed in Table 2. Figs. 6-7 show the periodogram of two found frequencies which are well inside in the range of δ Sct type pulsations (5-80 c/d, Breger 2000). Solution in both filters indicates that the most significant frequency (f_1) is about 18.7 c/d, which confirms the result of Mkrtichian et al. (2005). Multiple other lower frequencies appear in the periodograms, which are mainly the result of the non-optimal substraction of the binary model and the variations of nightly mean levels not pointed out in Fig. 6-7.

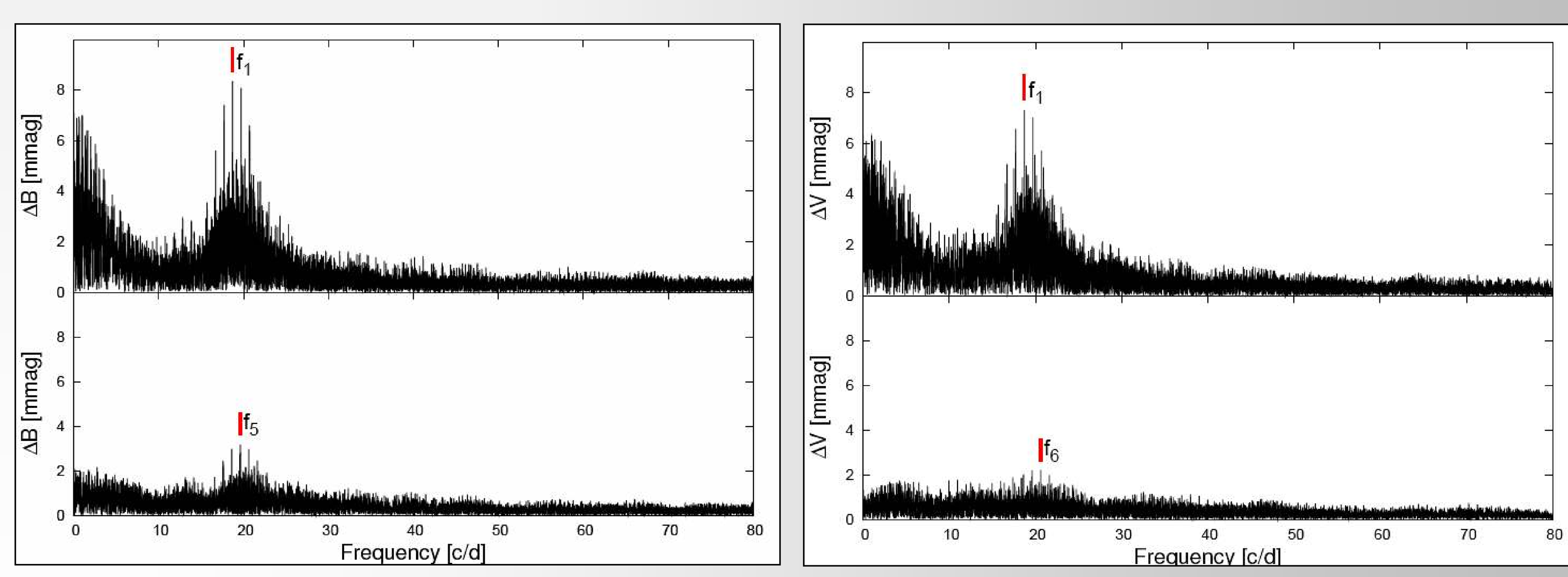

Fig. 6-7 The Fourier periodograms of the residuals in B- (left) and V-filter (right).

Additionally, the frequency f_6 found in V-filter is probably the 1 c/d alias of the frequency f_5 of B-filter. We did not find any reasonable frequency values with amplitudes larger than 2mmag and signal-to-noise ratio higher than 4, after prewhitening these two last frequencies in each filter. Agreement between the solution and the residulas on two longest days is also shown in Fig. 5.

Table 2. Results of the frequency analysis on the residual data.

Filter	ID	Frequency (c/d)	Error (c/d)	Amplitude $(mmag)$	S/N
B	f_1	18.7174	0.0003	8.3	18.2
	f_2	0.0128	fixed	7.8	12.0
	f_3	1.0518	fixed	4.9	6.6
	f_4	0.1067	fixed	3.9	5.6
	f_5	19.6126	0.0009	3.2	6.7
V	f_1	18.7177	0.0004	7.3	11.7
	f_2	0.0115	fixed	6.4	4.3
	f_3	2.0625	fixed	4.8	3.6
	f_4	0.2944	fixed	3.7	2.4
	f_5	1.1538	fixed	2.9	2.1
	f_6	20.6134	0.0006	2.2	4.1

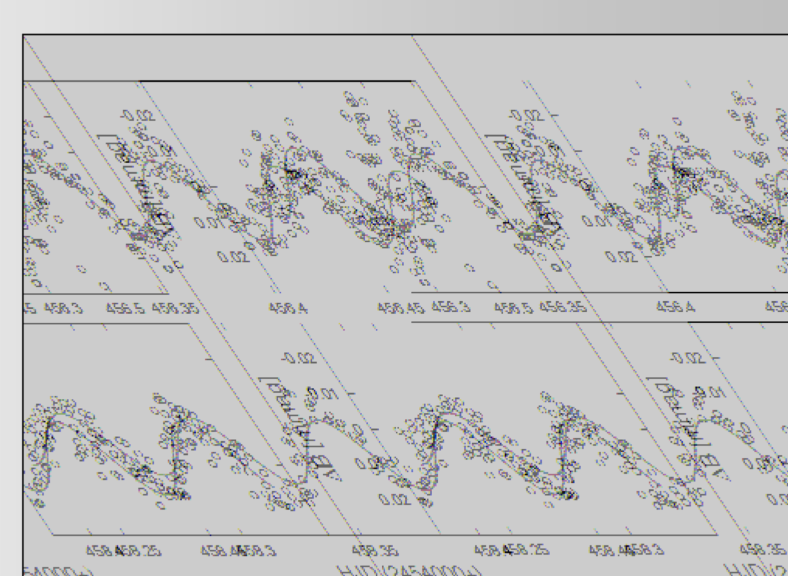

Fig. 8 The frequency analysis (red lines) on the residuals for two days of observations.

5. Discussion and Conclusions

New B and V light curves and photometric solution were obtained for the system TZ Eri. The light curve solution showed that the system is semi-detached with the secondary component filling its Roche Lobe. The temperature of the primary component differs from the one found by Barblan et al. (1998) and our solution shows that it should have a spectral type of A1/A2 instead of A5/A6. The frequency analysis revealed that the primary component pulsates with a frequency of ~18.7 c/d and its pulsational characteristics are very similar with those of a *δ* Sct star. A third light was also taken into account in the light curve solution, but the results showed that its contribution is ~ 1% in the total light. The O-C study of the system showed by Zasche et al. (2008) strongly supports the existence of a tertiary component with a minimal mass of 1.3$M_\odot$, revolving around the eclipsing binary, where mass transfer occurs. These two independent methods (O-C analysis and light curve analysis) come into agreement for the mass exchange between the two components, but not for the existence of the tertiary one. The photometric solution depends on the light contribution of the third body, while the O-C analysis depends only on the period changes. A low luminosity star, having enough mass to affect the binary's orbit (e.g. white dwarf, neutron star or even a black hole) might be the connection key between these two methods of analysis. Although, observations in high energy spectral range are needed in order to prove the existence and the nature of this additional component.

6. Acknowledgements

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