Updated analysis for the system V1464 Aql

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Abstract

New BVRI light curves of the system V1464 Aql (ellipsoidal variable with a δ Scuti component) were obtained. Using these observations and taking into account previous studies of the system, its light curve model was reproduced and the pulsation frequencies of the δ Scuti component were recalculated. Moreover, the derived parameters were used to estimate the evolutionary status of both components.

1. Introduction

Generally, eclipsing binary systems (hereafter EBs) offer unique information for the calculation of stellar absolute parameters and evolutionary status of stars. Especially, the cases of binaries with δ Sct components are extremely interesting, since they provide additional information (i.e. pulsation characteristics) for this part of the stellar lifetime. It has been shown that the δ Sct stars in classical Algols (oEA stars) show difference in their pulsational characteristics from time to time due to mass gain (Mkrtichian et al. 2004). Therefore, the calculation of their absolute parameters and the identification of their oscillating characteristics help us to obtain useful conclusions for this 'unstable' part of stellar lifetime.

V1464 Aql (m_V=8.98^m, P=0.69777^d) was initially classified as contact binary (Duerbeck 1997) and later as a RR Lyr pulsating star (Pojmánski 1997). The spectroscopic observations of Rucinski & Duerbeck (2006) revealed that V1464 Aql is an eclipsing binary of F1-2 spectral type and measured the radial velocity of the primary component as K_1 =31 (1) km/s. The most detailed study of the system was made by Dal & Sipahi (2013), who found, using their own data, one pulsation frequency and calculated the absolute parameters of the system using the q-search method. In the present work, we use our new BVRI light curves to create our model and to perform a detailed Fourier analysis in order to find the main characteristics of the pulsating component.

2. Observations, light curves analysis and absolute parameters' calculation

The system was observed during 13 nights in September of 2012 at the Athens University Observatory using a 40 cm Cassegrain telescope equipped with the CCD camera ST-10XME and the Bessell BVRI photometric filters. A total of ~2000 data points per filter (53.7 hrs in total) were collected in a time span of 16 days. Differential magnitudes were obtained with the software MUNIWIN v.1.1.29 (Hroch 1998). The mean photometric error was 4.1, 3.3, 3.2 and 2.3 mmag for B, V, R and I filters, respectively.

The light curves (hereafter LCs) have been analysed together with the primary component's radial velocity curve with the PHOEBE v.0.29d software (Prša & Zwitter 2005). The temperature of the primary component was used as a fixed parameter (T_1=7100 K), based on the classification of Rucinski & Duerbeck (2006), while the temperature of the secondary was left free. The q-search method was used in order to find the most probable "photometric" mass ratio of the system. The rest parameters were either given theoretical values or they were adjusted (for method and parameters details see Liakos et al. 2011). Finally, the best solution, using the χ^2 criterion, was found in the conventional semi-detached mode. The synthetic and observed light curves are shown in Fig. 1, the 3-D model of the system is given in Fig. 2, while the location of the components in a theoretical Mass-Radius diagram together with other stars of the same type is illustrated in Fig. 6. The derived model's parameters as well as the absolute parameters of the components are listed in Table 1.

Table 1. Light curve solution and absolute parameters of the components

System's parameters			**Filter dependent parameters**				
q_{phot}	0.15 (1)		Filter:	B	V	R	I
i [deg]	46.8 (7)		L_{prim}/L_T	0.958 (4)	0.943 (3)	0.937 (3)	0.932 (2)
α [R$_\odot$]	4.5 (1)		L_{sec}/L_T	0.042 (1)	0.057 (1)	0.064 (1)	0.068 (1)
			x_1	0.630	0.526	0.444	0.358
			x_2	0.777	0.632	0.559	0.471
Components' parameters							
	g	A	Ω	T [K]	M [M$_\odot$]	R [R$_\odot$]	L [L$_\odot$]
Primary	0.32*	0.5*	2.12 (4)	7100*	2.2 (4)	2.5 (6)	14 (1)
Secondary	0.32*	0.5*	2.07	5491 (105)	0.3 (1)	1.0 (2)	0.8 (2)

*assumed, L_T=L_{prim}+L_{sec}

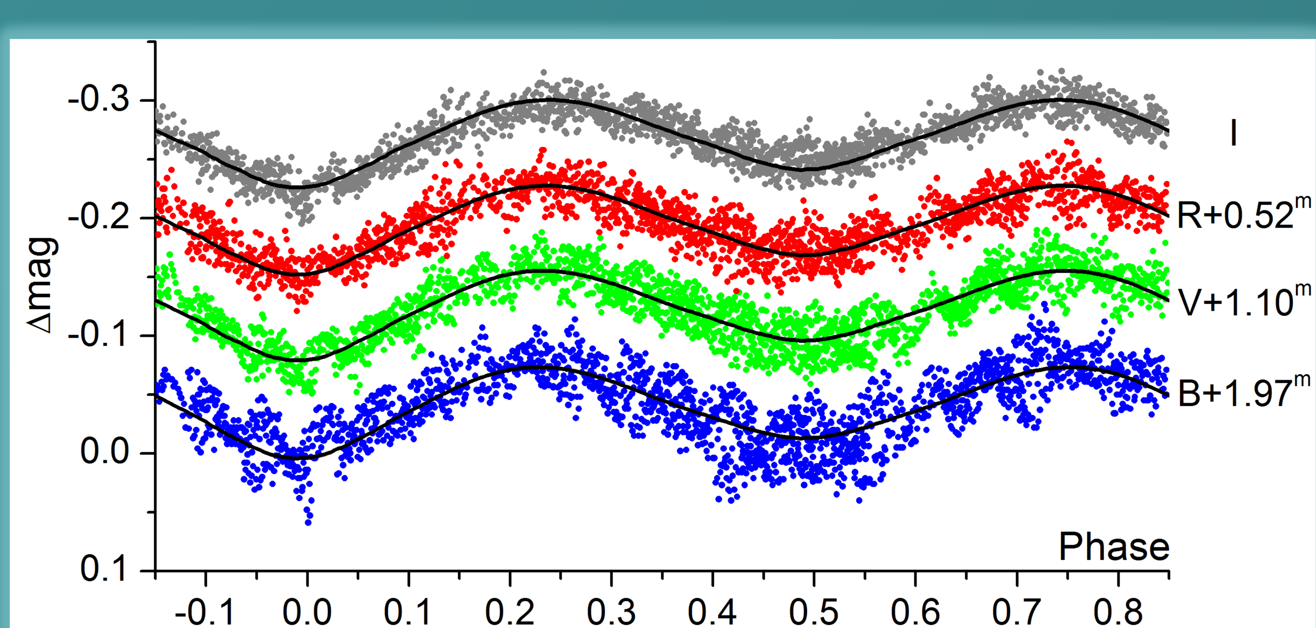

Figure 1. Synthetic (lines) and observed (points) light curves of V1464 Aql.

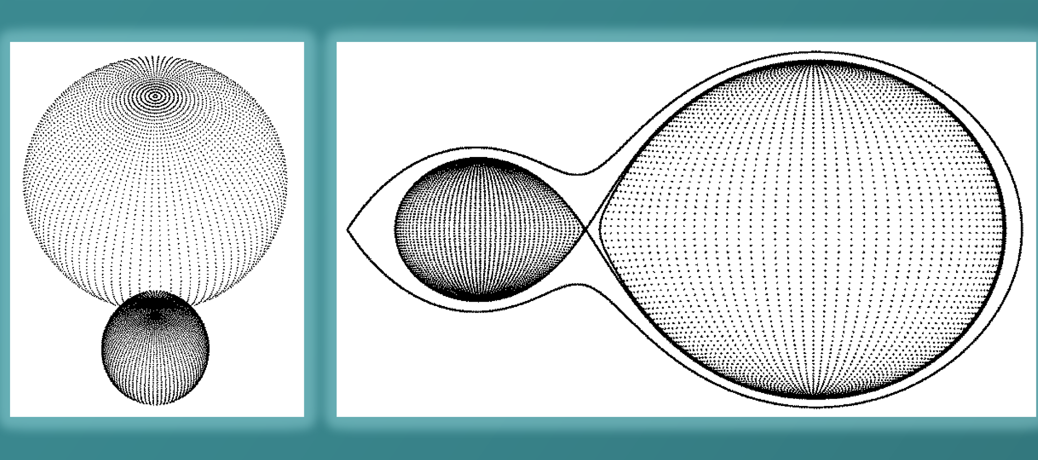

Figure 2. 3-D model of V1464 Aql during the primary eclipse (left) and at the phase 0.75 (right) where the Roche model lines are indicated. The larger star is the pulsating (primary) component.

3. Frequency analysis

The pulsating component of the system is the primary, since its temperature is well inside the range of δ Sct type stars (A-F spectral types). For the frequency search, the theoretical LCs of the binary model were subtracted from the respective observed data. Frequency analysis was performed on the LCs residuals with the software PERIOD04 v.1.2 (Lenz & Breger 2005), that is based on classical Fourier analysis. Given that typical frequencies for δ Sct stars range between 3–80 c/d (Breger 2000), the analysis was made for this range. After the first frequency computation the residuals were subsequently pre-whitened for the next one, until the detected frequency had S/N < 4, which is the programme's critical trustable limit.

The results showed that the star pulsates in a three frequency-mode. Although f_2 and f_3 found in the "cooler" wavelengths have S/N<4, they were also detected in B and V filters inside the trustable range, therefore we conclude that they are physical ones. Frequency analysis results are given in Table 2, where we list: frequency values f, semi-amplitudes A, phases Φ and S/N. Amplitude spectrum and spectral window plots are given in Fig. 3, while the Fourier fit on the longest data set is plotted in Fig. 4.

Table 2. Frequency search results for the pulsating component of V1464 Aql

No.	f [c/d]	A [mmag]	Φ [deg]	S/N	f [c/d]	A [mmag]	Φ [deg]	S/N
	B filter				V filter			
1	24.621 (1)	17.7 (3)	341 (1)	21.9	24.621 (1)	14.3 (3)	341 (1)	22.6
2	14.609 (4)	2.7 (3)	43 (6)	4.2	14.585 (3)	2.9 (3)	99 (5)	5.3
3	29.621 (4)	2.6 (3)	83 (7)	4.0	29.627 (4)	2.5 (3)	80 (6)	5.0
	R filter				I filter			
1	24.619 (1)	11.1 (3)	347 (2)	15.7	24.621 (1)	8.6 (2)	339 (2)	20.6
2	14.603 (5)	2.0 (3)	65 (9)	3.5	14.601 (6)	1.4 (2)	66 (10)	3.4
3	29.640 (6)	1.8 (3)	84 (10)	3.2	29.630 (5)	1.5 (2)	78 (9)	3.2

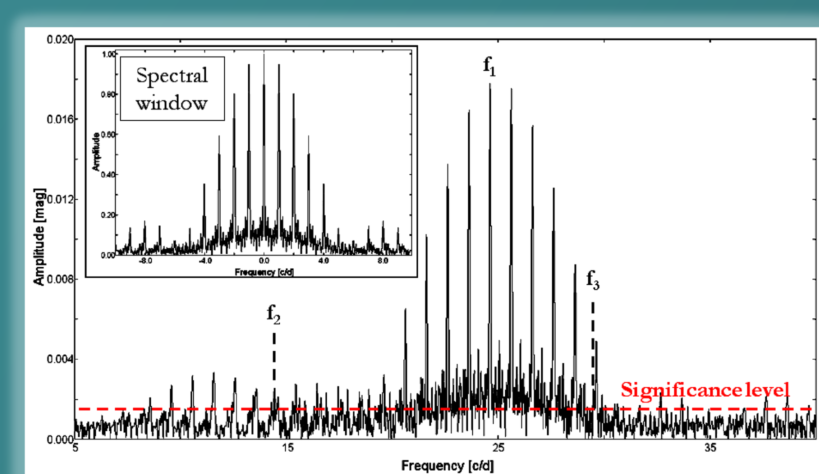

Figure 3. Amplitude spectrum of V1464 Aql in B filter where the detected frequencies and the significance level are indicated as well as the spectral window plot (inside panel).

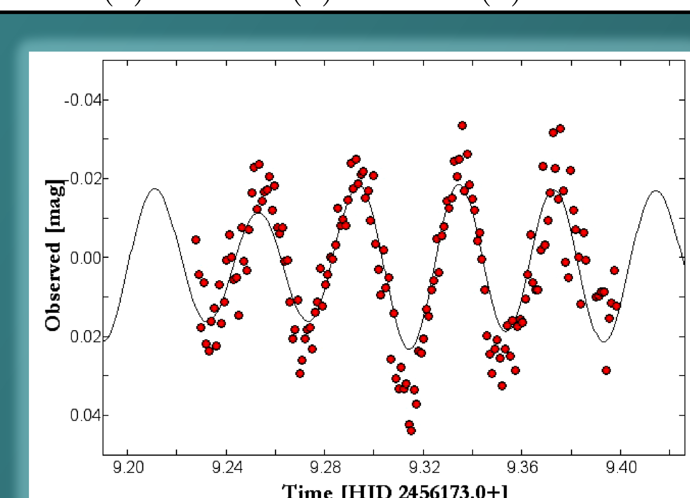

Figure 4. Fourier fit on the longest data set of V1464 Aql in B filter.

4. Discussion and conclusions

We analysed new multicolour LCs of V1464 Aql. New results for the absolute elements are derived and new pulsation frequencies were detected. The differences between our results and those of Dal & Sipahi (2013), regarding the evolutionary status of the components, probably come from the q-search method. More detailed spectroscopic observations are needed for final conclusions.

Two more pulsation frequencies for the primary component were found in comparison with the work of Dal & Sipahi (2013) increasing the total detected frequency number to 3. In M-R and P_{orb}-P_{pul} diagrams (Figs 5 and 6) it is shown that the present results for the pulsating component of V1464 Aql are compatible with other for δ Sct stars in binaries.

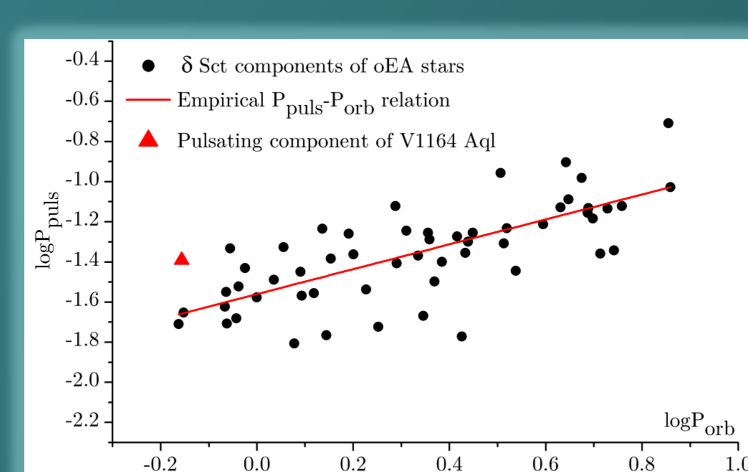

Figure 5. The position of the pulsating component of V1464 Aql in the P_{orb}-P_{pul} diagram together with other δ Sct stars-members of oEA stars and the empirical relation of Liakos et al. (2012).

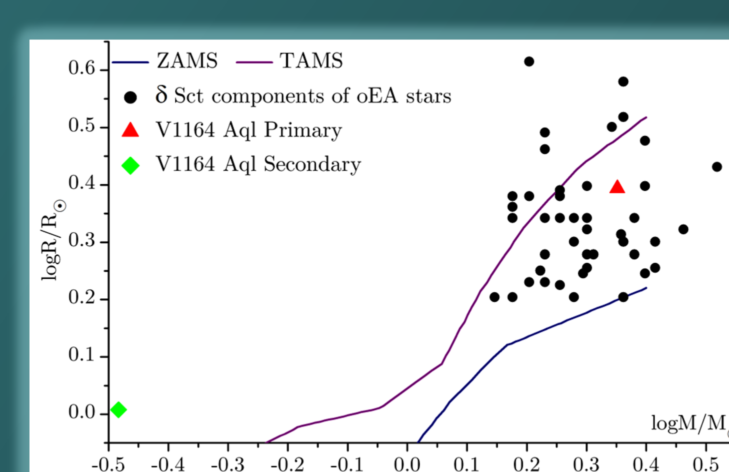

Figure 6. The positions of the components of V1464 Aql in the M-R diagram together with other δ Sct stars-members of oEA stars (taken from Liakos et al. (2012)).

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