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Photometric solutions for three eclipsing binary systems: SY Sge, V688 Aql, and CY Ari

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Abstract
We present a detailed light curve analysis of three eclipsing binaries, consisted of two Algol type systems, SY Sge and V688 Aql, and one W UMa type system, CY Ari, observed at the Ankara University Observatory. The light curves constructed in Johnson BVRI pass-bands were simultaneously analysed on the basis of Roche Geometry. Fourier coefficients method was applied on the light curve of W UMa type system to estimate a set of initial system parameters. Moreover, since there is not any radial velocity measurement of the systems, a q-search test was applied for all three systems to reach a minimized χ^2. Combining system parameters with photometric mass ratio allows us to obtain absolute parameters of the systems which leads to locate the systems on theoretical HR diagram and to estimate their evolutionary status.

Key words: binaries: eclipsing – stars: fundamental parameters – techniques: photometric

1 Introduction

The light curves of the three eclipsing binary systems studied in this paper were formed as a by-product of an observational project at the Ankara University Observatory which involves with surveying oscillating Eclipsing Algols (oEA). The SY Sge (HD 350944, m_v=$10^m.46$) and V688 Aql (HD 353804, m_v=$10^m.54$) systems are classified as eclipsing Algols (EA) in the catalogue of Kukarkin et al. (1971). However, CY Ari (m_v=$12^m.22$) is identified as a W UMa type system in the study of automated variable star classification by Hoffman et al. (2009). Although, there is not any solution attempt for those three systems found in the literature, some minima times of SY Sge and V688 Aql published by various authors, e.g., Kordylewski (1963), Dworak (1977), Nesterov et al. (1995), Agerer & Hubscher (1996), Hubscher et al. (2009), can be shown. All available times of minima were compiled by Kreiner et al. (2001) to produce corrected light elements of the SY Sge and V688 Aql systems. The other target, CY Ari, has no literature, except for sky survey catalogues of Hoffman et al. (2009) and Pojmanski (1997) where some observational parameters, such as magnitudes, coordinates and types of variability, are summarized.

In this study, the photometric solutions of those three eclipsing binaries are presented for the first time. Since there is not any measurement of spectroscopic mass ratio, the results of q-search test based on photometric solutions provide us to obtain a set of absolute parameters.

2 Photometric Observations

All photometric observations were carried out by the 40 cm Schmidt-Cassegrain telescope at the Ankara University Kreiken Observatory (AUKO) during 2010 and 2011 observing seasons. The telescope was equipped with a CCD camera of Apogee ALTA U47 and Johnson UBVRI filter set. Combining the f/10 telescope with the 1024x1024 CCD forms a field of view of $11'.3$x$11'.3$. Some information of the variable and comparison stars are summarized in Table 1. Observational standard errors in each filter, respectively, B, V, R, and I, were in the order of $0^m.05, 0^m.08, 0^m.09$, and $0^m.09$, which were derived from magnitude differences of comparison minus check stars.

Reduction process on CCD frames was performed by applying standart BDF (Bias, Dark, Flat) treatments by means of IRAF[1] tools. Aperture photometry was preferred to obtain instrumental differential magnitudes. We generated six minimum times of all systems with errors calculated on the basis of well-known Kwee-van Woerden method (Kwee & van Woerden 1956) which was implemented as a module into AVE (Analisis de Variabilidad Estelar) software developed by Grup d'Estudis Astronomics (astrogea.org). All available times of minima are presented in Table 2. It should be noted that, in the ASAS catalogue of Pojmanski (1997), given epoch for CY Ari corresponds to the secondary minimum, i.e., shallower minimum, in our light curves when depths of minima, especially in B filter, are compared (see Figure 1a). Therefore, we have used a properly corrected light elements. A combination of both epoches by fitting a linear function provides us an improved light elements of the CY Ari system as HJD(MinI)$=2452622.06 + 0^d.3801655(5) \times E$ which was used to generate our folded light curves. It was not attempted to perform any period study based on (O-C) variations for the SY Sge and V688 Aql systems since Kreiner et al. (2001) currently presented their updated light elements.

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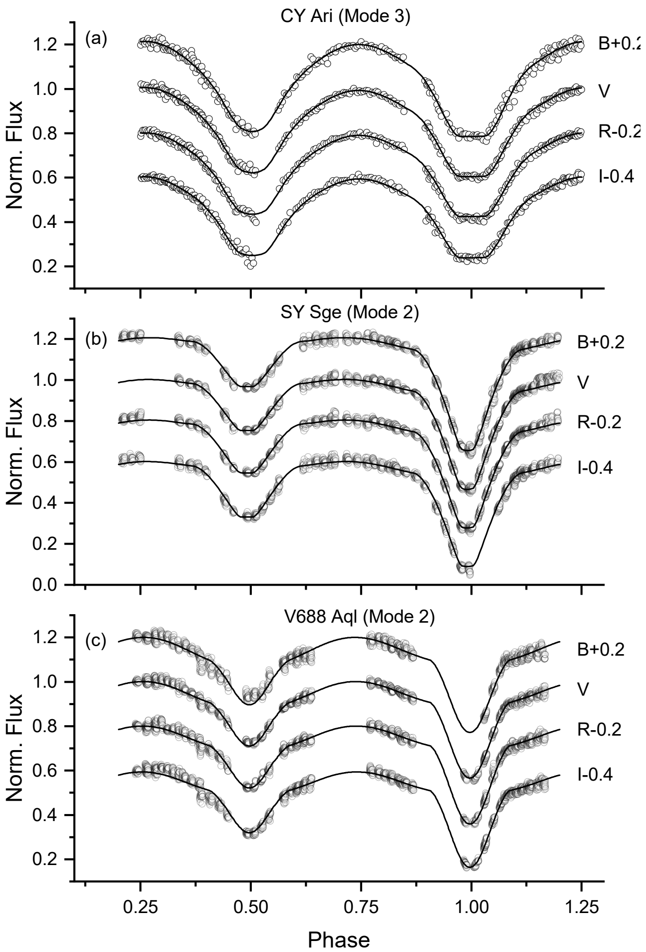

Figure 1. Observational light curves (grey symbols) in BVRI filters and corresponding theoretical solutions (solid lines) of three systems, (a) CY Ari, (b) SY Sge, (c) V688 Aql, are shown. Normalized light curves in B, V, R, and I filters are properly shifted to represent each curves seperately.

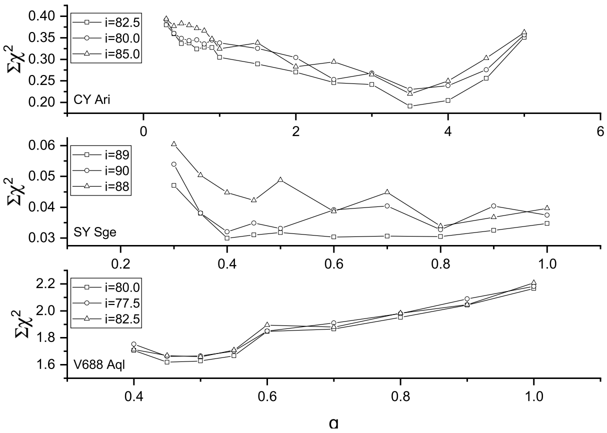

Figure 2. A graphical representation of q-searches of CY Ari, SY Sge and V688 Aql systems for three different inclination angles.

3 Analysis of the Light Curves

All light curves were analysed by using PHOEBE (Prša & Zwitter 2005) interface of version 0.31a for Windows which is based on the well-known Wilson-Devinney (WD) code (Wilson & Devinney 1971). The solution method is very sensitive to the mass ratio of the systems which can only be precisely determined from radial velocity measurements of spectroscopic observations. However, our targets in this study have no radial velocities. Therefore, we intented to obtain mass ratios of the systems deduced from theoretical fits on the light curves as providing a solution with minimum sum of residuals. This technique, also known as photometric mass ratio or q-search test which aims to reach a minimum of χ^2 in iterations, is preferable when radial velocities of binary star components are not available. However, some discrepancies may occur between the mass ratios determined by photometric and spectroscopic methods, in particular W UMa types with total eclipse (Niarchos & Duerbeck 1991). It is remarkable to report that the q-search test of CY Ari reaches a minimum χ^2 only with inverse mass ratio, which classifies the system to be a W-subtype of W UMa, namely the lighter is the hotter component. Hence, we refer the hotter component as the primary component which exposes a deeper minimum at 0.0 phase. Mass ratio searches of CY Ari, SY Sge and V688 Aql systems for three different inclination angles have been shown in Figure 2.

Another key parameter in the solutions is the spectral type, i.e., the effective temperature of the primary component, which leads to evaluate acceptable ranges of temperature of the secondary component. At this point, we have spectral determination of the SY Sge system, for which B2 type with worst quality was proposed by Giuricin et al. (1984) and Malkov et al. (2006) as indicated in SIMBAD astronomical database. The other target, V688 Aql, was recognized in the database as having a B0 spectral type with unknown quality, whereas the third one, CY Ari, has not any spectral determination in the literature. Therefore, for those two Algol systems, we decided to start the iterations by adjusting an effective temperature of the primary components corresponding to their crude spectral types. Then, the primary temperatures were properly adjusted as a free parameter through the iterations. For the CY Ari system, (H-K) colour index determined from near infrared (NIR) photometry which is less affected by interstellar reddening (Cutri et al. 2003) was used in temperature estimation. After then, a similar procedure was adopted to reach the final solution.

Since the light curves of SY Sge and V688 Aql systems resemble a detached configuration, we preferred MODE 02 module of PHOEBE for the solutions, whereas those of CY Ari are rather analogous to a contact situation with non-thermal coupling of components for which MODE 03 was choosen. The initial system parameters, namely, orbital inclination, mass ratio and fill-out factor for W UMa type system can be predicted from Fourier coefficient technique as described by Rucinski (1993). Therefore, fitting Fourier series on light curves of CY Ari before iterations in PHOEBE provided an initial set of those three parameters. The primary's temperature derived from corresponding near infrared, (H-K), colour index, as shown in Table 1, was taken as an initial value.

Some physical parameters, such as bolometric albedos (A_1, A_2, from Ruciński 1969), logarithmic limb darkening coefficients (x_1, y_1 and x_2, y_2 from van Hamme 1993) gravity darkening exponents (g_1, g_2, from von Zeipel 1924) were fixed

Table 1. Basic information of the variable, comparison, and check stars compiled from astronomical database (cds.u-strasbg.fr) are shown. Sp.T. B2 for SY Sge and B0 for V688 Aql correspond to worst and uknown qualities, respectively. Sp.T. K2 for CY Ari corresponds to [4846 K] which is deduced from Worthey & Lee (2011).

Name	Object	Sp.T.	m_V	J-H	H-K
SY Sge	Variable	B2	$10^m.46$	0.023	0.011
GSC 1620-1146	Comparison Star	A0	$10^m.22$	0.027	0.002
GSC 1620-2516	Check Star 1	-	$10^m.88$	-	-
GSC 1620-1812	Check Star 2	$11^m.01$	-	-	
V688 Aql	Variable	B0	$10^m.54$	0.008	-0.053
GSC 1615-1448	Comparison Star	G5	$9^m.94$	0.449	0.080
GSC 1615-2500	Check Star 1	F2	$10^m.75$	0.179	0.057
GSC 1615-2774	Check Star 2	K0	$10^m.27$	0.539	0.104
CY Ari	Variable	~K2	$12^m.22$	0.337	0.096
GSC 1766-423	Comparison Star	-	$12^m.17$	-	-

Table 2. Calculated minima times of the systems which are averaged over all pass-bands. Minimum time of CY Ari cerresponds to a secondary minimum in ASAS catalogue (Pojmanski 1997).

Name of the target	Times of minimum (HJD+2455000)	Types of minimum
SY Sge	748.3541±0.0005	1
	769.5411±0.0005	1
	810.2827±0.0003	2
V688 Aql	796.3745±0.0006	1
	798.3301±0.0004	2
CY Ari	520.2523±0.0001*	1

to their reliable theoretical values during iterations. Since none of the light curves reveal any clues of eccentric orbit, e.g., asymmetric minima, phase shift at the minima, we assumed circular orbits for all solutions. Furthermore, synchronous rotation of components ($F_{1,2}$=1.0) and no third light contamination (l_3=0.0) were adopted. In addition, we could not recognize any asymmetry or any extra variability in the light curves which might be indicator of any spot activity.

Detached configuration with non-filling Roche-lobe components (MODE 02) for Algol type systems (SY Sge and V688 Aql) and over-contact configuration with uncoupled surface temperatures (MODE 03) for W UMa type system brought the solutions to minimum residuals. All photometric solutions are presented in Table 3 and shown in Figure 1.

3.1 Absolute Parameters and Parallax Estimations

Simultaneous solutions of the light curves with photometric q-ratios allow us to obtain a set of absolute parameters of the systems. Unfortunately, the lack of any radial velocity measurements for the systems restricted us to use photometric mass ratios, which was successfully implemented by various authors, e.g., Acerbi et al. (2014) for W UMa type systems, Bulut et al. (2005), Bulut et al. (2006), Faulkner et al. (2007) for detached systems, Li et al. (2015) for a semi-detached system. Furthermore, Terrell & Wilson (2005) reported that the photometric mass ratios of eclipsing binaries for the over-contact and the semi-detached systems were reliable. Therefore, we concluded to construct our absolute parameters on the basis of photometric mass ratios. As the next step, a useful tool to estimate primary's mass of eclipsing binaries derived by the combination of Kepler's Third Law and the mass-luminosity relation (Budding & Zeilik 1987) was used. They constructed the relation by analyzing a group of RS CVn type systems composed of detached and semi-detached configurations after removing maculation effect from distorted light curves. The equation builds up a relation between the primary mass (M_1) and some other physical quantities of the system, such as, mass ratio (q), orbital period (P), fractional radius of the primary component (r_1), and surface temperature of the primary component (T_1). By referring this equation of Budding & Zeilik (1987), we performed an estimation of the primary masses of both non-contact systems. For the third system, which is a W UMa type contact binary, we considered an emprical relation given by Gazeas & Stępień (2008) in which they reported some reliable correlations based on observational data of W UMa type systems. Their Equation (4) was utilized to obtain an initial mass value for the massive component of the CY Ari. The calculated absolute parameters of all three systems with their errors are presented in Table 4 and evaluated to construct a 3D Roche geometry of the systems seen in Figure 3.

4 Conclusions and Discussion

Precise measurement of stellar distances is a rather challenging issue in astronomy. Particularly, W UMa type systems have special interest. There are a lot of emprical correlations for W UMa type systems, e.g., period-colour relation by Wang (1994), absolute magnitude vs. colour, effective temperature vs. period relation by Rucinski & Duerbeck (1997), and by Rucinski (1994), Rucinski (2004), period-mass relation by Gazeas & Stępień (2008). Rucinski (2004), based on the fact that the common envelope providing an identical surface brightness produces the same effective temperature, has proposed that the contact binary stars of the W UMa type could be used as distance tracers, although they are not as convenient as detached binaries. In a previous study, Rucinski (1994) revealed few emprical calibrations among the absolute magnitude (M_V), orbital period (P) and effective temperature (T_1) for W UMa type systems, deduced from a very limited number of samples. Using stellar absolute parameters of eclipsing binaries is also a convenient way to estimate distances to stars in the Galaxy or even in nearby galaxies, e.g., see Dworak (1974) where he evaluated distances to LMC, SMC and Andromeda Galaxy based on a modified method of parallaxes of eclipsing binaries. Among the other subsequent studies, Guinan et al. (1998), Clausen et al.

Table 3. Photometric light curve solutions of SY Sge,V688 Aql and CY Ari together with their standard errors. The parameters shown as bold face for CY Ari are initial estimates of Fourier method (Rucinski 1993).

Parameter	SY Sge MODE 02	V688 Aql MODE 02	CY Ari MODE 03
T_0 (HJD)	2440837.4300	2433543.2933	2452622.0600
P (days)	3.5392554	3.8897110	0.3801655
a ($R_\odot$)	20.94±0.01	19.45±0.06	2.58±0.04
i (°)	88.9±0.1	79.3±0.1	83.0±0.2, **77.0**
q	0.36±0.01	0.46±0.01	3.61±0.02, **0.4**
T_1(K)	20900	12840	4987
T_2(K)	11994±12	9502±19	4788±6
Ω_1	3.06±0.01	5.27±0.02	7.34±0.03
Ω_2	3.12±0.01	2.78±0.01	6.98
f(%)	-	-	0.12±0.02, **0.25**
A_1	1	1	0.5
A_2	1	1	0.5
F_1=F_2	1	1	1
$x_1,y_{1(B,V,R,I)}$	0.520, 0.284	0.608, 0.316	0.761, -0.164
	0.453, 0.253	0.519, 0.273	0.757, 0.080
	0.384, 0.223	0.430, 0.228	0.705, 0.209
	0.319, 0.198	0.347, 0.196	0.626, 0.248
$x_2,y_{2(B,V,R,I)}$	0.535, 0.286	0.615, 0.296	0.849, -0.020
	0.472, 0.264	0.532, 0.273	0.796, 0.103
	0.407, 0.239	0.448, 0.241	0.714, 0.170
	0.344, 0.218	0.373, 0.221	0.618, 0.188
$L_1/(L_1+L_2)_B$	0.802	0.412	0.297
$L_1/(L_1+L_2)_V$	0.798	0.430	0.287
$L_1/(L_1+L_2)_R$	0.791	0.447	0.276
$L_1/(L_1+L_2)_I$	0.777	0.441	0.269
$L_2/(L_1+L_2)_B$	0.198	0.588	0.703
$L_2/(L_1+L_2)_V$	0.202	0.570	0.713
$L_2/(L_1+L_2)_R$	0.209	0.553	0.724
$L_2/(L_1+L_2)_I$	0.223	0.559	0.731
$\overline{r}_1$	0.0576±0.0001	0.0090±0.0001	0.0217±0.0005
$\overline{r}_2$	0.0268±0.0001	0.0308±0.0002	0.1247±0.0010
$\sum\chi^2$	0.03	1.61	0.19

Table 4. Absolute solutions of SY Sge, V688 Aql and CY Ari. Total interstellar absorptions (A_V) through the sources were adopted from NASA's IPAC interface. Distance (d) corresponds to the lowest limit. Error bar of M_2 for CY Ari was derived based on Gazeas & Stępień (2008) where they recognize the massive component as primary. GAIA distance values are taken from Gaia Collaboration et al. (2016).

Parameter	SY Sge MODE 02	V688 Aql MODE 02	CY Ari MODE 03
$M_1(M_\odot)$	7.21±0.02	4.48±0.04	0.39±0.02
$M_2(M_\odot)$	2.62±0.01	2.05±0.04	1.26±0.07
$R_1(R_\odot)$	8.08±0.01	4.18±0.01	0.72±0.02
$R_2(R_\odot)$	6.29±0.01	6.21±0.02	1.29±0.02
$T_1(K)$	20900	12840	4987
$T_2(K)$	11994±12	9502±19	4788±6
$L_1(L_\odot)$	9703±4	432±3	0.304±0.010
$L_2(L_\odot)$	776±1	301±3	0.829±0.020
$a_1(R_\odot)$	5.58±0.02	6.11±0.10	2.02±0.04
$a_2(R_\odot)$	15.36±0.02	13.35±0.08	0.56±0.01
ρ_1 (cgs)	0.0205±0.0007	0.0945±0.0001	1.3662±0.1202
ρ_2 (cgs)	0.0161±0.0007	0.0124±0.0003	0.8225±0.0549
$log(g_1)$ (cgs)	3.48±0.01	3.86±0.01	4.26±0.10
$log(g_2)$ (cgs)	3.26±0.01	3.15±0.01	4.31±0.07
$M_V^{(m)}$	-3.25±0.01	-2.32±0.02	4.68±0.05
$A_V^{(m)}$	0.899	0.827	0.370
$d(kpc)$	3.61±0.01	2.54±0.02	0.27±0.01
$d_{GAIA}(kpc)^5$	10.72±5.55	4.76±0.94	0.339±0.005

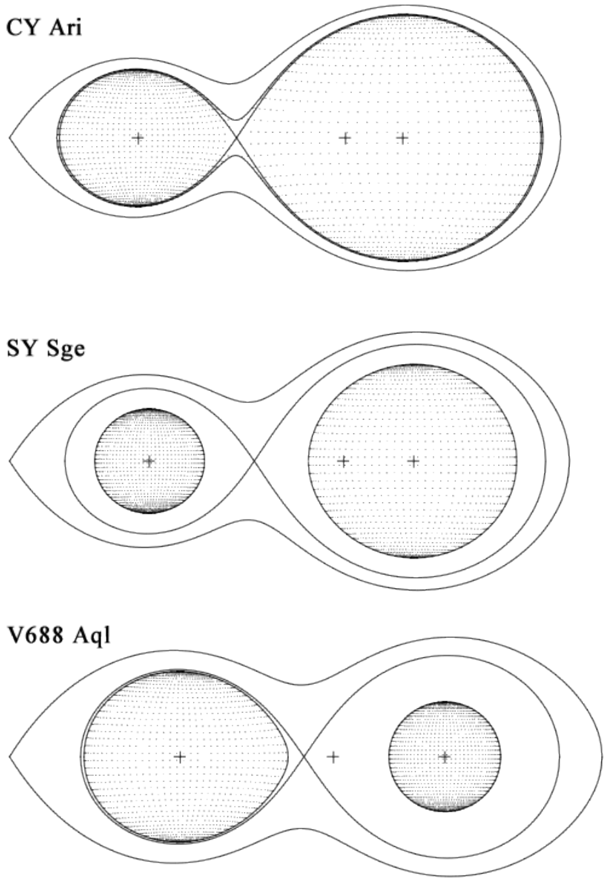

Figure 3. 3D representation of CY Ari (overcontact) at 0.25, SY Sge (detached) and V688 Aql (detached) at 0.75, from top to bottom.

(2003) and Ostrov & Lapasset (2003) can be shown. They used absolute solutions of eclipsing binaries belonging to LMC and SMC to establish distance estimations which are in good consistency. In distance estimations from the absolute solutions of eclipsing binaries, well detached binaries with spherical components are rather preferred. However, Wyithe & Wilson (2002) demonstrated that semi-detached eclipsing binaries may also be utilized for distance estimation and have substantial advantages against to detached eclipsing binaries. They used 36 semi-detached systems recognized as eclipsing binary in the OGLE catalogue (Udalski et al. 1998). It should be noted that the method strictly depends on the accuracy of two variables, i.e., mass ratio and primary's effective temperature which are key parameters of WD code. Another non-negligible issue in distance estimations is the effect of interstaller reddening through the source, which may bring the result to unplausible values.

For W UMa type eclipsing binaries, Rucinski (1994) and Rucinski (2004) proposed a few calibration relations as distance estimator. In the previous one, Rucinski (1994) derived empirical relations, deduced from a limited number of samples which establish a calibration for absolute magnitudes (M_V) with orbital period and colour indices (B-V and V-I_c) of W UMa systems. Combining absolute magnitude (M_V) for CY Ari with its apparent magnitude (m_V) leads to generate a distance module. During this proceduce, a total value of interstaller reddening as $0^m.37$ through the source was adopted by considering NASA's IPAC archive and accepting an extinction law of Schlafly & Finkbeiner (2011). This attempt locates the system at a distance of 270$\pm$10 pc. Furthermore, if the absolute magnitude presented in Table 4 is associated with the Equation (3) of Rucinski (1994), in which he established an emprical relation amongst absolute magnitude, orbital period and unreddened colour index, we can predict a de-reddened colour index of $(B-V)_0 = 0^m.676$, and then, a colour excess of E(B-V)=$0^m.384$, to the source, which is somewhat overestimation than the result of IPAC's derivation in the direction of the source given to be E(B-V)=$0^m.12$. A revised version of observational period-intrinsic colour relation for W UMa systems reported by Wang (1994) is also able to utilize to obtain a colour index of the CY Ari system, which results in $(B-V)_0 = 0^m.612$. If this reddening free colour index is combined with the system's appearent colour of $(B-V)_{obs} = 1^m.06$, we obtain E(B-V)=$0^m.448$. This colour excess still derives higher value as much as $0^m.328$ when it is compared to the total colour excess at the source direction derived from NASA's IPAC interface. If we accept the latter, it demonstrates a total amount of absorption through the source to be $A_V = 1^m.39$, which locates the system much closer distance of 170 pc. Without considering a medium level of interstellar absorption in the direction of the CY Ari system, which seems unplausible for its Galactic coordinates of $l = 149°.98$ and $b = -35°.41$, we could not predict any compatible distances by depending only such emprical correlations. It should be also noted that the relations given by Rucinski (1994) were derived from rather limited number of samples with moderate error bars. Additionally, probable uncertainties in the calibration of W UMa type eclipsing binaries, as noticed by Rucinski (2004), come from typical errors arising from trigonometric parallax measurements, light contamination of additional components, errors involved in de-reddened colour indices, effects of spot activity, dependence of metalicity, etc.

Absolute magnitudes of the other two systems, SY Sge and V688 Aql, derived from photometric solutions lead us to estimate their distances as given in Table 4. When performing calculations, a maximum value of interstellar absorbtion in the direction of the sources was adopted by using galactic dust reddening and extinction law belonging to IPAC's archive. Therefore, distance estimations to the SY Sge and V688 Aql systems, as well as, the CY Ari system, shoud be accepted as lower limits. Total absorption through the SY Sge system as A_V=$1^m.22$ given by Gontcharov (2012) seems to be an overestimation where they calculated interstaller extinction from the 3D analytical model of Gontcharov (2009).

Since the spectral types of the SY Sge and V688 Aql systems were determined with poor quality (see Nesterov et al. 1995), we intended to keep the primary temperatures as free parameter to final iterations. Best fits reached at minimum χ^2 bring the solution to much lower values than the initial temperatures adopted from corresponding spectral types. Furthermore, our final results on temperature well satisfy the near infrared colour indices which are less affected by interstellar reddening. Therefore, we propose that the effective temperatures of primary components belonging to the SY Sge and V688 Aql systems presented in this study seem to be much more reasonable. We propose, on the basis of our temperatures given in Table 4, that the more convenient spectral types of the systems are B2-B6 for SY Sge, B6-B7 for V688 Aql, and K1 for CY Ari under assuption of main sequence lumi-

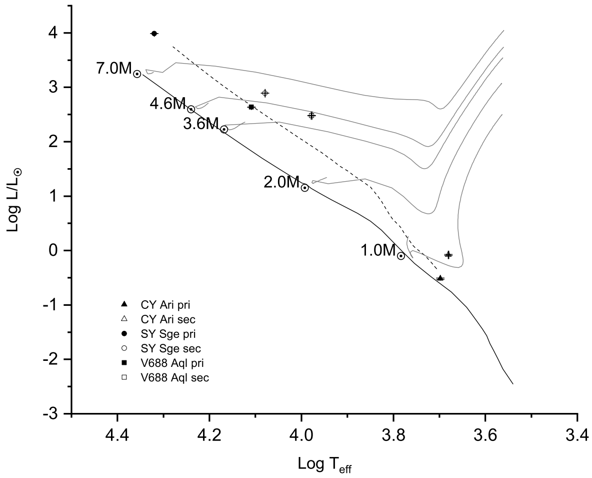

Figure 4. Absolute parameters of three eclipsing binaries on the theoretical HR diagram of Girardi et al. (2000) are shown. Bold continuous and dotted lines represent the lines of ZAMS and TAMS, respectively, whereas grey solid lines are for evolutionary tracks. Solar abundance was adopted. Corresponding masses in solar unit are seen at the beginning of each track.

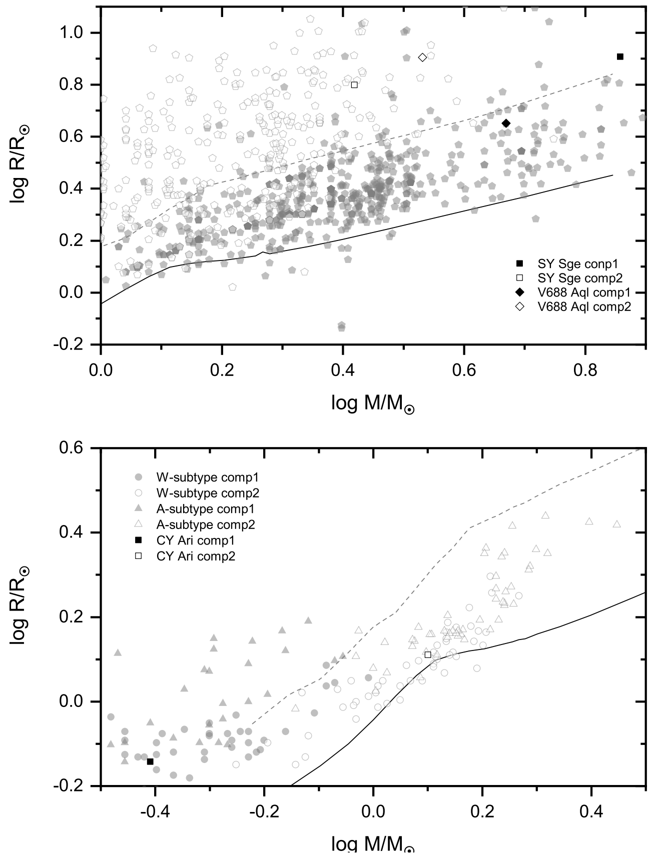

Figure 5. The locations of the components of involved systems on the mass-radius diagram are shown. Observational data gathered from detached type of eclipsing binaries (upper panel), were taken from the studies of Soydugan et al. (2006) and Surkova & Svechnikov (2004), whereas the data of over-contact configuration (lower panel) were collected from Yildiz & Doğan (2013). ZAMS (continuous line) and TAMS (dotted line) were adopted from Girardi et al. (2000). Filled and open symbols represent primary and secondary components, respectively. (see text for discussions)

nosity class and of solar abundance by considering calibration tables in Cox (2000). Additionally, it should be noted that the distances derived by combining the absolute parameters in Table 4 with temperatures adjusted from the uncertain spectral types given in Table 1 for the SY Sge and V688 Aql systems, indicate exaggeratedly distant values. The GAIA space mission (e.g. Perryman et al. 2001) was designed to measure stellar parallaxes with unprecedented quality until now. Parallax measurements of all three systems made by the GAIA satellite are also presented in Table 4 for comparison with our distance estimations. The dynamical parallax of the CY Ari system derived from its absolute solution as 270$\pm$10 pc, are in good consistency with the GAIA DR2 results. For V688 Aql system, our determined distance values somewhat consistent with GAIA. Probable discrepancy comes from uncertainty of temperature determination. This is the same case for SY Sge system, which shows largest discrepancy in distance values. Therefore, in distance estimations of stars, the dynamical parallax, derived from absolute dimensions of eclipsing binaries, can be considered as an alternative tool if the source remains well beyond the limits of trigonometric measurement. However, without knowing exact spactral types and precise amount of absorption through the source direction, this technique may lead to unsatisfactory estimations. This method was successfully applied to eclipsing binaries in LMC by, e.g. Clausen et al. (2003) and Ostrov & Lapasset (2003).

Parameters which were calculated from modelling light curves with WD code, have somewhat lower uncertainties then real values. These error values were not obtained from multi-dimensional search in parameter space. They comes from result of the differential correction algorithm. The same is true for absolute parameters, which were calculated mathematically from well-known equations. Although the actual error values are larger since there is no spectral data, they were left as they are, as it may be desired to compare them with any study that uses WD code in the literature.

Absolute parameters plotted on the theoretical HR diagram, i.e., temperature vs. luminosity relation, give an idea about the evolutionary status of each system. For this purpose, the theoretical HR diagram of Girardi et al. (2000) was constructed (Figure 4). Primary components of detached systems appear to be occupied near TAMS whereas secondaries look more evolved. In contrast, the primary, i.e., hotter but lighter component of CY Ari in our sample, is located near ZAMS although the secondary, like other systems, appears to be further evolved beyond TAMS. Former two cases are consistent with evolutionary scenarios of classical Algol type systems in which the secondary components are more evolved (Budding 1986). Latter case strongly implies that CY Ari is a W-subtype of W UMa systems, for which more luminous component has lower radius and mass (e.g. Binnendijk 1970). Furthermore, the locations of the components of CY Ari system in the logM-logR plane (see Figure 5), suggest that the system belongs to W-subtype. The most reliable conclusion about the subtype of CY Ari system will be verified by spectral observations.

We also intended to use another empirical tool, the mass-radius (M-R) relation based on the observational inputs of eclipsing binaries, to check evolutionary status of the systems. In logM-logR plane, each system is placed on its own diagram as shown for detached systems (upper panel) and for W UMa systems (lower panel) of Figure 5. It is seen that the primary components of the SY Sge and V688 Aql systems near TAMS and that of the CY Ari system near ZAMS are located. Furthermore, the locations of components of CY Ari are well matched with the region occupied by W-subtype of W UMa systems (see Yildiz & Doğan 2013), which also constitutes a convincing evidence for our solution. Therefore, we propose that both components of the SY Sge and V688 Aql systems are more evolved than the W UMa sample.

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